12.—PRELIMINARY REPORT UPON THE INVERTEBRATE ANIMALS INHABITING LAKES GENEVA AND MENDOTA, WISCONSIN, WITH AN ACCOUNT OF THE FISH EPIDEMIC IN LAKE MENDOTA IN 1884.

BY S. A. FORBES.

LAKE GENEVA.

My first visit to Lake Geneva was made in October, 1881, as an incident of work in progress on the Illinois State Natural History Survey, my purpose at the time being to compare the invertebrate fauna and the biological conditions of that lake with those of the much smaller and shallower lakes of the same series in northeastern Illinois. On this visit I hauled the dredge and beam-trawl and the surface net repeatedly in several parts of the lake, both along shore and in the deepest water, and carefully worked the product of the dredge and trawl through a set of assorting sieves, saving in alcohol everything collected. In August, 1887, I improved the opportunity of a casual visit to this lake to make much larger collections with the surface net, ran several lines of soundings across the lake, and collected from deep water, for analysis, the peculiar, soft, fine, mud—largely a chemical precipitate—which covers the bottom there to a great depth.*

* This mud has a peculiar rank, almost offensive, odor, and a soft, greasy feel, and rubs away largely between the fingers. It is of a pale slate-blue color when dry, darker when moist. Under the microscope it has a semi-crystalline appearance, and contains very little vegetable débris and not much sand. It effervesces freely in sulphuric acid, but does not wholly dissolve. A sample of this mud which had been taken from a depth of 20 fathoms was submitted to Prof. William McMurtrie, of the chemical department of the University of Illinois, who reported upon it as follows:

"The following are the results of analysis of lake mud:

	Per cent.
Carbon dioxide (CO_2)	25.00
Calcium oxide (CaO)	27.13
Magnesium oxide (MgO)	3.65
Organic matter	4.80
Insoluble residue	32.20
Ferric oxide (Fe_2O_3)	1.50
Aluminic oxide (Al_2O_3)	4.67

"These are doubtless engaged in combination as follows:

Calcium carbonate ($CaCo_3$)	48.445
Magnesium carbonate ($MgCO_3$)	7.665
Ferric oxide (Fe_2O_3)	1.500
Aluminic oxide (Al_2O_3)	4.670
Organic matters	4.800
Insoluble residue	32.200

"The insoluble residue consists of clay and sand."

Lake Geneva, in Walworth County, Wisconsin, is a clear and beautiful sheet of water about 7 miles long by 1½ in greatest width, with an extreme depth, according to my soundings, of 132 feet. It is a glacial lake, lying in a trough-like valley of the drift, the southern side of which formed part of the terminal moraine of the great Lake Michigan glacier. The valley is continued westward with a very gradual rise beyond the head of the lake, where a small stream empties its clear, cool water. By way of the outlet at its eastern end, its waters pass through Fox River into the Illinois. Its banks are high and rolling, but nowhere bluffy, and there is no rock anywhere in sight. The slopes of the bottom are mostly gradual, but off the "points" they may reach, for the first 500 or 600 feet, a descent of 1 foot in 5; while in the bays this is only about 1 in 50.*

The vegetation of this lake is chiefly confined to a narrow belt along the shore, except in Williams' Bay on the north side and in the shallow water near the outlet. In the deepest parts the bottom is perfectly destitute of living plants higher than diatoms, and there is also a remarkable scarcity and small variety of animal life in this situation.

In the shallow water, from the shore to a depth of 5 fathoms, the most abundant plants observed in 1881 were as follows: *Myriophyllum heterophyllum, M. scabratum, Ceratophyllum demersum, Potamogeton compressum, P. lucens, P. pauciflorum, Anacharis canadensis, and Chara contraria.*†

Swimming and creeping among the somewhat scanty growth of these aquatic plants, was a small variety of animals, the most abundant of which were the smallest of our common amphipod crustaceans (*Allorchestes dentata* Smith) and the larvæ of an abundant genus of gnats—*Chironomus*. A partial examination of the material collected by a dozen hauls of the dredge in this shallow water gave me the following imperfect list:

SHALLOW WATER COLLECTIONS, 1881.

INSECTA.

1. *Paraponyx* sp.? An interesting aquatic caterpillar, richly provided with tufted tracheal gills on all surfaces of the body, probably belongs to this genus of pyralid Lepidoptera. Two examples were taken among weeds growing on a gravelly bottom, in water 6 feet deep.
2. *Stenelmis crenatus* Say. Several adult specimens of this beetle were taken in a haul along shore, doubtless from the aquatic weeds.
3. *Dytiscidæ*. A single larva.
4. *Chironomus* sp. Very many specimens of small white larvæ belonging to undetermined species of these very abundant gnats.
5. *Phryganeidæ*. Various caseworms, mostly Leptoceridæ, with sand tubes, either straight and slender or short and curved. Tubes sometimes made of a webbed membrane covered with a thick layer of small spherical colonies of Rivularia or other similar Algæ. A remarkable larva of *Lagenopsyche* frequently occurred, the case transparent and commonly covered with diatoms. A single specimen of Sericostomidæ.
6. *Agrionina* and *Libellulina*. Nymphs of dragon flies.
7. *Ephemeridæ*. Most commonly nymphs of *Cænis*, of an undetermined species.

CRUSTACEA.

8. *Cambarus virilis* Hagen. Cray-fishes were not at all abundant in this lake, but a few young specimens of this species were taken in the dredge.

