The Unionidæ of Lake Maxinkuckee.

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During the physical and biological survey of Lake Maxinkuckee carried on by the writers at intervals from 1899 to 1913, under the auspices of the United States Bureau of Fisheries, considerable attention was devoted to the freshwater mussels or clams (Unionidæ) inhabiting that lake. This was justified by the rapid and astonishing development of the pearl button industry in America, which is dependent upon the shells of the mussels for its raw material. The recent development of methods whereby several species of Unionidæ are now successfully propagated artificially adds special interest to the study of these mollusks.

Lakes and Ponds as the Home of Mussels.

Generally speaking, lakes and ponds are not so well suited to the growth and development of mussels as rivers are; the species of lake- or pond-mussels are comparatively few, and the individuals usually somewhat dwarfed. Of about 84 species of mussels reported for the State of Indiana, only about 24 are found in lakes, and not all of these in any one lake, several of them but rarely in any. Of the 24 species occasionally found in Indiana lakes, but 5 are reported only in lakes, and only 3 or 4 of the species common to both lakes and rivers seem to prefer lakes.

In rivers, the essential feature favorable to the development of mussels is the current; and in rivers the mussel beds reach their best development on riffles, where the current is strongest. The importance of the current to the well-being of the mussels is indicated by the position these mollusks naturally assume in the beds, the inhalent and exhalent apertures of the creatures being upstream against the current. The importance of the current is not merely as a bringer of food; examina-

tions show that the mussels of the plankton-rich lakes and ponds usually contain more food material than those of the rivers. The current gives the river-mussels the advantage of a constant change of water, which means a more abundant supply of oxygen, and doubtless a more varied supply of mineral matter, from the various sorts of soil through which the river flows. The current is also probably of considerable importance in assisting in the fertilization of mussels, one of its results being the conveyance of sperm from mussels in upper portions of the bed to other mussels below. In places where there is no current, fertilization must be more largely a matter of chance.

Although the majority of species of mussels prefer a river where there is a good current, some are more fitted to the quieter parts of streams, or to ponds. These are chiefly thin-shelled species with weakly developed or undeveloped hinge-teeth, best represented by the genus *Anodonta*. In some places Anodontas are known as pond-mussels, to distinguish them from the heavier sorts, or river-mussels.

The distinction between lakes and rivers is not constant in degree; we have all sorts of gradations from the extreme form of lakes—isolated bodies without outlet—through lakes with relatively large, important outlets, to such lakes as are simply expansions of a river-bed, examples of the latter type being Lake Pepin, Minn., of the upper Mississippi, and the former English Lake in Indiana, an expansion of the Kankakee. As a usual thing, the more fluvatile a lake is, or the larger and more river-like its outlet, the more river-like will be its mussel fauna, both in abundance and species. In such lakes the mussels retain a vital continuity with the mussel beds of the river. In the less fluvatile lakes the mussels are more isolated, and there is more in-breeding. The large number (24) of lake-dwelling species recorded for Indiana is due to the fact that some of the lakes of Indiana are more or less fluvatile, and contain several species of river shells.

Origin and Character of the Maxinkuckee Mussels.

Lake Maxinkuckee, having a long, narrow, and relatively unimportant outlet, is a representative of one of the less fluvatile types of lakes, forming a pretty well marked contrast to the various lakes cited above, and bearing a pretty close resemblance to the neighboring lakes, such as Twin Lakes, Pretty Lake, Bass Lake, etc.

The Maxinkuckee mussels are doubtless derived from ancestors brought up the Outlet from the Tippecanoe River by ascending fishes. It is doubtful whether any have been introduced by the numerous plants of fish in the lake, though such a thing is possible. During various times the lake was visited, a few Tippecanoe River mussels were planted in the thoroughfare between the lakes, and a few Yellow River and Kankakee mussels were planted in the main lake.

The Outlet of Lake Maxinkuckee is now a narrow, shallow, winding stream, straightened in places by ditching, and bordered on each side by a flat sedgy plain which indicates the former breadth and importance of the stream. The colonization of the lake with mussels was probably effected chiefly during the period when the Outlet was a broad and relatively important stream. The situation has been carefully considered and seems to show that the mussels of the river and lake are isolated from each other and that there is no longer any vital connection between them. The strongest indication of the independence of the lake and river mussel faunas is the appearance of the Maxinkuckee mussels themselves; these are lake-mussels, easily distinguished for the most part from the river-mussels of the same species, and many of them are distinguishable also from the mussels of the neighboring lakes.

The Tippecanoe River is fairly well supplied with mussels. Although the number of species is considerably fewer, and the size of the individuals is generally smaller than those of the Wabash into which it flows, it compares very favorably with rivers of its size. At Delong, Ind., a short distance above the mouth of the Outlet of Lake Maxinkuckee, specimens were obtained in one bed representing twenty-four species of mussels, or about twice the number of kinds found in Lake Maxinkuckee.

Our knowledge of the extent and importance of migrations of fishes from the Tippecanoe River up to the lake and from the lake down to the river—a question which has a marked bearing upon the relationship of the mussel faunas—is not as complete as it should be, but indications are that they are not important or extensive. Inasmuch as the geographic distribution of a given species of mussel is coextensive with that of the species of fish which serves as its host, this question is

worthy of careful consideration. There are several species of fishes of the Tippecanoe River (*Etheostoma camurum, Hadropterus evides, Hybopsis amblops*, etc.), which were not found either in the Outlet or in the lakes, and other species (*Hadropterus aspro, Ericymba buccata, Diplesion blennoides*) which have pushed half way up the Outlet, but were found no further up.

In this connection, the mussel fauna of the Outlet is worthy of consideration, and on various occasions, but especially on a trip down the Outlet September 30, 1907, particular attention was paid to this feature.

The Outlet is not particularly well suited to the growth and life of mussels. The bottom is either a firm peaty soil or fine shifting sand; moreover, the course has been artificially changed in some places and the stream has naturally shortened its length in others by making cutoffs. In addition to this the mussel fauna of such a narrow shallow stream would be the prey of muskrats, minks, etc., the entire length and width of the beds.

