

AN ECOLOGICAL STUDY OF THE PLANKTON OF SHAWNEE CAVE.

WITH NOTES ON THE CAVE ENVIRONMENT.¹

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WITH THREE FIGURES.

During the year beginning September 7, 1907, the speleological fellowship of the department of zoölogy of Indiana University was held by the writer with residence on the Cave Farm of the University, three miles east of Mitchell, Ind.

A preliminary examination of the cave stream revealed the presence of considerable plankton. A systematic collection of the plankton was immediately begun and after some time a quantitative method applicable to the cave was developed.

The organisms constituting the plankton were found to be epigean forms. It developed that the seasonal distribution of the cave plankton is different from that of epigean streams and lakes. Its maxima and minima seemed more closely related to stream level than to any other factor of the environment.

These facts led to an examination of the surface of the region overlying the cave, in order to determine if possible the source of the plankton, and the relation of its source to its distribution in the cave. It was found that the plankton is derived from ponds in sink-holes of a particular type, and that its source is a primary factor in determining its distribution.

After the plankton enters the cave it is modified in various ways by its new environment. The cave environment is divided into two distinct regions, the terrestrial and the aquatic. These two regions are alike in that there is an absence of light in both, and that each influences the temperature of the other. They are also both affected by the form of the cave.

Some of their differences aside from their primary ones are : (I) the temperature of the air approximates the temperature of the walls of the cave very soon after entering it, while the tem-

¹ Contribution from the Zoölogical Laboratory of Indiana University, No. 104.

perature of the water approaches this constant slowly, (2) the rate of the air current in this cave is determined by the outside temperature, while the rate of water current is determined by its level, which in turn is determined by rainfall. Since the terrestrial region affects the plankton-inhabited aquatic, both regions need to be considered.

A careful examination of the bed of the stream was made for sessile and bottom-inhabiting forms with negative results.¹

Previous Work. — Previous studies on the microorganisms of caves have been confined for the most part to the enumeration and description of species. Claus, Schmeil and Joseph have investigated the zoöplankton of some of the European caves and have recorded the species.

In this country records of microorganisms inhabiting cave water have been made by Tellkampff ('45), Packard ('89), Banta ('07) and others. Kofoid ('99) has described a towing net collection taken in Echo River, Mammoth Cave, by Eigenmann. This catch contained twenty species. Ulrich ('02) reported twenty-one species from the water of an artesian well at San Marcos, Texas. Among these were two species of cyclops, both of which he regarded as new.

The Cave. — The cave² in which these studies were made is at present a rather simple tube with a few side passages. A stream of some size flows through its entire length. The openings of the cave are in Section Four (4), Township Three (3) North, Range One (1) East. These openings are five in number. The

¹I am greatly indebted to Dr. C. H. Eigenmann, professor of zoölogy, for his helpful criticisms and the loan of literature from his private library; also to Dr. Charles Zeleny, associate professor of zoölogy, for valuable suggestions. Messrs. F. C. Greene and N. E. McIndoo assisted in surveying the cave. They are entirely responsible for section II.

²The upper end of this cave is not known. It has been explored to a point about two miles above the outlet. At this point a mass of fallen rock nearly closes the passage. Mr. N. E. McIndoo has crawled through this passage, but it is too small to admit the boat. A stream, which drains a valley some two miles long, flows into an underground passage about four and one half miles southeast of the outlet of Shawnee Cave. This is known locally as "Mosquito Sinks" and is indicated by Newsom ('01) in section sixteen, township three, range one north. Possibly this is the upper limit of the cave. The openings where the stream "sinks" are too small to be explored. Five hundred wooden blocks, which had been soaked in paraffine, were placed in these openings, but none has been taken within the cave, to date.

lower one is the outlet and is known as Shawnee Cave. The four other openings have been formed by the collapse of two sections of the roof and are known as, Lower Twin Cave, Upper Twin Cave, Lower Dalton Cave, and Upper Dalton Cave, respectively (see map).

Vertically the cave is located in the Mitchell limestone, and has been formed by solution along seams in the rock. These seams follow approximately cardinal directions and hence cross at right angles. The result of this is that much of the cave consists of straight passages at right angles to each other. The erosive action of the stream being much greater in the eddies at the turns than in the straight passages deep pools are formed at these points.

Obstructions. — The cave stream has been obstructed more or less completely at four points in the region that I have explored. The upper obstruction has been formed by the collapse of the roof, possibly below a sink-hole, between the Dalton caves (I-36, 37).¹ The second in a similar manner between the Twin caves (I-32, 33). A large part of the upper dam has been removed by solution and erosion, so that the stream flows over it.