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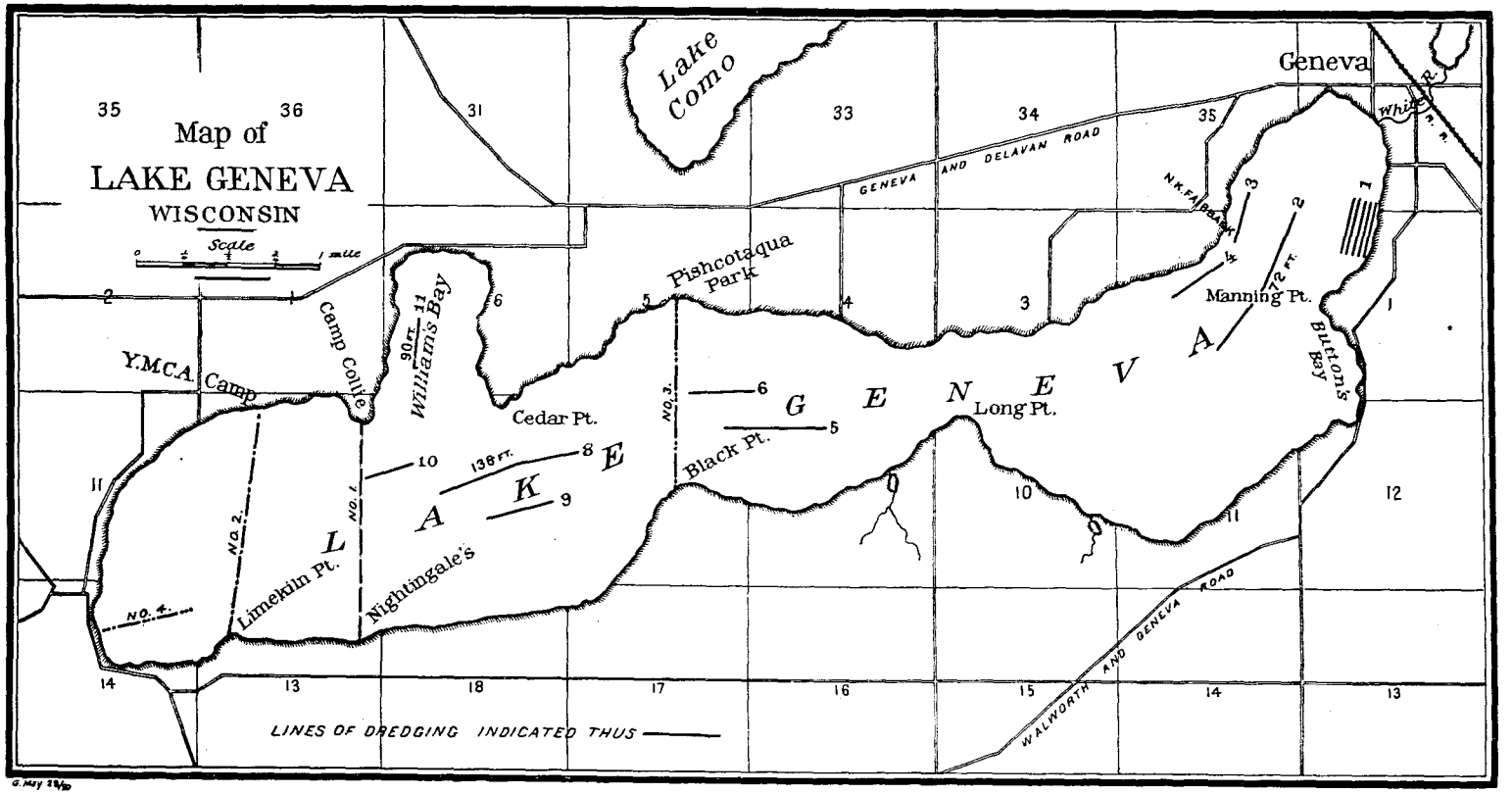
* See profiles, page 476.

† Determined for me by Prof. T. J. Burrill, of the University of Illinois.

PLATE LXXII.



Bull. U. S. F. C. 1888.—(To face page 474.) Forbes. Invertebrates.

9. *Gammarus fasciatus* Say. Occasional examples occurred.
10. *Allorchestes dentata* (Smith) Faxon. This was by far the commonest crustacean, and swarmed among the weeds.
11. *Candona elongata*? Herrick. This shelled entomostracan occurred but once in the dredge.

MOLLUSCA.

The common mollusks from my dredgings were *Unio luteolus* and *Anodonta footiana* (neither abundant), *Planorbis campanulata* and other species of that genus, *Pisidium adamsi* Pr.,* *P. compressum*,† *Sphærium solidulum*,† a few Physas and Limneas (the former the commoner), an occasional *Melantho*, a great number of *Amnicola cincinnatiensis*, and many examples of *Valvata tricarinata* and *V. sincera*.

VERMES.

The worms of these inshore collections were limited to a few leeches and planarians, occasional specimens of *Stylaria lacustris* Linn., and an undetermined species of *Pristina*.

Besides the foregoing, I obtained here only a small number of water-spiders (Hydrachnidæ), a few examples of our most abundant darter (*Boleosoma nigrum*), and a common sunfish (*Lepomis*).

DEEP WATER COLLECTIONS, 1881.‡

In the deeper water the collections were not especially different where the bottom was covered with vegetation. A haul of the beam-trawl made on a mud bottom in the eastern end of the lake at a depth of 12 fathoms, among *Ceratophyllum* and *Anacharis*, gave a nearly full assortment of the smaller mollusks of the lake (*Valvata tricarinata*, *V. sincera*, *Amnicola cincinnatiensis*, *Planorbis*, *Physa*, *Sphærium solidulum*, *Pisidium adamsi*, and *P. compressum*), *Physa*, *Sphærium*, and *Valvata sincera* being the most abundant.

Numbers of *Chironomus* larvæ, a dytiscid larva, and a caseworm were the only insects, and *Allorchestes* and *Candona* the crustaceans of the haul. Among the Vermes was a long and slender species (*Limnodrilus*) with four rows of notched or forked setæ arranged in short, transverse, comb-like ranks, each of four to six.

A short haul of the dredge at a depth of 15 fathoms in Williams' Bay, on a bottom of sandy mud covered with dead leaves, yielded a single *Physa*, a small *Planorbis*, a multitude of *Pisidium adamsi*, many *Valvata striatella*, many larvæ of *Chironomus* and pupæ and pupa cases of *Corethra*, a few *Candona elongata*, a multitude of dead branches of a polyzoan (apparently *Fredricella*), many *Limnodrilus*, and a few examples of *Stylaria lacustris*. The more highly organized crustaceans and insect larvæ were here altogether wanting, the principal animals being the smaller mollusks, *Pisidium* and *Valvata*, the worm-like larvæ of gnats, and the slender, reddish worm, *Limnodrilus*, living in the slime.

A single haul on a mud bottom near the eastern end of the lake, at 19 to 20 fathoms, gave only large red *Chironomus* larvæ in considerable numbers, several

* Determined by Mr. H. A. Pilsbry, of the Philadelphia Academy of Sciences.

† Named by comparison with specimens determined by Mr. G. W. Tryon.

‡ For the opportunity to dredge this lake to advantage I was greatly indebted to Mr. N. K. Fairbank, of Chicago, who placed at my disposal for this purpose his steam-yacht and its crew.

examples of *Pisidium adamsi* a single *Gammarus fasciatus* (doubtless taken in lifting the dredge), and one dead shell of *Planorbis campanulatus*.

Finally, two hauls of the trawl and two of the dredge in the middle of the lake, at a depth of 23 fathoms, yielded quantities of the softest black mud with some admixture of dead leaves, an abundance of large red *Chironomus* larvæ, *Pisidium adamsi*, and the undetermined worm (*Limnodrilus*) already mentioned. The only other specimens secured by this deep-water work (which aggregated over a mile of continuous hauling) were two specimens of *Sphærium*, one of *Valvata tricarinata*, one of *V. sincera*, a dead *Physa*, a few pupæ of *Corethra*, and three leeches. No living vegetation was found here except diatoms.

With the surface net, in open water, I secured at this time only a moderate number of a *Daphnia* closely resembling *D. retrocurva* Forbes (and possibly a variety of that species), a few examples of *Epischura lacustris* Forbes, a *Diaptomus* (apparently a variety of *sicilis*), another large copepod, *Limnocalanus macrurus*, and the remarkable cladoceran form, *Leptodora hyalina*.