On the trip mentioned above, about a mile below Lost Lake a fine example of *Lampsilis iris* was found. This is the farthest up stream any species of mussel was obtained, and as this species is fairly common in both lakes and abundant in the Tippecanoe River, we have here the nearest approach to a continuous fauna. Some dead shells but no living examples of *Quadrula undulata* were found a little farther down. Farther down stream from a quarter to half a mile, a short distance above the second cross-road south of the lake, was found a small mussel-bed of about forty or fifty mussels, the great majority of which were *Quadrula undulata*. A few living *Lampsilis iris*, two dead *Symphynota compressa*, one living *Symphynota costata* (gravid) and a few dead shells of *Quadrula coccinea*, complete the list. Below this point no mussels were found until near where the Outlet joins the Tippecanoe. Here, a few rods up the Outlet, a fair bed of *Quadrula coccinea* was found. Of the five species of mussels found in the Outlet, only two, *L. iris* and *Q. coccinea*, are found in the lake, the latter but rarely. The form and general appearance of the *Q. undulata* of the Outlet is quite peculiar and they can be picked out at once from collections from the various rivers of the country. They are unusually elongate, in this respect resembling some of the Tippecanoe mussels but differing from them in

being thinner, and in having the furrows between the plicæ unusually deep and sharp. The costæ on the posterodorsal slope are very marked, and the epidermis is jet black. The umbones are considerably eroded.

Distribution of Mussels in the Lake.

In rivers, where there is a great variety of conditions, such as differences of current, bottom, etc., one finds the different species of mussels inhabiting different localities and different situations. In the lakes, where we have comparatively few species of mussels and not such important differences of environment, the distribution of the various species is much the same. The same conditions, such as rather shallow water and moderately firm bottom, are equally suitable for all. A few important exceptions may be noted, as for example, the less common species of the lakes are often more or less local in distribution. The only well-marked bed of *Quadrula rubiginosa* in the lakes is in the Lost Lake mussel-bed below the Bardsley cottage, and this is the only place where *Lampsilis subrostrata* can be collected in any considerable numbers. *Lampsilis glans* has a marked preference for the shallow water at the edge of the thoroughfare between the lakes; occasional examples can, however, be picked up almost anywhere along the shore, and it appears to be increasing considerably along shore at Long Point. *Anodonta grandis footiana*, which can live in softer bottom than the other mussels, has a considerably wider distribution, and was dredged in deeper water than any of the other mussels.

The mussels are to be found almost anywhere in water from 2 to 5 or 6 feet deep where the bottom is more or less sandy or marly. The beds are composed chiefly of the three principal species of the lake, *Lampsilis luteola*, *Unio gibbosus* and *Anodonta grandis footiana*, with the less common species sparsely interspersed. Especially good mussel beds occur at Long Point, along shore by Farrar's and McDonald's, along the depot grounds in Aubbenaubee Bay out from the Military Academy, and in the shallow water just beyond the mouth of Norris Inlet. Mussels are fairly well scattered from Long Point more or less continuously all the way southward to beyond Overmyer's hill, and from a little north of the ice-houses all the way around to the Military Academy. They are quite abundant in the neighborhood of Winfield's

in shallow water, and occur scattered along the east side of the lake a little way out from the shore. A good mussel bed is found in Lost Lake along the east shore, extending from a little south of the Bardsley cottage to where the bullrushes and water lilies grow thickly in the soft black muck near the shore.

Movements.—Closely connected with the question of distribution is that of movement. The greater number of mussels of the lake, especially in the deeper water, spend their lives in a state of quiescence. Young mussels appear to be more active than older ones. The mussels retain the power of locomotion during all their lives, but after they have got well settled down, they only occasionally use this power. The mussels in shallow water near the shore move into greater depths at the approach of cold weather in late autumn or early winter and bury themselves more deeply in the sand. This movement is rather irregular and was not observed every year. It was strikingly manifest in the late autumn of 1913, when at one of the piers off Long Point a large number of furrows was observed heading straight into deep water, with a mussel at the outer end of each. The return of the mussels to shore during the spring and summer was not observed. Many of them are probably washed shoreward by the strong waves of the spring and summer storms, and some are carried shoreward by muskrats and dropped there. Occasional mussels were observed moving about in midwinter, even in rather deep water. During the winter of 1900-1901, an example of *Lampsilis luteola*, in rather deep water in the vicinity of Winfield's, was observed to have moved about 18 inches in a few days. Its track could distinctly be seen through the clear ice.

As a result of the quiescence of the lake mussels, the posterior half or third of the shells, which projects up from the lake bottom, is usually covered by a thick marly concretion which appears to be a mixture of minute algæ and lime. This marly concretion grows concentrically, forming rounded nodules, its development increasing with the age and size of the shell. This concretion, though most abundant on shells, is not confined entirely to them, but grows also on rocks that have lain undisturbed on the bottom. When growing on shells, it adheres to them very closely; and upon being pried loose sometimes separates from them much as the matrix separates from a fossil, and leaves the epi-

dermis of the mussel clean. In other cases it adheres more closely and is difficult to scrape off clean. On this marly growth, colonies of *Ophrydium*, much the size, color, and general appearance of grapes with the skin removed, are often found growing, and in the cavities and interstices of the marl, a handsome little water-beetle, *Stenelmis sulcatus* Blatchley, and its peculiar elongate black larvæ, lives in considerable numbers but apparently has nothing to do with the mussels. Various species of hydrachnids, one of them strikingly handsome with its green body sprinkled with bright red dots, also live in the cavity of the marl, and offer some suggestion as to how the parasitic mite *Atax* went a step farther and took up its habitation within the mussel itself.