At the Twin caves the obstruction is complete at ordinary stages of the stream. It occurs at a right-angled turn in the cave. A new passage is being formed cutting off the obstructed corner. The lower end of this new passage is a few feet below Lower Twin Cave, the location of its upper end is not yet positively determined. The passage is too small to be explored and insufficient to accommodate the stream in times of flood; in such times, the water flows over the obstruction between the two caves and resumes its original course.

The third obstruction is 1,400 feet below Lower Twin Cave at the so-called "Big Room" (I-15, 20). Here a number of old caves crossed the present stream at a higher level. The strata between these two cave levels fell and for a time completely dammed the stream. Deposits of gravel and clay were then formed above this point. In the side passages that are protected from erosion by the cave stream, the deposits still reach the roof. Much of the obstruction and resulting deposits have been removed by the cave stream.

¹ Numbers refer to map.

Eight hundred feet below the "Big Room" is the fourth obstruction (I-13). The roof has fallen from some cause that I was unable to determine, and has completely dammed the stream. A new channel has been formed from this point to the outlet, except for a distance of 40 feet, where it flows through an old cave. The direct result of these obstructions is the formation of pools having a maximum depth of about 10 feet.

Elevation. — The outlet of Shawnee Cave is 40 feet above the level of White River which is about two and one half miles distant. The Lower Twin Cave is 30 feet above Shawnee Cave and Upper Dalton Cave is 10 feet above Lower Twin Cave. The gradient of the stream in the lower part of the cave is 40 feet to the mile. It falls very rapidly from the outlet for about 800 feet, and then has a gradient of about 12 feet to the mile. Probably this slight gradient and the close approach of the stream to local base level prevents the stream from finding a lower level when obstructed, thus causing the effect of the obstruction to continue.

As a result of the pools at the turns and above the obstructions, the water in the cave may be divided into a *constant* which is the amount of water in the pools at all times and a *variable* which is the amount of water flowing through the cave. The ratio between the constant and the variable is much greater in the lower (ordinary) stages of water than in times of flood. At ordinary stages of water, it requires a given particle of water much longer to pass through the cave than if the cave were a straight tube.

Five hundred wooden cubes which had been soaked in paraffine were put in at Lower Twin Cave, and a trap of "hardware" netting (one half inch mesh) was set at Shawnee Cave. Fourteen days later the first blocks were caught at Shawnee Cave. In times of flood the current is very rapid. Just what the rate is could not be determined as no trap could be designed that would withstand the terrific force of the stream at Shawnee Cave. Certainly not more than a few minutes are required for water to pass from Twin Cave to Shawnee Cave in times of flood.

It is evident, then, that the plankton of the cave is subjected

to the cave environment for a much longer time during the lower stages of water than during the higher stages. This has a marked effect upon the number of species and the number of individuals constituting the plankton at the different stream levels.

Light. — This cave is like most others for the greater part of its length, in that there is an absence of light. It differs from most others, in that the stream is illuminated at the points where the roof has collapsed. The stream is fairly rapid in the sections exposed to light, so that the illumination is of short duration. The illumination is strong between Dalton caves and scarcely more than twilight at low stages of the stream between Twin caves. These short exposures to light may enable some of the zoöplanktonts to feed and cause some carbon assimilation in the phytoplanktonts. The effect is probably very slight.

Temperature. (*a*) *Air.* — The temperature of the air of the interior of the cave is between 52–56° F. throughout the year. The temperature has been recorded for the last two years on a thermograph stationed fourteen hundred feet below Lower Twin Cave. The variation exceeds the error of the instrument slightly. Where the air flows out at an opening it differs in observed cases less than one (1) degree Centigrade from the temperature of the interior. Inflowing air assumes the temperature of the air in the center of the cave gradually.

On September 7, 1908, a Centigrade thermometer carried into Lower Twin Cave showed that the interior temperature was reached 428 feet from the opening. During extreme temperatures above ground this point would be farther from the opening.

(*b*) *Water.* — The water temperature varies much more than that of the air for obvious reasons. During low water the temperature of the water approaches the temperature of the walls of the cave. During a flood, it varies toward the temperature of the water outside the cave. Floods, then, cause the temperature of the cave water to lower in winter, to rise in summer, but affect it slightly when the outer temperature is near 54° F. The variation is much less in summer than in winter, because the summer floods are not so great.

In every flood observed, the extreme water temperature occurred about twenty-four hours or more after the crest of the

flood. This may be due to the influence of the residual water in the cave (see Table I.).

TABLE I.

SHOWING THE RELATION OF FLOOD TO TEMPERATURE OF CAVE WATER.
Winter.