The material of 1887 was obtained mostly with a towing net, in eighteen collections, made at various points along the margin in shallow water and also in the deepest parts of the lake. The following lists, although not exhaustive, are sufficiently complete to show the dominant and associate species, and the conditions governing their relative abundance.

DEEP-WATER COLLECTIONS, 1887.

Upper end of lake, August 6, deep water, clear weather, sunrise, wind. A surface haul and a small collection, with much small vegetable drift.

1. Larvæ of *Chironomus*.
2. Young neuropterous larvæ.
3. A large hydrachnid, undetermined.
4. *Allorchestes dentata* Faxon. A few females bearing eggs.
5. *Daphnia retrocurva*, var. An occasional specimen.
6. *Daphnella brachyura*.
7. *Sida crystallina*.
8. *Cyclops*, sp.
9. *Epischura lacustris* Several specimens

August 5, deep water, at surface, sunset, calm. A small collection, obtained by dragging the towing net behind a steamer.

1. *Daphnia retrocurva*, var. A few specimens.
2. *Epischura lacustris*. The principal part of the collection.

August 5, deep water, 10 a. m., at surface, cloudy, calm. A small collection.

1. *Chironomus*. A few examples of larvæ and pupæ.
2. *Daphnia retrocurva*, var. The greater part of the collection.
3. *Epischura lacustris*. Several specimens.
4. *Diaptomus sicilis*, var. A few examples.

August 9, deep water (20 fathoms), 10 a. m., sunshine, net hauled about 10 feet below surface. A large collection.

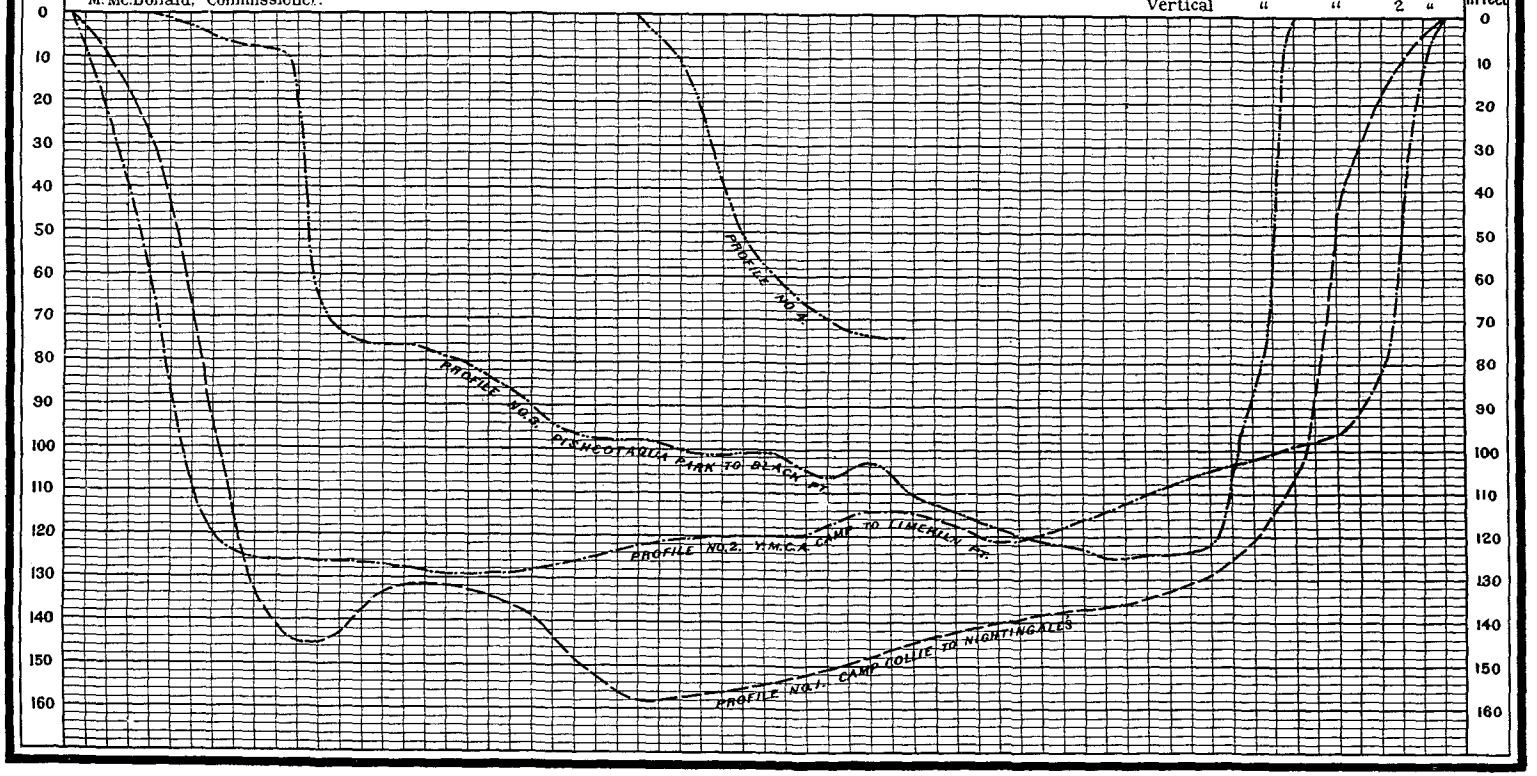
1. *Leptodora hyalina*. Several specimens.
2. *Daphnia retrocurva*, var. The greater part of the collection.
3. *Daphnella brachyura*. A few examples.
4. *Cyclops*, sp. A few examples.
5. *Epischura lacustris*. A few examples.
6. *Diaptomus sicilis* and var. A few.

DIAGRAM OF PROFILES ACROSS LAKE GENEVA, WISCONSIN.

Based on soundings by S. A. Forbes.

U. S. Commission of Fish and Fisheries,
M. Mc. Donald, Commissioner.

Horizontal spaces represent 100 feet.
Vertical " " 2 "



Bull. U. S. F. C. 1888.—(To face page 476.) Forbes. Invertebrates.

August 9, deep-water, 4 p. m. sunlight, net hauled about 20 feet below surface. A good collection.

1. *Leptodora hyalina.* Several.
2. *Daphnia retrocurva,* var. A great number.
3. *Daphnella brachyura.* Occasional specimens.
4. *Cyclops,* sp. Very few.
5. *Epischura lacustris.* Very abundant.
6. *Diaptomus sicilis,* var. An occasional example.

August 9, 10 a. m., sunshine, deep water, calm, net dragged about 90 feet below the surface. A very large collection.

1. *Leptodora hyalina.* A great number.
2. *Daphnia retrocurva,* var., with obtuse apex to helmet. A very large number.
3. *Epischura lacustris.* Occasionally seen.
4. *Diaptomus sicilis,* var. Not abundant. One female noticed bearing spermatophore.