Food and Feeding.—An examination of the stomach and intestinal contents of the various species of mussels of the lake showed no noticeable difference between the food of the different species. Enough of the bottom mud is generally present to give the food mass the color of the bottom on which the mussels are found. Thus the stomach-contents of the mussels found in the black bottom of Lost Lake were usually blackish, while that of those found in the lighter bottom at Long Point were grayish. Intermixed, however, with the whole mass was always enough algæ to give it a somewhat greenish tinge, this green being usually intermixed more or less in the form of flakes. A striking contrast between the stomach contents of mussels inhabiting lakes and those found in rivers is the much greater preponderance of organic matter in the food of the lake mussels. The stomach contents of river-mussels is generally chiefly mud, with a few diatoms, desmids, *Scenedsmus* and *Pediastrum* intermixed, as said above. Those of the lake mussels are almost always full enough of algæ to be more or less flecked with green and sometimes the whole mass is decidedly greenish. On being placed in a vial of preserving fluid (3 per cent formalin was generally used) and shaken, the material from the river mussels always retains the uniform appearance of mud; that from the lake mussels separates, the mud settling to the bottom and the organic material settling as a light flocculent mass above the more solid portion. This top layer is composed of the various plankton elements of the lake, and was found to vary considerably in different lakes. In the Lake Maxinkuckee mussels it was found to consist chiefly of such species as *Mi-*

crocystis æruginosa, *Botryoccus braunii*, *Cœlosphærium kuetzingianum*, various diatoms, such as species of *Navicula*, *Rhoicosphenia*, *Gomphenema*, *Cyclotella*, and *Cocconema*, various forms of desmids, especially *Cosmarium* and *Staurastrum*, various forms of *Scenedesmus*, considerable *Peridinium tabulatum*, and short filaments of *Lyngbya*. *Pediastrum*, both *boryanum* and *duplex*, are here, as almost everywhere, rather common objects encountered in the intestines of mussels. Casts of the rotifer *Anuræa cochlearis*, and one of the small entomostracan, *Chydorus*, were occasionally encountered. In one of the Lost Lake mussels, *Dinobryon*, an exceedingly frequent element of the mussel-food in Lake Amelia, Minn., but rare here, was found.

No opportunities were had to study the stomach contents during the winter, the mussel work having not been taken up to any extent during the earlier part of the survey. Mussels obtained quite late in autumn contained much the same material as in summer. The open and apparently active inhalent and exhalent apertures noted throughout the winter in some individuals would indicate that the mussels—at least some of them—do not hibernate, but carry on life processes more or less actively the year round. The presence of pretty well-marked growth rings would indicate, however, annual rest periods. As diatoms appear to be much more abundant in the water during the winter, it is probable that they enter more plentifully into the mussel's bill-of-fare during the late autumn, winter, and early spring, than during the summer. In considering the mussels as feeders on plankton elements, it is worth while to investigate whether these are not of benefit to the lake as reducers of the excessive amounts of such undesirable elements as *Lyngbya*, *Anabæna* and *Microcystis*, and whether a considerable increase in the mussel population by means of artificial propagation would not clear up the lake to a considerable extent.

The following studies of stomach contents and table of mussel food are by no means exhaustive, but represent hurried examinations and a record of the more easily recognized forms out of a mass of doubtful material. They are intended to be simply suggestive.

Closely connected with the question of food and nutrition is that of the size of the mussels. A marked feature of the mussels of Lake Maxinkuckee, as well as of the neighboring lakes, is the dwarfing of many of the species, and this is rather difficult to explain when one

considers the large amount of organic material they ingest. The mussels of a few northern lakes examined were thick-shelled and large. So this dwarfing may not be necessarily associated with lake conditions, that is, absence of current. A possible explanation is that of close inbreeding, there being no admixture of new blood with other distant colonies, such as is possible where the lake is in close connection with a large river and its mussel beds.

Breeding Habits, Reproduction, etc.—The reference to inbreeding above leads to a consideration of breeding and breeding habits. At first glance it would appear that lakes, having no, or only feeble, currents, would make fertilization of the ova of the female mussels largely a question of chance. It is not possible, with the data at hand, to make precise comparisons between number of gravid females of the mussels of lakes and rivers during the proper seasons, but the general impression gained from having examined the various mussels of numerous lakes and rivers through the different seasons is that there are fewer of the mussels of the lake that succeed in having their ova fertilized. Gravid mussels are indeed not rare in the lake at proper seasons, but they seem to be much fewer than one might expect. On October 17, 1907, for example, of 252 *Lampsilis luteola* examined, 41 were of the characteristic female form but only 25 were gravid. Likewise, of 18 Anodontas examined on the same date, only 2 were gravid. This is a considerably lower percentage than one would expect in rivers at this date. There are other indications that the functions of reproduction are much less prominent in the lake than in rivers. In the height of the spawning season certain species of mussels, especially *Lampsilis ventricosa* and *L. multiradiata*, exhibit, in the neighboring rivers, a very striking appearance, due to the excessive development and high coloration of portions of the mantle near the inhalent aperture. Though both these species are found in the lake, none was observed in this condition. In some rivers in densely crowding beds, moreover, one frequently encounters precocious individuals; small shells, usually apparently only 2 or 3 years old but gravid with the characteristic female contour markedly developed. This is possibly related to opportunities of fertilization of ova, and is most frequently observed in *L. ventricosa* and *L. luteola*. No such precociously developed mussels were found in the lakes.

A large and well developed female *Lampsilis ventricosa* was trans-

planted from Yellow River into Lake Maxinkuckee. On being examined two years later in the autumn, when this species is usually gravid, it was found to be sterile.

The natural infection of fishes of the lake with the glochidia of the mussels does not appear to be common. The gills of an immense number of fishes were examined for parasites, but no glochidia were noted. Some young bluegills and redeyes, exposed to the glochidia of *L. luteola* in the autumn of 1912, took very readily.

The young mussels were either few, or very difficult to find. Diligent search was made for them, especially in the sandy bottom near Long Point, the sand being scooped up and seived through fine-meshed seives. Numerous and varied forms of life were thus obtained, such as *Sphærium*, *Pisidium*, caddis cases, etc., and rather small but by no means minute examples of *L. luteola* found. These young shells were remarkably brightly rayed. Half-grown *Q. rubiginosa* were fairly common in the beds of Lost Lake.

Proportion of Various Species in the Lake.—Of a collection of 340 living mussels collected October 17, 1907, at Long Point, 252 were *Lampsilis luteola*, 41 *L. ventricosa*, 21 *Unio gibbosus*, 18 *Anodonta grandis footiana*, 5 *Strophitus edentulus*, and 3 *Lampsilis subrostrata*. In deep water *U. gibbosus* and *Anodonta* would have given a higher percentage, and in the Lost Lake beds *Quadrula rubiginosa* would be present in considerable relative abundance.

