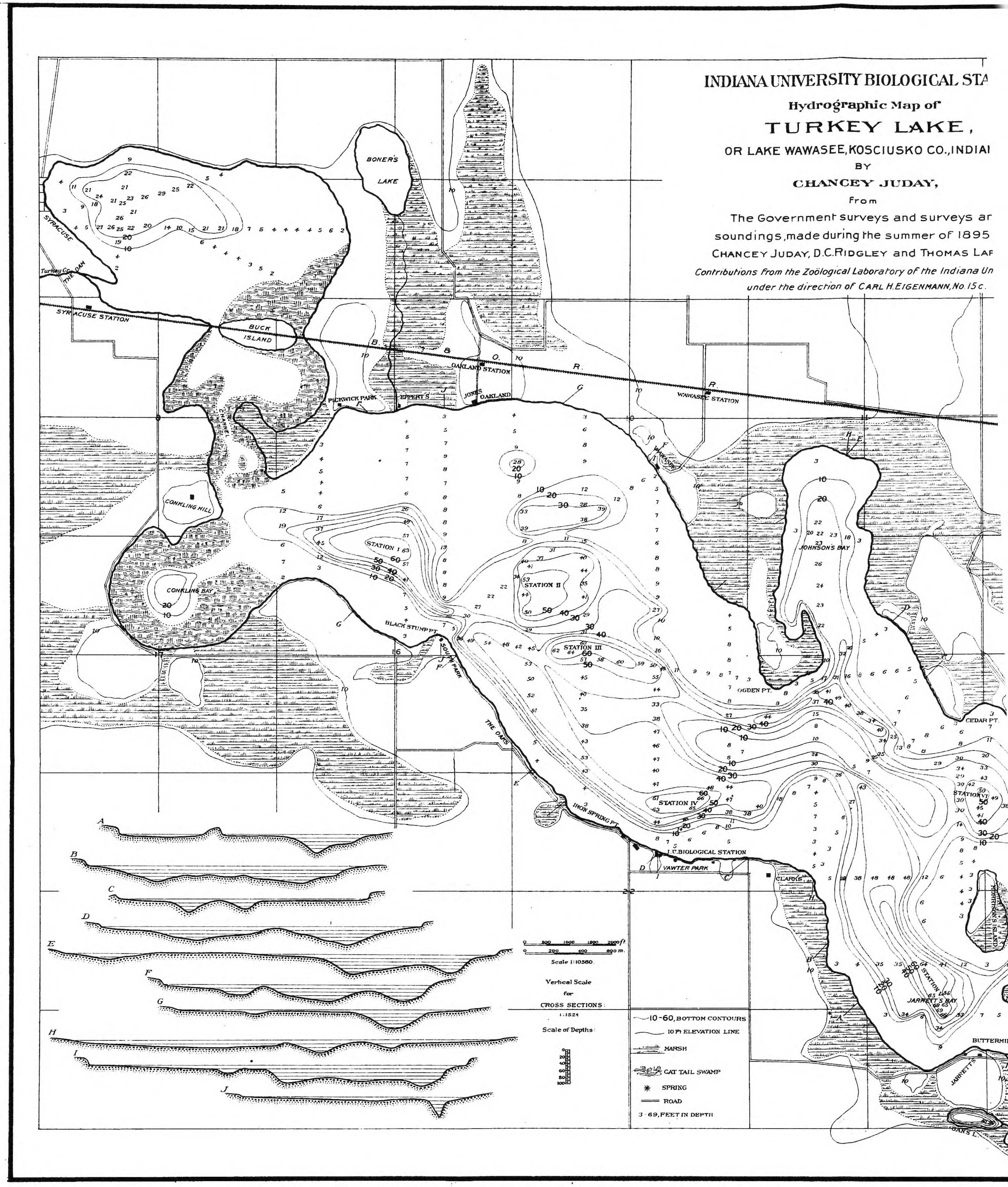
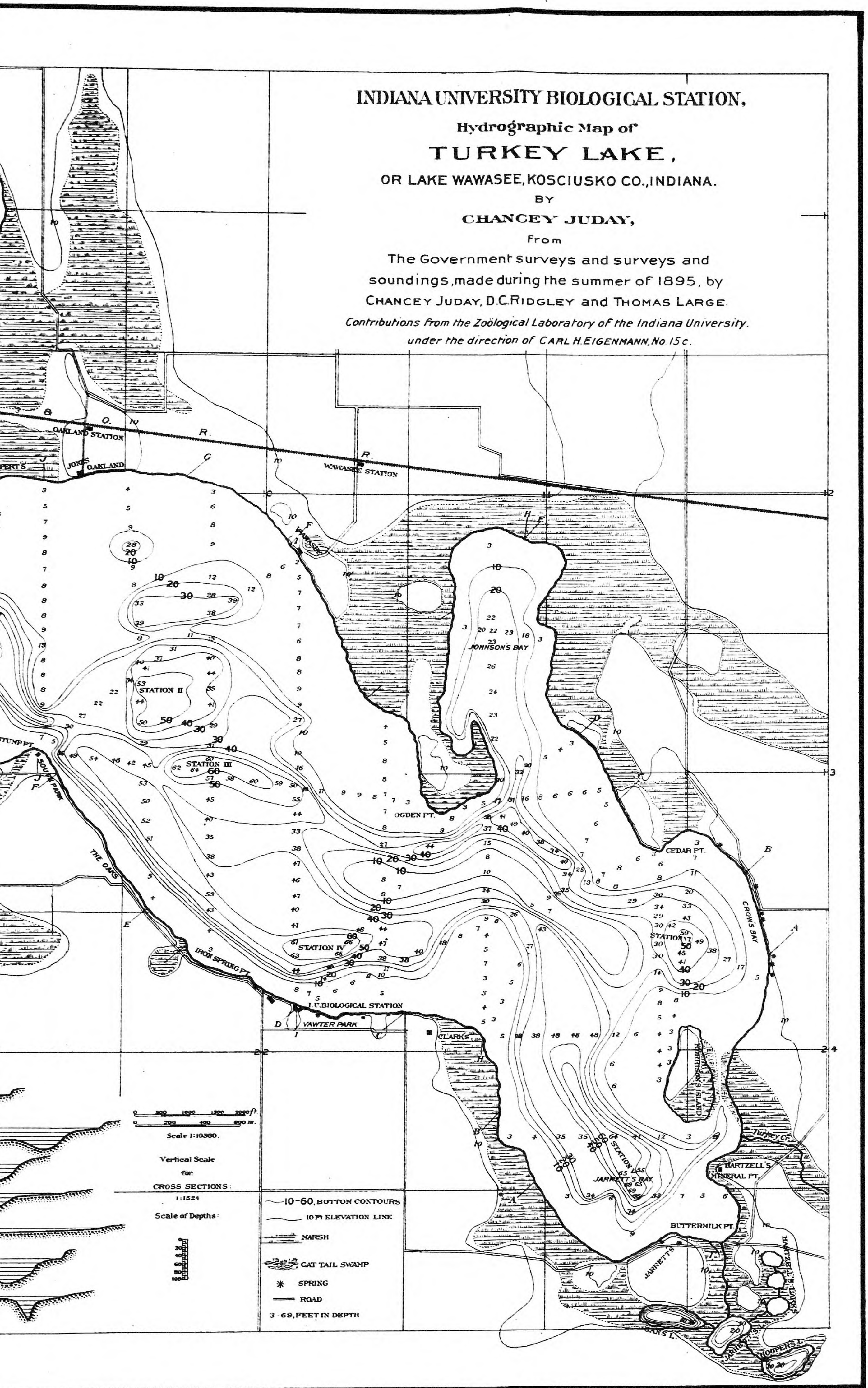

INDIANA UNIVERSITY BIOLOGICAL STA
Hydrographic Map of
TURKEY LAKE,
OR LAKE WAWASEE, KOSCIUSKO CO., INDIA
BY
CHANCEY JUDAY,
From
The Government surveys and surveys ar
soundings, made during the summer of 1895
CHANCEY JUDAY, D.C. RIDGLEY and THOMAS LA
Contributions from the Zoölogical Laboratory of the Indiana Un
under the direction of CARL H. EIGENMANN, No. 15 c.
BONER'S LAKE
SYRACUSE
THE DAM
Turkey Cr.
SYRACUSE STATION
BUCK ISLAND
B. & O. R. R.
OAKLAND STATION
WAWASEE STATION
PICKWICK PARK
EPPERT'S
JONES
OAKLAND
CHANNEL
CONKLING HILL
CONKLING BAY
STATION I
STATION II
STATION III
STATION IV
STATION VI
BLACK STUMP PT.
SOUTH PARK
THE OAKS
IRON SPRING PT.
I.U. BIOLOGICAL STATION
VAWTER PARK
CLARKS
OGDEN PT.
JOHNSON'S BAY
CEDAR PT.
JARRETT'S BAY
JARRETT'S
BUTTERMI
WAWASEE
Scale 1:10560.
Vertical Scale for CROSS SECTIONS: 1:1524
Scale of Depths:
10-60, BOTTOM CONTOURS
10 Ft ELEVATION LINE
MARSH
CAT TAIL SWAMP
SPRING
ROAD
3-69, FEET IN DEPTH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OAKLAND
JONES
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JOHNSON'S BAY
STATION II
STATION III
STATION IV
STATION V
STATION VI
OGDEN PT.
CEDAR PT.
CROW'S BAY
SOUTH PARK
THE OAKS
IRON SPRING PT.
I.U. BIOLOGICAL STATION
VAWTER PARK
CLARKS
JARRETT'S BAY
HARTZELL'S MINERAL PT.
BUTTERMILK PT.
JARRETT'S
HARTZELL'S LAKES
HOOPERS L.
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MARSH
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3-69, FEET IN DEPTH

FIRST REPORT OF THE BIOLOGICAL STATION.

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TURKEY LAKE* AS A UNIT OF ENVIRONMENT, AND THE VARIATION OF ITS INHABITANTS.

FIRST REPORT OF THE INDIANA UNIVERSITY BIOLOGICAL STATION. BY C. H. EIGENMANN.†

INTRODUCTORY.—At the last meeting of the Academy I outlined a plan for the future work of the zoölogical section of the biological survey of Indiana. It was, in brief, to study some lake as a unit of environment and the variation of its inhabitants. This plan has materialized, and I present this as the Biological Station's first report.

To select a suitable site I visited, in February, 1895, lakes Maxinkuckee, Eagle and Turkey. The lakes were frozen over, and I had a good long walk over Maxinkuckee and a sleigh ride over Turkey Lake. Turkey Lake seemed well suited for a starting point for the work in hand. In March I again visited this lake to look for a suitable laboratory and quarters. A laboratory was found in a large boat-house belonging to Mr. T. J. Vawter, the owner of Vawter Park. The boat-house is directly on the water's edge, in about 86° 18′ east longitude and 41° 23.5′ north latitude. In March the lake was still frozen over with but a narrow rim of free water near the shore. When I again visited the lake, to make the final arrangements, on the 30th of May, and captured snakes, turtles, frogs, and two species of spawning fishes, all within a hundred feet of the laboratory door, I was convinced that no mistake had been made in the selection of a locality. Deep water near the laboratory, a spring at the laboratory door, the situation of the laboratory nearly equidistant from either end of the lake, high land all about the laboratory, the nearness of such large bodies of water as Lake Tippecanoe of another river system, and a large number of smaller lakelets within a mile of Turkey Lake, all contributed to make the location selected as near perfect as could be expected.

*The only recorded name of this lake seems to be Turkey. It appears so in the government surveys of 1838, and on all the maps published since that time. I am told that it received that name from the fancied resemblance of the general outline of the lake to a Thanksgiving turkey. During the last few years the lake has been known to those personally acquainted with it as Lake Wawasee, and there seems to be a laudable ambition that this latter name should supplant the homlier, but more significant, name of Turkey. The lower lake is locally known as Syracuse Lake.

The following letter was received from the Director of the Bureau of American Ethnology: In response to your letter of December 6th last, I beg leave to inform you that the word "wa-wá-see," "wa-wá-si" or "wa-wá-sing," signifies "at the bend of a river."

Yours with respect, J. W. POWELL.

†Contributions from the Zoölogical Laboratory of the Indiana University, No. 14.

A twelve-room cottage was rented, in which fifteen of the members of the Station besides my family were quartered. While a summer cottage, thus peopled, is not a good place for consecutive thinking, this experience will also be remembered with pleasure. Most of the students rented a large dining tent and hired a cook. Others tented and boarded themselves. Their expenses ranged from $1.25 to $3 per week.

The laboratory was open from June 25 to September 1.

ACKNOWLEDGMENTS.—Mr. T. J. Vawter, besides placing the boat house at our disposal, gave us camping ground just back of the laboratory, and assisted us in various ways, both in fitting up the Station and during the entire summer.

I am under many obligations to the officers of the Baltimore & Ohio, the Vandalia and the Michigan Division of the Big Four for transportation over their lines leading to Vawter Park, and for other favors.

During our stay at Tippecanoe Mr. W. S. Standish assisted us very materially. He took the whole party on a tour of general inspection about the lake from end to end, and placed himself and his steamer at our disposal during our entire stay.

The Pottawatomie Club granted us the use of their reception room, where some of the lectures were delivered.

Professors Birge, Kellicott and Call have prepared accounts of material collected during the summer.

I must especially thank Dr. J. C. Arthur, Dr. G. Baur and Geologist Willis Blatchley, who visited the Station to deliver lectures before the members.

Lastly, I am indebted to Mr. J. P. Dolan, superintendent of the Syracuse schools. He first directly, and through Mr. Eli Lilly, of Indianapolis, called my attention to Turkey Lake, met me at Warsaw, and guided me to the lake and over and around it on my first visit. During the summer he furnished the Station with a splendid row-boat, and by his knowledge of the lake and its surroundings and personal acquaintance with the natives contributed much to the success of the undertaking.

EQUIPMENT.—The equipment of the Station consisted of a room 18x30 feet, with six windows on a side. In this space the twenty-two members of the Station were provided with tables. Continuous with this available laboratory space was a space 18x20, opening by very wide doors to the lake front. This space was utilized for storing apparatus. The apparatus, nearly all furnished by the Indiana University, was as follows: Compound microscopes (Zeiss), 21; dissecting microscopes, 3; microtome, 1; dredge, 1; plankton net, 1; Birge net, 1; dipnets; reagents, about 200 bottles; working library, about 200 volumes; Wilder's protected thermometer, 1; lamps, glassware, etc., the usual equipment of a laboratory table.; two boats; one sounding machine. The plankton net and sounding apparatus and the method of using them may be described here.

Plankton Net.—An idea of our plankton apparatus and its modus operandi can be gathered from one of the illustrations. The sounding boat was fitted in the stern with a swinging derrick. Through the end of this was attached a pulley, through which the rope supporting the net passed. The derrick was high enough to allow the net to swing clear of the sides of the boat, so that when a haul had been made, the net could be swung forward over a tray of tubes, ready to receive the condensed plankton. The depth through which hauls were made could be ascertained either by means of the sounding apparatus or by the direct measurement of the plankton rope. The plankton net was built essentially as devised by Hensen and Apstein, except that the straining net of No. 20 silk bolting cloth, Dufour's, was permanently attached to the truncated cone of canvas. The bucket which receives the plankton was from necessity greatly simplified, but as no measurements were made with it, and further improvement, both in efficiency and simplicity, have been devised, I will describe this instrument as it will be made for next summer

The diameter of the bucket will be made one and one-half inches. Its bottom will be of a sheet of brass or copper, hammered so that it will be slightly concave or cup-shaped. A hole will be punched from the inside and provided with a nipple soldered on the outside. The sides of the bucket will be made of one piece of wire net of the same caliber as the No. 20 bolting cloth of Dufour.* The upper part of the bucket will consist of a flat brass or copper ring soldered to the wire sides, and provided with openings through which the binding screws, fastening the whole bucket to the net, may pass. Three legs of narrow strips of copper passing from the upper ring along the sides of the bucket, being also fastened to the bottom, will give rigidity to the sides and form a support for the bucket when it is being emptied. To the nipple at the bottom of the bucket will be attached a short rubber tube. The opening in the bottom will be closed with a tight-fitting rubber stopper, manipulated from above by a glass rod passing through its middle. The whole cost of the bucket need not exceed $3.50. The estimate received on one of Hensen's pattern was $25.

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* Only part of the sides were made of the wire netting during the past summer. A piece of new bolting cloth was found to have 83 per cent. of its surface solid, 17 per cent. being open for the passage of water. The wire cloth used during the past summer had 77 per cent. of its surface solid, 23 per cent. being open for the passage of water. Repeated trials of forcing water thick with plankton through the bolting cloth and through the wire showed that the wire was under such conditions a more effective strainer than the cloth.

Sounding Apparatus and Method of Using it.—A flat-bottomed boat capable of running into shore at all points was manned by three persons. One who was an expert and steady oarsman at the oars, one in the stern to take notes and steer, and one in the bow to make the soundings. The sounding apparatus consisted of a wheel two inches wide with a circumference at the bottom of a flat marginal groove of one foot ten inches. (It had been ordered with a circumference of two feet.) On the drum was wound 175 feet of fine annealed wire. This, when wound, formed less than two layers over all parts of the drum. The weight consisted of a round pebble as large as a fist and was tied in a piece of cheese cloth. This was a very simple and efficient piece of apparatus. The weight, if lost, could easily be replaced by one of several others carried along, and the wire was found sufficient for the whole summer's work. The original cost plus the cost incident to its operation did not exceed $1.50. The wheel was provided with a crank and being of a definite circumference the depth was measured by the number of turns it took to raise the weight from the bottom to the surface. This apparatus would be efficient in any lake of moderate depth. To run a line of soundings the bearing to the objective point on the distant shore were taken from the starting point with a compass. The oarsman pulled thirty strokes, backed water and held the boat. A sounding was made in the bow and the depth recorded by the man in the stern. It was found that with the boat always used for the purpose, manned as above in calm weather, when all the sounding was done, 30 strokes moved the boat 300 feet. This method proved entirely satisfactory in short lines a mile and a half in length. In long lines it proved unsatisfactory.

Additions to the Equipment. A new laboratory 18x55 feet, two stories high, will be ready for occupation by June 1 of 1896.

A partial description of new apparatus devised for next summer's work may be given.

One flat-bottomed boat similar to sounding boat, 12 feet, 2 oars.

One flat-bottomed boat 15 feet, four oars. Plankton apparatus.

Three glass-bottomed galvanized iron boats about 12 inches in diameter to explore bottom.

One galvanized iron tube 2 inches by 20 feet, glass ends and funnels for filling or emptying, to determine color of water.

Automatic recording apparatus to observe seiches.

Plan of Work.—It must be understood that the undertaking was quite expensive both in time and in money. The Indiana University endorsed the plans and lent apparatus from the zoölogical laboratory with the provision that the Station be of no expense to the University. At the end of the season the University paid for some of the apparatus specially designed for the Station, which thus became the permanent property of the University. In order to defray expenses, a series of courses in elementary and advanced instruction were offered and given. Each one of the advanced students and the instructors took charge of some particular work of the survey. The preliminary reports of some of these, form part of this first report. The work was distributed as follows:

C. H. Eigenmann, Director.

W. J. Moenkhaus, Variations in Etheostoma.

F. M. Chamberlain, Variations in Lepomis.

J. H. Voris, Variations in Pimephales.

D. C. Ridgley, Physical Survey and Variations in Micropterus.

Bessie C. Ridgley, Variations in Labidesthes.

Thom. Large, Physical Survey and Variations in Fundulus.

Chancy Juday, Physical Survey and Planktonist.

Curtis Atkinson, Variations in Batrachians.

H. G. Reddick, Variations in Reptiles.

O. M. Meincke, Botanist.

J. P. Dolan, Meteorologist.

The work of but few has progressed far enough to justify even "forläufige" notices. We have but just begun our work, and the Station will remain at least three years longer at the same place. Excursions were made to lakes Tippecanoe, Webster, and Shoe in the Mississippi basins.

While much of this report is taken up with the physical features of the lake, and the enumeration of the inhabitants, it must be borne in mind that the physical studies are merely a means to an end. That however interesting in themselves, to us they are only interesting as far as they form part of the environment of the highest creatures making the lake their permanent home. It may even be that some of the things considered or to be considered, form in reality no part of the environment of the vertebrates, *i. e.*, that they in no way affect them, but this is a matter that must be determined, and for the present we must consider as many things as *may* influence them. The things probably most directly influencing the higher forms to be found in a lake are light, temperature and food. The last item is again conditioned as the highest forms are, so that nothing short of a complete understanding of the conditions will be sufficient. A lake seemed to me the ideal place because here the changes due to light, temperature, change of water or surface are reduced to the minimum to be found in this latitude. A small lake is better than a large lake, because the unknown elements can be reduced to a smaller number.

We have attempted to collect specimens of the higher creatures in such numbers and sizes, that had we collected all the specimens in the lake, our results would not be different. How far we have succeeded in this remains to be seen.

The main object of the Station is the study of the variation of the non-migratory inhabitants. I may be permitted to quote here the plan as stated in the circular issued by the Station last spring.

The main object of the Station will be the study of variation. For this purpose a small lake will present a limited, well circumscribed locality, within which the difference of environmental influences will be reduced to a minimum. The study will consist in the determination of the extent of variation in the non-migratory vertebrates, the kind of variation, whether continuous or discontinuous, the quantitative variation, and the direction of variation. In this way it is hoped to survey a base line which can be utilized in studying the variation of the same species throughout their distribution. This study should be carried on for a series of years, or at least be repeated at definite intervals to determine the annual or periodic variation from the mean. A comparison of this variation in the same animals in other similarly limited and well circumscribed areas, and the correlation of the variation of a number of species in these areas will demonstrate the influence of the changed environment, and will be a simple, inexpensive substitute for much expensive experimental work.

For this work the situation of Lake Wawasee, surrounded as it is by other lakes, some of them belonging to other river basins will be admirably adapted.

In connection with this study of the developed forms, the variation in the development itself will receive attention. For instance the variation in segmentation, the frequency of such variation, and the relation of such variation in the development to the variation in the adult, and the mechanical causes affecting variation.

This plan will be modified as our knowledge grows and our experiences dictate.

PART I. THE LAKE AS A UNIT OF ENVIRONMENT.

Introductory.—A lake is a depression in the ground filled with water more or less stagnant.

A glance at a good map of North America will show the following peculiarities in the distribution of lakes:

I. A large number of lakes are found in Florida.

II. A host of them are distributed in northern United States and Canada, including the greatest collection of fresh waters on the globe.

III. A good number in the Sierra Nevada and the Rocky Mountains.

The remainder of the country from the southern boundary of Georgia to the northern boundary of Pennsylvania west to the Rockies is practically free from lakes, except

IV. along either side of the lower Mississippi and Red Rivers.

These four groups of lakes are due to four different methods of lake formation, but all four are indicative of the fact that the lake-rich areas have undergone recent change.

The first series is due to the comparatively recent elevation of an irregular ocean floor. The second series is due to the action of ice in the irregular gouging and irregular dumping of debris. These are all of recent date, probably none of them being over 10,000 years old. The third series is due to the exigencies of mountain formations, including in this plication and plication hollows, craters and lava flows and the settling of small areas. The fourth is due to the change of channel on the part of the Mississippi and to the debris brought down by the Red River which it has deposited at the mouths of its tributaries.*

Of course the lakes of one of these regions need not be all of the same origin. Small lakelets around Lake Tahoe in the Sierra Nevada are certainly due to the gouging action of glaciers coming from a steep incline onto a comparatively level plain. Generally speaking, mountain regions, unless, as in the case of the Appalachian, they have outgrown their lake stage, contain lakes of the greatest diversity of origin.