Date.	Water Temp.	Outer Temp.	Crest of Flood.	Rainfall.
Dec. 12	11.6° + C.	} < 0° C.	Crest	1.48
" 13	11.5° + C.			
" 14	8.7° + C.			
" 15	8.0° + C.			
" 16	9.4° + C.			
" 21	rises to 11.0° + C.			
<i>Summer.</i>				
Aug. 13	12.5° C.	} max. 32.7° C. min. 21.1° C.	Crest	2.20
" 14	12.5° C.			
" 15	12.5° C.			
" 16	12.6° C.			
" 17	12.6° C.			

Air Currents. — The air in the cave is in almost constant motion. In general it flows up during the winter and down during the summer months. However, during the spring and autumn, the current reverses several times before the constant direction of the extreme season following is assumed. The direction of the current was down on October 14, and reversed on October 21, 22, 23, 26 and 30. After December 10 the air moved upward until the unstable period of spring began, which occurred about the end of March.

The rate of the current varies in different parts of the cave, being scarcely perceptible in the large rooms and very marked where the cave is small in cross-section. Observations taken at a single point indicate that the rate of the air current varies directly with the divergence of the subterranean and surface temperatures. Rate of air currents was measured with a meter recording a minimum of 30 feet per minute.

The upward moving current of cold air weathers the rocks in the regions of the lower openings of the cave, giving them in general a funnel shape. In this enlarged region there is always an upper stratum of air moving in the direction opposite to that of the primary cave air current.

The closed passages near Shawnee entrance have the ordinary

convection of a closed room, *i. e.*, a lower and an upper current moving in opposite directions. When the air currents were too weak to be measured, their direction was observed by means of a candle flame.

These results confirm and elaborate the results of Banta ('07) and Egli ('04). Banta found by weekly observations in Mayfield's Cave that the air currents reversed about October 1 and April 1. Egli found in Höll-Loch, a cavern explored by him, that the currents were down when the outer temperature was 8.1° Centigrade, and up when 2.3° Centigrade or below, being very strong at -8° Centigrade.

Method. — It is much more difficult to collect plankton in a cave than in ordinary waters. The lack of light, the dimensions of pools, the relatively small amount of plankton, the great and sudden variations in the cave stream, and the necessity of transporting and manipulating the apparatus unassisted, rendered many of the ordinary methods impracticable.

After various experiments the method finally adopted for all quantitative work was as follows: A net was constructed of bolting silk No. 20 (Dufour) after the pattern described by Kofoid ('97). The net was suspended in a pool with about 3 inches of its filtering surface exposed. Two hundred gallons of water were dipped and poured into it with a bucket ($1\frac{1}{2}$ gal. capacity) at the rate of 10 gals. per minute. The catch was preserved in a 4 per cent. solution of formalin. I am well aware that this method results in some error (Kofoid, '97), but it was the most practicable for this investigation.

For the examination of material, glass troughs were constructed by cementing glass strips on a slide, with marine glue. The width approximated the diameter of the field of the microscope ($\frac{2}{3}$ obj., 2 in. ocu.), the length 40 mm., and the depth about 1 mm. The material was pipetted into this trough until the surface film was parallel to the slide. The entire catch was counted in quantitative work.

When higher powers of the microscope were necessary for careful study, the material was removed from this trough to a slide on which strips of cover glass were glued for the support of the cover glass. After examination, the material was washed from the trough into a new vial with 4 per cent. formalin.

Amount of the Plankton.—The amount of plankton is small when compared with the amount taken in a lake or epigean stream. In low stages, 200 gallons contained less than 1 c.c. In times of flood the catch was increased very much (200 c.c. or 300 c.c.), but this increase was largely due to silt and vegetable débris carried in suspension.

Constituents of the Plankton.—No organisms were found that were not referable to known epigean forms. Rather marked variations from the type were observed in some of the crustacea, notably in the genus *Bosmina*. However, the recent work of Wesenberg-Lund makes it advisable to withhold judgment on this point, until the local and seasonal variations in the crustacea of the ponds of the region have been investigated.

The zoöplanktonts taken included Copepoda, Cladocera, Rotifera and Protozoa.

The phytoplanktonts belonged to the following genera: *Spirogyra*, *Zygnema*, *Volvox*, *Closterium*, *Micriasteria*, *Vaucheria* and *Pandorina*. In addition to these, diatoms, worms, insect larvæ and fragments of spiders occurred rarely.

The planktonts having the widest temporal distribution were *Bosmina cornuta*, *Cyclops bicuspidatus* and *Anura cochlearis*. *Cyclops prasinus* outnumbered *Cyclops bicuspidatus* in November and several species of Rotifera were quite common in May.