Parasites, Enemies, and Diseases.—As a general rule the mussels of lakes, ponds and bayous are more heavily infested with parasites than those of the swiftly flowing rivers, the probable reason being that in still waters the parasites can migrate more easily from one mussel to another than where there is a swift current. The mussels of the lake are not nearly so badly parasitized as those of the sloughs of the Mississippi, the dead waters in the Maumee above the dams, or those of the Twin Lakes a few miles to the north. The parasites will be taken up more fully in consideration of the various species of mussels. Several species of *Atax*, and *Cotylaspis insignis* are the most common parasites. Unlike the mussels of most of our rivers, the mussels of the lakes are comparatively exempt from destruction by man. A few are killed and used for bait, and now and then a mild case of pearl fever appears at the lake, but it is soon cured by the examination of a bushel

or two of mussels. On September 22, 1907, a man was seen at the south end of the lake with about a peck of shells which he had opened in a vain search for pearls; on October 8 of the same year, a pile of about a half bushel of shells, which had evidently been opened by pearlers, was found in Overmyer's woods. Another pearler was seen in 1907 who had collected a few slugs of almost no value. One of the citizens of Culver, in 1906, submitted a small vial of lake baroques for valuation, but they had no worth whatever. The greatest enemy of the lake mussels is the muskrat, and its depredations are for the most part confined to the mussels near shore. The muskrat does not usually begin its mussel diet until rather late in autumn, when much of the succulent vegetation upon which it feeds has been cut down by the frost. Some autumns, however, they begin much earlier than others; a scarcity of vegetation or an abundance of old muskrats may have much to do with this. The rodent usually chooses for its feeding grounds some object projecting out above the water, such as a pier or the top of a fallen tree. Near or under such objects one occasionally finds large piles of shells. The muskrat apparently has no especial preference for one species of mussel above another, but naturally subsists most freely on the most abundant species. These shell piles are excellent places to search for the rarer shells of the lake.

On September 24, 1907, about a bushel of shells, recently cleaned out by muskrats, was found at Long Point where a pier had been removed not long before. The shells were all of rather small size and were in about 18 inches of water. About half were taken and examined. Of these shells, 358 were *Lampsilis luteola*, 167 *Unio gibbosus*, 6 *Lampsilis iris* and 1 *Lampsilis multiradiata*. In the autumn of 1913 freshly opened shells of *Lampsilis glans* were common along shore at Long Point. The first shells killed are rather small and are probably killed by young muskrats.

In the winter after the lake is frozen, great cracks in the ice extend out from shore in various directions, and this enables the muskrat to extend his depredations some distance from shore in definite limited directions. During the winter of 1904 a muskrat was observed feeding on mussels along the broad ice-crack that extended from the end of Long Point northeastward across the lake. The muskrat was about fifty feet from the shore. It repeatedly dived from the edge of the ice-

crack, and reappeared with a mussel in its mouth. Upon reaching the surface with its catch, it sat down on its haunches on the edge of the crack, and, holding the mussel in its front feet, pried the valves apart with its teeth and scooped or licked out the contents of the shell. Some of the larger mussels were too strong for it to open, and a part of these were left lying on the ice. The bottom of the lake near Long Point, and also over by Norris's, is well paved by shells that have been killed by muskrats. Muskrats do not seem to relish the gills of gravid mussels; these parts are occasionally found untouched where the animal had been feeding.

Species of Mussels Occurring in Lake Maxinkuckee.

1. *Quadrula coccinea* (Conrad).

Rare at the lake; this is a river rather than a lake shell and would be expected in abundance only in fluviatile lakes, or lakes with broad short outlets and vital connection with river faunas. The few living mussels of this species found in the lake would probably represent a vanishing remnant of a fauna introduced when the lake had a broader outlet than at present and communication with the river below more active. A few dead shells were found along the north shore at various times. On October 25, 1907, a shell 1.75 inch long was found near the railroad bridge at Culver, and in 1909 another small shell was found along shore at Aubeenaubee Bay. Some fine large examples, brought up from the Tippecanoe were planted in the thoroughfare below the railroad bridge, but they have probably been covered and suffocated by sand.

2. *Quadrula rubiginosa* (Lea).

More common in Lake Maxinkuckee than *Q. coccinea*, but nevertheless rather rare, only a few dwarfed shells having been found. In Lost Lake below the Bardsley cottage it was a fairly common species. None of the shells found was of large size, but all were well-formed and handsome. The older shells are almost jet black and peculiarly elongate, with the umbones markedly anterior in position. They look considerably unlike those of either the Tippecanoe or Yellow River, but a form much like the Lost Lake shells was found in the lower course of the Kankakee. No gravid examples were found in the lake. Half grown examples are rather common in Lost Lake, but as they are usually buried consider-

ably deeper in the sand than the older shells, they are harder to find. These half-grown shells are of a peculiarly beautiful golden yellow color with a satiny epidermis, and are of the same shape as those found in the neighboring rivers, that is, the normal or usual shape of the species. The peculiar elongate form of the adult is therefore evidently the product of local influences. The young shells are very iridescent and translucent, much more so than those found in rivers.

Q. rubiginosa is at its best a very fair button shell, but the lake shells are too small to work up well. This species appears to be rather rare in lakes. The only lake examples of this species with which the Lost Lake shells were compared were some obtained in Lake Erie. The Lake Erie shells are much more dwarfed, but very solid.

Food.

The following is the result of an examination of the material found in the intestines of *Q. rubiginosa* from Lost Lake.

Sample 1. August 2, 1908. Mass fine flocculent rather brownish green material, cohering somewhat in cylinders; looks as if chiefly organic; not gritty to touch. Organisms present: *Scenedesmus, Fragilaria, Tetraedron, Navicula, Peridinium tabulatum, Anuræa,* and *Botryococcus braunii.*

Sample 2. August 20, 1908. A large amount of material. Appearance in vial: bottom black, top a fine flocculent sediment. In the top material are *Tetraedron, Scenedesmus, Microcystis æriginosa* and many disassociated minute cells. Black bottom composed of *Anuræa, Lyngbya æstuarii,* a long filament; *Scenedesmus,* many *Peridinium tabulatum, Tetraedron, Epithemia turgida, Merismopœdia,* cast of *Cyclops, Melosira crenulata, Glœocapsa, Staurastrum, Pediastrum boryanum, Gomphonema, Chætophora, Cosmarium,* sponge spicule, *Gomphosphæria aponina,* and *Botryococcus braunii.*

Sample 3. August 20, 1908. A small amount of flocculent brownish material. *Microcystis æruginosa, Peridinium tabulatum* many, and a good many empty cuirasses, *Chydorus, Eudorina,* a few; *Scenedesmus,* common; Diatoms, *Pediastrum duplex.*

Sample 4. August 20, 1908. Fine blue-green flocculent material. *Lyngbya æstuarii,* several filaments; *Microcystis æruginosa,* common;

Cœlosphærium kuetzingianum, Peridinium tabulatum, very abundant; *Chydorus, Anuræa, Botryococcus braunii, Cœlastrum, Staurastrum* 1, small. Naviculas, several.