Lakes are of interest to the geologist to determine the particular way in which a general cause has been modified to produce a particular effect at any particular lake; to the physicist to account for the various colors, temperatures, pressures, reflections, refractions, etc.; to the chemist to determine the degree of concentration of minerals and gases in solution; they are of interest to the naturalist to determine the organic inhabitants, their quantity and kind and their life histories; to the œcologist and evolutionist to determine the geological, physical and chemical characters in their effect on the organic inhabitants and these on each other.

Lakes may therefore be studied for other than purely economic interests, such as water supplies and highways for commerce or location of summer resorts.

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*The facts for the foregoing have largely been drawn from Russell's American Lakes. Ginn & Co., 1895.

Orientation.—A hight of land (morain) extends from the northeastern corner of Indiana directly southwest to south of Albion in Noble County, and from here westward between Turkey Lake and Tippecanoe Lake, then northwest through Nappanee in Elkhart County to near South Bend. In its range from the northeastern corner to south of Albion this ridge separates the Lake Michigan from the Lake Erie basin. West of this it separates Lake Michigan basin from the Ohio basin, and still farther west from the Mississippi basin proper. In the eastern half of Indiana this ridge is exceedingly rich in lakes. Most of these lie on the northern side of the divide, but about the headwaters of the Tippecanoe and Blue rivers many are also found on the south side of the divide. A glance at the map leaves the impression that this region is low and swampy, while in reality this whole region forms one of the highlands of Indiana, a considerable part being over 1,000 feet high.

Turkey Lake is the most western lake of this series lying north of the divide.

It lies in Turkey Creek Township, in the northeastern corner of Kosciusko County. South of the ridge separating the Mississippi and St. Lawrence basins at this point lie Webster and Tippecanoe lakes, and south of these the Barber lakes and Shoe Lake. Between the crest of the ridge and Turkey Lake the country is pitted and grooved. Many of the pits are filled with water, forming ponds of various sizes. One of these has recently been drained. Many more lakelets are found about the head of Turkey Lake, but the topography of this region will be dealt with in one of the following reports. This whole region gives one the impression that it has changed but little since the ice left it.

General Features.—The lake has a general trend from southeast to northwest. It is divided by a wide stretch of very shallow water, which is fast being reclaimed by various water plants. A deeper channel extends through this swampy region, connecting the upper and lower portions.

The greatest length from the head of Turkey Lake to the end of Syracuse Lake is five and one-half miles. The width, measured at right angles to such a line, rarely exceeds a mile. The greatest width is just east of Ogden Point, where it measures one and a half miles. The length of Turkey Lake from Mineral Point to Conkling Hill is about four miles. The total shore line is between twenty and twenty-one miles.

The excellent map prepared by Messrs. Juday and Ridgley, based as it is on numerous soundings, shows the lake bottom to be of the same rolling character as the surrounding region. A lowering of the surface of the lake ten feet would make the long stretch of territory between Syracuse and Turkey lakes dry land, and make the lake entirely landlocked.

The similarity of the lake bottom to the surrounding country, which seems to have been little changed by erosion, makes it quite certain that the lake basin is due to the irregular dumping in a terminal moraine, parts of it containing deeper kettle holes.

The lake was never much more extensive than now. There are evidences that the surface was a few feet higher. These will be considered in a later report. The lake is surrounded by extensive swamps on the east, north, and west; these would practically all be covered by water should the surface of the lake be raised five feet. The hydrographic basin is so small that at present but seven inches of water are removed from the surface by outflow, while thirty are removed by evaporation. The lake having a surface of 5.6 square miles, an increase of this surface by $\frac{7}{30}$, or about one and a third square miles, would be sufficient to allow all the water coming into the lake to be lost by evaporation except in wet seasons. The surface of the lake, therefore, can not have been very much higher than at present if the present precipitation and evaporation have been constant since the ice left this region. The lake has been about six or seven feet lower, having been raised to its present height by the building of a dam across its outlet. The changes due to this dam and to the encroachment of plants will be considered in another report.

Size.—The total area now under water is 5.659722 square miles. This area was obtained by weighing a sheet of paper of uniform thickness and of the shape of the whole area to be calculated, and comparing this weight with the weight of a square of the same paper covering a square mile. This method is much more expeditious than calculating such an irregular body as these lakes in the absence of a planimeter, and quite as exact. The same method was used in determining the areas below which there is a certain depth of water, with the following results:

Depth of Water.	Area in Square Miles.	Amount of Water in Cubic Miles.
1–10 feet	3.27777	.00310395
10-20 feet	.59027	.00167690
20–30 feet	.62500	.00314867
30–40 feet	.45833	.00303817
40–50 feet	.39583	.00337165
50–60 feet	.22918	.00231162
60–70 feet	.0694	.00082026
	5.64576	.0174712
Error to be distributed	.1396	
	5.65972	

Forel (Faune profonde des lacs Suisses, p. 5) proposed to estimate the volume of a lake by comparing it with a cone whose height is the maximum depth, and whose base is the surface of the lake. Estimated in this way he found the cone gave but .67 of the actual volume of Lake Geneva. A similar estimate for Turkey Lake will give us .024654 cubic miles, or considerably more than the actual value. The average depth obtained by dividing the cubic contents by the surface gives us 16.6 feet. All these measurements were made during the summer of 1895 when the lake was below the average height, so that 17 feet will probably be nearer the average depth. It will be found that by another method Mr. Ridgley obtained 21 feet as the average depth.

Over half the area contains water less than 10 feet deep. A reduction of thirty feet below the present level would reduce the lake to a Y-shaped figure extending nearly from end to end of the present lake. One of the horns of the Y would extend to Crow's Bay, the other to Mineral Point. The base of the figure would lie to the west of Black Stump Point. Between the horns of the Y we should have a peninsula continuous with Morrison's Island, which is the last of a series of islands left in the lake. During the ancient history of the lake the land about Buttermilk Point was an island, and ridges of land east and west of this formed the islands. One of these is seen in the illustration. The detailed description of the hydrography of the lake will be given in the map and Mr. Ridgley's report.

Relation of Water to Outflow and Evaporation.—Without any addition to the water of the lake the quantity now in the lake would be sufficient to supply the present outlet for 26 years.*

In other words, every cubic foot of water entering the lake will remain in it on an average of twenty-six years, unless removed by evaporation. Ridgley estimates that the inflow from springs equals the outflow, yet the lake was observed to fall on an average of one-quarter inch per day, rising of course during rains. That the outflow will not account for the fall of the lake is sufficiently shown by the fact that the calculated fall due to the outflow is but .0016 inches per day. (See Ridgley's report). The remainder of the fall must be due to evaporation and seepage, very largely to the former. Attempts were made to estimate the amount of evaporation from the surface, but they proved failures. It is self-evident that simply exposing water in an open dish will not answer the purpose of estimating the amount of evaporation in the lake for the reason that water in a shallow dish is heated to very different degrees from the water of the lake. An

*Based on Ridgley's and Juday's estimate of the outflow, and my estimate of the lake's contents.

apparatus which promised to measure the evaporation accurately and at the same time do several other things was devised, but it proved a failure because it could not be well protected in rough weather and still maintain natural conditions. The apparatus which we hope we shall be able to perfect is as follows:

A glass jar 9 inches in diameter and 12 inches high with a small hole near the bottom and open at the top is sunk into the lake to within two inches of its top. When the water in the jar has reached the level of the lake water a tight rubber stopper is inserted in the small opening from without. The column of water in such a jar would be as near as possible under the same conditions as the surrounding water, and the fall of the water in the jar, plus the amount of rainfall for the period, would very closely approximate the amount of evaporation. This apparatus would also enable one to get at the amount of water received from springs and other sources aside from rain falling directly into the lake. The amount of reduction due to outflow from the lake can readily be calculated by observing the outlet. Mr. Ridgley has estimated it at .0017 inches per day. If at the end of thirty days there was a difference between the water in the jar and the water in the lake, less the calculated reduction of the lake due to outflow, the difference would represent the inflow from springs and other tributaries during thirty days.

The lake is frozen over about four months in a year. During the remaining eight months evaporation is going on at a maximum rate of one-fourth inch per day and a minimun of 0. Taking one-eighth inch per day as the average, we obtain about thirty inches as the amount of the annual evaporation. At this rate the lake, if without income, would become dry in twenty-eight years. Four years would reduce the lake to half its present size.

Outflow and evaporation operating together would reduce the level at the following rate:

Time in Years.	Reduction by Outflow.	Reduction by Evaporation.	Total Reduction.
3	1 ft. 9 in.	7 ft. 6 in.	9 ft. 3 in.
3	4	7 6	11 6
2	3 2	5	8 2
2	4 8	5	9 8
2	6 8	5	11 8
1	5 2	2 6	7 6
1 about	17 7	2 6	10 1
14	33 2	35	68

These figures do not claim any great degree of accuracy; they simply help to form an estimate of the length of time it would take both the outflow and evaporation together to empty the lake. But while it would take both the outflow and the evaporation fourteen years to empty the lake, one-fourteenth does not express the per cent. of the water of the lake changed annually under present conditions. Since the vertical reduction is the same whether the surface is large or small, it is evident that a much larger amount would be evaporated while the surface is large. In reality, if a bulk were to be taken from the lake equal to the outflow, plus the evaporation over the present area, about six years would be sufficient to empty the lake, or, to put it in other words, during average years every cubic foot of water entering the lake remains on an average six years. During very wet seasons the amount of loss may reach a much larger proportion of the whole contents.

Constancy of Turkey Lake as a Unit of Environment.—From the preceding chapter it must be evident that the conditions in the lake, from month to month and from year to year are but little changed, that the conditions, as far as the water is concerned, are remarkably constant, especially if we compare these conditions to those obtaining in the lower courses of such rivers as the Wabash or the Illinois.

In the early part of this century a dam was built across the mouth of the outlet forming an effective barrier to the ingress of fishes from below. The lakes being at the headwaters, nothing has entered it from above. A few forms were planted in recent years by Col. Lilly of Indianapolis.

The level of the lake was changed by the building of the dam, and as late as 1840 trees were standing in water six to seven feet deep. Many of the stumps still remain. Their location and the effect of the dam upon the lake will be discussed elsewhere.

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A Preliminary Report on the Physical Features of Turkey Lake. By D. C. Ridgley.*

ACKNOWLEDGMENTS.

Most of the data on which this preliminary report is based were collected during the summer of 1895 at the Indiana University Biological Station at Vawter Park, Kosciusko County, Indiana, under the direction of Dr. Carl H. Eigenmann. I wish to acknowledge the aid of his valuable suggestions, both in the collection of the data and the preparation of the report. I wish to acknowledge also the

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* Contributions from the Zoölogical Laboratory of the Indiana University, No. 15a.

PLATE I.

No. 1.

Indiana University Biological Station.

No. 2.

Interior of the Laboratory.

PLATE II.

No. 3

Vawter Park Hotel from the Laboratory.

No. 4.

Black Stump Point From the Laboratory. Plankton Boat.

PLATE III.

No. 5.

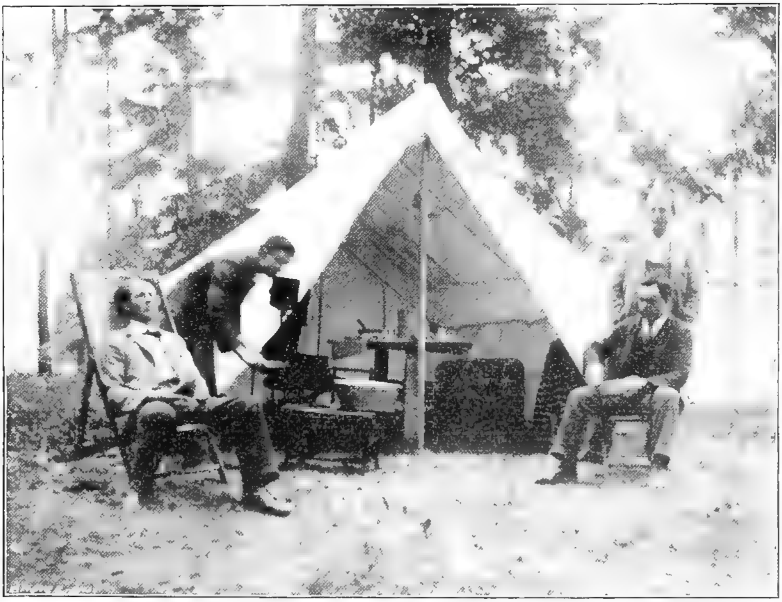
Looking Toward Ogden Point from the Laboratory. Plankton Boat in Forewater.

No. 6.

Ogden Point from Near the Pottawatomie Club-House.

PLATE IV.

No. 7.



Students' Camp in Vawter Park.

PLATE V.

No. 8.

General View from Moraine at Head of Turkey Lake.

GAN'S LAKE.
HOOPER'S LAKE.
HARTZELL'S LAKE, I.

OLD ISLAND.

TURKEY LAKE.
HARTZELL'S LAKE, II.
HARTZELL'S LAKE, III.

PLATE VI.

No. 9.

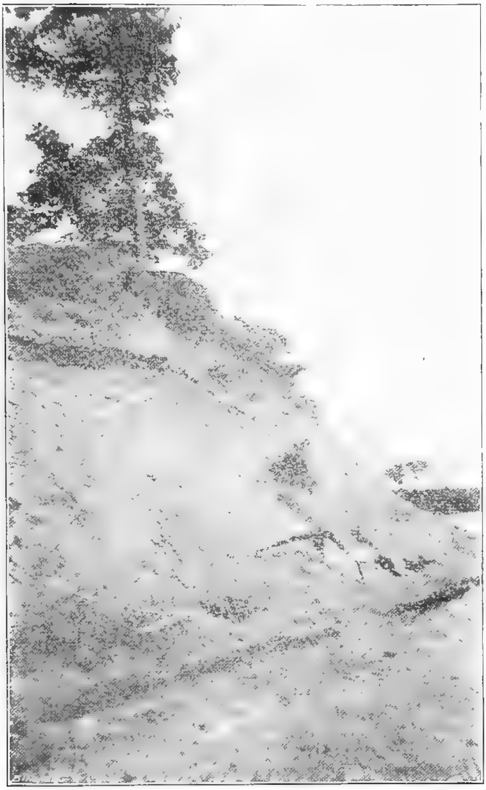
West Beach of Morrison's Island

No. 10.

Crow's Bay Showing Ice Beaches.

PLATE VII

No 11.



CEDAR POINT.

No. 12.

BEACH WEST OF CEDAR POINT.

PLATE VIII.

No. 13.

In the Channel Between Turkey and Syracuse Lakes.

No 14

At the Head of Syracuse Lakl.

assistance of Mr. Chauncey Juday, Mr. Thomas Large and others in taking the soundings of the lake; of Mr. Juday, in making a survey of the shore and for copies of the accompanying map with which he has furnished me and from which the report on the topography of the bottom is largely drawn; of Mr. J. P. Dolan for records of daily observations of lake phenomena and for the history of the lake in years past; of the officials of the Baltimore & Ohio Railroad who furnished data with reference to elevations and whose generosity has made it possible for me to make frequent visits to the lake during the winter.

GENERAL FEATURES OF THE LAKE.

Turkey Lake is made up of two parts, connected by a channel. The channel is three-quarters of a mile in length and from one hundred feet to a half mile in width. Its depth varies from one to five feet. The part of the Lake north of the channel is known as Syracuse Lake. It includes an area of three-quarters of a square mile, which is approximately one-eighth of the area of the entire Lake. The larger part of the Lake, to the south and east of the channel, may be known as the main lake.

The general direction of the lake is from southeast to northwest. Its greatest length is five and a half miles, and its greatest width at a right angle to its length is one and a half miles. The entire shore line is between twenty and twenty-one miles in length, and the area of the lake is a little more than five and a half square miles. No very prominent irregularities occur around Syracuse Lake, while in the main lake a number of evident indentations are to be found. The east end of the main lake is made up of three bays. Johnson's Bay, extending to the north, is one mile long and three-eighths of a mile wide. Ogden Point lies to the west of the entrance of this bay and Cedar Point to the east. The east end of the main lake is Crow's Bay, with Cedar Point on its north and Morrison's Island on its south. Jarrett's Bay extends to the southeast, with Morrison's Island to the east of its entrance and Clark's Point to the west. In the west end of the main lake is Conkling Bay, circular in form and with the surrounding marsh a half mile in diameter. It lies south of Conkling Hill. These are the most prominent indentations. Between the channel and Ogden Point, which are two and a quarter miles apart, the shore line curves gently northward three-quarters of a mile, forming Sunset Bay. Between Clark's Point and Black Stump Point, one and three-quarters miles to the northwest, the shore line bends southward one-third of a mile.

The following places are located for convenience in referring to different parts of the shore line and lake: The town of Syracuse lies on the west side of Syracuse Lake near Turkey Creek, the outlet of the lake. Pickwick Park is on the north shore of the main lake a half mile east of the channel. Eppert's is 1,000 feet east of Pickwick Park, and nearly a half mile further east is Jones' Landing. Three-fourths of a mile east of Jones' Landing is Wawasee. Jarrett's Landing is at the middle of the southern extremity of Jarrett's Bay. Vawter Park is a half mile west of Clark's Point and directly south of Wawasee. The laboratory of the Indiana University Biological Station is located on the shore of the lake near the west end of Vawter Park.

TOPOGRAPHY OF THE BOTTOM.

The data from which the topography of the bottom has been determined consist of numerous soundings taken throughout the lake between June 29 and August 21, 1895. The water was very low during this period. For our purpose we may consider all soundings taken when the lake had the level of July 6, 1895. This level has been marked and is used for a bench line from which to read the fluctuations in level On August 21 the lake had receded 5 inches from this level. Soundings were taken along 28 lines in the main lake and 4 lines in Syracuse Lake. These soundings were taken about 300 feet apart along all lines. Where water deeper than 60 feet was found, numerous soundings were made to determine the extent of such areas. Below is given the number and location of each line along which soundings were taken, except No. 3 and No. 9 in the main lake, neither of which was used in drawing contour lines or in computing average depth.

IN MAIN LAKE.

No. of Line.	Location.
1	From Biological Station to Ogden Point, North 37° East.
2	From Ogden Point to east end of Crow's Bay, South 53° East.
4	From Biological Station to Wawasee, North.
5	From Wawasee to Black Stump Point, South 52° West.
6	From Biological Station to Cedar Point, North 64° East.
7	From Cedar Point to Morrison's Island, South.
8	From Morrison's Island to northeast corner of Crow's Bay, North 8° East.
10	From south end of Jarrett's Bay to mouth of Bay, North 7° West.
11	From east margin of Ogden Point to north end of Johnson's Bay, North 1° West.
12	From north end of Johnson's Bay to mouth of Bay, South 10° East.
13	From east side of Ogden Point across Johnson's Bay, North 60° East.
14	From middle of east side of Johnson's Bay, across the Bay, North 79° West.
15	From Clark's Point to Morrison's Island, East.
16	From mouth of Turkey Creek across Jarrett's Bay, West.
17	From a point ⅜ of a mile west of Biological Station across the lake, North.
18	From Clark's Point to east side of Ogden Point, North 5½° East.
19	From point a half mile east of Biological Station, North.
20	From Ogden Point to Black Stump Point, North 83° West.
21	From west side of Jarrett's Bay to Mineral Point, East.
22	From Clark's Point to east side of Johnson's Bay, North 30° East.
23	From north end of No. 22 to Ogden Point, South 85° West,
24	From point one-half mile west of Wawasee across lake, South.
25	From Black Stump Point, North.
26	From Eppert's South.
27	One-quarter of a mile west of No. 26 and parallel with it.
28	One-quarter of a mile west of No. 27 and parallel with it.

IN SYRACUSE LAKE.

No. of Line.	Location.
1	From middle of east end of Syracuse Lake, South 80° West.
2	From point 700 feet southeast of west extremity of Lake, North 70° East.
3	From a point on north shore one-half mile east of west extremity of lake, South 10° West.
4	From west extremity of lake, South 80° East.

In the accompanying map, constructed by Mr. Juday, the hypothetical contour lines of the bottom of the lake were drawn from the soundings along the above mentioned lines, and numerous other soundings taken to determine the extent of certain depths of water. The contour lines indicate intervals of ten feet in depth. From the same data were constructed ten vertical sections of the bottom. In constructing the vertical sections a base line was drawn from Pickwick Park to Mineral Point, and seven of the vertical sections, from "A" to "G" inclusive, were made at right angles to this line at intervals varying from one-quarter of a mile to two-thirds of a mile. Vertical section "H" is a short distance east of No. 18, "I" is along No. 4, and "J" along No. 25 of the lines of soundings in the main lake. The remarks on the topography of the bottom are drawn largely from a study of these contour lines and vertical sections.

The average depth of the lake, found by taking the average for the soundings at regular intervals of 300 feet along the lines of soundings is 21 feet 6 inches in the main lake, 13 feet 6 inches in Syracuse Lake, and 20 feet 5 inches for the entire lake. By a different method, as explained in his report, Dr. Eigenmann has computed the average depth at a little more than 17 feet. The maximum depth found in the main lake is 68 feet 7 inches, one-quarter of a mile from the southern extremity of Jarrett's Bay; 1,000 feet northeast of the Biological Station a depth of 66 feet 5 inches was found; three-quarters of a mile north and one-quarter of a mile west of the Station the water is 60 feet deep; and a half mile northwest of Black Stump Point it is 63 feet 3 inches deep. The deepest water found by us in Syracuse Lake is 28 feet 10 inches. A depth of 35 feet is recorded for this lake in the State Geologist's Report for 1875.

An examination of the contour lines of the map shows that if we consider water having a depth of 30 feet or more as deep water, we have in the main lake four areas of deep water varying greatly in size, and connected with each other by channels.

In Crow's Bay the greatest depth found was 49 feet 9 inches. These waters enter the main body of the lake through a channel deeper than 30 feet, and 200 feet wide at its narrowest point. This channel flows across the mouth of Johnson's Bay, meeting a short arm deeper than 30 feet from that bay, and comes within 600 feet of the southeast extremity of Ogden Point. This channel continues less than 400 feet wide to a point two-thirds of a mile west of Ogden Point where it joins the channel deeper than 30 feet from Jarrett's Bay. The deepest water in Jarrett's Bay is 68 feet 7 inches, and the area deeper than 30 feet is one-fourth of a mile wide, extending north beyond the mouth of the bay and to within 700 feet of its southern shore. This 30-foot depth joins the main body of the lake a half mile north of Clark's Point where the channel 30 feet deep is only 100 feet wide. Turning to the west, 1,000 feet northeast of the Biological Station this channel deepens to 66 feet 5 inches, and widens to a half mile directly north of the Station. Here it meets the narrow channel 30 feet deep from Crow's Bay.

The two channels merge into one and form an area of water from 30 feet to 66 feet in depth, one mile in length and with a maximum width of three-quarters of a mile. This area of deep water lies nearer the south shore, its center being one-third the distance from the south shore to the north shore. Near Black Stump Point the deep water narrows abruptly from the north, and 500 feet out from Black Stump Point its width is but 200 feet. West of Black Stump Point the deep water widens abruptly to the north to a width of one-quarter of a mile and deepens to 63 feet 3 inches. West of this the area of deep water narrows again and the water having a depth of 30 feet ends one-quarter of a mile southeast of the entrance to the channel between the main lake and Syracuse Lake.

Between the deep channels from Crow's Bay and Jarrett's Bay the area having a depth less than 30 feet is one and one-quarter miles long, 1,300 feet wide, and contains an area one mile long and 500 feet wide over which the water is less than 10 feet deep.