The lorica probably enables rotifers to withstand cave conditions as all the Rotifera except two belong to the suborder Loricata. These two were found when the current was quite rapid and disappeared when the water became low and the current reduced. There may be other factors in the organization of the Loricata besides the lorica that enables them to exist under these conditions. That the rotifer fauna of the cave is included with rare exceptions in this subclass is certainly significant.

Diatoms were very rare. This was probably due to two things — (1) these forms live on the bottom of the ponds and consequently few are carried into the cave, (2) they soon succumb in the cave.

Other algæ were never taken in large quantity, but *Volvox* and *Closterium* were present in most of the catches throughout the year. Filamentous algæ were found at Shawnee Cave only in the higher stages of the stream.

The Source of the Cave Plankton. — To understand the distribution of the cave plankton, it is necessary to understand its source. It has been assumed that the plankton (at least in part) inhabiting a cave stream has been derived from the surface through sink-holes.¹ An examination of the local sink-holes made it clear that probably only a small part of the total number contribute.

Sink-holes may be divided into two principal classes, compound sink-holes and simple sink-holes. A compound sink-hole is a large depression having secondary sinks on its slopes. These arise in most cases probably by the reduction of the divides of the compound sinks by erosion. Sinks may arise secondarily on the slope of an old one.

A simple sink-hole is one without secondary sinks. Simple sink-holes agree in having the form of an inverted cone and are of three types. The first type has an opening at the apex of the cone leading to an underground passage.

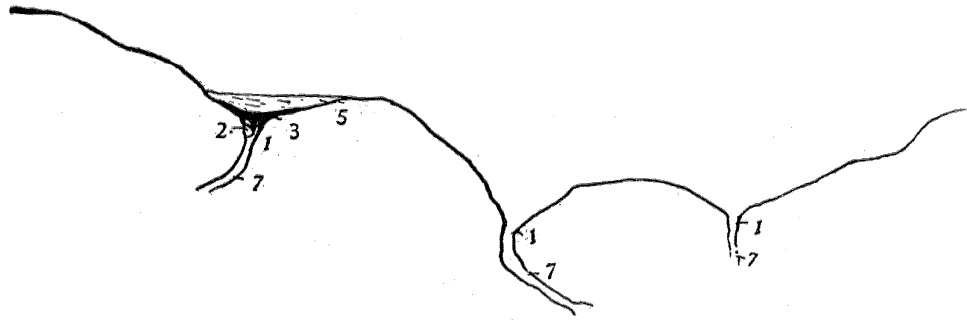
The second type has this opening closed. This closure is inaugurated by rocks and earth caving in from the sides of the opening. Sediment composed of the fine clay from the sides is then deposited over this, and forms a very impermeable layer. This results in a more or less permanent pond.

The third type of simple sink-holes is like the second, except that a new opening to a subterranean passage has been formed on its sides a short distance above its lowest point. This new opening is formed from below, but the details of the process I could not determine. The result is a pond, which at its higher levels overflows into the new opening.

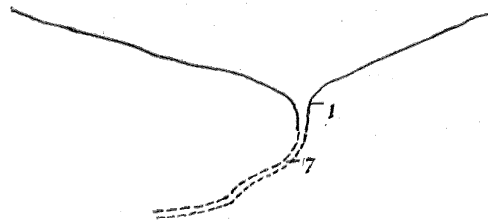
Open sink-holes are the rule in land covered with timber, because the erosion in such areas occurs slowly.

The plankton is derived from the simple sink-holes of the third type and compound sink-holes in which the lower sinks are open and the upper are closed, and in which the divides are low enough to allow the upper ones to overflow into the lower. The first type of simple sink-holes allows the water to flow so quickly into the underground channel, that organisms do not have time

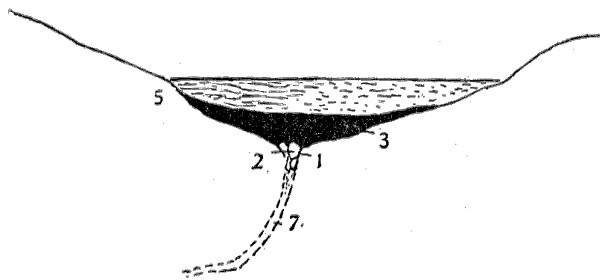
¹The cave region is a plateau which has not yet developed surface streams. The surface of this region is drained by funnel-shaped depressions called "sink-holes."



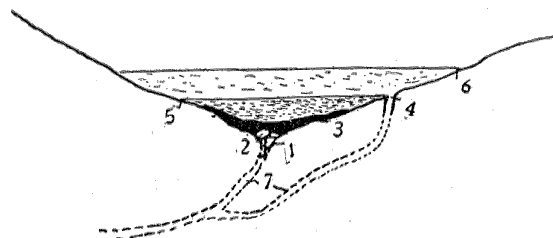
TYPE I.