August 9, deep water, 4 p. m., 10 feet below surface, sunshine, calm. A good collection.

1. *Leptodora hyalina.* A few.
2. *Daphnia retrocurva,* var. The main part of the haul.
3. *Epischura lacustris.* A few examples.
4. *Diaptomus imperfectus.* A few examples.

August 4, upper end of lake, deep water, 9 p. m., moonlight, at surface. Fine and large collection.

1. *Daphnia retrocurva,* var. Many examples.
2. *Daphnella brachyura.* Occasional young.
3. *Epischura lacustris.* The principal part of the catch.

August 7, upper end of lake, deep water, 9 p. m., at surface, stiff breeze. A large collection.

1. *Leptodora hyalina.* Occasionally observed.
2. *Daphnia retrocurva,* var. The greater part of the collection. Females were bearing eggs and young in various stages of development, the germinal disk just forming in some, and others nearly ready to leave the brood cavity. The female usually carries but a single egg. These Daphnias were feeding on unicellular Algæ, as shown by crushing specimens on a slide.
3. *Daphnella brachyura.* A few young examples.
4. *Epischura lacustris.* Many specimens. One male seen with a slender spermatophore partly extruded.
5. *Diaptomus sicilis.* Occasional specimens.

A repetition of the foregoing.

1. *Leptodora hyalina.* A half-grown example.
2. *Daphnia retrocurva.* Only occasionally seen.
3. *Epischura lacustris.* This collection consisted almost wholly of this species. Evidently breeding here rapidly, the ovaries containing ova, as many as ten to fifteen in each female, and the abdomens of all having the spermatophore attached. Many of the ova had a large, central, orange globule, and floated when detached. Most of the males with developed spermatophores.
4. *Diaptomus sicilis,* var. Several specimens .8 to .9^{mm} long. Males with well developed spermatophores.

A single short haul of the towing net in the mud of the bottom, at a depth of 10 fathoms, yielded several specimens of *Pisidium adamsi* (the characteristic deep-water mollusk of this lake), an occasional *Daphnia retrocurva* var., several cyprids (including *Candona elongata*), a few dead branches of Polyzoa (apparently *Fredricella*), and a single *Limnodrilus*—the common mud-worm of the interior of the lake.

SHALLOW-WATER COLLECTIONS, 1887.

Several collections made from the margin of the lake to a depth of 9 or 10 feet gave a much more miscellaneous list than those from the open water.

1. *Corethra.* Pupa.
2. *Chironomus.* Larvæ and pupæ, the former occurring in every haul.

3. *Ephemeridæ.* Nymphs of several species, not determined. Most commonly belonging to the genus *Cœnis;* one example closely allied to *Ecdyurus,* and undoubtedly of that group by Eaton's Monograph; another similarly related to *Ephemerella.*
4. *Phryganeidæ.* Undetermined larva.
5. *Hydrachnidæ,* sp.
6. *Allorchestes dentata.* Abundant, especially among the weeds.
7. *Alona,* sp. Several times occurring. One allied to *A. tuberculata* Koch, but probably distinct.
8. *Acroperus leucocephalus.* Noticed but once.
9. *Eurycercus lamellatus.* More abundant.
10. *Ophryoxus gracilis* (?) Sars. Examples of a species of this genus not distinguishable from *gracilis* as described by Sars* were obtained among weeds in water 6 to 9 feet deep. This is apparently identical with *Lyncodaphnia macrothroides* Herrick.
11. *Daphnia retrocurva,* var. Only a single specimen.
12. *Moina rectirostris.* Taken at the margin.
13. *Latona setifera.* Three specimens of this somewhat rare crustacean were taken among weeds in water 6 feet deep.
14. *Sida crystallina.* Rather abundant in our collections.
15. *Cyclops,* sp. Several specimens; not critically studied.
16. *Epischura lacustris.* Only a few examples in one of the hauls at the margin.
17. *Diaptomus sicilis,* var. A few specimens among weeds, in water 9 feet deep.
18. *Stylaria lacustris.* A single example near the margin.
19. *Ophrydium,* sp. A few colonies of this protozoan taken from the weeds along shore.
20. *Arcella,* sp. Taken as above.
21. *Difflugia,* sp. Taken as above.

August 5, among the weeds at outlet, 5 p. m., sun, wind.

1. *Chironomus,* larvæ. Two or three examples.
2. *Agrionina.* A single larva of these dragon flies.
3. *Ephemeridæ.* Several larvæ, mostly of the Ephemerella group. (Eaton's Monograph, Pl. 40, Fig. 18.)
4. *Hydrachnidæ.* Four specimens taken.
5. *Allorchestes dentata.* Not abundant.
6. *Cypridida,* sp. Several examples, among them representatives of *Cypris vidua.*
7. *Eurycercus lamellatus.* Several specimens.
8. *Simocephalus,* sp. A dozen specimens similar to *americanus,* but differing apparently in specific characters.
9. *Moina rectirostris.* Two examples.
10. *Daphnella brachyura.* Several examples, including young
11. *Sida crystallina.* A few.
12. *Cyclops pectinifer* Cragin.
13. *Epischura lacustris.* A large number of this species, making, in fact, the chief contents of the collection.
14. *Diaptomus sicilis,* var. A few examples.

August 8, upper end of lake, sandy bottom, with *Chara contraria.*

1. *Chironomus,* larvæ. A slender white species.
2. *Cœnis,* sp. A single larva.
3. *Allorchestes dentata.* Several examples.
4. *Leptodora hyalina.* Several examples.
5. *Acroperus leucocephalus.*
6. *Ophryoxus gracilis* (?). Three examples.
7. *Daphnia retrocurva.* A very few.
8. *Latona setifera.* A single specimen.
9. *Sida crystallina.* Several examples.

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* Oversigt af de Omgegnen af Christiania iagttagne Crustacea cladocera. Forhandlinger i Videnskabs-Selskabet i Christiania, 1861, p. 158.

10. *Epischura lacustris.* A very few.
11. *Diaptomus gracilis.* Only one specimen.
12. *Ophrydium*, sp. A single colony.

A haul of the towing-net in swift water at the mouth of the inlet, made at 9 p. m., gave the following list:

1. *Corethra*, sp. A few pupæ about ready to emerge.
2. *Corixa*, sp. Several young.
3. *Ephemeridæ.* The collection was largely composed of larvæ of this family, mostly of the genus *Cœnis.* One dissected, had filled the alimentary canal with fine dirt, containing a few filaments of Algæ and occasional diatoms. Other larvæ were allied to *Callibætis* of Eaton's Monograph. The palpi of the first and second maxillæ had, however, but two joints each. One ally of *Ecdyurus* was also noticed.
4. *Hydrachnidæ.* Several examples.
5. *Allorchestes dentata.* A single one.
6. *Daphnia retrocurva*, var. A few.
7. *Sida crystallina.* Several examples.
8. *Cyclops*, sp. Occasional examples; not determined.
9. *Epischura lacustris.* Several specimens.
10. *Limnodrilus* sp. A single specimen of this mud worm.