Sample 5. August 20, 1908. Fine bluish-green material. *Peridinium tabulatum,* abundant; *Cocconema cymbiforme, Navicula,* a few; *Anuræa cochlearis, Microcystis æruginosa, Chydorus,* 1 entire, and other fragments; *Pediastrum duplex, Cœlosphærium kuetzingianum; Cosmarium, Coscinodiscus, Scenedesmus,* very common; *Merismopœdia glauca.*

Sample 6. August 20, 1908. A small amount of flocculent grayish material. *Peridinium tabulatum,* abundant, agglutinated in masses; *Microcystis æruginosa,* very common; *Navicula, Staurastrum, Cosmarium,* several; *Chydorus,* fragment; *Scenedesmus,* small forms, common; *Pediastrum boryanum, Cocconema cymbiforme, Tetraedron,* common; various diatoms; *Rotifer,* an elongate species; *Merismopœdia glauca; Cœlastrum,* Desmids.

Sample 7. August 21, 1908. A small amount of rather coherent fine flocculent greenish material. *Peridinium tabulatum,* very common; *Anuræa cochlearis,* a few; *Microcystis æruginosa,* frequent; *Lyngbya æstuaria,* short filament; *Pediastrum boryanum, Cocconema cymbiforme, Cymatopleura, Epithemia argus, Gomphonema, Synedra, Tetraedron, Scenedesmus,* occasional; *Dinobryon, Staurastrum,* rather slender form.

Sample 8. August 20, 1908. A small amount of flocculent bluish material. *Peridinium tabulatum,* most abundant; *Cœlosphærium kuetzingianum; Pediastrum duplex, Microcystis æruginosa, Anuræa cochlearis,* Sponge spicule, Diatoms (*Navicula, Cocconema,* etc.), *Scenedesmus.*

Sample 9. August 20, 1908; a fair amount of flocculent grayish brown material with a greenish cast. *Peridinium tabulatum,* most abundant; *Microcystis æruginosa, Anuræa cochlearis, Staurastrum, Pediastrum duplex, Botryococcus braunii; Tetraedron minimum, Cœlosphærium kuetzingianum; Pediastrum boryanum, Chydorus, Lynbya æstuarii, Glococupsa,* Diatoms—*Cocconema cymbiforme, Navicula.*

3. *Unio gibbosus* Barnes.

This mussel, known among clammers as the "spike" or "lady-finger" is, next to *Lampsilis luteola,* the most abundant shell in the lake.

It is found wherever the other mussels are; that is, in sandy or somewhat marly bottom in rather shallow water most of the way around the lake, and in the shell-bed in Lost Lake below Bardsley's. In Lake Maxinkuckee one of the best beds is at Long Point. It is abundant also at Norris Inlet, and by McDonald's and Farrar's.

No very young of this species were found in the lake; they are, however, hard to find in numbers anywhere, even in rivers where the species is abundant—except in cases where portions of the river go almost dry, and this of course never happens to the beds in the lake. The half-grown examples are solid, rather cylindrical shells, the same neat form that is known as the "spike" among the clammers. The old shells develop into a peculiar form, being flattened, arcuate along the ventral border and very thin posteriorly, so that they usually crack badly in drying; they represent the form described by Simpson as var. *delicata*. In general outline they remind one somewhat of *Margaritana monodonta*. This form is not strictly confined to the lake; some similar shells were collected in the Wabash near Terre Haute.

As found in the lake, *Unio gibbosus* is very constant in its characters, the only noteworthy difference between individuals being the change in shape already referred to as being due to age. In rivers this shell exhibits considerable variation in shape, size, color of nacre, etc., but the shells of the lake are quite constant in almost every respect. The nacre is a deep purple, never varying to pink or white as it frequently does in rivers.

Like *Lampsilis luteola* this species is frequently preyed upon by muskrats and the cleaned out shells are common where these rodents have had their feasts.

Although *U. gibbosus* of the Tippecanoe River near the mouth of the Outlet are very commonly infested with a distomid parasite along the hinge-line which brings about the formation of irregular baroques, this parasite does not occur in the lake so far as known. Small species of *Atax* are common parasites of this species in the lake, and in 1909 one was found affected by the large *Atax ingens*.

Even the large strong river shells of *Unio gibbosus* have as yet no value in the manufacture of buttons because of their purple color, and lack of luster. (The white-nacred shells are sometimes used.)

The only other lake examples with which the Lake Maxinkuckee specimens of this species have been compared, are some collected in Lake Erie at Put-in-Bay. The Lake Erie shells are much unlike the Maxinkuckee specimens, being short, humped and remarkably solid and heavy. Similar shells to those of Lake Erie are found in some of the small southern rivers.

We have no notes referring to gravid examples in the lake. This was probably because the most active work in collecting and examining mussels was carried on in the autumn, and the breeding period of this species is in early summer.

4. *Alasmidonta calceola* (Lea).

Judging from the dead shells found scattered along shore, this is not a particularly rare species in the lake. The shells were found most abundantly along the north shore of the lake, although they were also found along the east and southeast portion and were not infrequent between Arlington and Long Point. No living examples were found. On account of its small size and its habits, this is a rather difficult species to find, even where common, except under favorable conditions such as exceptionally low water, when the mussels move about more or less. Nothing was therefore learned of its habits in the lake. In the Tippecanoe River near Delong, Ind., this species was rather common in stiff blue clay near shore, and it is fairly abundant in Yellow River at Plymouth. Here, although the dead shells were common, the living examples were difficult to find until, during a period of very low water, they began actively moving about and could be tracked down. The species, which reaches an unusually large size in Yellow River, was there found gravid in autumn (September and October). The glochidia are of the Anodonta type, chestnut-shaped or rounded-triangular in outline, with large hooks at the ventral tips of the valves.