If the level of the lake were lowered 30 feet there would remain four bodies of water connected by channels from 100 feet to 200 feet wide and less than 10 feet deep. These four bodies of water would be: (1) a small area in Crow's Bay with a maximum depth of 19 feet; (2) about one-half of Jarrett's Bay with a maximum depth of 38 feet; (3) the main body of the lake, its width decreased almost one-half, and its maximum depth being 36 feet; (4) a small area northwest of Black Stump Point with a maximum depth of 33 feet. Lower the level of the lake 10 feet more, that is, 40 feet below its present level and these four bodies of water would remain as separate lakes, the connecting channels now being dry.

Great changes in the shore line will take place if the level of the lake be lowered to a much less extent. By observing the map it will be seen that a lowering of the level of the lake to the amount of 10 feet would move the shore line to the first contour line. This would leave one-half the bottom of Johnson's Bay dry land; it would move the shore line along Crow's and Jarrett's Bays from 400 feet to 1,000 feet into the lake. Clark's Point would extend 2,000 feet further north, and the distance between Clark's Point and Ogden Point would be reduced from 4,000 feet to 1,800 feet. The south shore line from Clark's to Conkling Bay would be moved northward distances varying from 250 feet at Iron Spring Point to 1,000 feet along the shore west of Black Stump Point. The north shore line from Ogden Point to the Channel would be moved southward from 900 feet to 2,000 feet, and at one place—between Jones' Landing and Black Stump Point—4,000 feet, reducing the width of the lake at this place from 1 mile to 500 feet. The Channel between the main lake and Syracuse Lake would be drained, and the greater part of Syracuse Lake would become dry land.

Judging from the contour of the land, the level of the lake has probably never been more than 5 feet below its present level.

TOPOGRAPHY OF THE SHORE.

The shore of 20 miles is about equally divided between dry shores and marshy shores. The shores of Syracuse Lake and of the west end of the main lake were not carefully surveyed, but accurate measurements and notes were taken of the shore line of the east end of the main lake from a point on the north shore three-eighths of a mile to the northwest of Wawasee, around the east end of the lake to a point directly south of the starting-point. These data were used in mapping a ten-foot elevation line around this part of the lake. For this reason the shores of the east end of the lake are treated more in detail than the others.

The dry shores are composed of sand and gravel. Some are less than 5 feet high, but more often they are abrupt bluffs from 10 to 30 feet high, or hills which ascend rapidly to a height of 40 feet. The west, north and northeast shores of Syracuse Lake are bluffs or hills. The east shore is marshy. The shore south of Turkey Creek, the outlet, is also marshy, and these marshes extend along both sides of the Channel between Syracuse Lake and the main lake. Pickwick Park is located on a gravelly shore less than 10 feet above the level of the lake. Between Pickwick Park and Eppert's is the Gordoniere Marsh extending northwest to the Channel. Pickwick Park and the land to the west of it is surrounded by the main lake, the Channel and the Gordoniere Marsh and is known as British Island. The shore between Eppert's and Jones' is mainly marsh. From Jones' one-quarter of a mile east the shore is a bluff from 10 feet to 15 feet high. From this point almost to Wawasee the land near the shore is at present a dry marsh. The bluff at Wawasee is 15 feet high and extends along the shore 1,700 feet. This bluff extends back from shore 500 feet where it joins the marsh which stretches along the shore to Ogden Island, and also to the east to Johnson's Bay. Ogden Island, which is surrounded by the lake only on the southwest side and on all other sides by marshes, extends a half mile to the northwest of Ogden Point and is from 300 feet to 1,000 feet wide. Its greater part is from 3 feet to 6 feet above the level of the lake. About one-half of that part of the island which touches the lake is a bluff from 10 feet to 18 feet high. The area higher than 10 feet is 1,100 feet long and from 175 feet to 400 feet wide. The marsh around Johnson's Bay is known as the Johnson Marsh. It skirts the southeast and east sides of Ogden Island, surrounds a piece of timbered land 700 feet in diameter north of Ogden Island known as Oak Island, borders the bay on the north, sending off a broad marsh across the country to the northeast, and continuing along the east side of the bay with a width of a half mile, joins a narrow marsh extending to the southeast. On the east side of Johnson's Bay are two bluffs, one reaching a height of 23 feet and extending from Cedar Point northwest one-quarter of a mile along the shore and having 500 feet for its greatest width; the other is 1,000 feet further to the northwest, and is between 10 feet and 15 feet high, 700 feet long and 150 feet wide. Lying to the northeast of these bluffs and extending between them is an arm of the Johnson Marsh from 50 feet to 800 feet in width, which joins Crow's Bay just east of Cedar Point. From the northeast corner of Crow's Bay the bluffs extend south along the east end of the lake for a half mile. They are from 10 feet to 27 feet in height. The 10-foot elevation line then leaves the shore and extends almost south to Turkey Creek, leaving an area of well timbered dry land along the lake with an elevation of from 3 feet to 10 feet and attaining a width of 1,000 feet.

The land on both sides of Turkey Creek, the inlet of the lake, is marshy. Lying to the north of the mouth of the creek this marsh is 400 feet wide and extends one-quarter of a mile north along the lake. This marsh is separated from the marsh along the east margin of Morrison's Island by a shallow channel of water. The west side of Morrison's Island is a bluff reaching a height of 21 feet. From Turkey Creek to Buttermilk Point the shore is skirted with marsh from 200 feet to 400 feet wide. Mineral Point is 200 feet from the lake and ascends abruptly from the marsh to a height of 25 feet. A half mile south of Turkey Creek the lake is entered by Jarrett's Creek which is the outlet of a chain of small lakes lying southeast of Jarrett's Bay. This stream flows through a marsh 400 feet wide, and all the small lakes are bordered by marsh land. The marsh along the lake ends at Buttermilk Point, and for a quarter of a mile the shore is dry and sandy. The land along this shore is not a perpendicular bluff, but rises rapidly from the lake to the south and reaches a height of 40 feet at a distance of 400 feet from the shore. The west side of Jarrett's Bay is skirted by a marsh from 150 feet to 1,000 feet wide. West of the marsh is a bluff from 10 feet to 15 feet high continuous with the land south of the bluffs of Vawter Park. West from Clark's the south shore of the lake is a perpendicular bluff reaching a height of 29 feet in Vawter Park and extending west beyond the point where our survey of the summer ended. This bluff is cut by a ravine 50 feet wide at the Biological Laboratory and by a small stream entering the lake a quarter of a mile west of Vawter Park. The shore extending west to and around Black Stump Point is from 5 feet to 15 feet above the level of the lake. The high bluffs from Clark's Point to Black

Stump Point is by far the longest stretch of highland along the shore, being nearly two miles in length. Conkling Bay during the summer months contained an area of water about 300 feet in diameter and 20 feet deep, bordered by wide stretches of marsh containing a few small pools of very shallow water. To the north of Conkling Bay, Conkling Hill ascends rapidly to a height of 40 feet or more. This hill is conical in shape and slopes to the water on the south and east, and to marsh and lowland on the north and west.

It will be noticed that the perpendicular bluffs of the main lake face to the south at Jones' Landing; to the southwest at Wawasee, Ogden Island and Cedar Point; to the west along Crow's Bay and Morrison's Island; and to the north along Vawter Park. The high hills at Jarrett's and Conkling's are without precipitous shores. All of these bluffs are bordered by wide areas of shallow water, and it will be noticed that the 10-foot contour line of the bottom does not approach the shore much nearer than 400 feet, and is usually much further from shore. As a rule, the bluffs facing to the south and southwest have a much wider margin of shallow water than those facing to the west or north.

Wherever there is a long stretch of shore, bordered by marsh, there is no beach formed, but the muddy bottom of the lake merges into the mud of the marsh along the shore line. Along all the dry shores, and along the marshes of small extent lying between bluffs, the beach is composed of gravel and sand. This gives a gravelly or sandy beach around Syracuse Lake, except on the east and southwest; along the north shore of the main lake, from the Channel to Ogden Point; along the east shore of Johnson's Bay, from Cedar Point northwest to the extremity of the dry shores; from the northeast corner of Crow's Bay to a point east of the north end of Morrison's Island; along the south end of Jarrett's Bay; from Clark's Point along the south shore for a short distance beyond Black Stump Point. These beaches along the bluffs are formed by erosion and deposit along the base of the bluffs. The sandy and gravelly beaches along marshes are found where the adjoining bottom of the lake is composed of sand and gravel. These beaches have most probably been formed by the action of ice.

Around the main lake a number of beach formations of this kind are found. From Wawasee a half mile west the beach is composed of sand and gravel. It is about three feet above the water's level, and is higher than the land back of it. From the east end of the bluffs of Wawasee to the dry land of Ogden Island is a distance of a half mile, and the marsh along the shore is very little, if any, higher than the level of the lake. Between the marsh and lake is a beach composed of sand and gravel. This beach is two feet or more above the level of the water, and 30 feet wide. The beach along the bluff of Ogden Island is of the usual formation, but this beach continues along the shore for one-fourth of a mile beyond the bluff as a very sandy beach a foot or more above the water's level and 50 feet wide; then the beach grows narrower and is on the level of the water, the sand becomes less plentiful, and the beach is composed of a small amount of coarse gravel and then merges into the marsh, where the shore line of Ogden Point turns north. The same formation is found running a short distance north of the bluffs on the east side of Johnson's Bay.

Between the two bluffs on the east side of Johnson's Bay is a beach 1,000 feet in length, with the lake on one side and a marsh containing pond lilies on the other. This beach is from 20 feet to 80 feet wide, 3 feet above the water's level, and composed of sand and coarse gravel. The margin of the beach further from the lake is the higher, and is covered with a growth of willows, cedar and other small trees. Along the lowlands of Crow's Bay is a broad beach composed of coarse gravel about three feet high and on a level with the land back of it. Along the south end of the west side of Morrison's Island, which is lowland, the beach is from 15 feet to 25 feet wide, three feet high, and composed of coarse gravel. The beaches along marshes and lowland are broader and higher, and contain much more material than those along bluffs.

The action of the ice is an important factor in the formation of these beaches. For the explanation of the action of ice on beaches as well as the formation of ice cracks, I am indebted to I. C. Russell's excellent book, "Lakes of North America." The lake freezes over and by expansion the ice is pushed up along the shore carrying sand, gravel and stones with it. Numerous ice cracks form during the winter and fill with water. This water freezes and pushes the ice still further up the shore carrying the beach forming material still higher. These ice cracks are very numerous and may be as much as three inches wide. The amount of lateral pressure brought to bear on the shores by this means is very great, and beach ridges are begun and added to each year. The action of the ice in forming beaches along marshes is very great, while along bluffs it is small. In the first case no great resistance is met with in expansion, and the material for building the beach will be carried up to the full extent of the expansion of the ice, while along the bluffs the ice crowds against the shore and is itself broken at every expansion. A recent ice formation is evident at the northwest end of the Gordoniere Marsh, between the marsh and the Channel. In 1891 this marsh was under water, but since that time the water of the lake has receded and left the marsh dry. Separating the marsh from the Channel is a ridge of earth more than one foot high running parallel with the water's edge. This ridge can be accounted for by the action of the ice subsequent to the time when the marsh was left without water. Some of the most striking examples of ice action in the formation of beaches are found along the east side of Johnson's Bay; along Crow's Bay; at Morrison's Island, where two ice beaches, separated by a few feet, are now covered by trees; at Clark's Point, where an old beach extending as much as 200 feet from shore is found, and at Black Stump Point.

CHARACTER OF BOTTOM.

In the shallower parts of the lake the bottom is composed of sand, gravel, and small boulders, except along the low marshy shores, where it is composed of mud. At several places, both in Syracuse Lake and in the main lake, dredgings were taken at depths from 25 feet to 60 feet. Here the bottom was covered with a deposit of marl in which were found many diatoms and shells.

Further investigations will be carried on to determine more fully the character of bottom at different depths.

ICE.

For information concerning the freezing of the lake I am indebted to Mr. J. P. Dolan, who has given me the history of ice formations as he has observed them during years past, and he has furnished me with records of careful observations made since the first formation of ice in October, 1895. These observations, unless otherwise indicated, are for Syracuse Lake. Ice forms on the main lake at the same time, but it does not freeze entirely over so soon as Syracuse Lake.

The lake begins to freeze along the edge, except where strong springs enter near the margin. Information has been obtained concerning the influence of springs only at Crow's Bay and Vawter Park. Springs are numerous along Crow's Bay for a half mile and the water along the edge is kept open after the lake is frozen over, but I have not yet learned to what extent these springs influence the freezing of the edge of the lake in this locality. From Mr. Smith Vawter, who has observed the springs at Vawter Park for a number of years, I learned that the spring, which is near the margin of the lake and 200 feet east of the Biological Laboratory, keeps the edge of the lake open throughout the winter. If the weather is not severe, ice does not form for 25 feet along the shore, and from 12 feet to 15 feet from shore. In the severest weather the lake is kept open for 2 or 3 feet from the margin.

The ice spreads rapidly from the shore towards the center. The lake freezes over quite rapidly when the general temperature remains below 32° Fahrenheit and there is no accompanying wind. All parts of the lake freeze, except where it is kept open by springs, but the last place to freeze is a narrow strip from 20 feet to 30 feet wide, extending from the north end of the Channel to Turkey Creek, the outlet of the lake. Ice sometimes forms to a thickness of 6 or 8 inches along the margins of this channel before it freezes over. This is due to a current along this narrow channel towards the outlet. The ice is always thinner here than elsewhere.

Accurate information could not be obtained concerning the exact date of freezing in 1894, but from Mr. Dolan's observations we can give an accurate account of ice-formation during the fall and winter of 1895.

The first ice of the season was observed on October 20. The temperature of the air at 7 A. M. was 28°. A thin layer of ice 4 or 5 feet wide had formed along the edge of the lake. It melted during the day. At 7 A. M. October 30, the temperature of the air was 26°, and about one-fourth of Syracuse Lake was frozen over. Not quite all the ice melted, but it all disappeared on the following day. At 7 A. M. November 2, the temperature of the air was 22°. The mill race was covered with ice three-eighths of an inch thick. Only the edge of the lake was frozen, as the wind blew during the night. On November 21, the temperature of the air at 7 A. M. was 13°, and ice had formed from shore to shore on Syracuse Lake; at 12 M. the ice was nearly all melted, and at 5 P. M. the lake was free of ice. This was the first date on which the ice extended entirely across the lake. On November 23, at 7 A. M., the temperature of the air was 30°. Ice had formed on the mill race, but no ice formed on the lake, owing to a slight wind. On November 27, the temperature of the air at 7 A. M. was 16°, and a wide belt of ice had formed around the lake, but it disappeared on the following day. On December 2, the night was clear and calm. There was no ice at 4 P. M., but at 7:30 P. M. a thin sheet of ice had formed and extended apparently from shore to shore. On December 3, Syracuse Lake was completely covered with ice. The temperature of the air during the day was 6° at 7 A. M., 16° at 12 M. and 12° at 5 P. M. On December 5, the ice was 2 inches thick near shore. On December 7, the ice near shore was $3\frac{3}{4}$ inches thick, and 500 feet out from shore $1\frac{1}{4}$ inches thick. I visited the main lake on December 7, and the ice appeared to extend over the entire lake. Warren Colwell had skated over the lake during the forenoon as far east as Ogden Point. The only place where he found the lake open was a space about 20 feet square, half way between Ogden Point and Black Stump Point. Three dozen ducks and mud-hens had congregated in this open space.

The increase and decrease in the thickness of the ice from December 9, to December 20, are shown in the following table. The measurements were taken 50 feet or more from shore.

Day of Month.	Thickness of Ice in Inches.	Temperature of Air at 5 p. m.	Condition of Weather.
9	4	18°	North wind; cloudy.
10	4½	26°	Wind, southwest to south.
11	5	36°	Snow and rain.
12	5¼	20°	Clear.
13	5½	24°	East wind; clear.
14	6¼	36°	Wind, south to southwest.
15	6¼	26°	Clear.
16	5½	39°	East wind.
17	5	46°	Southwest wind; rain.
18	4¼	52°	South wind; rain.
19	2¼	54°	South wind; rain.
20	0	52°	South wind.

On December 13, ice cutting for commercial purposes was begun, with the ice 5½ inches thick. Last winter no ice was cut until January 1, 1895, when the ice had reached a thickness of 6 inches. On December 15, the ice had reached a thickness of 6¼ inches, after which it grew thinner, owing to the rise in temperature and the heavy rains. By December 20, the ice had melted so that only slush ice remained. On the morning of December 21, this ice had drifted to the north and northeast parts of the lake and at 5 p. m. of the same day the ice had all melted.

Mr. Dolan has given me accurate information concerning the ice on the lake from January 1, 1895, to March 25, when the ice left the lake. On January 1 the ice was 6 inches thick and kept increasing in thickness for more than a month. The maximum thickness, observed by persons engaged in fishing through the ice, was noted in the early part of February and found to be from 24 inches to 28 inches. The greatest thickness is found where the ice has been kept clear of snow by the wind. In January and February the snow lay about nine inches on the level, but it was drifted in many places on the lake while other areas were without snow.

In the spring the ice sometimes wears into holes out in the open lake, and breaks up in the center of the lake first, the last ice to break being along the shores. This is the case when the ice goes off in cloudy weather and with heavy rains. Usually the ice begins to melt along the shore, with some holes further out. A heavy wind then breaks the ice and carries it ashore. For the past ten years the ice has gone off with a west or southwest wind and has been piled up on the east or northeast shores.

In the spring of 1895, the ice went off the lake in an unusually short time. The lake had remained completely frozen over until March 24. During this day the ice began to melt along the shores. On the morning of March 25, the ice had melted to a distance of 20 feet from shore. At noon the ice had receded 400 feet from shore. A heavy west wind was blowing all day, and the cracking of the ice could be heard. At 3 p. m. the noise caused by the crushing of the ice became very loud and could be heard for a quarter of a mile. The ice was broken into huge cakes. The wind now began to lift the ice and drive it eastward. At 4 P. M. all the ice was piled along the east shore. The height to which the ice is piled depends on the character of the shore and the strength of the wind. The piles are not so high along a low marshy shore as along an inclined or abrupt shore. Occasionally a great sheet of ice is pushed up a smooth inclined surface 6 or 7 feet without breaking the ice to any great extent. An instance of this kind was observed by Mr. Dolan on the northeast shore of Syracuse Lake last March. No ice formed on the lake after March 25.

Ice cracks are very numerous from the time the ice forms entirely across the lake and has attained sufficient stability. They form before the ice has reached the thickness of one inch. When the first cracks formed in December the ice was so thin that it sagged slightly along the crack. The water came through the crack and spread over the surface of the ice sufficiently to melt the small amount of snow covering the ice, to a distance of 5 or 6 feet on each side of the crack.

The explanation of ice cracks as quoted from Gilbert by Russell in his "Lakes of North America" is so applicable to the case in hand that I reproduce the quotation here:

"The ice on the surface of a lake expands while forming, so as to crowd its edge against the shore. A further lowering of the temperature produces contraction, and this ordinarily results in the opening of vertical fissures. These admit the water from below, and, by the freezing of that water, are filled, so that when expansion follows a subsequent rise of temperature the ice can not assume its original position. It consequently increases its total area, and exerts a second thrust upon the shore. When the shore is abrupt, the ice itself yields, either by crushing at the margin or by the formation of anticlinals (upward folds) elsewhere; but if the shore is gently shelving, the margin of the ice is forced up the acclivity and carries with it any boulders or other loose material about which it may have frozen. A second lowering of temperature does not withdraw the protruded ice margin, but initiates other cracks and leads to a repetition of the shoreward thrust. The process is repeated from time to time during the winter, but ceases with the melting of the ice in the spring."

The formation of these cracks is accompanied with noise, and, when the ice has reached the thickness of four or five inches, the noise resembles the distant booming of cannon. These cracks may be mere seams in the ice, or they may be several inches wide. On December 7, I measured a crack three-eighths of an inch wide in ice one and three-fourths inches thick. On December 9, Mr. Dolan measured one two and three-fourths inches wide in ice four inches thick. On the same day he counted eleven loud reports caused by the formation of ice cracks in five minutes. They form during all parts of the day and night. They cross the lake in every direction, and, while the cracks are slightly zig-zag, their general courses are in straight lines.

The ice is very clear and pure, especially out from the shore, where there is no vegetation near the surface. Is is used very largely for commercial purposes, the ice being cut from about one-fourth of the surface of Syracuse Lake each year.

INLET.

The only stream flowing into the lake and containing water throughout the year is Upper Turkey Creek, which enters the lake on the east side of Jarrett's Bay. During the summer months it was filled with an abundant growth of water vegetation, and was without any perceptible current. When the water is high the chain of small lakes lying to the southeast is drained into the large lake through Jarrett's Creek, entering Jarrett's Bay a half mile south of Turkey Creek. During the past summer no water entered the lake from this source. A small stream one-fourth of a mile west of Vawter Park, and another from the east side of Johnson's Bay, contribute water to the lake when the water is high, but not during the dry summer months. There are no springs around Syracuse Lake, but springs are found along the margin of the main lake wherever the shore rises fifteen feet or more and extends across the country as elevated territory. These springs usually enter the lake near high water mark. This gives springs along Crow's Bay, Mineral Point, the south and west sides of Jarrett's Bay, and along the south shore from Vawter Park one mile west. No springs are found along the bluffs at Jones', Wawasee, Cedar Point, Morrison's Island, or Conkling Hill, but in each case these highlands are narrow and surrounded by marsh or lowland. For a half mile along Crow's Bay the bluff is more than twenty feet high. All along the foo of the bluff the water percolates from the gravel, and at places it flows from quite strong springs. At Mineral Point there are a number of strong springs. At Buttermilk Point and along the base of the bluffs west of Jarrett's Bay are a number of springs. The margin of the lake from Vawter Park one mile west is very springy, but the flow of water is not so strong as along Crow's Bay. The waters from all these springs show traces of iron more or less strongly.

OUTLET.

The waters of the lake flow into Lower Turkey Creek through which they enter the Elkhart River near Goshen, Indiana; then through the Elkhart and St. Joseph rivers they reach Lake Michigan.

Near the outlet of the lake the creek, during the summer, was about 20 feet wide and had an average depth of less than 6 inches. The volume of water discharged through the outlet was computed from measurements taken in the creek and the overflow of the mill race July 18, 1895. The outflow through the creek was 103 cubic feet, or 772½ gallons, per minute; through the mill race, 41 cubic feet, or 307½ gallons, per minute, making a total of 144 cubic feet, or 1,080 gallons, per minute. At the same time the volume of the creek a half mile below was computed at 137½ cubic feet, or 1,031 gallons, per minute.

By taking the outflow of the lake at 144 cubic feet per minute, finding the amount discharged in twenty-four hours, and computing the amount the level of the lake, with an area of 5½ square miles, would be lowered by such an outflow with no inflow, we find it to be .016 of an inch. At this rate it would require 62½ days to lower the lake one inch. In one year of 365 days, at the same rate, the level would be lowered 5.84 inches. The inflow, during the summer months, is almost entirely due to springs, and probably equals the outflow. The lowering of the level of the lake, during the summer months, seems to be due almost entirely to evaporation.

ELEVATION.

The elevation of the lake above the sea and above Lake Michigan is shown in the following list of stations and their respective elevations. The list of stations with their respective elevations above mean tide at Sandy Hook, New York, was furnished by the General Superintendent of the Baltimore & Ohio Railroad. The elevation of each station above Lake Michigan was found by subtracting 582 feet, the elevation of the surface of Lake Michigan above the sea, from the elevation of the station above the sea:

ELEVATIONS OF STATIONS ON BALTIMORE & OHIO RAILROAD FROM SOUTH CHICAGO, ILL., TO PATTON SIDING, IND., THE MOST EASTERN STATION IN INDIANA.