A small collection made by turning stones in the water along the shore gave several larvæ of *Psephenus*, probably *lecontei*, but differing noticeably from Kellicott's figure of that curious and interesting animal, as given in the "Canadian Entomologist," Vol. XV., p. 191. A *Cœnis* nymph, another of the Ecdyurus group, and a phryganeid pupa in its sand tube, were the only other insects. A single fresh-water shrimp (*Palæmonetes exilipes*) was taken here, together with a few examples of *Gammarus*—possibly young of *fasciatus*, but too small for determination. Also *Allorchestes dentata*, a single *Gordius*, and several small leeches.

It is evident from the foregoing that even in a lake of so moderate size as this, the smaller inhabitants are quite clearly divided into pelagic and littoral groups, the latter containing the greater number of species, but the former not less numerous in individuals; and a comparison of the results of dredgings shows that this difference applies to the animals of the bottom as well as to those swimming freely above it.

This pelagic group of Entomostraca includes *Leptodora hyalina*, *Daphnia retrocurva*, and *Epischura lacustris*, as its principal species, *Diaptomus sicilis*, another pelagic form, being, apparently, not very abundant in this lake; while the characteristic animals of the *bottom* of the interior parts of the lake are *Pisidium adamsi*, a large red *Chironomus* larva, and a species of *Limnodrilus*—both this worm and the larva just mentioned making tubular burrows in the mud.

It is also apparent from the product of the towing net in deep water under varying conditions, that the pelagic Entomostraca avoid the surface by day, whether it be rough or calm, or the weather cloudy or clear; but that they do not necessarily withdraw to any great depth—hauls 10 feet below yielding "good" or "large" collections when the sun was shining. By night, on the other hand, the yield at the surface was large, even in a high wind.

LAKE MENDOTA.

I first visited Lake Mendota in August, 1884, at the request of Prof. S. F. Baird, U. S. Commissioner of Fish and Fisheries, for the purpose of making a study of a most remarkable mortality among the fishes of a single species in the lake—the common perch (*Perca flavescens* Mitch.).

In August, 1885, I returned, again at Professor Baird's request, with Prof. H. Garman, then my assistant, for some further studies bearing on the same subject.

Fourth Lake, or Lake Mendota, Wisconsin, is the uppermost and largest of a chain of lovely glacial lakes lying about the State capital, finding an outlet through a small stream into Rock River. It measures about 5¾ miles in greatest length, from east to west, and about 3⅛ in width, from "University Landing" to the head of Catfish Bay. It is thus wider than Lake Geneva, but not so long, and is not nearly so deep. The deepest sounding made by me was but 79 feet, and the average of six soundings, well distributed over the trough of the lake, was 10 feet less. The bottom is more diversified than that of Lake Geneva, showing reefs of rock and of sand, and a large area of weedy shallows. Its waters consequently swarm with fish—especially with the common perch—and the amount and variety of invertebrate life is doubtless greater than in the more uniform Lake Geneva. The bottom in the deeper water is not different in character from that of the other lake, but is covered by the same soft calcareous mud, with its peculiar little group of animal inhabitants.

Catfish Bay, about a mile and a half across, and half as deep, is bordered by an extensive marsh, which is drained by Catfish Creek, the principal feeder of the lake. There are about 80 acres of marsh at other points around the lake, but the shores are otherwise rolling, or even bluffy, especially in the narrower and deeper eastern division of the lake; and here are also several unfailing springs. Many other springs are said to open along the shores, below the water-level. This lake differs from the others of the chain by the fact that it has much the largest drainage area and receives a larger affluent than any other; and this, as already said, drains a swamp. The waters of the lower lakes come mostly from Lake Mendota, in which they must have deposited much of their sediment, and where much of their organic matter must undergo decomposition before they flow off through its outlet. On the other hand, about three-fourths of the sewage of the city goes into Third Lake, or Lake Wenona, the next below.

DREDGINGS.

My general collections from the lake in 1884 were limited, by want of time, to three hauls of the dredge, made with the aid of a small steamer, one in shallow water (8 to 9 feet) on a sandy bottom, one on a rocky reef at a depth of 12 to 18 feet, and a third on a mud bottom at 12 to 12½ fathoms.

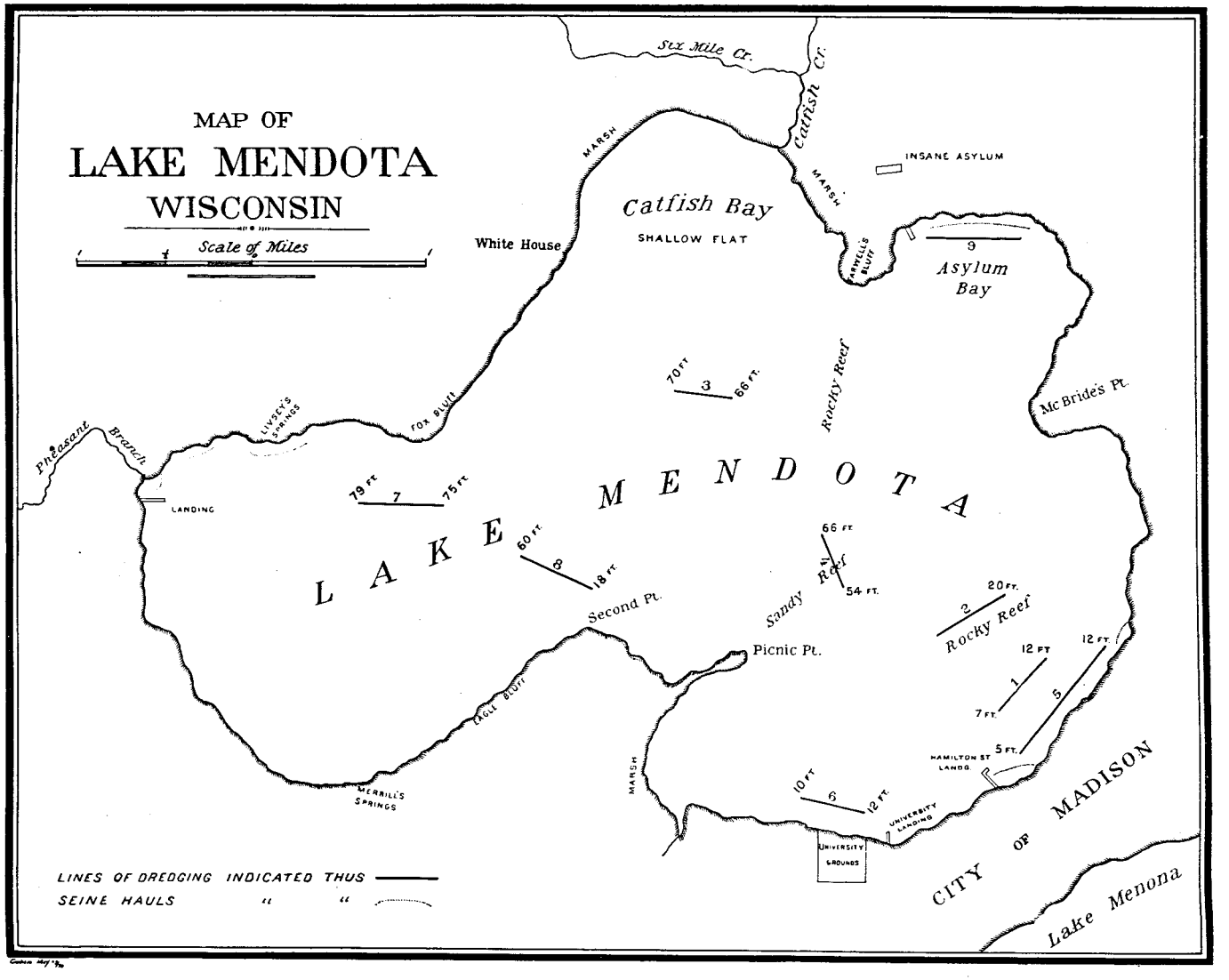
The first haul, on a sandy bottom covered with *Nitella*, yielded a great number of small white larvæ of *Chironomus*, with several small amphipod crustaceans (*Allorchestes dentata*), two or three small mollusks (*Amnicola*), a few worms (*Stylaria lacustris*), a single larval ephemerid (*Cœnis*), and two Entomostraca (*Eurycercus lamellatus* and a species of *Cypris*.) The collection was a small one, the entire product a cubic half-inch.