5. *Anodonta grandis footiana* (Lea).

Although the genus *Anodonta* is generally regarded as the "Pond-mussel" *par excellence*, the species of which might naturally be expected to be at home in lakes and ponds and thrive in such places even better than in rivers, the Anodantas of Lake Maxinkuckee show, along with the river species proper, the dwarfing influence of the lake. Moreover, *Anodonta* is not as one might naturally expect, the most abundant mussel in

the lake, but is outnumbered, in some beds at least, by both *Lampsilis luteola* and *Unio gibbosus*. Its relative scarcity in some of the shore beds is in part made up by its wider distribution in the deeper waters of the lake than the others reach, and on its presence on the isolated bars, where it was occasionally taken up by the dredge.

On account of the great variability of *Anodonta grandis* and the difficulty in distinguishing the various forms, particular attention was paid to this species as found in the lake, and the lake specimens were compared with numerous examples from the neighboring lakes and river. No Anodontas were found in the Tippecanoe River near Lake Maxinkuckee Outlet, and we were therefore unable to compare our lake specimens with the form that would be most interesting in this connection.

The mussels of Tippecanoe Lake at the head of Tippecanoe River were examined in this connection. Blatchley (Indiana Geological Report for 1900, p. 190) has reported *Anodonta grandis* as common, and the subspecies *footiana* as frequent in Tippecanoe Lake. The Anodontas of that lake differ markedly both in the size and shape of the individuals from those of Lake Maxinkuckee. The difference in size can be easily explained by the more favorable conditions in Tippecanoe Lake. This body of water is more fluviatile than Lake Maxinkuckee, being directly connected with the Tippecanoe River, which is already a fairly large stream when it leaves the lake, and the mussel beds of the lake and river are continuous. The upper part of Tippecanoe Lake is exceptionally favorable for Anodontas; the living mussels are large and abundant, and the dead shells almost pave the bottom near shore, several dead shells often being telescoped within each other. Some of the shells reached a size not often surpassed in the neighboring rivers; one example measuring 172.5 mm. long, 95 mm. high and 65 mm. in diameter. A few were thickened with a tendency to form half pearls, or "blisters", but most were thin. A number of the shells approached *Anodonta corpulenta* in general form, and one flattened, rounded shell resembled *A. suborbiculata*. The Anodontas from other lakes of the Tippecanoe River system, such as Center Lake and Eagle Lake near Warsaw, resemble those of Lake Maxinkuckee, but are generally smaller and shorter.

The Anodontas of Lake Maxinkuckee were also compared with those of Yellow River a few miles to the north, and with the various lakes

of the Kankakee system, including Upper Fish Lake, Lake of the Woods (Marshall Co.) Pretty Lake, Twin Lakes, Bass Lake and Cedar Lake. Some of the Yellow River Anodontas were normal, oval shells such as are common in the rivers of Northern Indiana; a few were exceptionally thin and exceedingly inflated, resembling *A. corpulenta*. Those of Upper Fish Lake—originally a fluviatile lake containing other fluviatile shells such as *Q. undulata*—were large shells like those of Tippecanoe Lake. The Anodontas of each of the other lakes differed more or less from those of the others, though all probably had a common origin. The only lake of this group the Anodontas of which closely resembled those of Lake Maxinkuckee is Bass Lake, and even there the shells were somewhat different, being smaller and with the epidermis more deeply stained. Even the Anodontas of Lost Lake differ slightly from those of Lake Maxinkuckee, being somewhat more inflated and with the epidermis green rather than brown, and in having the shell usually somewhat thinner. Some of the shells near the outlet of Lost Lake are exceedingly thin, some of them so much so that ordinary print can easily be read through them; they are so fragile that it is almost impossible to keep them.

Of the collection from Lake Maxinkuckee, mostly from Long Point, 26 examples were carefully compared. The smallest measured 68 mm. long, 38 mm. high and 24.6 mm. in diameter, and the largest 93.5 mm. long, 50 mm. high and 37 mm. in diameter. Among variant forms was one female, gravid when collected, which was unusually elongate, its measurements being 86 mm. long, 43.5 mm. high and 32.5 mm. in diameter. In outline this shell closely resembled *Anodontoides ferussacianus subcylindraceus*.

Some of the larger specimens are rather humped and arcuate, the ventral margin of one being somewhat concave. This is a variation which is quite likely to occur in old shells of any species.

Although gravid Anodontas were found rather frequently during the late autumn, no infected fishes were seen, and no young were found.

The Anodontas of the lake are fairly free from parasites, a few *Atax* and *Cotylaspis* and occasionally a few distomids on the mantle next to the umbonal cavity being the only ones present in any numbers. In some of the other lakes the Anodontas were very badly infested; a colony found in one of the Twin Lakes being infested to a remarkable

degree by a distomid which formed cysts in the margin of the mantle.

Food and Parasites of Various Examples.—The following is the result of the examination of various examples of Anodontas: Sample No. 10. Vial containing intestinal contents of *Anodonta grandis footiana*, Lost Lake, September 7, 1908. The vial contains a considerable amount of material (in formalin) which was separated into black fine mud below and fine flocculent light green above. Upper portion—*Microcystis æruginosa*, most common; *Peridinium tabulatum*, some; *Pediastrum boryanum; Melosira crenulata*, a few filaments; *Cœlastrum microporum, Botryococcus braunii* and *Scenedesmus*. Bottom layer—*Lyngbya æstuarii, Microsystis æruginosa*, very common; *Peridinium tabulatum, Anuræa cochlearis, Cocconema cymbiforme* and *Navicula*.

Sample No. 11. Food of *Anodonta grandis footiana*, Lake Maxinkuckee, near Norris Inlet, August 20, 1908. A good mass of flocculent fine green material; no mud.

Microcystis æruginosa, most common, *Melosira*, filament, *Oscillatoria*, short filament; *Anuraea cochlearis*, several; *Cocconema cymbiforme; Gomphosphæria aponina; Peridinium tabulatum; Cœlosphærium keutzingianum, Lyngbya æstuarii, Epithemia argus, Chydorus*, and what appears to be fragments of *Ceratium hirundinella*.

