FIRST REPORT OF THE BIOLOGICAL STATION.

CONTENTS.—DIRECTORS' FIRST REPORT OF BIOLOGICAL STATION.

Introductory.

Acknowledgments.

Equipment.

Plankton net.

Sounding apparatus.

Additional equipment.

Plan of work.

PART I.—TURKEY LAKE AS A UNIT OF ENVIRONMENT.

Introductory.

Orientation.

General features.

Size.

Relation of water to outflow and evaporation.

Constancy of Turkey Lake as a unit of environment.

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

Hydrographic map of Turkey Lake—C. Juday.

Temperature of Turkey Lake—J. P. Dolan.

PART II.—THE INHABITANTS OF TURKEY LAKE.

Note on Plankton—C. H. Eigenmann.

General Fauna—C. H. Eigenmann.

Leeches—Mrs. B. C. Ridgley.

Rotifera—D. S. Kellicott.

Cladocera—E. A. Birge.

Decapoda—W. P. Hay.

Mollusca—R. E. Call.

Fishes—C. H. Eigenmann.

Batrachia—C. Atkinson.

Snakes—G. Reddick.

Turtles—C. H. Eigenmann.

Water Birds—F. M. Chamberlain.

PART III.—VARIATION.

The study of Variation—C. H. Eigenmann.

Variation of Etheostoma caprodes—W. J. Moenkhaus.

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.

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*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.

* 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 ecologist 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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