NAME OF STATION.	No. Miles from Grand Central Station, Chicago.	Elevat'n Above Mean Tide at Sandy Hook, New York, in Feet.	Elevat'n Above Lake Michigan, in Feet.
STATIONS IN ILLINOIS.			
South Chicago	19	593.0	11.0
Rock Island Junction	....	593.5	11.5
STATIONS IN INDIANA.			
Whitings	....	598.5	16.5
Edgemoor	....	596.5	14.5
Wilsons	....	604.5	22.5
Millers	37	617.0	35.0
Dock Siding	....	621.5	39.5
Willow Creek	....	640.3	58.3
McCools	....	640.5	58.5
Babcock	....	652.0	70.0
Woodville	....	687.8	105.8
Suman	....	748.6	166.6
Coburg	....	786.0	204.0
Alida	57	788.8	206.8
Wellsboro	64	760.0	178.0
Union Centre	71	718.5	136.5
Walkerton	79	716.0	134.0
Teegarden	85	800.7	218.7
La Paz	....	859.0	277.0
La Paz Junction	88	856.0	274.0
Bremen	96	819.0	237.0
Berlinton	....	853.0	271.0
Napanee	104	880.0	298.0
Milford Junction	112	840.2	258.2
Syracuse	116	869.2	287.2
Wawasee	120	882.2	300.2
Cromwell	125	935.2	353.2
Kimmell	....	923.2	341.2
York	....	901.6	319.6
Albion	135	926.2	344.2
Ripley	....	970.2	388.2
Avilla	145	961.2	379.2
Garrett	150	890.0	308.0
Auburn Junction	153	871.7	289.7
Inverness	....	864.2	282.2
St. Joe	163	812.2	230.2
Patton Siding	....	849.7	267.7

Syracuse is the station having most nearly the elevation of the surface of Turkey Lake. The mean level of the lake is about 5 feet below the station at Syracuse. This gives the lake an elevation of 864 feet above the sea, and 282 feet above the surface of Lake Michigan.

CHANGES IN LEVEL.

Changes in the level of the lake have been due to three causes: erosion, the dam which is built across Turkey Creek just below the outlet of the lake, and climatic conditions.

Old beach formations give evidence that the level of the lake was formerly 5 or 6 feet higher than at present. By erosion the channel at the outlet was cut 10 feet below this ancient level, and the dam has raised the level of the lake 5 feet to its present level.

The history of the dam as given by an old settler is as follows:

A small dam was built in 1828, to which additions were made in 1831. This dam washed out in 1833, and the present dam and mill race were begun in the same year. This raised the level of the lake so that timber stood in water 5 feet deep. Much of this timber remained uncut in 1840, and some was still standing as late as 1865.

The vertical distance between the level of the water in the creek below the dam and the top of the waste gate, December 7, 1895, was five feet. This would be the amount the dam, when in working order, would raise the level of the lake. The dam is not in use at present and a small portion has been removed. which allows the water to pass into the creek at a level 16 inches below the top of the waste gate. This present condition of the dam holds the water of the lake 3 feet 8 inches above the level of the water in the creek below.

The submerged stumps in many parts of the margin of the lake is the best evidence that the dam had the effect of increasing the area of the lake. These stumps stand at present in water from a few inches to two feet or three feet deep. Along the margin of Syracuse Lake the stumps are most abundant at the point of the lake extending furthest west, and on the east shore along the edge of the marsh. Turkey Creek, from the lake to the dam, is sixty feet wide, and only twenty feet along the middle is clear of stumps. This was the channel of the creek before the dam was built, and the stumps now standing in water are the remains of the timber which grew along the banks of the creek. On the north and south sides of Buck Island, at the south end of Syracuse Lake, areas of submerged stumps indicate that this island was formerly one hundred feet wider in each direction. On the east side of the entrance of the main lake to the channel are many submerged stumps. Along Johnson's Bay much timber stood in water, especially on the east side of Ogden Point and on the east side of the bay just north of the bluffs. In these localities the stumps are very numerous, and among the largest in the lake. There are a few stumps along the marsh just east of Cedar Point. Others are found in the vicinity of Morrison's Island and go to indicate that this island, before the building of the dam, was a part of the mainland. It is so represented in the government survey of 1838. On the west side of Jarrett's Bay submerged stumps are numerous, especially along the southeast corner, where much small timber is still lying in the marsh at the margin of the lake, and at Clark's Point where many large stumps are found in the water. Submerged stumps are also found west of Black Stump Point. The elevation of the lake by the dam, not only increased its area but must have rendered much of the low level land in the vicinity of the lake marshy, which would have been tillable. It is claimed by persons living in the vicinity of the lake that the dam rendered four thousand acres of land untillable.

The fluctuations in the level of the lake are caused by climatic conditions, and vary with the inflow and outflow, rainfall and evaporation. In Mr. J. P. Dolan's report will be found the record of changes of level as observed during the past few months. Annual fluctuations are estimated to be about two and one-half feet. The level of the lake is usually highest about May 1, after the heavy spring rains, and lowest in August, although this year it kept lowering until November 2, owing to the very light rains up to that time. It was then ten and one-half inches lower than on July 6. The lake was lower on November 2, than at any time since 1871, when the marshes around the lake were drier than in 1895. Since November 2, the lake has been rising until, on December 25, it was fifteen and three-quarters inches higher than on November 2.

In May, 1891, the lake was higher than at any time during the past twenty years. The difference between well-remembered high water marks of that time and the level of November 2, 1895, is four and one-half feet, which is the maximum fluctuation during recent years. Each spring since 1891, has found the level of the lake lower than during the preceding spring. This gradual lowering of the level of the lake has decreased its area and has shown marked changes in the marsh land along the margin of the lake. Four years ago the water in Conkling Bay covered an area a half-mile in diameter, now it is reduced to three hundred feet in diameter; a small shallow lake just west of Conkling Bay contained water throughout the year, now it is dry and growing good crops; fields lying west of the channel were almost marsh land, the crops being greatly damaged by water, but during the past two years no difficulty has been experienced in tilling them; two or three feet of water flowed over the Gordoniere Marsh, which is now dry with beach lines forming along its margin; and boats were rowed over all parts of the Johnson Marsh, while at present hardly any of its surface is submerged.

Consult Hydrographic Map Next to Front Cover.

Temperature of Turkey Lake. By J. P. Dolan.*

In making these observations a Charles Wilder standard, protected, thermometer was employed. They were begun the 13th of July, during which month four soundings were taken in the deepest parts of the lake from the surface to the bottom at every five feet. Then on October 5 two records were made at about the same points, and again on November 2.

September 17 a rain guage was set up and from that day to the present a regular record of temperature, precipitation, direction of wind and rise and fall of lake has been kept, but the observations have been confined to the northwest part of the lake; properly, Syracuse Lake.

I. TEMPERATURES OF TURKEY LAKE, 1895.

	July.				Oct. 5.		Nov. 2.	Dec. 14.	Dec. 24.
	Indiana University Biological Station.				I. U. Bio. Stat'n.	Jarrett's Bay.	I. U. Bio. Stat'n.	Black Stump Point.	
	13th, 10 A. M.	16th, 8:45 A. M.	17th, 9:30 A. M.	23d, 8:45 A. M.	11 A. M.	1:45 P. M.	11:10 A. M.	10 A. M.	
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	
Air	81½	83½	78½	72	65	...	50	28	...
Surface	74	75	75	76½	60½	61½	43	34½	...
5 feet	...	...	...	...	60	60¼	...	34½	...
10 "	73	74	75	71	60	59	43	34½	...
15 "	72½	74	74½	70	59	59	...	...	...
20 "	71	71	73½	67½	58½	58½	43	...	...
25 "	68	65	68½	61½	58½	58½	43½	35	...
30 "	65	63	68½	...	58½	58½	...	...	...
35 "	60	62	...	58½	58½	58½	...	35½	...
40 "	60	60	...	...	58½	58	...	...	...
45 "	59	57	...	58	58½	58	...	35½	...
50 "	59	...	...	58	58½	58	...	...	...
55 "	58	...	...	...	58½	58	...	...	...
60 "	58	...	...	58	58¼	57½	...	...	...
65 "	58	...	...	58	58	56¼	...	...	...
67½ "	...	...	...	...	...	53¼	...	...	...

*Contributions from the Zoölogical Laboratory of the Indiana University, No. 15.

VI. SUMMARY OF SOUNDINGS OF TURKEY LAKE.

	Difference in Degrees First 20 ft.	20 to 25 ft.	25 to 30 ft.	30 to 35 ft.	35 to 40 ft.	40 to 45 ft.	45 to 50 ft.	50 to 55 ft.	55 to 60 ft.	60 to 65 ft.	Total.	Maximum.	Minimum.	Mean.	Average.
	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg	Deg
I. U. Bio. Station	3	3	3	5	2	2	2	2	2	2	16	74	58	66	71.9
July 13	......	......	......	......	......	*3	......	......	......	......	......	......	......	......	......
July 16	4	4	2	1	2	3	......	......	......	......	16	75	57	69	66⅞
July 23	6½	2½	6	......	3	......	......	......	......	......	18½	76½	58	67¼	65.06
Oct. 5	2	......	......	......	......	......	......	......	¼	¼	2½	60½	58	59¼	58.84
Nov. 2, A. M.	0	½	0	0	0	½	......	......	......	......	......	......	......	......	......
Nov. 2, P. M.	0	0	0	0	0	0	0	0	0	0	0	43	43	......	......
Dec. 14	...	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Dec. 24	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......

* Bottom.

II. TURKEY LAKE TEMPERATURES, 1895.

September	22	23	24	25	26	27	28	29	30							
Air	86	45	37	......	......	55	......	......	......							
Surface	73	68	65	68	68	......	......	......	56							
Bottom	69	69	68	67	67	....	......	......	57							
Precipitation	......	.01	......	1.40	......	......	.03	.09	......	Tot	al in	ches	1.53			
October	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Air	56	58	68	68	65	62	64	45	38	45	49	45	40	54	48	46
Surface	54	......	63	60½	60½	57½	......	56	55	53	......	52	51½	......	53	52
Bottom	55	......	58	56	58½	56	......	56½	56	53½	......	52½	51	......	53	52½
Near shore	......	.	....	......	......	......	......	48	......	......	......	45	47	......	......	50
Precipitation	......	......	......	......	......	......	......	......	......	......	......	......	......	....	......	......
October	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Air	45	49	26	28	28	......	......	......	60	60	48	40	38	34	34	
Surface	51	......	......	46	46½	......	......	......	......	45	44	43	......	......	39	
Bottom	51½	......	......	48	47	......	......	......	......	46½	46	44	...	......	39	
Near shore	......	......	....	40	45	......	......	......	......	40	......	......	......	......	......	
Precipitation	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	
November	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Air	30	22	54	60	61	60	60	45	32	32	28	26	....	......	......	......
Surface, 25 ft	38	43	43	41½	42	43	43	43	42	......	42½		......	......	......	......
Bottom, 25 ft	43	43	43	42	41	45	43	43	44	43	......	43	......	..	......	......
Surface near shore	......	36	......	......	42	......	50	......	38	......	......	......	......	......	......	......
Precipitation	......	......	......	......	......	.02	.78	1.10	......	......	......	......	.02	......	.07	......

November	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
Air	...	52	34	22	20	35	33	35	35	22	16	35	36	32		
Surface	...	43½	41	39	...	...	39	*	*	*	...	...	...	34		
Bottom	...	43	42	39	...	...	39	*	*	*	38†	...	...	35		
Surface near shore	...	46	38	34	...	...	...	*	*	36†	36‡	...	...	...		
Precipitation	...	...	...	...	...	...	...	...	...	...	...	...	...	...		

December	1	3	4	6	7	8	9	10	11	12	13	14	15	16	17	18
Air 7:30 A.M.	...	6	...	12	36	28	24	28	32	18	2	28	32	24	40	45
Air 5:00 P.M.	...	12	...	26	33	24	18	26	36	20	24	36	26	39	43	52
Surface	...	...	...	34	33	33	33	33	34	33½	...	34½	34	...	-33½	33½
Bottom	...	...	...	35	36	35	35	36	36	35½	...	35½	35	...	35	35
Near shore	...	34	...	...	32	33	33	...	...	...	...	...	...	...	...	...
Precipitation	.56	...	.07	...	...	...	...	...	.11	...	...	...	.07	...	.13	1.15

December	19	20	21	23												
Air 7:30 A.M.	52	52	40	...												
Air 5:00 P.M.	54	52	39	...												
Surface	33½	35½	37	...												
Bottom	35	37½	37	...												
Near shore	...	43	...	38												
Precipitation	1.87	.96	.12	.58												

* Broken thermometer. † Under ice. ‡ Common thermometer.

SUMMARY OF TEMPERATURES.

		September.		October.		November.		December.	
		Date.	Deg.	Date.	Deg.	Date.	Deg.	Date.	Deg.
Maximum.	Air	22	86	3	68	5	61	19	54
	Surface, 25 ft	22	73	3	63	18	43½	21	37
	Bottom	22	69	8	56½	26	45	20	37½
Minimum.	Air	24	37	19	26	27	16	{ 6 { 13	12 2
	Surface, 25 ft	30	56	31	39	30	34	7, 8, 9, 10	33
	Bottom, 25 ft	30	57	31	39	26	36	6, 8, 9, 15, 17, 18, 19	35
Averages.	Air	...	56	...	47.8	...	36.7	...	31 2/7
	Surface	...	66⅔	...	51.7	...	41.2	...	33 13/14
	Bottom	...	66⅓	...	51.57	...	41.93	...	35 19/28

N. B.—Water general average for three months higher than air.

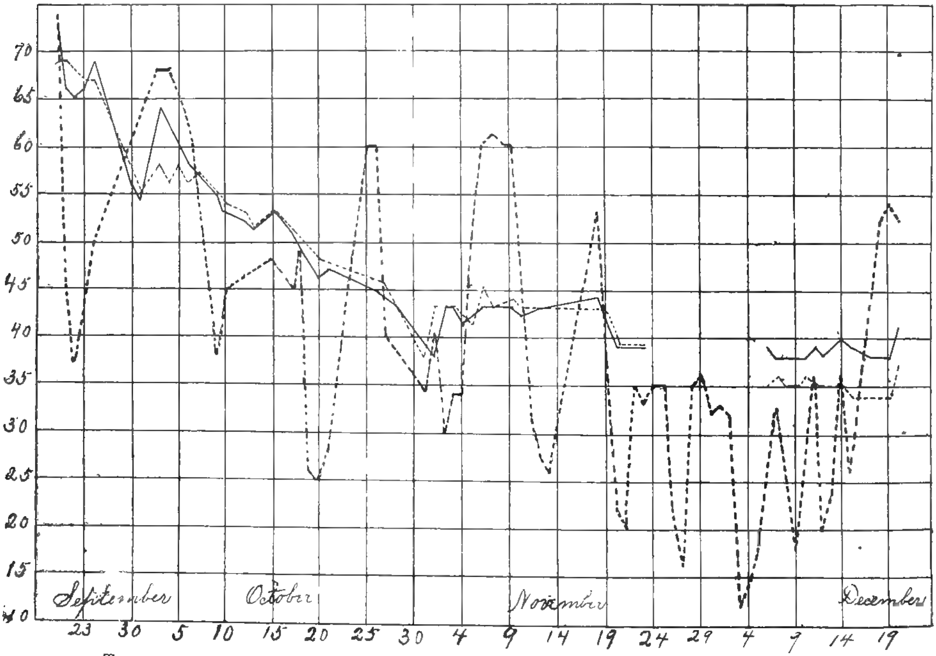
	Air.	Surface.	Bottom.
Grand average for four months	42.94	48.37	48.87

From December 3 to noon of the 20th the lake was covered with ice. During this period the surface temperature varied from 33° to 34½° and the bottom from 35° to 36°.

At 5:00 P. M. of the 20th, ten hours after the ice started to move in a body from the lake, the surface showed 35½°, a gain of 2½°; the bottom 37½°, another gain of 2½°, and in the shallow water, fifty feet from south shore, where it had been 32°, 33°, 33° on the 7, 8 and 9th respectively, it was now 43°, a gain of 10°.

The next day surface and bottom both registered 37° degrees at the twenty-five-foot station.

The results of these observations are embodied in the accompanying profile chart, in which it has been attempted to show the absolute and relative movements of the air, surface, and bottom of lake at a depth of twenty-five feet.



Temperatures from September 23 to December 23. Broken line, temperature of air; dotted line, temperature of water 25 feet below surface on the bottom; continuous line, temperature of water at the surface at the same place.

(*a*) A few well-known facts are emphasized, the variableness of the atmosphere and the persistence of the water; that water is a poor (*b*) radiator and an indifferent conductor of heat, and responds slowly to atmospheric changes.

(*d*) It shows also that the great volume of Syracuse lake at no time has been stagnant, but that a condition of activity has obtained throughout the entire period of observation.

(*c*) For the four months in which a large number of observations were made the general average of the water, both surface and bottom, is higher than that of the air.

A difference of 10° between the water one foot deep near the shore and the surface mid-lake during a rain the day the ice left the lake, shows that the surface drainage is no small factor in winter and spring in raising the temperature of the whole body.

PART II. THE INHABITANTS OF TURKEY LAKE.*

PLANKTON.

By plankton, Hensen, the author of the word, means everything floating in the sea and passively driven about by the waves and currents. Haeckel includes under plankton all organisms swimming in the sea. Haeckel says: "The totality of the swimming and floating population of the fresh water may be called limnoplankton." Limnoplanktonic studies have been made whenever a collector scooped for protozoa, diatoms or other minute organisms. Planktonic studies of this sort have been carried on for a long time. Recently plankton has been studied in a new way, first in the ocean and more recently in fresh water. This more recent study has been the quantitative and qualitative estimation of the plankton in a given volume of water. There seem to have developed in a remarkably short time two schools of planktonists, the one headed by Hensen asserting that planktonic organisms are uniformly distributed, the other, headed by Haeckel, being equally sure that planktonic creatures are to be found in clouds or schools. We are interested in plankton only in so far as it is part of the environment of the vertebrates inhabiting the lake. That it is not an unimportant element of the environment is due to the fact that it forms the primitive food of most of the fishes and that at the most plastic period in the life of the individual. The amount of plankton, as well as its composition from year

*Contributions from the Zoölogical Laboratory of the Indiana University, No. 16.

to year, is therefore of prime importance in the search for the causes of the differences in the same fish in two contiguous lakes or in two successive years in the same lake.

Our plankton apparatus was completed too late to enable us to make any systematic measurements, especially as our planktonist was actively engaged in the physical survey of the lake. But plankton was collected and some of its different constituents will be reported upon.

A good historical account of planktonic studies, as well as exact definitions. are to be found in the Planktonic Studies of Haeckel, translated by G. W. Field, and published in Commissioners' Report. 1889-91. U. S. Com. Fish and Fisheries, pp. 565-641.

In the following sketch several groups of animals are not at all considereds and others but briefly. The only groups found in the lake of which we approximate a complete list are the fishes, batrachians and reptiles. Deficiencies will be removed in subsequent reports when a classification of the material into *littoral*, *bathybial* and *pelagic* will also be attempted.

PROTOZOA.

The *Protozoa* were not represented by a large array of species during the summer. No detailed work has been done on them as yet, but I want to mention two characteristic forms.

The most striking *Protozoan* is *Ophridium*. It is found in clumps varying from microscopic minuteness to the size of walnuts, and in different parts of the lake the pebbles and exposed parts of clam shells are covered with these colonies to such an extent as to suggest young lettuce beds.

Ceratium hirudinella is as striking and abundant in the *pelagic* regions as *Ophridium* is in the *littoral*.

In this connection two plants may also be noticed.

Rivularia is very abundant during the whole summer. It is conspicuous in calm weather, when it rises to the surface. Toward the end of August and in early September it collects in such numbers as to form large patches and streaks, forming a true *Wasserblüthe*.

Various forms of *Palmella* are abundant during the whole summer, and in October, when *Rivularia* has disappeared, it forms large patches on the surface forming the *Wasserblüthe* of the late fall.

PORIFERA.

Sponges are not abundant in the lake. They are found in small patches on boards, sticks and other things near the margins of the lake. They grow much more luxuriantly in the outlet of the lake where they sometimes form patches several square feet in extent.

CNIDARIA.

Hydra viridis L. Specimens of *hydra* were exceedingly rare. On one occasion a few were taken on a submerged stick near Black Stump Point.

PLATHELMINTHES.

Flat worms were not systematically collected and none of these collections have been identified. Of *Turbellarians* there were several species. *Amia calva* is infested by a tape worm and by a *Distomum*.

NEMATHELMIA.

No attempt was made to collect thread worms. *Gordius* is exceedingly abundant on the margins during the latter part of summer. I counted as many as twelve in the area of one foot square.

ANNELIDA. BY BESSIE C. RIDGLY.

No *Chaetopoda* were collected.

No systematic attempt was made to get large numbers of leeches, but specimens were preserved whenever found. In the classification I have followed Verrill.

Nephelis quadristriata Grube. Thirteen specimens from Turkey Lake.

Nephelis fervida Verrill. Fourteen specimens.

Clepsine parasitica Diesing. Three specimens.

Clepsine ornata stellata Verrill. This species was not found in Turkey Lake. Two specimens were taken in Tippecanoe Lake.

Clepsine ornata rugosa Verrill. Four specimens.

Clepsine ornata variety d Verrill. Ten large specimens corresponding with the second specimen described by Verrill were found, most of them on turtles.

Clepsine papillifera Verrill. One specimen.

Clepsine papillifera carinata Verrill. Three specimens. One of these, one-half inch long, was found under a stone in front of the laboratory. A number of young were attached to it.

Clepsine pallida Verrill. One specimen.

Clepsine pallida variety b Verrill. One specimen.

Clepsine elegans Verrill. Five specimens.

ROTIFERA. D. S. KELLICOTT.

I received in September three vials of plankton, from Mr. Chancey Juday with the request to report upon the *Rotifera* found therein. The vials were marked and described as follows: "I. Contains plankton caught at the surface of the water of Wawasee Lake, Indiana, by using a plankton net; taken August 28, 1895; killed in picro-sulphuric acid; washed in 35 per cent. and 50 per cent. alcohol and preserved in 85 per cent. alcohol." "II. Depth of haul, 60 feet (Wawasee); depth of water, 65 feet; taken July 20, 1895; killed in Flemming's Fluid; washed in 35 per cent. and 50 per cent. alcohol, and preserved in 85 per cent. alcohol." "III. From Tippecanoe Lake; depth of haul, 110 feet; depth of water, 117 feet; taken August 7, 1895; killed in Flemmings's Fluid; washed in 35 per cent. and 50 per cent. alcohol, and preserved in 85 per cent. alcohol."

I find that the *Rotifera* were much better preserved in II and III than in the first. The illoricate species in I were scarcely recognizable; in fact three species found in this vial I have not been able to place more nearly than the probable genus. Those in II and III have all been satisfactorily identified. While the whole number recognized in these collections is not large some interesting facts are brought to light. Three species not hitherto reported from this country are among the number, and others rarely. It is certain that the *rotiferal* fauna of these lakes is rich and will yield many unique forms as a reward to any student who may be able to work in the region, to take and study them in the fresh state, and in all their varied relations and situations of residence.

I shall enumerate, with remarks, the species found in each haul separately, although it will cause some repetition, and in the order of Hudson and Gosse's *Rotifera*, without citing the bibliography farther than a description where the partial bibliography, however, will usually be found.

I.

1. *Floscularia mutabilis* Bolton. Not infrequent. It is quite unexpected that a floscule should occur among pelagic species, and yet there are four known species of these *Rhizota* that cut loose and become sailors. Mr. H. S. Jennings has found three of them in St. Clair and lakes of Michigan. Of this one he says: "Very common in towings from Lake St. Clair, either at the surface or near the bottom. Hudson and Gosse, I, 56.