The haul on a rocky bottom gave only some small mollusks, not yet identified.

The deep-water dredging gave precisely the same group of animal forms as those in the mud of Lake Geneva, namely, a good collection of *Pisidium adamsi* Pr., several large deep red *Chironomus* larvæ, and a species of the tube-making worm *Limnodrilus*.

The principal collections of 1885 were made by nine hauls of the dredge, three of a fine-meshed seine, and seven of the surface net.

Those from the deeper water did not differ in any way from those of the preceding



Bull. U. S. F. C. 1888.—(To face page 480.) Forbes. Invertebrates.

year; but a haul in only 20 feet of water on the rocky reef above mentioned gave the common deep-water forms, *Pisidium adamsi* and the red *Chironomus*,* with an occasional *Corethra* larva also.

The shallow-water dredgings of 1885 were much more fruitful than those of 1884, giving many times the number of individuals, and especially a greater number of case-worms and small crustaceans (*Allorchestes*).

A cursory examination of a haul of the dredge made on the sandy shallow, likewise dredged in 1884, showed an abundance of *Allorchestes dentata* and small white *Chironomus* larvæ, a multitude of case-worms of various genera (including the curious *Heliopsyche* in its spiral tube of sand grains), *Amnicola*, *Valvata tricarinata* and *V. sincera*, *Sphærium*, leeches, planarians, etc., and a few Entomostraca. A fine *Plumatella* occasionally occurred encrusting the stems of weeds in shallow water.

The ordinary Unionidæ of these waters were *Unio luteolus* and *Anodonta footiana*, both of which were very abundant.

In the surface net occurred immense quantities of a helmeted *Daphnia* with head of truly monstrous size, sometimes larger than the body, apparently the *Daphnia kerusses* of Cox, rather imperfectly described and figured† from Fox River, the general outlet of this chain of lakes. With this were also many Daphnias of a species apparently new. Associated with these were frequently found large numbers of *Leptodora hyalina*, a few *Cyclops*, *Diaptomus*, and *Epischura*, occasional larvæ of *Chironomus* and *Corethra*,‡ examples of *Daphnella* and of water-mites (Hydrachnidæ), and immense and astonishing quantities of a shelled flagellate infusorian, *Ceratium longicorne*, with now and then the curiously similar rotifer, *Anurea longispina*. These minute forms fairly lined the net, and clouded the alcohol in which the specimens were preserved.

If any useful comparison of the biological conditions prevailing in Lake Mendota during these two years may be made on the rather slender basis of my collections, it would lead to an inference that invertebrate life was very much more abundant in 1885 than in 1884, and would suggest an over-population of the lake in the latter year which had greatly reduced the usual food of fishes of indiscriminate carnivorous habit. The vast abundance of the perch especially, in this lake, is shown by the fact that they formed nearly the whole product of three hauls made with the seine in 1885, notwithstanding that approximately 300 tons of this species had died here during the epidemic of the year before.

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* This blood-red larva, so often mentioned, is uniformly segmented, and about 30 millimeters long. It bears on the back of the penultimate segment four clavate anal appendages about as long as the segment itself, and on the antepenultimate segment two pairs of similar appendages, one at the anterior third and the other at the posterior margin. At the posterior margin of the dorsal surface of the penultimate segment are two prominent chitinous tubercles, each bearing three long recurved hairs. The labrum bears fifteen teeth, the middle one large and blunt with a very small coherent tooth each side. The remaining six on each side diminish in size outwards, the inner one of the series being larger than the median tooth. This tooth and the second are very closely united, the others free. The antennæ are five-jointed; the first joint cylindrical, stout, and very long, more than twice as long as the other four taken together. It bears articulated to its inner distal margin a long spine, lobed at the base, and as long as the remainder of the antenna. The next joint is also cylindrical, and about one-fifth as long as the first; the third joint is thick and short; the fourth longer but more slender; and the last minute.

† Amer. Monthly Micros. Jour., Vol. IV (1883), p. 88.

‡ Our collections were all made by day.

THE FISH EPIDEMIC IN LAKE MENDOTA IN 1884.

Early in July, 1884, public attention was attracted, at Madison, Wisconsin, to the extraordinary numbers of fishes dying and floating ashore in Fourth Lake or Lake Mendota. By the middle of the month the accumulation of their rotting bodies along shore had become a public nuisance, and the street commissioner began to cart them away from the city front and bury them. By the 19th not less than 15 tons had been thus removed, and by August 4 from 75 to 100 tons. As the city borders only a small part of the lake, it was estimated that fully 300 tons had died up to that time. On August 7, the Madison Transcript reported that 200 tons had been hauled away by the city authorities during the four weeks preceding, and that the fishes were still dying. August 15, when the writer arrived at the lake, this remarkable epidemic had practically ceased, and during the week following (about six or seven weeks after its beginning) it disappeared completely, not to return that season or the following summer.

By far the greater part (perhaps 90 per cent.) of the fishes which perished were the common perch (*Perca flavescens*), much the most abundant species in the lake. Next came the lake herring (*Coregonus artedi*),* locally called the "white fish;" while pike-perch, white bass, and sunfish (*Lepomis*) were much less numerously represented.