TYPE II.



TYPE III.



Diagrammatic section of compound and simple sink holes. 1, original opening; 2, obstruction; 3, impervious layer of clay; 4, second opening; 5, ordinary water-level; 6, flood water-level; 7, subterranean passage.

to develop. A few wind-blown eggs and cysts may be carried into the cave and develop there, but I think it extremely doubtful. The second type of simple sinks develops many organisms, but they are not admitted to the cave stream.

Temporal Distributions.—The temporal distribution of the plankton in this cave is puzzling and the causes of this distribution are so complex that their analysis is difficult.

Although qualitative methods only were used during the fall and winter, there was less plankton in early winter than in the autumn. From this it was tentatively concluded that the main outlines of the temporal distribution of the cave plankton coincide with that of lakes and rivers in temperate latitudes, in having spring and autumnal maxima, and summer and winter minima.

After a rain of 4.71 inches which fell on February 13 and 14, I was unable to detect any organisms in the catch. Possibly a few were present and were overlooked because of the great amount of silt.

In March a series of quantitative collections was begun and continued for six months. During this period, two maxima occurred. One was on May 14, and the other was on August 13. These were maxima both in number of individuals and in number of species. Each was preceded by a very heavy rain. Between these maxima there were no rains sufficient to affect the volume of the cave stream. The maximum of May was larger than that of August (see Table II).

The February flood was accompanied by a marked decrease, but those of May and August were accompanied by a sudden increase and followed by a gradual decrease.

From these facts it is safe to conclude that excessive rainfall influences the amount of plankton per gallon of water in the cave, but not always in the same way. Excessive rainfall affects the amount of plankton in three ways. (1) The pools in plankton producing sinks of the land surface over the cave overflow and the organisms contained in them are carried into the cave. (2) The plankton is diluted in the sink where it is produced and is further diluted in the cave by the water from sink-holes of the first type. (3) The stream level is raised and the current is increased. This increase in the current causes many organisms to

TABLE II.

SHOWING INFLUENCE OF FLOOD UPON TEMPORAL DISTRIBUTION.

Date.	CLASS OR GENERA.					Rainfall in Inches for Week Ending
	<i>Cyclops.</i>	Nauplii of <i>Cyclops.</i>	Rotifera.	<i>Diffugia.</i>	<i>Bosmina.</i>	
March 24	85	63	28	5	0	.53
“ 30	75	93	74	6	0	.89
April 7	44	50	42	6	1	1.26
“ 14	29	20	12	6	1	1.13
“ 21	14	12	15	6	3	.32
“ 28	11	46	18	3	1	.31
May 7	count incomplete on account of large amount of silt.					5.46
“ 14	410	319	717	21	1998	.00
“ 26	85	47	24	30	32	.85
June 2	34	30	20	16	6	.00
“ 9	10	10	5	4	5	.66
“ 16	11	23	14	2	6	.17
“ 23	22	55	2	7	0	.00
“ 30	17	42	3	10	0	.20
July 7	9	31	1	4	1	.12
“ 14	28	139	3	18	0	.00
“ 21	21	92	3	2	0	.15
“ 30	18	84	15	5	15	.85
Aug. 7	277	325	32	34	38	1.85

be carried through the cave that would succumb to the cave environment at ordinary stream levels. The first and third of these effects of excessive rainfall are therefore positive and the second negative.

The cycle of pond life in this region is not well known, but is being investigated. It is very probable that in its main outlines it resembles that of lakes in the same latitude.

The minimum of February was due to two things, the small number of organisms produced in the pond and the great dilution by rain water.

The increase in the amount of plankton after the heavy rains of May and August was due to the fact that the amount contributed was so great that the dilution was insufficient to reduce it to the amount per gallon previously present in the cave. The increase in the number of species was caused by the rapid current carrying through many of the forms that would have succumbed to the destructive influences of the cave environment at lower stages of the water. The subsequent gradual decrease in amount and number of species was due to the destructive cave environment.

The temporal distribution of the plankton in this cave depends

upon: (1) the production of the plankton in the ponds, (2) the overflow of the ponds into the subterranean passages, (3) the dilution by rain water and interstratal seepage, (4) the rate of current in the cave stream, (5) the ability of the planktonts to live in the cave environment.

Local Distribution. — Observations taken at Dalton Cave and at Shawnee Cave indicate that the amount of plankton in the lower portion of the cave is less than in the upper portion, the amount at Shawnee varying from 40 per cent. to 80 per cent. of the amount at Upper Dalton. This is due, I think, principally to the destructive influence of the cave environment (see Table III.).

TABLE III.