2. *Œcistes brachiatus* Hudson. A large number were found, but it was impossible to identify them surely. The tube conforms to the figures and descriptions of that of *Brachiatus;* it is cylindrical, smooth, compact, perfectly hyaline,

often containing a slight amount of adhering matter, often containing several eggs, which, however, are not so elongate as the figures represent those of *Brachiatus;* the long narrow foot and the long non-retractile antennæ agree well with the type. I am pretty confident that it is *Brachiatus*, yet I am surprised to find so many of them, or any of them, in a surface tow, as it is evidently normally anchored; perhaps they were attached to floating algæ which apparently are not uncommon in the lake. H. and G., I, 83.

3. *Philodina megalotrocha* Ehrenberg. Numerous. I have often taken it at a distance from land, particularly in shallow lakes or among floating algæ. H. & G., I, 101.

More than one species of *Rotifer* which could not by any means be identified were present.

4. *Sacculus viridis* Gosse. Rare. H. and G., I, 124.

5. *Polyarthra platyptera* Ehrenberg. Many seen. The serrations on the edges of the broad plates are coarse and more distant than in the type. H. and G., II, 3.

6. *Dinocharis pocillum* Ehrenberg. One individual. It is a bottom feeding species and rarely occurs in a surface tow. H. and G., II, 71.

7. *Dinocharis collinsii* Gosse. One. Bottom feeding species. It has not been observed in this country before. No species exceeds it in beauty. I could not make out the pair of spines on the foot and the edge of the lorica appears to be set with a row of small spines, rather than being serrate as described and figured. H. and G., II, 72.

8. *Anuræa cochlearis* Gosse. Exceedingly abundant. Our form differs slightly from Gosse's figure since the mesal ridge of the lorica does not extend straight from end to end, but has a decided angle at each pair of facets, the anterior median one is not divided. H. and G., II, 124.

9. *Notholca longispina* Kellicott. Not rare. This rotiferon was first known in the water supplies of cities along the Great Lakes. Soon after it was described in 1879, it was found in Olton Reservoir, Eng., and then by Imhof in the Swiss Lakes. More recently it has been found in lakes of America. Mr. Levic reports finding the eye spot double, or so far separated as to be regarded as two eyes. I have seen several in these collections with the same peculiarity.

II.

1. *Polyarthra platyptera* Ehrenberg. Few.

2. *Triarthra longiseta* Ehrenberg. Comparatively few in this vial. H. and G., II, 6.

3. *Ploesoma lenticulare* Herrick. Very many. It occurs in the lakes of Europe. In this country it has been reported only from Lake St. Clair, both in bottom and surface tows (Jennings). Zoöl. Anz., Bd. 10, 577.

4. *Brachionus militaris* Ehrenberg. Rare. I have found this an abundant species in ponds of western New York; it is a good sailor, preferring small seas, however. Authors have recorded the fact that the posterior spines are not in the same horizontal plane. This seems to be in relation to the habit of always turning on its long axis as it swims; they appear to bore their way through the water H. and G., Sup. 82.

5. *Anuræa cochlearis* Gosse. Many, but far less numerous than in I.

6. *Notholca longispina* Kellicott. More abundant than in I.

III.

1. *Asplanchna priodonta* Gosse. Quite numerous. Jennings reports this fine species as abundant in Lake St. Clair, both at the surface and in deep water. H. and G., I, 123.

2. *Polyarthra platyptera* Ehrenberg. Several found.

3. *Triarthra longiseta* Ehrenberg. Numerous.

4. *Diaschisa valga* Gosse. Only one seen. It appears to agree well with the figure and description. H. and G., II, 77.

5. *Anuræa cochlearis* Gosse. Not common.

6. *Notholca longispcia* Kellicott.

CLADOCERA. A. BIRGE.

The following letter on the *Cladocera* of Turkey Lake has been received:

I enclose list of *Cladocera* in your bottles.

1. *Holopedium gibberum Zad.*, few; *Daphnia hyalina and retrocurva* Forbes. Much *algal* material, chiefly *Clathrocystis.*

2. *Holopedium gibberum D. retrocurva Sida. crystallina O. F. M.*, *Diaphanosoma brachyurum* Liev.

3. *D. retrocurva*, extreme form of hemlet, like that of Lake Mendota, *Diaph. brachyurum.* Material looks as if it had been dried.

4. *D. retrocurva Diaph. brachyurum Ceriodaphnia lacustris* Birge. *Leptodora hyalina Lillj.*, *Holopedium gibberum*, one specimen.

5. *Diaph. brachyurum*, *Sida crystallina*, *Cer. lacustris.*

6. *Holo. gibberum*, *Diaph. brachyurum*, *D. retrocurva*, *Algae* like No. 1.

7. *Diaph. brachyurum*, *D. retrocurva*, *Cer. lacustris*, *Leptodora hyalina.*

Great number of *Epischura lacustris*, far more than I ever saw before.

8. *D. retrocurva*, *Sida crystallina*, *Diaph.*, *brachyurum.*

9. *Diaph. brachyurum*, *D. retrocurva*, not an extreme form, *Daphnia longiremis* Sars, *Sida crystallina*, very few.

Most of these species are predictable, that is, they would be found in almost any pelagic collection from this general region. I do not think that *H. gibberum* has been found so far south as this collection shows it. *Cer. lacustris* has not been found outside of Wisconsin before. The specimens are much more thin-shelled than those which I have seen before. It is remarkable that *D. retrocurva* is far more numerous than is *D. hyalina.* The reverse has been true in all lakes which I have studied, except Pine Lake, Wisconsin. In most of the bottles examined it was difficult to find *D. hyalina*, while the other species was quite plenty. It is to be noted that this species of Forbes is really a variety of *D. kahlbergiensis* Sch, but as the form is well marked and the full name intolerably long, I have quoted it by the varietal name only.

D. longiremis has been found before only in Lake Geneva, Wisconsin. In size, form and shape of head it exactly agrees with my figures and description in Trans. Wis. Acad.; Vol. IX, p. 299, pl. XI, figs. 4-10.

In all bottles there were many *Cyclops* and *Diaptomus*, and in one, as already noted, large numbers of *Epischura.*

I should gladly write more, but have been too busy for a longer report. Will send bottles to Marsh for Copepods and try to get up a full account later.

Very truly,

E. A. Birge.

Data of the lots of specimens numbered in the above letter:

I. Taken Aug. 28, 1895, between 1 and 2 P. M., from surface of water. Killed in picro-sulphuric acid. Preserved in 70 per cent. alcohol.

II. Taken June 27, 1895, at 8 A. M. Skimmed from surface of water, using No. 2 Bolting Cloth. Killed in picro-sulphuric acid. Preserved in 70 per cent. alcohol.

III. Taken Aug. 14, 1895, at 5 P. M. Depth of haul, 60 ft. Killed in picro-sulphuric acid. Preserved in 70 per cent. alcohol.

IV. Taken July 27, 1895. Skimmed from surface of water, using No. 2 Bolting Cloth. Killed and preserved in 10 per cent. formalin.

V. Taken June 27, 1895, at 8 A. M. Skimmed from the surface with a No. 2 Bolting Cloth net. Killed and preserved in 10 per cent. formalin.

VI. Taken July 29, 1895. Depth of haul, 25 ft. Killed and preserved in formalin.

VII. Taken July 12, at night. Surface skimming, using a No. 2 Bolting Cloth net. Killed and preserved in 10 per cent. formalin.

VIII. Taken Aug. 1, 1895, at 9 A. M. Depth of haul, 10 ft. Killed in Flemming's fluid. Preserved in 70 per cent. alcohol.

IX. Taken Aug. 7, 1895, at 4 P. M. Depth of haul, 110 ft. Killed in Flemming's fluid. Preserved in 70 per cent. alcohol.

I, II, III, IV, V, VI, VII, VIII are from Turkey Lake or Lake Wawasee; IX is from Tippecanoe Lake.

DECAPODA.

The following crayfishes from Turkey Lake were identified by Mr. W. P. Hay, of Washington, D. C.:

Cambarus blandingii acutus Girard.

Cambarus propinquus Girard.

Cambarus virilis Hagen.

ON A SMALL COLLECTION OF MOLLUSKS FROM NORTHERN INDIANA. BY R. ELLSWORTH CALL, M. D., PH. D.

The mollusks herewith reported on were collected by the members of the Indiana University Biological Station during the past summer. The region is sufficiently well characterized in the report of Dr. Eigenmann, the Director of the Station, and it is necessary here only to allude to its salient features.

The locality is on the divide separating the drainage areas of the Great Lakes and the Wabash River. In certain places the two drainages are practically identical and thus afford opportunity for the intermingling of the two faunas. The lakes and streams are all well within the limit of glaciation in former ages and their beds and shores are boulder-covered or lined. The bottoms of shallower portions of the lakes are gravelly or muddy, while the deeper portions are either muddy or sandy. Corresponding with these physical factors are certain features of molluscan distribution and modification, which it is the object of these notes to adduce and emphasize.

UNIONIDÆ.

Anodonta decora Lea. Two specimens of this form were found, both of which were obtained in Syracuse Lake. The specimens were very much more fragile and far thinner than is usual for this species, even when secured from lakes and ponds. The epidermis is quite pale, the lines of growth crowded, and the nacreous deposit very white. Forms from sluggishly flowing streams in southern Indiana and elsewhere in the Ohio basin are very highly colored, both interiorly and without. As in other members of this family from these lakes the optimum habitat does not appear to be here. Many of the shells are coated with heavy deposits of calcareous matter, indicating a chemic condition of the water that is unfavorable to the normal development of the several species.

Anodonta ferussaciana Lea. One specimen from Turkey Creek; three specimens from Syracuse Lake.

The resemblance of these shells to the *Anodonta subcylindracea* is very marked indeed. The lake form is lighter both in texture and color than the one specimen from the creek.

Anodonta footiana Lea. Three specimens from Syracuse Lake; one specimen from Turkey Creek.

The shells submitted are very characteristic of this form, which may not, ultimately, be separated from *Anodonta lacustris* Lea. Like its congeners from the same locality the lake form is very pale in color and unusually thin and fragile. A very interesting fact is illustrated in the littoral distribution of this species and *Sphærium* from the same lake. Those which occur in comparatively deep water are very much thinner and lighter in color than the shore forms. Also, those which are found on the northern shores are thinner and more fragile than those on the southern beach. The reason possibly may lie in the prevailing winds, which are from the northeast. The southern beach is also more gravelly than the northern. The conditions of environment then, in this case, favor thicker development of the shell in the forms living on the southern beach; they need greater powers of resistance, are subjected to rougher conditions of habitat and this finds expression in heavier secretion of nacreous material. The shells which live at the lake's bottom are also beyond the disturbing influence of waves and being deeply imbedded in mud develop to greater size, but with thinner shells.

Margaritana calceola Lea. A single dead specimen, from Turkey Creek.

This specimen is a very characteristic one, the deposit of calcareous matter on the inner surfaces of the valves being marked; this is a pathologic feature, well marked in the type specimens which Dr. Lea studied. This form and *Margaritana deltoidea* Lea are synonyms.

Margaritana rugosa Barnes. Represented by eight specimens from Turkey Creek, all of which are characteristic.

Unio coccineus Lea. One specimen, dead, from Turkey Creek.

The nacre of this shell is quite white, a fact true of the majority of shells which fall under this form, though the type-form was beautifully pink. It is often found in collections labelled *Unio rubiginosus* Lea, but is easily separated by the characters of the cardinal teeth and the rounded, nonangulate character of the posterior slope. In *Unio rubiginosus* there is a well marked ridge extending quite to the posterior margin. The flat and white nacred form also may occasionally be seen in collections as *Unio gouldianus* Lea, now a well recognized synonym.

Unio fabalis Lea. Twelve specimens from Tippecanoe Lake.

This is one of the smallest of our *Unios*. The shells submitted do not present any variant features other than the very light coloration so characteristic of all the lake shells which we have seen. *Unio lapillus* Say is a synonym.

Unio gibbosus Barnes. This form is represented by three specimens from Turkey Creek. These are all much thinner and lighter than the same species from the Ohio and Wabash rivers, in both of which it is a common shell. It seems to be very abundant in certain of the lakes of northern Indiana, notably Lake Maxinkuckee. The nacre of these three individuals is very dark purple. Similar shells to these probably have led to the reference of *Unio complanatus* Solander to the western fauna.

Unio iris Lea. Two characteristic specimens from Turkey Creek. Like its near relative—which is probably also a synonym—*Unio novieboraci* Lea, this shell occurs most commonly and abundantly in creeks and other small streams. It most affects soft muddy bottoms in rather still waters.

Unio luteolus Lamarck. Ten specimens from Syracuse Lake; seven specimens from Turkey Creek.

This species is the most widely distributed shell of the family. It occurs in every stream, lake and pond in Indiana in which shell life of any sort occurs at all. It is also the most abundant *Unio*, and, correlated with abundance and wide distribution, is a range of variations that are of the greatest import in evolutionary processes. All the shells submitted, particularly those from Syracuse Lake, are well covered, posteriorly, with carbonate of lime in heavy masses. The lake specimens also have beautifully marked green rays widely separated over a polished disk, thus constituting them the form to which Anthony gave the name of *Unio distans*. The epidermis usually has the peculiar coloration of forms which live in muddy bottoms, though in the lake specimens the epidermis is, for some hidden chemical reason, quite red posteriorly. This peculiar coloration has often been noticed in shells submitted to us from the lake region of Northern Indiana.

Unio occidens Lea. Nine characteristic specimens from Turkey Creek. None present features different from shells found elsewhere in the State.

Unio pressus Lea. One specimen from Turkey Creek.

A great many shells of this species have been seen from time to time from various places in Indiana. Very many of them, as this one well does, present a peculiar diseased or pathologic condition of the cardinal teeth not altogether unlike the condition exhibited by the interior surface of *Margaritana calceola*. In this instance the cardinal teeth are nearly destroyed and are represented by distorted and imperfect vestiges. It would be interesting indeed if the Station, during the next season, could investigate this phenomenon as a study in the physiology of *Unio*, a field yet uncultivated.

Unio rubiginosus Lea. Two specimens from Turkey Creek, one of which is pathologic.

These shells are intermediate between *Unio trigonus* Lea and typical *Unio rubiginosus* Lea. They are somewhat more trigonal than the latter shells are commonly found, and, on the other hand, are less heavy and trigonal than the ponderous river form. The whole group is sadly confused and needs painstaking revision.

CORBICULADÆ.

Sphærium rhomboideum Prime. A single specimen only was taken, from Turkey Lake, in muddy bottom and in comparatively deep water. The specimen is very much thinner than usual.

Sphærium solidulum Prime. Ten specimens from Turkey Lake. These are all smaller than common and quite heavy; they came from the beach at Vawter Park.

FRESH-WATER UNIVALVES.

Amnicola porata Say. Eight specimens of this small univalve were obtained in Tippecanoe Lake. Neither it nor others of the univalves found present any characters different from shells found in streams throughout the State.

Campeloma decisum Say. Five dead specimens from Turkey Lake.

Campeloma integrum Dekay. One dead specimen from Turkey Creek.

Campeloma rufum Haldeman. About twenty specimens from Tippecanoe Lake; thirteen, one of which was reversed or sinistral, from Turkey Creek.

There is no difficulty in recognizing these several forms, though tyros annually make the discovery that there are no valid species but one. *Campeloma rufum* differs from both the others constantly by the outlines of the whorls, the shape and color of the aperture, the pink character of the apical whorls, a feature which is best illustrated in the very young and which is a constant character, and in the polished epidermis, which presents a character seen in no other member of the genus. Reversed forms are not uncommon, but yet may be justly considered rare. The type of the genus is a reversed specimen of *Campeloma ponderosum* from the Ohio River, taken by Rafinesque near Louisville, Ky.

Planorbella campanulata Say. Very abundant in all parts of Tippecanoe Lake.

Helisoma trivolvis Say. Two specimens from Turkey Lake; three specimens from Turkey Creek. The form submitted from Turkey Creek is a very large one, and is rather heavy in texture. The species must be very abundant in favorable localities.

Limnophysa humilis Say. Five specimens of this small limnæid were obtained along the shores of Turkey Lake.

Limnophysa caperata Müller. A single specimen of this common form only was secured. It came from Turkey Lake.

Physa ancillaria Say. Four specimens taken alive, entirely white, from Turkey Lake. This shell is usually honey yellow in coloration, but these specimens were a snow white.

Physa gyrina Say. Only two specimens of the "tadpole" physa appear in the collections, and these came from Tippecanoe Lake. It is one of the most widely distributed and most abundant of the Limnæidæ.

Goniobasis pulchella Anthony. Nine specimens from Turkey Lake; very abundant in Tippecanoe Lake, from which many dead specimens were submitted. This form is widely distributed throughout Indiana. Sometimes associated with it is *Goniobasis livescens* Menke, a form decidedly characteristic of the lake drainage.

Pleurocera subulare Lea. Very abundant in Lake Tippecanoe, from which many dead examples were seen.

Valvata tricarinata Say. A single specimen from Tippecanoe Lake.

LAND MOLLUSCA.

Limax campestris Binney. Four specimens of this widely distributed form were obtained from Vawter Park.

Succinea obliqua Say. This species is represented by ten alcoholic specimens. All taken at Vawter Park.

Zonites arboreus Say. Three alcoholic specimens from Vawter Park.

None of the univalves present features worthy of special mention. The whole collection is rather the result of incidental work than of careful collecting, and is to be taken as somewhat indicative of the wealth of molluscan life in favored localities in Indiana. It is submitted as a local contribution, in the form of a special report, that may help to a general knowledge of Indiana mollusks. Cincinnati, Ohio, November 3, 1895.

The Odonata. By D. S. Kellicott.

I received for identification last fall two small collections of Dragonflies from Professor Eigenmann. They have been studied and compared with a determined collection; the following species were included:

1. *Calopteryx maculata* Beauv. It occurs throughout the Eastern United States and is usually abundant wherever it is found, preferring shady streams or rivulets of spring water.

2. *Heterina americana* Fabr. Several examples of both sexes. This species extends over a wide eastern range and is represented in the Gulf States by a well marked form known in the lists as *H. basalis*, and on the Pacific Slope by another, *H. Californica*. Flies late, often until the middle of October, in Ohio. The scarlet patches at the base of the wings of the male make it a beautiful and conspicuous insect.

3. *Enallagma hageni* Walsh. This appears to be a rare species, but has now appeared in Illinois, Indiana and Ohio.

4. *Enallagma signatum* Hagen. Extends from the Gulf to Maine.

5. *Æschna clepsydra* Say. Two males and one female (?) were sent. All the *æschnas* fly late in the season. The three species *constricta, clepsydra* and *verticallis* resemble one another so closely that they are often regarded as one species; the females can not be separated by any one as yet.

6. *Anax junius* Drury.

7. *Tramea lacerata* Hagen.

8. *Libellula basalis* Say.

9. *Libellula pulchella* Drury.

10. *Plathemis trimaculata* DeGeer.

11. *Celithemis eponina* Drury.

12. *Diplax vicina* Hagen. This is doubtless the last odonat on the wing in our latitude. In central Ohio it has been taken pairing and ovipositing as late as November 8.

13. *Mesothemis simplicollis* Say.

14. *Pachydiplax longipennis* Burm.

I am surprised at the absence of all Gomphines and that so few Agrionines are present. Collecting in the early summer would doubtless disclose several species of both groups.

Fishes. By C. H. Eigenmann.

Fishes were collected in much larger numbers than any of the other vertebrates. They will form the subject of our most extented study of variation. I present here simply a few dates on the spawning time and the distribution of the various species in the localities examined. Half of these localities are on the St. Lawrence side of the divide; the other half on the Mississippi side. To show the relation of the fauna to that of the State I present a complete list of Indiana fishes.

SPAWNING SEASONS.

Most of the fishes spawn in the spring before the Station opened. This was true of all the larger species except a few stragglers of *Lepomis pallidus*.

Noturus flavus. This species is common under boards and logs in Turkey Creek, at Syracuse. Eggs were found in all stages of development the latter half of June. They are laid in little depressions in the gravel under boards, and are apparently watched by the adult. The eggs adhere to each other in masses large enough to fill the hollow of the hand. The eggs are very flabby, the membrane being not tense, as usual in fish eggs. After hatching the young remain together in the nest, and if they are uncovered by raising the board they quickly scatter to hide under another object or under the board again if this has been turned over. The blastoderm forms a narrow nodule well separated from the yolk by a deep constriction.

Pimephales notatus. The eggs of this species are laid on the under surface of various objects submerged in the margin of the lake to a depth of one or two feet. The fish is usually found with the nest, and the immediate neighborhood of the nest is kept clean of weeds and mud. The eggs were found during the whole of June and the greater part of July. The young swim near the surface and are very abundant the latter half of June.

Fundulus diaphanus menona. On June 24 eggs of this species were dragged up by the seine from the grass of the bottom. They are bound together by filaments.

Zygonectes notatus. Many taken on June 27 in Turkey Creek were with ripe eggs.

Etheostoma caprodes. This species was spawning on May 30, a single ripe female was taken about June 25.