My own first visit to the lake was made in consequence of a request from Professor Baird, then U. S. Fish Commissioner, conveyed in the following letter received by me at Normal, Illinois, August 13:

WOOD'S HOLL, MASSACHUSETTS, *August* 10, 1884.

DEAR SIR: Would it be convenient for you to visit the districts in Wisconsin where the mortality among the fish has developed itself to a very great degree? If you can, I will be glad to have you make a thorough investigation of the circumstances of the case. * * * I consider it a matter of very great importance, and one that should occupy the careful attention of specialists. I requested specimens to be sent to Mr. Ryder for his examination, but an investigation in the field on the sick and dying fish will be of much more importance.

Yours truly,

SPENCER F. BAIRD.

I arrived at Madison August 15 at 2.30 p. m., with seine, dredge, microscope, and a suitable apparatus for studying the fresh fluids and tissues of the diseased fishes, and for the permanent preservation of material of all kinds likely to throw any light on the subject under investigation. Through the kind assistance of Hon. Philo Dunning, of Madison, president of the Wisconsin State Fish Commission, a work-room was obtained at once in the boat-house of the steamer company, at the principal landing, and I spent two hours on the lake the same afternoon in search of dead and dying fish. I remained here until August 22, making collections as opportunity offered, carefully examining the freshest obtainable specimens for evidence of fungous parasitism, making numerous autopsies of fishes recently dead, preparing and staining slides of the blood and other fluids of those not yet dead when taken, for bacteriological study, and preserving the tissues of such fishes for later histological work. I also dredged the lake along shore and in deep water, as described in a foregoing part of this paper, but lack of time prevented my making as extensive general collections as was to be desired.

* This fish was introduced from Lake Michigan some years before, according to information given me by Mr. Philo Dunning and others.

During the first two or three days it was not difficult to find floating on the lake, among hundreds of putrescent bodies, now and then one which presented a fairly fresh appearance, the gills unaltered, the eyes not sunken, and the color bright. During many hours rowing, however, I saw but two perch in the act of dying and succeeded in capturing but one. The actions of these perch were precisely those described by previous observers as characteristic of the death struggle of the diseased fish. They were at the surface, fluttering their fins, spinning irregularly about or scarcely moving at all, often gasping as if for breath, rolling over on their sides or backs between convulsions, and occasionally, for a few moments, disappearing from sight or swimming feebly and irregularly along. The single sick fish captured, I took while it was still struggling, but it scarcely moved after it was landed in the boat. Slides of the blood of this fish, taken with a pipette from the auricle of the heart and from the venous sinus, were at once prepared, and its viscera were placed in 94 per cent. alcohol within a half hour of its death. I made similar preparations of the fluids and organs of other perch that had died of the disease—the freshest I could obtain—and dissected twenty-four of them for a study of the contents of their alimentary canals. In preparing the blood, I used the common method of making slides for bacteriological study, drying rapidly upon a cover glass a thin film of the blood, flaming it in the blaze of an alcohol lamp, staining with a glycerine solution of methyl violet or of Bismark brown, and mounting in Canada balsam.

The general appearance of recently-dead specimens was that of a healthy fish. They were, almost without exception, in good average condition, often fat and plump; a fact noticed with astonishment by all who gave the matter any close attention. The color was always bright, and the surface everywhere clean, and without a trace of fungous attack. The gills were very commonly congested, but not appreciably more so than those of a fish dying in the air. Their mucous membrane was seemingly always quite uninjured, and was certainly so in several specimens of which I examined the filaments microscopically; and there was no trace of parasitism, fungous or animal, in the gills of any fish I took. The heart was always distended with blood and sometimes so gorged that the bulging of the venous sinus was visible from without. The liver was likewise congested, but seemingly by mechanical causes, as its tissues gave no evidence of infiltration. The blood itself was normal, the corpuscles in perfect condition, and both they and the plasma free of bacteria. The alimentary canal presented no unusual appearance, and was commonly fairly well filled with food, much of which had evidently been eaten rather recently. Many of the large Chironomus larvæ, which composed the greater part of it in every case but one, were entire and still retained their dark red color.

Concerning the histological condition of the principal tissues of the diseased perch I have unfortunately very little to report. My removal during the autumn of 1884 from Normal to the University of Illinois at Champaign, and the consequent transfer of the laboratory equipment and collections under my charge, made it impossible for me then to prepare and mount the material obtained for histological study, and this was kindly undertaken for me by a microscopist in Chicago. From him I received later a good series of sections of liver, spleen, heart, brain, kidney, stomach, and intestine of the lake herring, but all the material from the single perch taken alive was destroyed by an unfortunate accident while in his possession, and I had left for study

only some slides of the brain, heart, liver, and spleen, hurriedly prepared in the field from two perch which had been dead an unknown length of time when taken.

Apart from the gorging of the heart and congestion of the liver already mentioned and a noticeable amount of cellular degeneration in the liver and especially in the spleen, these slides gave no definite hint of the nature of the disease. This degeneration, very much more abundant in the herring, consisted of a conversion of the contents of the cells into a yellow, dark brown, or black mass of minute spherical granules which had the appearance of micrococci; but as they did not stain with aniline they were very probably pigment granules instead; a supposition rendered more plausible by the equal or greater pigmentation of the viscera which I have since noticed in many seemingly healthy fishes. These altered cells were more abundant near the larger blood vessels, and where considerable numbers of them had undergone degeneration their walls were often broken down, and the cells were thus replaced by a collection of their dark yellow or black contents.

From a general study of my fish collections and of the conditions prevailing in Lake Mendota a number of additional facts of some significance may be selected.

(1) The herring, or so-called whitefish, of the lake were perishing in extraordinary numbers during the entire period of this outbreak, with symptoms precisely like those of the perch, and taking into account the relative numbers of these species in the lake, perhaps in as large or even larger proportion. These herring, like the perch, are, as is well known, bottom feeders, and in midsummer remain in the deeper waters. Furthermore, they die every summer, according to the uniform testimony of those with whom I talked, in precisely the same way as in 1884, but in very much smaller numbers. The condition of the bodies of the fresh herring examined, two of which were taken before death, was precisely that of the diseased perch, except that there was a greater amount of cellular degeneration of the viscera, particularly of spleen and kidney. Substantially all the substance of the former organ except the gorged blood vessels was replaced by masses of the spherical granules already described, or by cells filled with them, and the kidneys of the specimens examined were so loaded with them as to be black to the naked eye.

There follows from the above a considerable probability that the perch were affected by the same cause as the herring, or else that the disease was a contagious one and taken from the herring directly. It is further likely that this cause is present every year, as is shown by the regular death of a small number of the latter fish, but that its action was greatly intensified in 1884.

(2) The majority of the perch dying were full grown, and absolutely no young were seen either by myself or by any one with whom I talked. The captain of the passenger steamer, who spends most of his time on this lake, had seen none dead less than 5 or 6 inches in length and of an estimated age of three or four years. The smallest specimens which I saw were at least half grown; but according to Professor Birge, of the University of Wisconsin, a few specimens were seen not over 3 or 4 inches long.