Genus or Class.	Number per 200 gal. at Upper Dalton Cave.	Number per 200 gal. at Shawnee Cave.
<i>Cyclops</i>	59	41
Nauplii of <i>Cyclops</i>	89	64
<i>Daphnia</i> (immature).....	0	1
<i>Diiflugia</i>	11	3
<i>Arcella</i>	1	0
<i>Edogonium</i>	1	0
<i>Pandorina</i>	2	0
Rotifera.....	2	4
Total	165	113

Feeding and Reproduction of the Plankton in the Cave. — The alimentary tracts of the crustacea always contained some food. In the alimentary tracts of *Cyclops* and *Bosmina* at ordinary stages of the cave stream, there was nearly as much food as in members of these genera taken above ground. In the lower stages of the stream the amount of food contained decreased.

Eggs were common in the egg sack of *Cyclops*, in the brood chambers of *Bosmina*, and upon *Anura cochlearis*. They were also observed in *Daphnia*, but the individuals of this genus were rare.

Nauplii of *Cyclops* were common throughout the year and the young of *Daphnia* and *Bosmina* were observed.

It is evident that some of the planktonts are able to continue their nutritive and reproductive processes under cave conditions, although this environment inhibits them. Whether these forms

would be able to maintain themselves in a permanent pool cut off from the cave stream is conjectural, as no such pool exists in this cave.

That the algæ could not live in the total darkness of the cave is certain. The method was not adapted to the investigation of the bacteria and the infusoria.

Relation of the Cave Plankton to the Permanent Cave Fauna.—The plankton of this cave does not form nor can it become a part of the permanent fauna of the cave, because the current of the stream in its higher stages is powerful enough to carry out of the cave all forms that are not strong swimmers, or have not developed the habit of living under rocks or on the bottom. *Cæcidotea*, *Crangonyx* and *Cambarus* live on the bottom and under rocks. *Amblyopsis* is a fairly strong swimmer and when struck by a current goes to the bottom or under a rock. These animals are examples of forms whose habits prevent them from being carried out of the cave.

Banta has taken *Cyclops* from the stomach of *Amblyopsis spelæus*. This suggests that the plankton is a source of food for some of the permanent cave animals.

The organisms of the cave plankton are essentially pond forms and their presence in the cave is accidental. They do not migrate into the cave to colonize it.

Summary and Conclusions.—1. The form of the cave is determined by the direction of the seams in the limestone, the obstructions, and a factor X, which is probably elevation.

2. The form of the cave thus determined results in a large amount of residual water in the cave.

3. This residual water causes the extreme flood temperature to occur twenty-four hours or more after the crest of the flood. It also causes the rate at which the plankton is carried through the cave to vary directly as the stream level varies.

4. Water temperature varies much more than the air temperature in the interior of the cave.

5. Air currents in this cave are caused by and their rate varies directly with the divergence of terranean and subterranean temperature.

6. The amount of plankton in the cave is relatively small.

7. The plankton is composed of epigean forms and is derived from ponds in such sink-holes as have an opening above their lowest points.

8. Temporal distribution of the plankton depends upon three principal factors, the production of the plankton in the pools, excessive rainfall, and the ability of the planktons to withstand cave conditions.

9. At ordinary stages of the stream more plankton occurs in the upper part of the cave than in the lower part.

10. Some of the planktonts feed and reproduce in the cave, but these processes are more or less inhibited.

11. The plankton is not a part of the permanent cave fauna but is essentially a pond fauna accidentally carried into the cave. It is either carried through the cave or perishes in it.

LIST OF SPECIES.¹

PROTOZOA.

Arcella vulgaris Ehrenberg.

Diffugia globosa Dujardin.

D. pyriformis Perty.

D. lobostoma Leidy.

D. acuminata Ehrenberg.

Euglena sp.

ARTHROPODA.

Cyclops bicuspidatus Claus.

C. prasinus Fischer.

C. viridus Jurine.

C. serrulatus Fischer.

C. edax Forbes.

Canthocamptus sp.

Daphnia pulex DeGeer.

Ciriodaphnia consors Birge.

Bosmina bohémica Hellick. (?)

B. cornuta Jurine.

Cydorus sphaericus Mueller.

¹ Diatoms were taken occasionally. The collections sometimes contained spiders which doubtless had fallen from the walls of the cave. One round worm and two segmented worms were observed during the year.

Pleuroxus hamatus Birge.
Cypris sp.
Campodea staphylinus (?) Westwood.
 Larvæ of diptera and coleoptera rarely.

TROCHELMINTHES.