	St. Lawrence Basin.						Mississippi Basin.					
	String Lake.	Turkey Creek (Upper).	Turkey Lake.	Channel.	Syracuse Lake.	Turkey Creek (Below Dam).	Webster Lake.	Webster Lake (Below Dam).	Tippecanoe Lake.	Tippecanoe River (Above Dam).	Tippecanoe River (Below Dam).	Shoe Lake.
Ammocœtes branchialis L. Brook Lamprey						†						
Ichthyomyzon concolor Kirkland												
Polyodon spathula Walbaum. Spoon-bill Cat									†			
Scaphirhynchus platyrhynchus Raf. Shovel-nosed Sturgeon												
Acipenser rubicundus Le Sueur. Lake Sturgeon												
Lepisosteus osseus L. Common Gar Pike			†		†				†			
Lepisosteus platystomus Rafinesque. Short-nosed Gar-pike			†									
Lepisosteus tristœchus Bloch and Schneider. Alligator Gar												
Amia calva L. Bow-fin, Mud-fish, Dog-fish		†	†	†	†				†			
Ictalurus furcatus Le Sueur. Chuckle-headed Cat												
Ictalurus punctatus Rafinesque. Channel Cat												
Ameiurus lacustris Walbaum. Great Cat-fish												
Ameiurus natalis Le Sueur. Yellow Cat	†		†			†	†	†	†	†	†	
Ameiurus nebulosus Le Sueur. Common Bull-head, Horned Pout									†			
Ameiurus melas Rafinesque												
Leptops olivaris Rafinesque. Mud Cat												
Noturus flavus Rafinesque						†						
Schilbeodes exilis Nelson												
Schilbeodes miurus Jordan												
Schilbeodes eleutherus Jordan												
Schildeodes gyrinus Mitchill	†		†	†		†						
Schilbeodes nocturnus Jordan and Gilbert												
Ictiobus cyprinella Cuv. and Val. Common Buffalo Fish												
Ictiobus urus Agassiz. Razor-backed Buffalo												
Ictiobus bubalus Rafinesque. Sucker-mouthed Buffalo												
Carpiodes carpio Rafinesque												
Carpiodes difformis Cope												
Carpiodes velifer Rafinesque. Quill-back												
Cycleptus elongatus Le Sueur. Black Horse												
Catostomus catostomus Foster. Northern Sucker												
Catostomus commersoni Lacépède. Common Sucker, White Sucker		†				†						

	St. Lawrence Basin.						Mississippi Basin.					
	String Lake Creek.	Turkey Creek (Upper).	Turkey Lake.	Channel.	Syracuse Lake.	Turkey Creek (Below Dam).	Webster Lake.	Webster Lake (Below Dam).	Tippecanoe Lake.	Tippecanoe River (Above Dam).	Tippecanoe River (Below Dam).	Shoe Lake.
Catostomus nigricans Le Sueur. Hog Sucker						†						
Erimyzon sucetta oblongus Mitchill. Ch		†	†	†		†	†	†	†	†	†	
Minytrema melanops Rafinesque. Striped Sucker						†						
Moxostoma anisurum Rafinesque. White-nose Sucker												
Moxostoma aureolum Le Sueur												
Moxostoma breviceps Cope.												
Placopharynx duquesnii Le Sueur												
Lagochila lacera Jordan and Brayton. Hare-lip Sucker												
Compostoma anomalum Rafinesque. Stone Roller						†						
Chrosomus erythrogaster Rafinesque. Red-bellied Minnow												
Hybognathus nuchalis Agassiz												
Pimephales promelas Rafinesque												
Pimephales notatus Rafinesque			†			†		†	†			†
Cliola vigilax Baird and Girard. Bull-head Minnow												
Notropis anogenus Forbes			†									
Notropis bifrenatus Cope			†			†						
Notropis heterodon Cope			†	†		†	†	†	†			
Notropis microstomus Rafinesque			†									
Notropis cayuga Meek												
Notropis boops Gilbert												
Notropis hudsonius Clinton. Spawn-eater									†			
Notropis whipplei Girard. Silver-Fin												
Notropis megalops Rafinesque. Common Shiner		†	†			†	†	†	†	†	†	
Notropis jejunus Forbes												
Notropis ariommus Cope												
Notropis ardens Cope. Red-fin												
Notropis atherinoides Rafinesque												
Notropis arge Cope												
Notropis dilectus Girard												
Notropis rubrifrons Cope												
Ericymba buccata Cope												
Rhinichthys atronasus Mitchill												
Hybopsis dissimilis Kirtland												
Hybopsis amblops Rafinesque												
Hybopsis storerianus Kirtland												

	St. Lawrence Basin.						Mississippi Basin.					
	String Lake.	Turkey Creek (Upper).	Turkey Lake.	Channel.	Syracuse Lake.	Turkey Creek (Below Dam).	Webster Lake.	Webster Lake (Below Dam).	Tippecanoe Lake.	Tippecanoe River (Above Dam).	Tippecanoe River (Below Dam).	Shoe Lake.
Hybopsis watauga Jordan and Evermann												
Hybopsis kentuckiensis Rafinesque. Horny Head, River Chub, Jerker		†				†		†		†		
Hybopsis hyostom Gilbert												
Semotilus atromaculatus Mitchill. Horned Dace, Creek Chub		†				†		†				
Phoxinus elongatus Kirtland												
Opsopœodus emiliæ Hay												
Notemigonus chrysoleucus Mitchill			†	†			‡	†	†			
Hiodon alosoides Rafinesque												
Hiodon tergisus Le Sueur. Moon-eye												
Clupea chrysochloris Rafinesque. Skip-jack												
Dorosoma cepedianum Le Sueur. Gizzard Shad												
Coregonus quadrilateralis Richardson												
Coregonus clupeiformis Mitchill												
Coregonus labradoricus Richardson												
Coregonus hoyi Gill												
Coregonus artedi Le Sueur												
Coregonus artedi sisco Jordan									†			
Salvelinus namaycush Walbaum. Trout												
Percopsis guttatus Agassiz. Trout Perch												
Amblyopsis spelœus De Kay. Blind Fish												
Typhlichthys subterraneus Girard												
Fundulus diaphanus menona Jordan and Copeland			†									
Zygonectes notatus Rafinesque. Top Minnow		†				†					†	
Zygonectes dispar Agassiz								†	†		†	
Gambusia patruelis Baird and Girard. Top Minnow												
Umbra limi Kirtland. Mud-minnow, Dog-fish	†						†	†		†		
Lucius vermiculatus Le Sueur. Little Pickerel	†	†	†	†	†	†	†	†	†	†	†	†
Lucius lucius L. Pike, Northern Pickerel												
Lucius masquinongy Mitchill. Muskallunge												
Anguilla anguilla rostrata Le Sueur. Eel												
Pygosteus pungitius L. Nine-spined Stickleback												
Eucalia inconstans Kirtland. Brook Stickleback												
Labidesthes sicculus Cope. Brook Silverside			†	†	†	†			†			
Aphredoderus sayanus Gilliams. Pirate Perch	†					†						

	St. Lawrence Basin.						Mississippi Basin.					
	String Lake.	Turkey Creek (Upper).	Turkey Lake.	Channel.	Syracuse Lake.	Turkey Creek (Below Dam).	Webster Lake.	Webster Lake (Below Dam).	Tippecanoe River.	Tippecanoe River (Above Dam).	Tippecanoe River (Below Dam).	Shoe Lake.
Centrarchus macropterus Lacépède	..	..	..	..	..	..	..	..	..	..	..	..
Pomoxis sparoides Lacépède. Calico Bass	..	..	†	..	..	..	..	..	..	..	..	..
Pomoxis annularis Rafinesque. Crappie	..	..	..	..	..	..	..	..	..	..	..	..
Ambloplites rupestris Rafinesque. Rock Bass, Red Eye	..	..	†	†	..	†	..	†	†	..	..	..
Chaenobryttus gulosus Cuv. and Val. War Mouth	..	..	†	†	..	..	†	...	†	†	..	†
Lepomis cyanellus Rafinesque. Green Sunfish	..	..	†	..	..	†	..	†	..	..	†	..
Lepomis macrochirus Rafinesque	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis humilis Girard	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis pallidus Mitchill. Blue Sunfish	..	..	†	..	..	..	..	†	†	†	†	†
Lepomis megalotis Rafinesque	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis garmani Forbes	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis euryorus McKay	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis heros B. and G. McKay	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis notatus Agass. McKay	..	..	..	..	..	..	..	..	..	..	..	..
Lepomis gibbosus L. Common Sunfish	..	..	†	†	..	..	..	†	†	†	†	†
Micropterus dolomieu Lacépède. Small-mouthed Black Bass	..	..	†	..	..	†	..	..	†	†	..	..
Micropterus salmoides Lacépède. Large-mouthed Black Bass	..	†	†	..	..	†	..	†	†	†	†	†
Etheostoma pellucidum Baird. Sand Darter	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma asprellus Jordan	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma nigrum Rafinesque. "Johnny"	..	..	†	..	..	†	..	†	†	†	..	†
Etheostoma chlorosoma Hay	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma blennioides Rafinesque. Green-sided Darter	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma coplandi Jordan	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma histrio Jordan and Gilbert	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma shumardi Girard	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma uranidea Jordan and Gilbert	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma caprodes Rafinesque. Log Perch, Hog-fish	..	..	†	..	..	†	†	†	†	..	..	..
Etheostoma macrocephalum Cope	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma ouachita Jordan and Gilbert	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma aspro Cope and Jordan	..	..	..	..	..	†	..	†	†	..	..	..
Etheostoma phoxocephalum Nelson	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma scierum Swain	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma evides Jordan and Copeland	..	..	..	..	..	..	..	..	..	..	..	..
Etheostoma variatum Kirtland	..	..	..	..	..	..	..	..	..	..	..	..

	St. Lawrence Basin.						Mississippi Basin.					
	String Lake.	Turkey Creek (Upper.)	Turkey Lake.	Channel.	Syracuse Lake.	Turkey Creek (Below Dam).	Webster Lake.	Webster Lake (Below Dam).	Tippecanoe Lake.	Tippecanoe River (Above Dam).	Tippecanoe River (Below Dam).	Shoe Lake.
Etkeostoma zonale Cope												
Etheostoma camurum Cope												
Etheostoma maculatum Kirtland												
Etheostoma flabellare Rafinesque								†				
Etheostoma squamiceps Jordan												
Etheostoma tippecanoe Jordan and Evermann												
Etheostoma iowæ Jordan and Meek			†			†	†	†	†			†
Etheostoma cœruleum Storer. Rainbow Darter						†		†		†		
Etheostoma cœruleum spectabile Agassiz												
Etheostoma jessiæ Jordan and Brayton												
Etheostoma fusiforme Girard												
Etheostoma eos Jordan and Copeland												
Etheostoma microperca Jordan and Gilbert			†							†	†	
Perca flavescens Mitchill. Yellow Perch		†	†	†	†	†	†	†	†	†	†	†
Stizostedion vitreum Mitchill. Wall-eye												
Stizostedion canadense C. H. Smith. Sauger, Sand Pike												
Roccus lineatus Bloch. Striped Bass												
Roccus chrysops Rafinesque. White Bass									†			
Morone interrupta Gill. Yellow Bass												
Aplodinotus grunniens Rafinesque. Fresh Water Drum												
Cottus ricei Nelson												
Cottus bairdi Girard. Miller's Thumb											†	
Cottus pollicaris J. and G												
Cottus hoyi Putnam												
Lota lota maculosa Le Sueur. Burbot												

BATRACHIA. By CURTIS ATKINSON.

Siren lacertina Linnaeus. A single specimen of this species was taken in the seine in the channel. Mr. Dolan secured another late in September, and afterwards, through his students, secured a nest of eleven, which were uncovered while cleaning a lot near Syracuse. These had evidently gone into winter quarters. Five of them are still alive. Turkey Lake is the most northern locality so far recorded for the siren.

Necturus maculatus Rafinesque. Three specimens of this species were secured. It is said to be abundant, but no other specimens were noted. On June 28, a number of eggs were found fastened to the lower surface of a board, which was well imbedded in the mud of the bank of Turkey Creek. The young were already quite active in the loose, flabby bags forming their covering.

Amblystoma jeffersonianum Green? A single specimen under a log near the lake.

Bufo lentiginosus Shaw. The ubiquitous toad was present, but not in great numbers at Syracuse, Turkey and Tippecanoe lakes.

Acris gryllus crepitans Baird. Abundant along the shallow margins of the lake among rushes and lillypads. Detailed localities where it was taken are outlet of String Lakes, Turkey Lake, Syracuse Lake, Turkey Creek, Webster and Tippecanoe Lakes and Tippecanoe River.

Rana virescens Kalm. Very abundant and variable. I am not at all certain that the varieties described by Cope and Hay are to be found among our material, but it seems quite certain that there is no correlation in the variations of different parts of the body. If varieties are to be distinguished it must be by separating them on single characters.

I have made measurements of a number of characters to determine whether the 120 specimens collected could be grouped according to any of these.

The relation of the tibia in the length of the body gave the length of the tibia .55 that of the body as the most common relation between the parts.

From this there is a gradual reduction to a length of .49 on the one hand and an increase to .70 on the other. But .20 of the specimens had the tibia with the most common length. This character is then perfectly useless in separating varieties in my specimens.

The same may be said of the length of the head in the length of the body, .33 is the relation occurring oftenest and from this there is a variation to .20 on one hand and .27 on the other; .20 of all the specimens have the length of the head .33 of the length of the body.

The relation of the fifth toe to the length of the third toe gave a very jagged curve with the length of the fifth toe .95 of the length of the third as the condition occurring in .20 of the specimens. From this a very irregular curve extends to .89 on one side and to 1.00 on the other.

The relation of the diameter of the tympanum to the diameter of the eye gave the most irregular curve. Thirty-five per cent. of all the specimens had a tympanum with a diameter equal to .60 of that of the eye. From this we have a saw-toothed curve to .48 on one side and .70 on the other. A comparatively large per cent.—15 per cent.—have a relation of .50. Attempts to get system out of this curve by breaking it up into age curves did not succeed entirely. But these separate curves for the different ages show that in the young the tympanum is comparatively small, and that the peak noted at the .50 mark is due to the young included in the general curve.

The whole study emphasized the fact that there is little or no coördination in the variation in this frog. No two characters, in fact, seem to vary together and all the specimens may be referred to but one variety.

I have in the following grouping, in the shape of the conventional key, separated the specimens according to their color patterns. All but one or two of the combination of patterns contains individuals which have the vomerine patches of teeth forming a straight line, and others with these patches inclined to each other at a more or less distinct angle. They clearly show that there is no coördination in the different parts of the color pattern. Each region varies apparently independently of the others.

KEY TO THE COLOR PATTERNS.

a. A spot on the nose.
 b. Two complete series of spots on the back.
  c. Two cross bars on the femur.
   d. Tibia with a mixture of spots and bars. 5 specimens.
 bb. Two complete series of spots on the back, with a third broken series between.
  e. Two cross bars on the femur.
   f. Tibia, with a mixture of spots and bars. 16 specimens.
   ff. Tibia, with a row of spots on the anterior and another on the posterior edge, upper surface unspotted. 1 specimen.
  ee. Three cross bars on the femur.
   g. Tibia, with a mixture of spots and bars.
    h. Spots on back, many and small. 21 specimens.
    hh. Spots on back, few and large. 13 specimens.

gg. Tibia, with a row of spots on the anterior and another on the posterior edge, upper surface unspotted. 9 specimens.

eee. Four or five cross bars on femur.

i. Tibia, with a mixture of spots and bars. 16 specimens.

ii. Tibia, with a row of spots on the anterior and another on the posterior edge, upper surface unspotted. 2 specimens.

aa. No spot on the nose.

j. Two series of spots on the back.

k. Two cross bars on femur. Tibia, with a mixture of spots and bars. 4 specimens.

kk. Three cross bars on the femur. Tibia, with a mixture of spots and bars. 4 specimens.

kkk. Irregular number of cross bars on femur, always more than three.

l. Tibia, with a mixture of spots and bars. 2 specimens.

ll. Tibia, with a row of spots on the anterior and posterior edge, upper surface unspotted. 2 specimens.

jj. Two complete series of spots on the back, with a third broken series between them.

m. Two cross bars on the femur. Tibia, with a mixture of spots and bars. 4 specimens.

mm. Three cross bars on the femur.

n. Tibia, with a mixture of spots and bars. 11 specimens.

nn. Tibia, with a row of spots on the anterior and another on the posterior edge, upper surface unspotted. 4 specimens.

mmm. Four or five cross bars on the femur.

o. Tibia, with a mixture of spots and bars. 1 specimen.

oo. Tibia, with a row of spots on the anterior and another on the posterior edge, upper surface unspotted. 4 specimens.

String Lakes, Upper and Lower Turkey Creeks, Turkey, Webster and Tippecanoe Lakes.

Rana palustris LeConte. One at the String Lakes, one at Turkey Lake, five at Tippecanoe Lake.

Rana sylvatica LeConte. A single specimen at Turkey Lake.

Rana clamata Daudin. Abundant at Upper and Lower Turkey Creek, Turkey and Tippecanoe Lakes.

Rana catesbiana Shaw. Abundant among lily pads, especially in parts of the lake not frequently visited. Turkey and Tippecanoe Lakes.

Snakes of Turkey Lake. By G. Reddick.

The number of specimens of snakes taken amount to about 225. They belong to five genera and eight species.

Bascanion constrictor Linn. is common around Turkey Lake and is the largest of the snakes found here. This snake is of course no part of the lake fauna. This snake was also taken at Lake Tippecanoe.

Eutainia sirtalis Linn. is very abundant along the margin of the lake, feeding on frogs and fish. One specimen was secured with a cat-fish spine sticking through the body wall of the snake.

Young taken from this snake July 17 averaged a slight fraction over seven inches in length and were almost grown, only a very small amount of the yolk being left. These young as soon as they were liberated would try to crawl away, and upon provocation and some without provocation would open their little mouths and flatten their heads and strike as viciously as old snakes.

As high as seventy-two young were taken from one snake, and often from thirty to forty. The average appearing to be between thirty and forty. This snake was also secured from Tippecanoe Lake.

Eutainia saurita Linn. is not nearly so abundant nor is it nearly so prolific. Eggs were taken from only three or four specimens, six being the highest number taken from any one. Specimens of this snake were also taken from the margins of Lake Tippecanoe.

Eutainia butlerii Cope. Only one specimen of this was taken. It was fourteen and one-half inches long. This snake is short and chubby and its movement is very characteristic of it. It does not have the gliding movement of *E. saurita* nor the swift but yet very active movement of *N. sipedon*, but seems rather to exert a large amount of force to do little crawling. The movement is so characteristic that I believe any one, having once seen the peculiar way in which it tries to hurry itself away, would ever after be able to recognize it at a distance. No specimen was taken from Lake Tippecanoe.

Natrix leberis Linn. is rare in Turkey Lake, but common in Lake Tippecanoe. Twelve is the highest number of embryos taken from any one specimen.

Embryos taken August 5 contained a considerable amount of yolk; probably enough to nourish the embryo for a month or more.

Natrix sipedon Linn. is the most abundant of snakes found in this region, but not the most prolific, *E. sirtalis* standing ahead of it. Thirty-four was the highest number of eggs taken from any one specimen. One snake which was kept in confinement gave birth to fourteen young the third week of September.

Among the bullrushes is a favorite abode for this snake, and also under anything whatever that happens to be lying along the margin of the lake, especially if it happens to be lying partly in the water.

Sistrurus catinatus Raf. This snake is very common around Turkey Lake and also around Lake Tippecanoe. Several specimens were secured and others killed. It lives chiefly in the swamps.

A specimen taken August 6 contained five eggs and the embryos were seven inches long.

Storeria dekayi Holb. Only one specimen of this was secured. It was taken along a highway running by the side of a swamp.

TESTUDINATA. BY C. H. EIGENMANN.

Turtles are at all times and everywhere abundant. They frequent especially the shallower portions of the lake. Many specimens of all ages were preserved. The number of variations in the shields is large. I present here simply a list with notes on their abundance and breeding habits.

Chelydra serpentina Linnæus. This species is abundant in Turkey Lake, and reaches a larger size than any of the others. It is caught for the markets. It is much shyer than the other species of turtles and is not frequently seen. It inhabits the shallower muddy parts of the lake, being abundant in the kettle and about Morrison's Island. No eggs were found.

Trionyx spiniferus LeSueur. The soft-shelled turtle is very abundant. It is the second in size and is caught for the markets. Its round eggs are laid in the sand and gravel near the water's edge during June and July. On June 26 one was seen digging a nest in the gravel banks at Syracuse, and on the 27th we obtained eggs from five nests about Ogden Point and other places about the kettle. Other fresh nests were found July 9. The time of hatching was not determined.

Several empty nests were found in July, but some eggs, examined as late as September 1, contained young which would have been ready to hatch about a month later. The number of eggs found in several nests was as follows: 9; 12; 17; 18; 27; 32.

Aromochelys odorata Bosc. This species is abundant, but not conspicuous. Individuals were oftenest seen the latter part of June and first part of July while laying their eggs. The eggs are laid in the rotten wood in the tops of stumps standing in the margin of the lake. The turtles were frequently found in the tops of these stumps, and some of their eggs wedged as far into the rotten wood as a finger could bore. Rotten logs removed some distance from the water are also favorable places for egg laying, and in a mucky place of small area at the edge of the lake 362 eggs were taken at one time. The number of eggs laid by one individual varies from 4 to 7, this number being usually in a cluster. At this rate about sixty turtles must have contributed to the nest of 362. While passing along a wheat field some turtles were seen coming from it, and on inspection it was found that they had deposited their eggs in the ground in depressions made by a cow while walking over the ground when it was soft. Still other eggs were found in bundles of rushes drifted together. An interesting change of habit seems to have taken place among these turtles during the last fifty years. Before that time the number of stumps standing in the margin of the lake must have been exceedingly small. The present large number is due to the rising of the lake after the building of the dam and the subsequent cutting down of the trees whose boles had become submerged. The habit of laying eggs in stumps can not be of much more than fifty years' duration.

The time of laying must be scattered over considerable time, for many eggs were found hatched in August, while some obtained about then hatched at various times from September 15 to November 1. These were, however, kept in a box in a room and therefore removed from normal conditions. The age of this, as of all other hard-shelled turtles, can be estimated by the lines of growth on the horny cuticle. The originally exposed part of the plate occupies the medio-cephalic corner of the plate and additions occur as smooth strips along the outer and posterior margins. The strips are quite distinct in early years, but become more or less obscure with age.

Chrysemys marginata Agassiz. This appears to be the most abundant turtle of the lake. How far its apparent abundance may be due to its habits I am unable to say. It is found floating or quietly paddling along, its head out of the water, but on nearer approach it always turns tail and seeks refuge in the abundant chara fields or in other hiding places. The chara fields are traversed by narrow paths and tunnels made by this turtle. The eggs are laid later in the summer and farther from the water than those of the other species. Many were leaving the water in late August; the eggs were found but once.

Malaclemmys geographica LeSueur. Next to Chrysemys the most abundant of the turtles. It goes by the appropriate name of Housetop.

Emys blandingii Holbrook. Found in moderate numbers in the lake and along the banks of Turkey Creek.

Clemmys guttata Schneider. But two specimens were seen.

Cistudo carolina Linnæus. One specimen of this species was taken. It, however, in no sense forms a part of the fauna of the lake.

Water Birds of Turkey Lake. By F. M. Chamberlain.

The following birds were taken between July 1 and September 1, on or near Turkey Lake. Only those of more or less aquatic habits are listed:

1. *Hydrochelidon nigra* L.
2. *Botaurus lentiginosus* Montaga.
3. *Botaurus exilis* Gmelin.
4. *Ardea virescens* L.
5. *Rallus elegans* Audubon.
6. *Rallus virginianus* L.
7. *Gallinula galeata* Lichtenstein.
8. *Fulica americana* Gmelin.
9. *Actitis macularia* L.
10. *Aegilites vocifera* L.
11. *Ceryle alcyon* L.
12. *Agelaius phoenicus* L.
13. *Clivicola riparia* L.
14. *Cistothorus palustris* Wilson.

PART III—VARIATION.

THE STUDY OF VARIATION.* BY C. H. EIGENMANN.

VARIATION AND ITS IMPORTANCE. No two individuals are exactly alike. The differences of whatever sort, whether in structure or habit, between the individuals of a species, whether these individuals are related to each other as parent and child, or belong to the same brood, are termed variation.

The whole basis of the Darwinian idea of evolution is this individual variation. At present we have two estimates of the importance of individual variation.

I. The individual variations are of the utmost importance, and all species are the result of natural selection working on the varying individuals of any species.

II. Individual "variation offers us little hope of learning the real facts of evolution," "species are not the result of the selection of a few favorable variations out of a large number of haphazard changes," but to "the orderly advance (of the mean specific form) towards the final goal, deviating very little from the direct line."†

We subscribe to neither of these views, wishing to view the facts as they are presented by the conditions of the environment at Turkey Lake and the lakes in the neighborhood, in a perfectly impartial way.

The causes of variation are still unknown, though several explanations have been attempted. This is not surprising since the variations in no species are sufficiently known to formulate any satisfactory explanation, in fact little has been attempted but to determine the extent of variation in comparatively few cases where the variation is great, resulting in the naming of new varieties and in the recording of abnormalities. The statistical method of studying variation is of the most recent date, but much promises to be done with this method.

DISTRIBUTION OF VARIATIONS. Variations are to be found at all times and at all places where organisms exist. They are found under conditions where the environment is in a state of stability. The conditions under which the greatest variability is found (in fishes) are:

1. Wide distribution. A large territory is, usually, though not necessarily, inhabited by more or less stable varieties.

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*Contributions from the Zoölogical Laboratory of the Indiana University, No. 17.

†This wording is from Scott, but since the paragraphs are selected from isolated parts of his paper, I do not wish to convey the idea that they state his views as he would like to have them stated. The paragraphs state an extreme view.

2. Great physical and climatic differences, even in comparatively narrow limits. No more striking illustration can be imagined than is offered by the streams of the Pacific slope of North America, which are inhabited by extraordinary variable species, without stable varieties.

These are simply statements under which variation seems to find its optimum condition and do not approach any explanation of its causes.

Classifications of Variations.—Students of variation have found it advantageous to analyze the phenomena, and the result of this analysis has given us the following classifications:

Continuous variation, including all gradual modifications and transitions.

Discontinuous variation; any sudden and wide modifications or saltations.