Sample No. 12. *Anodonta grandis footiana*, near Norris Inlet, Lake Maxinkuckee, August 20, 1908; a small mass of flocculent blue material.

Microcystis æruginosa most abundant; *Lyngbya æstuarii, Melosira, Epithemia, Anuræa cochlearis, Pediastrum boryanum, Cosmarium intermedium* and a few others, *Staurastrum* sp?, *Spirulina* and *Pediastrum duplex*.

Sample No. 13. *Anodonta grandis footiana*, 97 mm. long. Edge of Lake Maxinkuckee east of Norris Inlet, August 29, 1908.

Parasites; 9 *Atax*, free among gills. Mussel gravid, with anterior end of shell indented and with some brown spots on the nacre. Food mass fine golden brown, abundant in quantity, containing *Anuræa cochlearis*, many; *Microcystis æruginosa*, most abundant element; *Lingbya æstuarii*, frequent; *Scenedesmus*, a few; *Botryococcus braunii*, frequent; *Cocconema cymbiforme; Staurastrum, Navicula; Fragilaria; Chydorus*, a few; *Cœlosphærium kuetzingianum;* the diatoms are not abundant.

Sample No. 14. *Anodonta grandis footiana* apparently old, 90 mm.

long, near Norris Inlet, Lake Maxinkuckee, Ind., August 29, 1908, the shell stained somewhat brown inside, with one steel-blue stain on the right valve anteriorly.

Parasites; *Atax* 7, large, full of eggs, one small, one very small, these all free among the gills; *Cotylaspis insignis* 1, in axil of gill.

Food abundant; *Microcystis æruginosa*, abundant; *Lyngbya æstuarii*, common; *Pediastrum duplex*, *Botryococcus braunii*, a few; *Cosmarium; Anuræa cochlearis*, several; *Scenedesmus; Ankistrodesmus*, and many diatoms, among which are *Cocconeis pediculus*, *Melosira*, *Gomphonema*, *Navicula*, *Epithemia turgida*, etc.

Sample No. 15. *Anodonta grandis footiana*, 101 mm. long, Lake Maxinkuckee, near shore, by Norris Inlet. August 29, 1908.

Parasities; 5 *Atax*, free in gills, some full of eggs, 2 smaller in size, larval *Atax* (black) scattered in gills. *Cotylaspis insignis*, 2, axil of inner gill.

A large amount of food material in intestines, very fine, of a yellowish brown color.

Microsystis æruginosa, *Anuræa cochlearis*, *Lyngbya æstuarii*, *Botryococcus braunii Cœlosphærium keutzingianum*, *Cosmarium*, *Navicula*, an elongate form, *Cocconema cymbiforme*, *Pediastrum duplex*, *P. boryanum;* red cysts apparently of *Peridinium*.

Sample No. 16. *Anodonta grandis footiana*, 90 mm. long, sandy bottom of Lake Maxinkuckee near Norris Inlet. August 29, 1908. Mussel gravid. Parasites: *Atax*, 3, free among gills, *Atax* embryos scattered through gills.

Food material scarce, fine golden brown in mass, consisting of *Microcystis æruginosa*, abundant; *Cœlosphærium keutzingianum*, abundant; *Lyngbya æstuarii*, a few filaments; *Anuræa cochlearis* and another rotifer; *Botryococcus braunii; Sorastrum*, *Cœlastrum*, *Scenedesmus*, *Pediastrum duplex*, *Navicula*, several; *Melosira tabulata*, *Synedra*, *Epithemia turgida*, *Cocconema cymbiforme;* and other small diatoms rather numerous. *Cosmarium*, a few.

Sample No. 17. *Anodonta grandis footiana*, 93 mm. long, sandy bottom of Lake Maxinkuckee near Norris Inlet, August 28, 1908. Mussel gravid. Parasites: 1 *Atax*, free among gills. Intestines almost empty. *Microcystis æruginosa*, one of most abundant elements; *Lyngbya æstuarii*, *Cœlosphærium kuetzingianum*, *Botryococcus braunii;*

Cosmarium, Pediastrum, Cocconeis pediculus, Epithemia turgida; Navicula (1 actively moving), *Gomphonema, Melosira tabulata, Anuræa cochlearis, Chydorus.*

Sample No. 18. *Anodonta grandis footiana,* 95 mm. long. Lake Maxinkuckee near Norris Inlet, August 29, 1908. Mussel gravid. Parasites: 6 *Atax* free among gills, one a minute red species. Many young Atax embryos in inner side of mantle, not in gills.

Food material golden brown, with some green intermixed, very fine. *Microcystis æruginosa,* common; *Lyngbya æstuarii,* a few filaments; *Cœlosphærium keutzingianum; Botryococcus braunii; Pediastrum duplex; Anuræa cochlearis* a few; *Epithemia turgida; Navicula,* common; *Cocconema cymbiforme; Cocconeis pediculus,* several; *Cosmarium; Chydorus.*

Sample No. 19. *Anodonta grandis footiana,* Lake Maxinkuckee, near Winfield's. Mussel gravid. Parasites: Young *Atax* in gills; Distomids on mantle (a slug pearl near hinge.)

Food: *Botryococcus braunii; Microcystis æruginosa; Lyngbya æstuarii, Cœlosphærium kuetzingianum, Pediastrum duplex, Navicula, Cocconema cymbiforme.*

Sample No. 20. *Anodonta grandis footiana.* Lost Lake. Young transparent shell, gravid, length 77 mm., height 41 mm., diameter 30 mm., live weight 1 oz., shell 1-4 oz. Parasites, several *Cotylaspis insignis* in axil of gills, food chiefly *Microcystis æruginosa;* considerable *Botryococcus braunii.*

Sample No. 21. *Anodonta grandis footiana,* Lost Lake. Parasites: 1 young *Atax* in gill; *Cotylaspis insignis* in axil of gill. Food chiefly *Microcystis æruginosa,* a little *Botryococcus braunii, Lyngbya æstuarii* and *Pediastrum boryanum.*

6. *Strophitus edentulus* (Say). Squawfoot.