Asplanchna ebbesborni Hudson.
Triarthra longisetæ Ehrenberg.
Cathypna luna Ehrenberg.
Monastyla lunaris Ehrenberg.
M. bulla Gosse.
Branchionis militaris Ehrenberg.
B. bakeri Ehrenberg.
Noteus quadricornus Ehrenberg.
Anura cochlearis Gosse.
Notholca longispina Kellicott.

ALGÆ.

Ædogonium sp.
Cladophora sp.
Vaucheria sp.
Spirogyra sp.
Zygnema sp.
Closterium subcostatum Nord.
C. lanceolatum Kg.
Cosmarium sp.
Micrasterias sp.
Volvox globator Ehrenberg.
V. aureus Ehrenberg.
Pandorina morum Bory.
Pleurococcus sp.
Pediastrum boryanum Menegh.
Scenedesmus sp.
Sphærocystis schræteri Chod.
Nostoc minutissimum Kg.
Oscillatoria sp.

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EXPLANATION OF MAP.

- Shawnee Cave (the outlet). Sec. I., No. 1.
Closed chamber caused by collapse of roof at Sec. I., Nos. 2-3.
Cascade. Sec. I., No. 6.
Double passage. Sec. I., Nos. 7-8.
Old cross cave. Sec. I.; Nos. 9-10.
New passages. Sec. I., Nos. 1-8 and 11-13.
Opening in roof leading to *upper older* levels of cave. Sec. I., No. 14.
"Big Room." Sec. I., Nos. 15, 16, 17, 18, 19, 20, 21, 22.
"Fallen Rock." Sec. I., No. 31.
Lower Twin Cave. Sec. I., No. 32.
Upper Twin Cave. Sec. I., No. 33.
Roof too low for passage of boat. Sec. I., No. 34.
Deepest water in cave, 10 feet 4 inches. Sec. I., No. 35.
Lower Dalton Cave. Sec. I., No. 36.
Upper Dalton Cave. Sec. I., No. 37.