(3) There was a marked contrast in food between the dead and diseased fishes and the healthy ones taken by the use of the seine in the shallow waters along shore. The former had eaten, almost without exception, little or nothing but a large red Chironomus larva living, as shown by the notes on collections given in the preceding part of this paper, in the mud of the deeper water, while the healthy fishes taken in the seine had not fed at all upon these large red larvæ, but only upon smaller white

larvæ of another species of Chironomus and upon a variety of the smaller animal forms occurring among the weeds in the shallow water. The following are the details of the food of fourteen diseased perch and of nine healthy ones taken by hook or seine at the same time, the numbers being those from my laboratory catalogue of accessions.

FOOD OF DISEASED PERCH.

4929. The intestine of this specimen was empty, but the stomach was well filled with larvæ and pupæ of the large red Chironomus.

4947. Full of large red Chironomus larvæ* 20 to 25 millimeters in length, and pupæ of the same species 16 millimeters long.

4948. A great quantity of food, consisting of the usual large red larvæ and pupæ of Chironomus, 15 millimeters long, with some very fine dirt.

4949. A moderate amount of the large Chironomus larvæ and pupæ.

4950. A rather small quantity of larvæ and pupæ of red Chironomus, with some very fine dirt.

4951. A moderate amount of the same material.

4952. Red Chironomus larvæ and pupæ, as usual, in very large quantity. A single crushed entomostracan of the order Cladocera.

4953. The usual larvæ and pupæ of Chironomus only.

4954. As above, the larvæ 20 millimeters in length.

4955. A great quantity of food of the usual character and nothing else, the pupæ predominating.

4956 and 4957. Larvæ and pupæ of the red Chironomus only.

4958. This specimen furnished the only exception to the usual food of the dead perch taken. The stomach contained a moderate number of nymphs of Ephemera and a few small white larvæ and pupæ of Chironomus, the larvæ 10 millimeters long. Although dead when taken, it is possible that this fish had not perished by disease. The objects which it had eaten are those found in relatively shallow water.

4961. A rather small amount of food, not recently taken, the pupæ and larvæ of the red Chironomus being chiefly in fragments.

The contents of the alimentary canal of ten other specimens, not examined microscopically, was evidently of the same character.

FOOD OF HEALTHY PERCH.

4945. Chiefly larvæ and pupæ of Chironomus, the former white, 10 millimeters long; also two or three specimens of *Allorchestes dentata*, and a long and slender caseworm with tube of sand.

4946. A considerable number of small larvæ and pupæ of Chironomus, white in color, several *Allorchestes dentata*, a single caseworm with sand tube, one specimen of *Eurycercus lamellatus*, and a single Cyclops.

* The food of these larvæ, determined by dissection, consisted of very fine mud, with a great quantity of minute vegetable débris, composed of various kinds of cellular structures. These were evidently in a state of decomposition, as shown by the vast numbers of bacilli and other bacteria everywhere among the contents. There was also occasionally a filamentous alga resembling Oscillaria, and a few unicellular algæ were noted.

4959. Chiefly the small white Chironomus larvæ, and pupæ of the same, several examples of *Allorchestes*, a few nymphs of the genus Ephemera, a single *Eurycercus lamellatus*, and fragments of filamentous Algæ; with some other vegetable particles.

4960. A considerable quantity of the larvæ and pupæ of Chironomus already mentioned,—the former 9 to 10 millimeters long,—together with immature Ephemeræ and fragments of filamentous Algæ.

4962. This specimen added to the usual Chironomus larvæ and pupæ which formed the greater part of the food, a few *Allorchestes*, a young larva of Ephemera, a Corixa larva, a small leech, and a single young Sphærium.

4963. Many specimens of *Allorchestes dentata*, a few caseworms with their sand-tubes, several nymphs of Ephemera, a considerable number of small chironomid larvæ, and two specimens of Cyclops.

4964. Chiefly larvæ and pupæ of the small Chironomus. Besides these a few caseworms and specimens of *Allorchestes*.

4965. (From Third Lake.) Several of the usual small Chironomus larvæ, a larva of Corethra, and the mollusk Physa.

4988. The stomach of this example contained only larvæ and pupæ of the small Chironomus. In the intestine, besides the above, there were two caseworms in their cases.

(4) All the facts just cited tend to show that the perch perishing were ranging in the deeper water, and that they had almost invariably made their last meal of insect larvæ found only in the mud of the deeper parts of the lake; that they had been, in short, in company with the herring likewise notably diseased. I was informed by a fisherman familiar with the lake and its inhabitants that it was an extraordinary thing to find the perch ranging into deep water in midsummer, although they were frequently found in numbers in the depths of the lake in winter, when fished for through the ice. In these winter specimens red "worms" (Chironomus larvæ ?) were often noticed.

(5) The mud from the deeper part of the lake, as has been already mentioned, had a peculiar rank and almost stinking odor, and contained a considerable quantity of organic matter undergoing more or less rapid decay.

(6) A comparison of my collections from Lake Mendota with those from Lake Geneva, reported in this article, and especially with my much more abundant collections made from the lakes in northern Illinois, shows an unusually small proportion of cray-fishes, Aselli, Allorchestes, and other crustaceans ordinarily common in our lakes among the weeds and shallower waters generally, and a correspondingly large percentage of Chironomus larvæ in the food of all the perch examined,—a fact which hints at the probable deficiency in this lake of the kinds of insect larvæ and crustaceans usually selected by the perch.

(7) The weather of the summer had been warm and rather showery, but not in any way especially remarkable. There was, however, one heavy flooding rain not long before the outbreak of the fish disease, which may well have washed into the lake unusual quantities of organic matter from the swamp beyond Catfish Bay and from the surrounding country. Any organic accumulations due to such an occurrence would necessarily have been more evident in Lake Mendota, the uppermost of the chain, and that with the largest drainage basin, than in any of the lakes below.

(8) What seem, from the best information I can obtain, quite similar cases of destruction of our native fishes, are of rather common occurrence in the rivers of Illi-

nois in the hottest weather of the year. They usually, if not always, follow upon flooding rains, and thus occur when the streams are full or overflowing with turbid water loaded with the products of decay. They are sometimes succeeded by great deposits of rotting fish along the river front of towns, requiring burial to protect the general health.

We have in the facts reported here abundant material for surmise and the construction of hypotheses; but no means of precise verification. Arriving at Lake Mendota after the practical cessation of the epidemic argued a disappearance or a great reduction of its cause, and unable to obtain good material enough from which to generalize, I have withheld this report in the hope that a similar occurrence within my reach might enable me to complete the investigation. Several of the kind have, in fact, been noticed in Illinois within recent years, knowledge of which has reached me through our State Fish Commission, but always much too late to permit successful study. It therefore now seems to me best merely to put on record the facts already ascertained, and to postpone discussion until more evidence has been collected.