Using other features as the basis of classification, we have:

Meristic variations dealing with the change in the number of successive parts.

Substantative dealing with the chemical modifications of parts.

Another classification gives us:

Indeterminate, or fortuitous and aimless variation. This is largely individual and pertains to series of variations either geographically or geologically.

Determinate and adaptive, leading to definite end.

The most essential and at the same time the most difficult to define is the distinction between—

Ontogenetic variation including all those deviations appearing at any time, from any cause, during the life cycle of an individual;

Phylogenetic variations change from the specific characters appearing at some time in the life cycle of an individual, or better still, a large number of individuals, reappearing in the next generation, finally becoming hereditarily fixed.

I have in the following directions omitted the use of the terms ontogenetic and phylogenetic. Recently (Osborn, 1894), the distinction between ontogenetic and phylogenetic variation in the study of evolution has been strenuously insisted upon as the only possible way of determining the value of any given variation in the process of evolution. However, it is certainly impossible in many cases to determine whether a given variation is ontogenetic or phylogenetic as defined by Osborn. To give a concrete case. The ancon sheep of evolutionary classics was born with short legs. Were they ontogenetic or phylogenetic? Subsequent events proved that they were phylogenetic, but certainly the short legs in themselves enabled no one to make the distinction; the hereditary transmission decided the matter. Sports, therefore, of which the ancon sheep was certainly one, may be phylogenetic. Scott, however, has recently shown, Am. J. Science, 369, 1894, that many if not most saltatory variations are of an entirely different nature from the variations that in the past have given rise to phylogenetic series. In a deviation much less marked, such for instance as the presence of one more than the normal number of spines in a fin, this ultimate criterion of transmission might fail us even were it practicable to put it to the test. A surer way of determining phylogenetic variation is to measure variation in the bulk by means of curves. If, say one thousand individuals of a definite time and place, show in the aggregate a character different from that normal to the species, it is phylogenetic. Such variations may occur in successive years or at isolated places. The phylogenetic character is in such a case really made up of a large number of ontogenetic variations which must also be capable of reappearing; that is, they must also be phylogenetic. A better way of stating the problem would seem to me to be that:

All variations are ontogenetic, some are at the same time immediately phylogenetic and many if not all may become so—a phyletic series. This leaves open the question of the conditions under which ontogenetic variation becomes phylogenetic and ignores the unchanged germplasm theory which from purely embryological grounds is untenable.

The paragraphs pertaining to this subject in the following direction are: 7. 8, 13, 15, 16.

Nearly synonymous terms with ontogenetic and phylogenetic are the terms variation and mutation as used by Newmayr, Waagen, and Scott. Variation is here applied to locally different forms, while mutation is applied to the chronological changes or "steady advance (of the mean) along certain definite lines." The latter term may for our purpose be still further restricted by applying it not only to the changes of the mean in successive geologic periods, but to the changes in the mean which may occur in two successive years or broods.

To quote Newmayr, pp. 60-61 (from Scott, p. 372), "Weil ein Theil der Merkmale gleichmässig nach einer Richtung im Laufe der Zeit mutirt, zeigen andere Charactere regellose Abänderungen und jede Mutation entwickelt denselben Varietätenkreis." Scott illustrates this process by comparing the mutation to the progress of a cyclone center and the continual circlet of variations to the circulating winds.

DETAILED DIRECTIONS FOR COLLECTING AND STUDYING SPECIMENS.

The following directions and explanations have been prepared for the students at the Biological Station for the study of the variation of the inhabitants of lakes Turkey and Tippecanoe and the small lakelets in the neighborhood.

1. Collect at random all available specimens, to the number of several hundred, the last week in June, in both Turkey and Tippecanoe lakes, keeping the exact location where each lot of specimens was collected.

It is necessary to collect at random or the personal element of the collector may become a disturbing factor in determining the variation. The date, which is not necessarily fixed for any particular week, has been selected because at this time many very young specimens, but a few weeks old, can be secured. It is necessary to collect in both lakes at approximately the same date in order to secure corresponding ages.

2. Collect in the same manner and an equal number of specimens in each lake near the end of August.

From this second collection the rate of growth and any elimination taking place early in life may be determined.

3. Arrange the material of each date according to the size, to determine whether the broods of successive years can be separated.

If specimens have been collected at random and include all sizes this can usually be done for the preceding few years. Among the older individuals the gradation in size is usually too perfect to permit any grouping according to age.

4. Determine the variation in two or more prominent characters in each brood of specimens, keeping the record and labeling the specimens in such a way that the specimen for any record can at any time be re-examined. Determine at the same time the sex.

This is by far the most laborious and time killing operation, but absolutely essential to determine anything further. The characters measured in fishes can always be the number of rays in the dorsal and anal fins, and the number of scales in the lateral line. Other characters will vary with the species, as one species has one, another a different character that lends itself especially to the study of variation. In reptiles deviations in the number and characters of plates are available characters for the study of variation. Of course any character can be taken, but one in which the variation can be numerically expressed and the number be determined by a simple count instead of a measurement, is vastly superior, since nothing can be left to the judgment, and the personal element is therefore much less important.

5. Are there external sexual differences, and is the amount and extent of variation different in the sexes?

This determination can usually be left till later; it is introduced here so as not to mar the sequence of the following points.

6. Is there a successive modification in going from younger to older specimens indicating a structural modification with age?

It may be possible with some species, for instance, that the number of rays increases directly with the age. Should such a case exist it might give rise to entirely erroneous notions as to the influence or effect of selective destruction.

7. Is the variation of each year grouped about a mean common to all the specimens, or is each year's variation grouped about a center of its own?

While the idea of the annual variation or the reaction of each brood to a slightly varying environment was supposed to be a possible element, and suggested as such in my first announcement of the station, I was entirely unprepared for the startling annual variation in such a prominent character as the number of dorsal spines which has been discovered by Mr. Moenkhaus and reported upon in another paper.

The neglect of the consideration of the environment during the early period of development in modifying successive broods in different ways may lead to entirely erroneous ideas of the structural modifications of growth on the one hand, or the entirely erroneous ideas of the action of selective destruction on the other. To determine the latter it is absolutely necessary to take individuals of the same year's broods at successive periods or successive years. Whether as great an annual fluctuation is present in crabs as has been observed in Etheostoma I can not presume to say. But the entire neglect of this element vitiates the results of Prof. Weldon, of the committee of the royal society for "Conducting statistical inquiries into the measurable characteristics of plants and animals," which Mr. Thistelton-Dyer (Nature, Mch., 1895. considers to be "among the most remarkable achievements in connection with the theory of evolution."

I quote from Prof. Weldon to show his methods and results. (Nature, Mch. 7, 1895, p. 449.) "In order to estimate the effect of small variations upon the chance of survival, in a given species, it is necessary to measure, *first*, the percentage of young animals exhibiting this variation; *secondly*, the percentage of adults in which it is present. If the percentage of adults exhibiting the variation is less than the percentage of young, then a certain percentage of young animals has either lost the character during growth, or has been destroyed. The law of growth having been ascertained, the rate of destruction may be measured, and in this way an estimate of the advantage or disadvantage of a variation may be obtained.

In order to estimate the effect of deviations of one organ upon the rest of the body, it is necessary to measure the average character of the rest of the body in individuals with varying magnitude of the given organ."

Conclusions reached by an application of these principles to a study of the shore crab gave as a result that—*a*. There is a period of growth during which the frequency of deviations increases. *b*. That in one case the preliminary increase is followed by a decrease in the frequency of given magnitude, in the other case it was not. *c*. Assuming a particular law of growth the observations show a selective destruction in the one case and not in the other.

8. What is the relation of the annual fluctuation (mutation) in variation to the annual fluctuation in the different elements of the environments?

9. What is the difference in the variation of the youngest brood early in the season and late in the season, and what is the difference in the variation in succeeding years of the same brood? Is this difference, if any exists, due to modifications with age or to selective destruction, *i. e.*, has a larger percentage of individuals with one characteristic been eliminated than of individuals with this characteristic slightly different? In what part of the curve of variation have the greatest changes been produced?

10. If certain individuals with definite characters seem to survive, can it be determined in what way this variation brings about the survival?

11. At what age or stage of growth are variations greatest?

12. Can variations arising with age be referred to habits or environment?

13. What is the relation of sports or saltatory variations to the continuous variation numerically?

By saltatory variations are meant all those variations not connected with the mean by intermediate steps.

14. Are saltatory characters always bilateral? If not, to what degree are they bilateral?

The fact that a saltatory variation is confined to one side or is found on both sides, may enable us to determine whether the deviation began in the germ before the appearance of bilaterality or is of later origin.

15. In how far is the repetition of a character due to the repetition of the environment as shown in the correlation of annual fluctuations in environment with annual variations? See under 8.

Whitman Biological Lectures, 1894, p. 4: "An epidemic of metaphysical physics seems to be in progress—a sort of *neo-epigenesis*. In place of the *vis essentialis* of the old epigenesis, the new epigenesis sets up as its fetich the *vis impressa*. The new god is preferred because it works from the outside instead of the inside. It represents the sum of external conditions and influences at the present moment, and is proclaimed all-sufficient for building up organisms out of isotropic corpuscles. Previous conditions are not, indeed, quite ignored, for they have resulted in special molecular constitutions called germs, and these display molecular activities known as metabolism, growth and division. The long past can bring forth only a molecular basis; a few hours of the present can supply all, or nearly all, the determinations of the most complex organism. Impotent past; prepotent present. We have no longer any use for the 'Ahnengallerie' of phylogeny. Heredity does not explain itself or anything else, and it detracts from the omnipotence and universality of molecular epigenetics. We are no better off for knowing that we have eyes because our ancestors had eyes. If our eyes resemble theirs it is not on account of geneological connection, but because the molecular germinal basis is developed under similar conditions. The reason this basis becomes an eye rather than an ear or some other organ is wholly due to its position and surroundings, not to any inherent predeterminations. If the material for the eye and the ear could be interchanged in the molecular germ, that which in one place would become eye would in the other place become ear, and *vice versa*."

16. In what characters does the same species in the neighboring lakes differ, and in what respects does the variation differ in the different lakes?

17. Are variations in one part of the body correlated with variations in another part of the body?

In many cases this can only be determined by converting the variations in part into the terms of the variation of another part. The method for doing this has been suggested by Galton, whose method is discussed at the end of this paper.

18. What correlation is there in the variation of different species under the same environment?

As far as I am aware, no systematic studies of this description have been made. With us this study resolves itself into the determination of whether the fishes in Turkey Lake all differ from those in Tippecanoe along definite, determined ways, so that given the characters of a species for Turkey Lake the characters for the same species in Tippecanoe could be predicted.

Similar but exotic instances are the absence of ventral fins in some of the fishes inhabiting even widely separated mountain lakes, and the presence of enlarged scales along the base of the anal in the Cyprinidæ inhabiting mountain streams of India; or, to come nearer home, the peculiar color patterns of the fishes in some regions of upper Georgia.

METHOD OF PRESENTING RESULTS. Results of statistical inquiries into variation can best be presented by frequency of error curves, and these will be used wherever possible. The abscissa will in all cases be made to represent the size of the organ, the ordinate the percentum of individuals having the particular size.

To convert variations in one organ into the terms of another organ the scheme of distribution will be used with the formula given by Galton for comparing one such curve with another. The process of comparing any curve "a" with any curve "b," multiply each of "a's" height by $\frac{\text{Q of "a"}}{\text{Q of "b"}}$
The Q of any scheme of distribution is one-half the difference between any two grades. The same grades in the two curves to be compared being used to determine their Q for this purpose, 25 per cent. and 75 per cent. are suggested as most convenient by Galton.

Ideally the variations occurring in a single organ expressed by a frequency of error curve, when a large number of individuals have been examined, will form a symmetrical curve which is called a "normal." Such a curve may always be expected when the material under consideration is of a single origin and has developed under the same environment. Unfortunately for non-mathematical evolutionists, the converse does not seem to be the case, for a symmetric curve may be made up of two symmetric curves with axes not far apart, a fact that can only be determined mathematically. Says Pearson, "There will always be the problem: Is the material homogeneous and a true evolution going on, or is the material a mixture? To throw the solution on the eye in examining the graphical results is, I feel certain, quite futile."

It is not hoped that the data can be treated with the mathematical refinement suggested by Pearson, nor is it probable that such treatment of our material will become absolutely necessary, since there can be but little question of the unity of origin of the material in any given small lake.

While usually, as stated above, the curve resulting from the study of a large number of specimens will be symmetric, it will frequently be asymmetric. Samples of the different sort of curves actually observed are given.

Asymmetric curves may be the result,

1. Of the selective influence working on one side of a symmetric curve and be then found in more or less mature specimens.

2. Of the reaction to a change in the environment and indicative of a mutation or change in the mean specific form.

3. Of the double origin of the material under consideration, and may then have a great variety of forms, from slightly asymmetric curve to one with a broad top or with many peaks.

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VARIATION OF NORTH AMERICAN FISHES. II.

THE VARIATION OF ETHEOSTOMA CAPRODES RAFINESQUE IN TURKEY LAKE AND TIPPECANOE LAKE.* BY W. J. MOENKHAUS.

INTRODUCTION.—In a former paper on the "Variation of *Etheostoma caprodes* Rafinesque" (Am. Nat., Aug., 1894), I determined the geographical distribution of this fish and the geographical variation of its color-pattern and fins.

It was found that this species inhabits practically all the fresh waters of the Atlantic slope east of the 100th meridian and west of the Alleghany Mountains. Its northern and eastern limits are the Great Lakes and Lake Champlain; its southwestern, the Rio Grande in the extreme southern part of Texas.

The following conclusions were reached among others:

1. Each river system from which specimens were examined possesses a peculiar variety. This peculiarity is most striking in the color-pattern.

2. All the variations are continuous.

*Contributions from the Zoölogical Laboratory of the Indiana University under the direction of C. H. Eigenmann, No. 18.

3. The variation in the anal rays and dorsal spines are determinate with the latitude, the southern specimens having a slightly larger number of rays and spines.

4. The color-pattern variations are determinate, varying through definite stages from a simple to more complex pattern.

In Table A and B are given the data on the anal rays and dorsal spines. The localities are arranged in the order of their latitude from north to south. From these we see that there is both an increase in the average number of rays and spines and in the number that prevails in each case from north to south. In the anal fin 10 is the prevailing number north, and 11 and 12 south, of the Ohio River. Fourteen and fifteen are the prevailing number of dorsal spines in the north and 15, 16 and 17 in the south.

TABLE A.

LOCALITY.	Number of Specimens.	Average Number of Anal Rays.	Number of Specimens with 10 Rays.	Number of Specimens with 11 Rays.	Number of Specimens with 12 Rays.
Torch Lake, Mich	7	$10\frac{1}{7}$	6	1	......
Cedar Rapids, Iowa	1	12	......	......	1
White River, at Indianapolis	1	10	1	......	......
Gosport, Ind	5	10	5	......	......
Bean Blossom, Ind	17	$10\frac{9}{17}$	8	9	......
Rushville, Ind	1	10	1	......	......
Wild Cat Creek, Ind	1	11	......	1	......
Pike Creek, Ind	2	11	......	2	......
Illinois	1	10	1	......	......
Nipisink Lake, Ill	2	$10\frac{1}{2}$	1	1	......
Monongahela River	1	10	1	......	......
Hartford, Ky	4	$10\frac{1}{4}$	3	1	......
Green River, Greensburg, Ky	3	$10\frac{2}{3}$	1	2	......
Little Barren River, Osceola, Ky	4	11	......	4	......
Little South Fork Cumberland River, Wayne County, Ky	1	11	......	1	......
Eagle Creek, Olympus, Tenn	2	11	......	2	......
Obeys River, Elizabethtown, Tenn	13	$11\frac{6}{13}$	1	5	7
Watauga River, Elizabethtown, Tenn	2	$10\frac{1}{2}$	1	1	......
North Fork Holston River, Saltville, Va	1	12	......	......	1
Eureka Springs, Ark	1	......	......	......	......
Chocola Creek, Oxford, Ala	4	$11\frac{1}{4}$	......	3	1
San Marcos Springs, Tex	2	11	......	2	......

TABLE B.

LOCALITY.	Number of Specimens.	Average Number of Dorsal Spines.	Number of Specimens with 13 Rays.	Number of Specimens with 14 Rays.	Number of Specimens with 15 Rays.	Number of Specimens with 16 Rays.	Number of Specimens with 17 Rays.
Torch Lake, Mich.	7	$14\frac{4}{7}$	....	3	4	....	....
Cedar Rapids, Iowa	1	14	....	1	....	....	....
White River, at Indianapolis	1	14	....	1	....	....	....
Gosport, Ind.	5	$14\frac{4}{5}$	....	1	4	....	....
Bean Blossom, Ind.	17	$14\frac{6}{17}$	1	9	7	....	....
Rushville, Ind.	1	14	....	1	....	....	....
Wild Cat Creek, Ind	1	15	....	....	1	....	....
Pike Creek, Ind	2	$14\frac{1}{2}$	....	1	1	....	....
Illinois	1	15	....	....	1	....	....
Nipinsik Lake, Ill.	2	$14\frac{1}{2}$	....	1	1	....	....
Monongahela River	1	15	....	....	1	....	....
Hartford, Ky.	4	15	....	1	2	1	....
Green River, Greensburg, Ky	3	15	....	....	3	....	....
Little Barren River, Osceola, Ky.	4	15	....	1	2	1	....
Little South Fork Cumberland River, Wayne County, Ky	1	16	....	....	....	1	....
Eagle Creek, Olympus, Tenn	2	$16\frac{1}{2}$	....	....	....	1	1
Obeys River, Elizabethtown, Tenn.	13	$16\frac{6}{13}$	....	....	2	3	8
Watauga River, Elizabethtown, Tenn	2	$15\frac{1}{2}$	....	....	1	1	....
North Fork Holsten River, Saltville, Va	1	16	....	....	....	1	....
Eureka Springs, Ark	1	16	....	....	....	1	....
Chocola Creek, Oxford, Ala.	4	$15\frac{1}{2}$	....	....	2	2	....
San Marcos Springs, Tex	2	$13\frac{1}{2}$	1	1	....	....	....

The color-pattern varies from a probably primitive, simple pattern consisting of alternate whole and half cross-bars distributed along the entire length of the body through the pattern consisting of whole, half and quarter bars, having an incomplete longitudinal series of lateral spots to a pattern having a very prominent longitudinal series of dark lateral blotches with fine reticulations on the back. Between these different patterns all stages exist, so that they can be connected by regular steps. Those specimens inhabiting the lakes were found to possess a peculiar color-pattern. This was derived from the primitive, simple pattern by supposing the lower part of the whole bars to have become much broader than the upper part, and then to have shifted backwards slightly.

This lake variety (*manitou*, Jordan) is one of the most abundant of the fishes in Turkey and Tippecanoe Lakes, and upon it the results given in the following pages are based.

Six hundred specimens, all that were collected from Turkey Lake, and three hundred of those collected from Tippecanoe Lake, have been examined with a view, first, of making a comparison of this species in the two lakes, and second, of determining the range and character of its variation within Turkey Lake itself. The number of species collected from Tippecanoe Lake is much greater than 300, but this number was thought sufficient to give fairly good results. The effect of natural selection will be taken up at a later time.

Etheostoma caprodes has two dorsal fins, the first, a spinous one, well separated from the second, which is composed of soft rays. The anal fin is composed of two rather strong spines followed by a number of soft rays. The scales are very regularly arranged, so that they can be definitely counted along the complete lateral lines. The number of spines and rays in these fins, and the number of scales in the lateral line of both sides of the body have been determined. Besides these characters the presence or absence of scales on the nape has been determined. These structures have been taken because, with the exception of the last, they present definite, countable elements, so that in the results the personal factor is entirely eliminated.

Curves have been constructed to represent the variation in these structures. In all the curves the horizontal distances represent the countable elements, and the vertical distances the per cent. of specimens possessing these varying elements.

COMPARISON OF TURKEY LAKE AND TIPPECANOE SPECIMENS.

Coloration.—The coloration of these fishes in the two lakes will be taken up in detail later. The color-pattern of Turkey Lake specimens is, on the whole, of a more blotched character than that of Tippecanoe Lake specimens, and shows a slighter affinity to the simple, primitive coloration characteristic of the Wabash River forms. The connection of Tippecanoe Lake with the Wabash River may account for this greater affinity.

Squamation of Nape.—In Turkey Lake the nape is as a rule naked, while in Tippecanoe Lake it is usually scaled. Table I will bring out the difference.

TABLE I.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having no scales on nape	88.00	19.32
Per cent. of specimens having few scales on nape.............	8.00	23.87
Per cent. of specimens having several scales on nape	4.00	28.32
Per cent. of specimens having nape thinly scaled.............	0.20	16.67
Per cent. of specimens having nape closely scaled	0.00	11.74

Lateral Line.—The specimens of Turkey Lake have on an average two more scales in the lateral line. The average number for Turkey Lake is 89.46 for the left side, 89.74 for the right side; for Tippecanoe Lake, 87.69 for the left side, 87.45 for the right side. Fig. 1 represents the curves for the scales of the right side. The continuous line represents the conditions in Turkey Lake, and the broken line those of Tippecanoe Lake. It should be noticed that the entire curve for Turkey Lake is two units to the right of that of Tippecanoe Lake, showing that practically all the Turkey Lake specimens have a greater number of scales. Table II contains the summary of the counts for the scales in the lateral line.

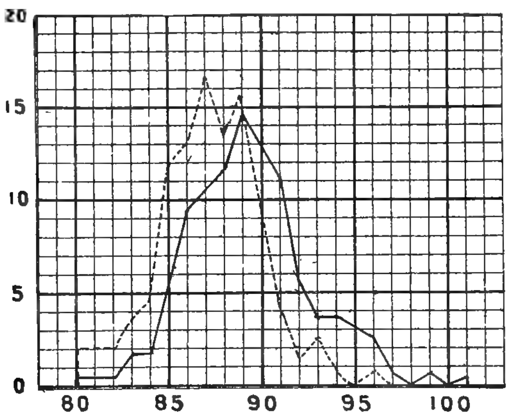

Fig. 1.

TABLE II.

	Turkey Lake.		Tipp'canoe Lake	
	Left Side.	Right Side.	Left Side.	Right Side.
Per cent. of specimens having 78 scales....	0.17	....	....	....
Per cent. of specimens having 79 scales....	....	....	....	....
Per cent. of specimens having 80 scales....	0.17	0.34	....	....
Per cent. of specimens having 81 scales....	....	0.34	0.50	....
Per cent. of specimens having 82 scales....	0.17	0.34	1.00	2.00
Per cent. of specimens having 83 scales....	1.37	1.55	2.50	3.50
Per cent. of specimens having 84 scales....	3.44	1.89	7.00	4.50
Per cent. of specimens having 85 scales....	3.78	5.17	8.50	11.50
Per cent. of specimens having 86 scales....	6.88	9.30	11.50	13.00
Per cent. of specimens having 87 scales....	11.02	10.68	15.00	16.50
Per cent. of specimens having 88 scales....	12.56	11.55	15.00	13.50
Per cent. of specimens having 89 scales....	17.72	14.82	16.00	16.00
Per cent. of specimens having 90 scales....	12.39	12.93	11.50	10.50
Per cent. of specimens having 91 scales....	8.08	11.03	7.50	4.00
Per cent. of specimens having 92 scales....	6.53	5.67	1.50	1.50
Per cent. of specimens having 93 scales....	5.16	3.62	1.00	2.50
Per cent. of specimens having 94 scales....	3.61	3.78	0.50	0.50
Per cent. of specimens having 95 scales....	2.58	3.27	0.50	....
Per cent. of specimens having 96 scales....	1.37	2.41	0.50	0.50
Per cent. of specimens having 97 scales....	1.03	0.51	....	....
Per cent. of specimens having 98 scales....	0.17	....	....	....
Per cent. of specimens having 99 scales....	0.34	0.34	....	....
Per cent. of specimens having 100 scales....	....	....	....	....
Per cent. of specimens having 101 scales....	0.17	0.17	....	....
Per cent. of specimens having 102 scales....	0.17	....	....	....
Per cent. of specimens having 103 scales....	0.17	....	....	....