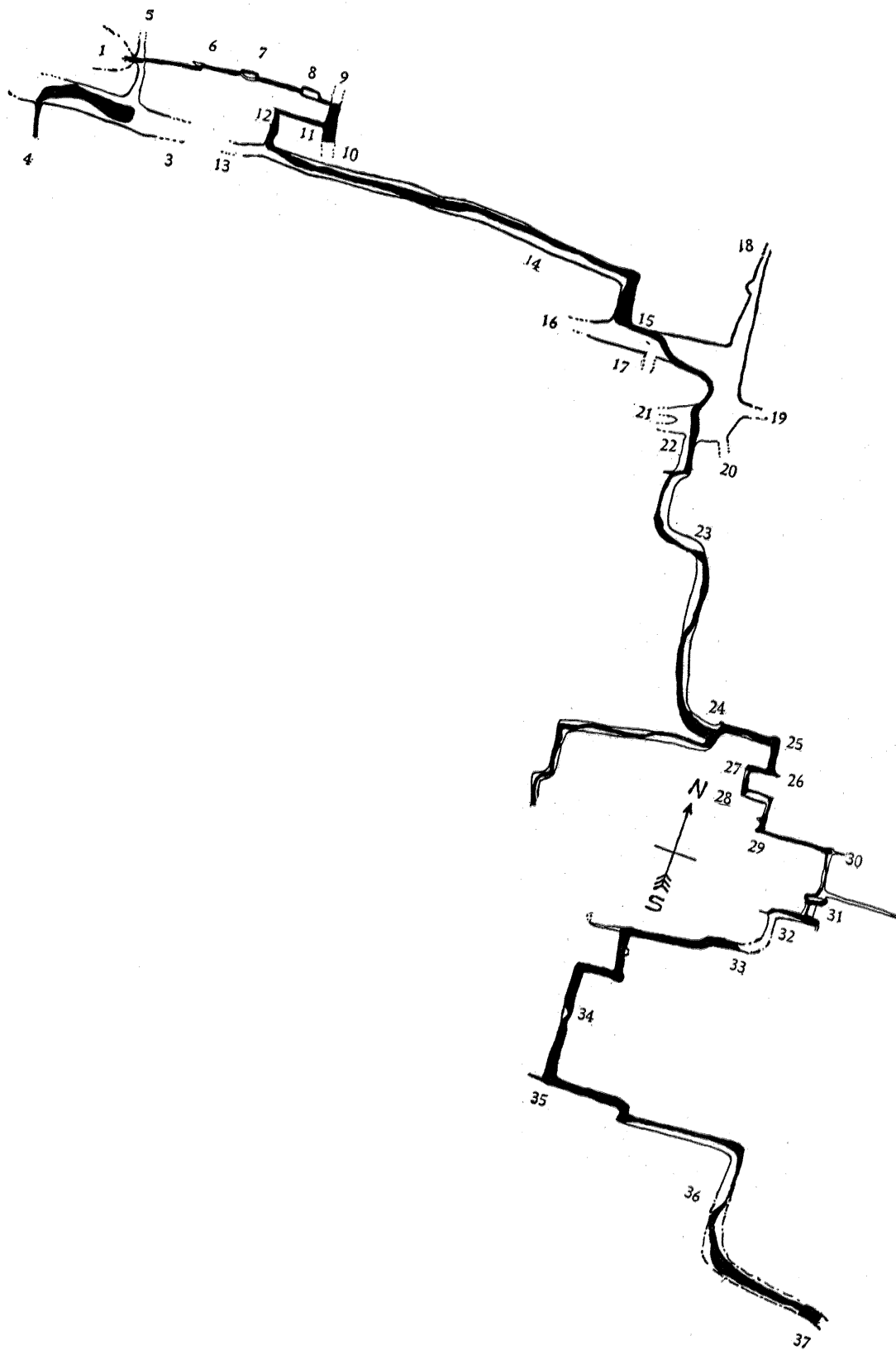


FIG. 1. Map of Shawnee Cave, section I, from Shawnee to Lower Dalton. Length 4,453 feet. Scale 200 feet to the inch.

EXPLANATION OF MAP.

Upper Dalton Cave. Sec. II., No. 37.

“Cross bedding” in limestone. Sec. II., Nos. 46-47.

“Old passages.” Sec. II., Nos. 56-57.

Obstruction past which boat cannot be taken. Sec. II., No. 63.

End of exploration. Sec. II., No. 64.

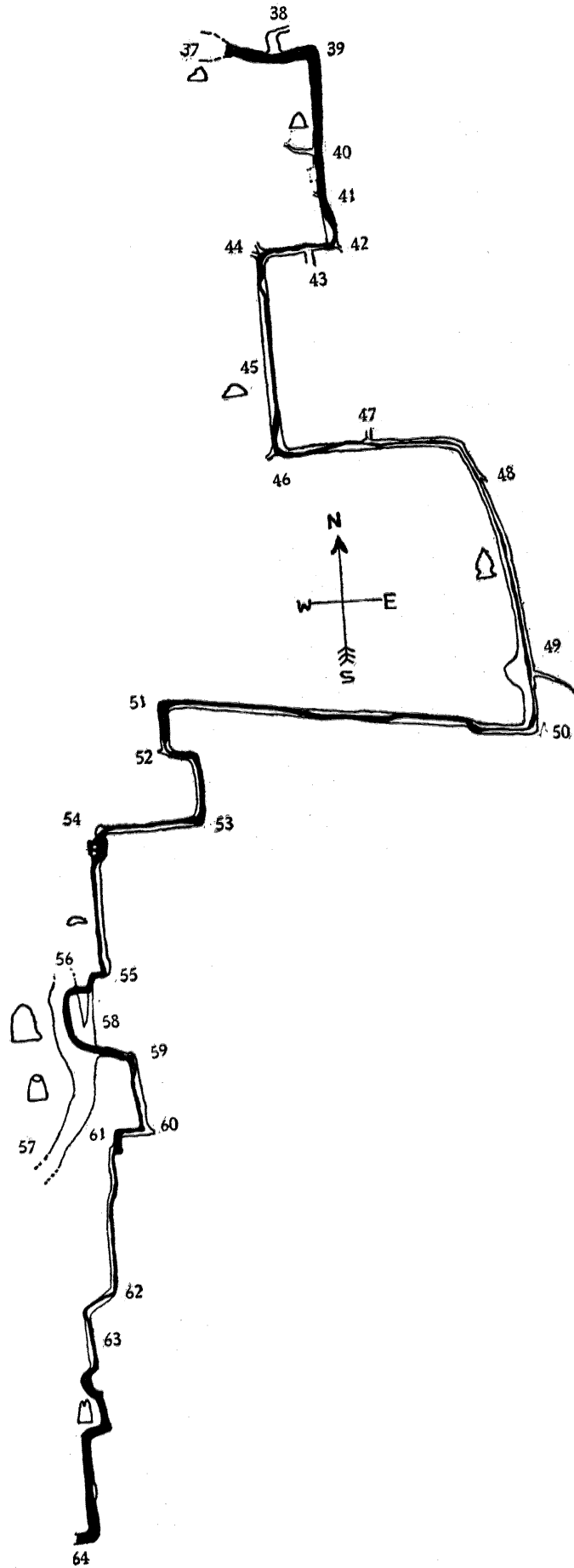


FIG. 2. Map of Shawnee Cave, section 2, from Lower Dalton to unexplored part. Length 4,674 feet. Scale 200 feet to the inch.