Anal fin.—The number of spines in the anal fin varies from the normal in only nine specimens from Turkey Lake and in six from Tippecanoe Lake. This variation is always toward a lower number, and extends only through one spine.

Turkey Lake specimens have on an average fewer rays in the anal than Tippecanoe Lake specimens. The averages are 10.87 for the former, 11.15 for the latter. Fig. 2 represents the curves for the anal rays. Here again, and also in the succeeding curves for the comparison of the two lakes, the continuous line represents Turkey Lake and the broken line Tippecanoe Lake. Table III gives the summary of the anal rays for both lakes.

The prevailing number of rays in both lakes is 11; 53 per cent. from Turkey lake, and 56 per cent. from Tippecanoe Lake having that number. The number of rays in the next highest per cent. is 10 for Turkey Lake and 12 for Tippecanoe Lake, about 27 per cent. in each case.

The range of variation is two greater in Turkey Lake. This may be due to the greater number of specimens from this lake.

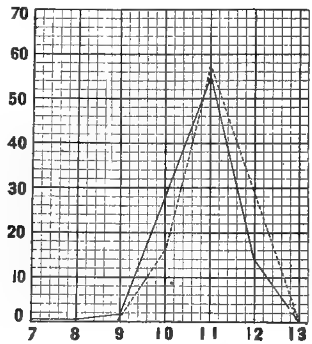

FIG. 2.

TABLE III.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having 7 anal rays	0.16	....
Per cent. of specimens having 8 anal rays	0.16	....
Per cent. of specimens having 9 anal rays	1.48	0.77
Per cent. of specimens having 10 anal rays	26.80	15.50
Per cent. of specimens having 11 anal rays	53.43	56.21
Per cent. of specimens having 12 anal rays	14.13	27.13
Per cent. of specimens having 13 anal rays	0.49	0.35

DORSAL SPINES.—Turkey Lake has on an average more dorsal spines, the average being 14.52 for Turkey Lake and 14.23 for Tippecanoe Lakes. Fig. 3 represents the curves for this structure. The range of variation is the same, from 12 to 17. Although the average number of spines differs but slightly in the two lakes, the preferences shown for a given number of spines are quite different. In the Tippecanoe Lake specimens the preference is decidedly for 14. In the Turkey Lake specimens the preference is for 15, although not so decided. From Table IV and the curves, it will be seen that the number of individuals in Turkey Lake having 14 spines and 15 spines are about the same, 41 per cent. having 14 and 44 per cent., 15, while in Tippecanoe Lake this is not the case, 60 per cent. having 14, and only 25 per cent. having 15.

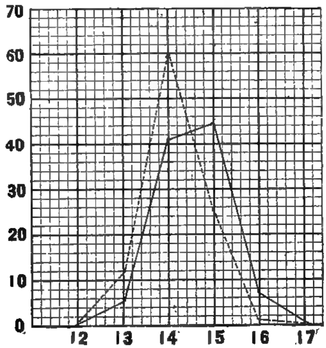

FIG. 3.

TABLE IV.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having 12 dorsal spines...............	0.32	0.38
Per cent. of specimens having 13 dorsal spines...............	5.09	11.24
Per cent. of specimens having 14 dorsal spines...............	41.26	60.85
Per cent. of specimens having 15 dorsal spines...............	44.22	25.96
Per cent. of specimens having 16 dorsal spines...............	6.90	1.16
Per cent. of specimens having 17 dorsal spines...............	0.65	0.38

DORSAL RAYS.—The average number of dorsal rays for Turkey Lake is 14.87, for Tippecanoe Lake, 16.40, the latter having on an average almost two more. The curves are given in Fig. 4. From this and Table V it will be seen that Turkey Lake specimens show a decided preference for 15 rays, while the Tippecanoe Lake specimens show just as decided a preference for 16 rays, 52 per cent. of the specimens having these numbers in both lakes. The range of variation is two greater in Turkey Lake, from 12 to 18 as compared from 14 to 18 in Tippecanoe Lake. This again may be due to the greater number of specimens.

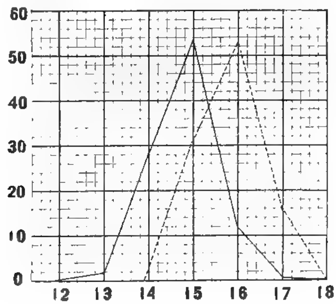

FIG. 4.

TABLE V.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having 12 dorsal rays	0.32	....
Per cent. of specimens having 13 dorsal rays	1.48	....
Per cent. of specimens having 14 dorsal rays	28.77	3.48
Per cent. of specimens having 15 dorsal rays	52.26	31.78
Per cent. of specimens having 16 dorsal rays	12.16	52.32
Per cent. of specimens having 17 dorsal rays	1.64	15.11
Per cent. of specimens having 18 dorsal rays	0.16	0.77

Table VI presents all the combinations of dorsal spines and dorsal rays from both lakes. The spines are represented by Roman numbers and the rays by Arabic numbers. The commonest combination in Turkey Lake is XIV–15 and XV–15; XIV, XV, occurring most frequently in the spinous dorsal, and 15 most frequently in the soft dorsal. The per cent. of specimens having these combinations is 22.46 and 24.49 respectively. In Tippecanoe Lake, XIV–16 is the commonest combination, XIV being the prevailing number in the spinous dorsal and 16 in the soft dorsal. 32.11 per cent. of the specimens have this combination.

TABLE VI.

		From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having the combination	XII–14.....	0.16	....
Per cent. of specimens having the combination	XII–15.....	0.16	....
Per cent. of specimens having the combination	XII–16.....	....	0.37
Per cent. of specimens having the combination	XIII–14.....	0.84	0.37
Per cent. of specimens having the combination	XIII–15.....	3.71	2.22
Per cent. of specimens having the combination	XIII–16.....	0.67	5.92
Per cent. of specimens having the combination	XIII–17.....	....	2.59
Per cent. of specimens having the combination	XIV–12.....	0.16	....
Per cent. of specimens having the combination	XIV–13.....	1.01	....
Per cent. of specimens having the combination	XIV–14.....	11.99	1.48
Per cent. of specimens having the combination	XIV–15.....	**22.46**	20.37
Per cent. of specimens having the combination	XIV–16.....	5.74	**32.11**
Per cent. of specimens having the combination	XIV–17.....	0.33	6.66
Per cent. of specimens having the combination	XIV–18.....	....	1.11
Per cent. of specimens having the combination	XV–13.....	0.67	....
Per cent. of specimens having the combination	XV–14.....	13.51	1.85
Per cent. of specimens having the combination	XV–15.....	**24.49**	8.14
Per cent. of specimens having the combination	XV–16.....	5.40	14.44
Per cent. of specimens having the combination	XV–17.....	0.84	1.48
Per cent. of specimens having the combination	XV–18.....	0.16	....
Per cent. of specimens having the combination	XVI–12.....	0.16	....
Per cent. of specimens having the combination	XVI–13.....	0.16	....
Per cent. of specimens having the combination	XVI–14.....	2.36	....
Per cent. of specimens having the combination	XVI–15.....	3.04	1.11
Per cent. of specimens having the combination	XVI–16.....	0.84	0.37
Per cent. of specimens having the combination	XVI–17.....	0.33	....
Per cent. of specimens having the combination	XVII–14.....	0.50	....
Per cent. of specimens having the combination	XVII–15.....	....	0.37
Per cent. of specimens having the combination	XVII–16.....	0.16	....
Per cent. of specimens having the combination	XVIII–14.....	0.16	....

In Table VII is given the variation in the two dorsal fins taken together. The average number for the two fins is 29.21 for Turkey Lake and 30 for Tippecanoe Lake. In Turkey Lake 36.82 per cent. have the average number; in Tippecanoe Lake, 41.8 per cent. The range of variation in the fins separately is six for the spinous dorsal and five for the soft dorsal in Tippecanoe Lake, and seven in each dorsal fin in Turkey Lake. With an exception in the spinous dorsal in Tippecanoe Lake the range of variation is, in each case, one greater for the two fins taken together, than for the fins separately. Although the extent of variation is only one greater for the two fins together, the per cent. of specimens having the average number is much smaller than the per cent. of specimens having the average number in the fins separately. In Turkey Lake nearly 37 per cent. have the average number of the fins taken together, while 44 per cent. and 52 per cent. have the average number in the spinous and soft dorsal respectively. In Tippecanoe Lake 41 per cent. have the average number for both fins, while 52 per cent. and 61 per cent. have the average number in the spinous and soft dorsals respectively.

TABLE VII.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having 26 rays in the dorsals	0.33	....
Per cent. of specimens having 27 rays in the dorsals	2.02	0.37
Per cent. of specimens having 28 rays in the dorsals	16.38	4.07
Per cent. of specimens having 29 rays in the dorsals	36.82	28.15
Per cent. of specimens having 30 rays in the dorsals	32.59	41.80
Per cent. of specimens having 31 rays in the dorsals	9.28	22.22
Per cent. of specimens having 32 rays in the dorsals	1.85	3.33
Per cent. of specimens having 33 rays in the dorsals	0.67	....

SUMMARY.

1. This species is equally abundant in the two lakes.

2. The color pattern of Tippecanoe Lake specimens shows a greater affinity for the primitive, simple Wabash River pattern than does that of Turkey Lake specimens.

3. In Turkey Lake the nape is usually naked; in Tippecanoe Lake the nape is usually scaled.

4. Tippecanoe Lake specimens have a smaller number of scales in the lateral line.

5. The anal spines vary but little, and show the same variation in the two lakes.

6. The anal fin is somewhat larger in the Tippecanoe Lake specimens.

7. Turkey Lake specimens have one more dorsal spine.

8. Tippecanoe Lake specimens have one more dorsal ray, 16 rays is the mean in Tippecanoe Lake and 15 in Turkey Lake.

9. The combinations of the dorsal spines and rays are determined by the numbers that prevail in the fins separately.

10. The range of variation in the total number of dorsal spines and rays combined is one greater than the variation in the fins separately.

11. The number occurring most frequently is 29 in Turkey Lake and 30 in Tippecanoe Lake.

12. The preference shown for a given number is less decided for the two dorsal fins taken together than for the dorsal fins taken separately.

13. The variation is in all cases continuous.

THE VARIATION IN TURKEY LAKE.

Many of the facts on the extent and character of the variation of the 600 specimens from Turkey Lake, taken as a whole, have been given in the preceeding.

The lengths of the 600 specimens from Turkey Lake were measured and upon comparison were found to fall into three quite distinct groups. Fig. 5 represents the curve for all. Each of the smaller horizontal distances represents one mm. and each of the larger verticle distances one per cent. The sizes ranged from 27 mm. to 102 mm. The first group ranges from 27 mm. to 60 mm.; the second from 60 mm. to 80 mm., and the third from 79 mm. to 103 mm. The three curves of Fig. 5 represent these three groups. I have watched the growth during the first summer, and know the first curve to represent the first summer's fish. The second curve in all probability represents the second year's fish, and the third curve, those three years old and over. The growth, thus, is most rapid during the first summer, the rate of growth decreasing each year after. The fish reaches practically its full size the third year, though the more gradual slope to the right of the last curve shows that it does not cease growing entirely.

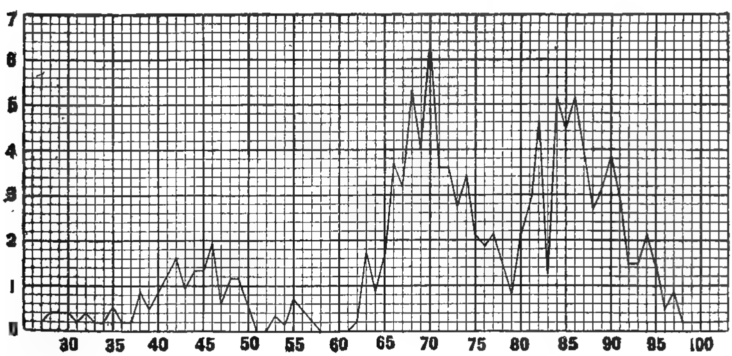

FIG. 5.

Having grouped them into three definite ages, a summary of the characters for each was made, and curves constructed. Figs. 6, 7, 8 and 9 represent the curves for these characters. In all the curves constructed for these ages, the continuous line is for the third year specimens, the broken line for the second year specimens and the dotted line for the first year specimens.

LATERAL LINE.—Below is the table of the average number of scales in the lateral line of the three ages.

	1st year.	*2d year.*	*3d year.*
Right side	87.84	90.80	88.39
Left side	88.00	89.80	88.78

From this it is seen that the first and third year specimens are most nearly alike. The second year specimens have about two scales more. By reference to the curves, Fig. 6, and Table VIII below, it will be seen that the great bulk of the specimens of all three ages have from 85 to 92 scales. The increased average in the second year is due to a larger per cent. having 93, 94, 95 and 96 scales than in the first and second years.

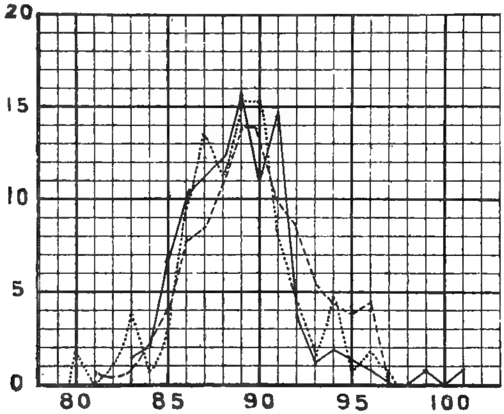

FIG. 6.

TABLE VIII.

	Per Cent. of Specimens Having 80 Scales.	Per Cent. of Specimens Having 81 Scales.	Per Cent. of Specimens Having 82 Scales.	Per Cent. of Specimens Having 83 Scales.	Per Cent. of Specimens Having 84 Scales.	Per Cent. of Specimens Having 85 Scales.	Per Cent. of Specimens Having 86 Scales.	Per Cent. of Specimens Having 87 Scales.	Per Cent. of Specimens Having 88 Scales.	Per Cent. of Specimens Having 89 Scales.	Per Cent. of Specimens Having 90 Scales.	Per Cent. of Specimens Having 91 Scales.	Per Cent. of Specimens Having 92 Scales.	Per Cent. of Specimens Having 93 Scales.	Per Cent. of Specimens Having 94 Scales.	Per Cent. of Specimens Having 95 Scales.	Per Cent. of Specimens Having 96 Scales.	Per Cent. of Specimens Having 97 Scales.	Per Cent. of Specimens Having 98 Scales.	Per Cent. of Specimens Having 99 Scales.	Per Cent. of Specimens Having 100 Scales.	Per Cent. of Specimens Having 101 Scales.
First year specimens	1.99	....	.96	3.84	.96	3.84	9.97	13.45	11.52	15.38	15.38	5.69	4.50	1.99	4.50	.96	1.92	.96	......	......	......	......
Second year specimens	....	.85	.42	.85	2.14	4.29	7.72	8.58	10.73	13.73	13.73	9.87	8.58	5.57	4.29	3.86	4.29	4.29	......	......	......	......
Third year specimens	....	....	....	1.22	2.04	7.35	10.24	11.47	12.28	15.57	11.06	14.34	3.67	2.47	2.86	3.68	.81	.40	......	.81	......	.40

Anal Fin.—Five out of 116 first year specimens have one anal spine; 6 out of 236 of the second year, and 3 out of 246 of the oldest specimens.

The average number of anal rays are 10.56 for the first year, 10.74 for the second year and 11.00 for the third year specimens.

The curves in Fig. 7 and Table IX, below, show that the anal fins of the first and second year specimens more nearly resemble each other. All three ages show a preference for 11.00 rays. The per cent. of specimens having this number are 51.69, 52.53 and 61.60 for the first, second and third year specimens respectively. The per cent. of specimens having 10 rays is reduced from 36.43 in the first year to 20.57 in the third year, and the per cent. of those having 12 rays is increased from 5.09 in the first year to 20.16 in the third year. There is a very evident increase in the number of spines with the age.

The extent of variation of the second and third year specimens is the same. The first year specimens, although only half as many, exceed the other ages two rays in the extent of variation.

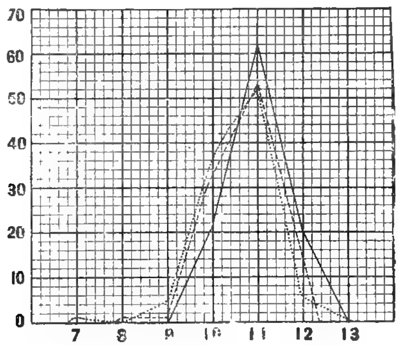

Fig. 7.

TABLE IX.

	First Year.	Second Year.	Third Year.
Per cent. of specimens having 7 anal rays	0.84	....	....
Per cent. of specimens having 8 anal rays	....	0.42	....
Per cent. of specimens having 9 anal rays	5.09	1.69	0.82
Per cent. of specimens having 10 anal rays	36.43	32.19	20.57
Per cent. of specimens having 11 anal rays	51.69	52.53	61.60
Per cent. of specimens having 12 anal says	5.09	13.12	20.16
Per cent. of specimens having 13 anal rays	0.84	....	0.82

Several important facts brought out by the preceding comparison are worth consideration.

1. No two of the ages here compared are alike in all the characters.

2. In the anal fin and soft dorsal there is a definite increase in the number of rays with the age.

3. Variation of this nature is not present in the other structures.

4. The extent of variation in the different ages is about the same.

Dorsal Rays.—The average number of dorsal rays are 14.57, 14.76 and 14.98 for the first, second and third year specimens, respectively. There is a slight increase with age. The summaries for this structure are given below in Table XI, and the curves in Fig. 8. The prevailing number of rays is 15 for all three ages, the per cents. being 53.39, 52 53 and 55.69 for the first, second and third year specimens, respectively. The per cent. of specimens having 14 rays decreases from 40.72 in the first year to 22.35 in the third year specimens, while the per cent. of specimens having 16 rays increases from 3.38 in the first year specimens to 16.73 in the third year specimens. The extent of variation is from 12 to 16 in the first year, from 12 to 17 in the second year and from 13 to 18 in the third year specimens. As in the anal fin there is a tendency toward a greater number of rays as the fish grows older.

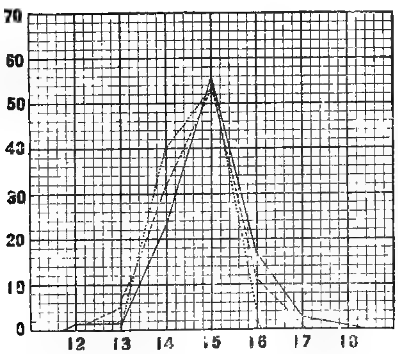

Fig. 8.

TABLE XI.

	First Year.	Second Year.	Third Year.
Per cent. of specimens having 12 dorsal rays	0.84	0.42	....
Per cent. of specimens having 13 dorsal rays	1.69	2.96	1.21
Per cent. of specimens having 14 dorsal rays	40.72	30.50	22.35
Per cent. of specimens having 15 dorsal rays	53.39	52.53	55.69
Per cent. of specimens having 16 dorsal rays	3.38	11.48	16.73
Per cent. of specimens having 17 dorsal rays	....	0.84	3.25
Per cent. of specimens having 18 dorsal rays	....	....	0.40

Dorsal Spines.—The averages for this structure are 14.69 for the first year, 14.39 for the second and 14.65 for the third year, the first and third years being almost identical, and the second year having a fewer number. Fig. 9 represents the curves for this structure. The curves of the first and third years are almost identical, both showing a preference for 15, with about 35 per cent. for 14. The second year shows as decided a preference for 14, about 35 per cent. for 15. This structure varies from 13 to 16 in the first year specimens, from 12 to 17 in the second year specimens and from 13 to 17 in the third year specimens. Table X contains the summaries for this structure.

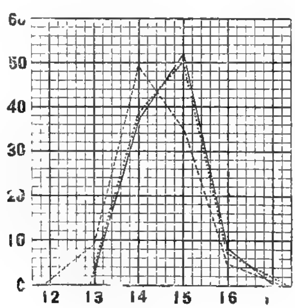

Fig. 9.

TABLE X.

	First Year.	Second Year.	Third Year.
Per cent. of specimens having 12 dorsal spines....	....	0.84	....
Per cent. of specimens having 13 dorsal spines....	1.69	8.47	3.65
Per cent. of specimens having 14 dorsal spines....	38.98	49.14	36.17
Per cent. of specimens having 15 dorsal spines....	50.00	35.16	51.62
Per cent. of specimens having 16 dorsal spines....	7.62	5.50	8.13
Per cent. of specimens having 17 dorsal spines....	....	0.42	0.40

The first and third year specimens resemble each other very closely in regard to the scales in the lateral line and the dorsal spines. In these characters the second year specimens show a decided difference. These have on an average two more scales in the lateral line, and have 14 as the prevailing number of dorsal spines instead of 15, the number in the first and third year specimens.

Several explanations might be suggested to account for a part or all of these differences.

The explanation suggesting itself most readily is that an additional spine and ray are added during the life of the individual. I have gone over all the specimens carefully with this point in view, but find no evidence either of the splitting of a ray or spine, or of the new growth of these, except at the anterior of the dorsal fins. Here may be found numerous instances of shorter spines and rays from two-thirds to one-fourth the normal length. But among so many specimens it is entirely probable that these spines and rays would be found in every possible stage of growth. But this is not the case. The spines and rays, although sometimes only one-fourth the full length, are always strong and suggest aborted rather than immature structures. Besides, if this were the case, we would expect to find the tendency toward a lower number of spines, and rays very decided in the first year specimens. While this condition is true in the dorsal and anal rays, it is decidedly not true in the dorsal spines, where the characters in the first years are almost identical with those of the third year.

Natural Selection.—The principle of natural selection, the influence of which upon this species I hoped in the onset of this work to find, can not be applied in explanation of the difference in the number of scales and dorsal spines without serious objections. If natural selection were the determining factor in producing these differences, we should expect all the variations graduated with the age. We would expect to have a narrower range of variation as the specimens grow older. Neither of these conditions obtain. There are neither 18 dorsal rays nor 13 anal rays represented in the second year specimens; and in the first year specimens 17 dorsal rays are not represented. In the dorsal spines where the difference is most pronounced we have in the first year specimens the exact duplicate of that of the third year specimens, while the second year specimens are quite different. The scales in the lateral line present the same difficulty.

ANNUAL VARIATION.—The explanation that seems to meet all the conditions most satisfactory is that the species varies with the varying conditions of successive years.

The difference in the dorsal spines of the different ages accounts thus for the abnormality of the curve for the dorsal spines of all the Turkey Lake specimens, Fig. 4. The 600 specimens for which the curve is constructed is a composite lot of three age varieties.

This conclusion, however, should be held with some reservation. It will be noticed that nearly all the curves of Figs. 7, 8 and 9 are abnormal curves, which may possibly be due to the presence of local races in the lake. While this may possibly be the case, it is not at all probable, because, in the first place, the curve constructed for the dorsal spines of 100 specimens of three year olds, taken within a distance of 100 yards along the shores where the conditions were undoubtedly uniform, gave a curve identical with that for all the three year olds. In the second place, the second and third year specimens are found in about equal abundance together, and since these were promiscuously preserved it is altogether probable that from any given locality, an equal number of each age was taken.

The sex has been determined in all, and a summary shows that the sexes do not differ in the characters entering into the above considerations.