Not very common in the lake. Occasional shells can be picked up along shore, especially between Long Point and Arlington, and along the north shore. Living examples were also taken in small numbers from the mussel bed at the mouth of Norris Inlet, and at Long Point. In a collection of about 300 living mussels collected at the latter place in the autumn of 1907, only three were of this species.

As found in the various rivers of the country, this is one of the

most variable of shells, and the exact limits of the species and its various forms are not yet well worked out. The lake examples, though differing considerably from those of the neighboring rivers and from river shells in general, do not exhibit a very large range of variation. They are all markedly dwarfed, the average length being about 2 1-2 inches or 63.5 mm. All have a well-developed rounded posterior ridge. The epidermis is deeply stained, that of the exposed portion of the shell being a rich yellowish brown, while the anterior portion, in the living shell buried in the soil of the bottom, is a deep shining brown black. The anterior margin is not nearly so heavy and produced as one frequently finds it in river examples. The beaks of the lake shells are not so angular as they usually are in river shells, and the high wavy ridges are more numerous and pronounced. In the Maxinkuckee shells, also, a number of fine hair-like lines or ridges, much like growth lines, extend along the posterior border of the umbone, parallel with the posterior ridge of the earlier stages of the shell.

The nacre of the lake shells is a rich rosy salmon. Unlike the salmon color of "*Anodonta salmonea*", this is a natural color, not due to diseased conditions; the nacre surface is very smooth and the color extends deeply into the shell. In some cases the inner nacreous surface appears to be a secondary thickening of the shell, laid on the older portions like an enamel. Below this extra nacreous deposit the growth lines are very distinct on the inner surface of the shell. The rest periods are distinct black lines, often plainly visible through the translucent shell when held up to the light. Rays are always invisible by reflected light in the lake shells, but in some examples they were visible by transmitted light. The animal has orange-colored flesh. The few living examples examined indicate that parasites are common; one contained three old *Atax ypsilophorus*, and several young.

One gravid example was found, October 17, 1907. The youngest example found was 42 mm. long and exhibited four rest periods.

7. *Lampsilis glans* (Lea).

Fairly common in the main lake; dead shells are often found along shore, and occasionally the living mussels are to be seen in shallow water at the various mussel beds at the lake. It is quite abundant along the edges of the thoroughfare joining the lakes, and is common in Lost Lake.

The examples found in the thoroughfare and Lost Lake were of unusually large size; this is one of the few species of mussels which are as large or larger in the lake than in the neighboring rivers. *L. glans* appears to prefer shallow water along shore. A good number of shells recently cleaned out by muskrats was found near the water's edge at Long Point in the late autumn of 1913.

In the Tippecanoe River at Delong this was a very abundant species in the greasy whitish blue clay along shore, and was here one of the favorite morsels of the muskrat. With the exception of *Micromya fabalis* this is the smallest species of mussel found in the lake. It can be easily recognized by its black epidermis, small size and purple nacre.

8. *Lampsilis iris* (Lea).

Rather common in the lake in shallow water near shore, found scattered among the other species in the various shell-beds. There is a good colony in the Lost Lake bed, and it is fairly abundant off the Depot grounds, by Kruetzberger's pier, at Long Point, and at the bed near the mouth of Norris Inlet.

The lake shells differ markedly from those of the neighboring rivers so much that it is easy to separate the lake and river shells at a glance. The lake shells are considerably more elongate, and the epidermis is stained a deep brown, mostly concealing the rays; when these are visible they are brownish rather than green, and the umbones are rather eroded. The shells, indeed, resemble somewhat the males of *L. subrostrata*, with which they are associated. The lake shells exhibit a tendency to have their posterior margin somewhat broader than the river shells, and the shells are flatter at the posterior tip, becoming somewhat produced. The river shells are more solid and heavy.

Lampsilis iris is one of the few species of mussels which does not show a marked decrease of size in the lake; indeed, some of the larger lake examples run actually larger than those from the neighboring rivers. Some of the largest lake shells examined have the following dimensions:

No.	Length mm.	Alt. mm.	Diam. mm.
1	69.6	37.3	21.0
2	65.9	34.9	21.0
3	68.0	34.6	22.0

No.	Length mm.	Alt. mm.	Diam. mm.
4	64.9	35.8	22.7
5	67.0	36.8	20.9
6	67.7	33.8	21.5

No young shells were found, even the smallest appear rather old. The smallest three measure:

Length mm.	Alt. mm.	Diam. mm.
41.4	21.2	12.5
38.9	21.5	12.5
37.0	20.0	12.3

For comparison with the lake shells, the dimensions are given of the largest two shells found in Yellow River:

No.	Length mm.	Alt. mm.	Diam. mm.
1	67.0	34.5	22.9
2	64.0	33.5	21.0

Only one gravid example was found; this was obtained at Lost Lake bed September 7, 1908.

Of all the species of mussels in the lake, *L. iris* has the best connection, through scattered individuals along the Outlet, with the shells of the Tippecanoe River, a few shells having been found almost through the whole length of the Outlet. The Outlet shells, like those of the rivers, are brightly rayed. The species is abundant in the Tippecanoe River at Delong. A number of examples were noted in spawning condition there in late August and early September in 1908. Observations in the Maumee River indicate that this species, *L. parva* and *L. multiradiata*, do not have exactly the same breeding season as many other species of *Lampsilis* (*lutcola, recta, ligamentina*, etc.), but are sometimes fertilized in July, spawning in August and September. Being small and an early developing species, it is probable that they have somewhat different habits; indeed, it is possible that they have more breeding seasons per year than the other species.

The Tippecanoe mussels of this species were a favorite food of the muskrat, and were killed in great numbers every autumn, the dead shells being thickly strewn along the bank, or piled in heaps at the bases of rocks which the rodent used as a feeding place.

Lampsilis iris has a well marked tendency in the lakes and Outlet to produce pearls and baroques; but these are too small to be of any value.

9. *Lampsilis subrostrata* (Say).

Lampsilis subrostrata reaches its best development along the muddy shores of lagoons, not being perfectly at home either in swiftly flowing streams or in perfectly quiet lakes, although occasional examples may be found in either. It is considerably more abundant in Lake Tippecanoe and Upper Fish Lake than in any other Indiana lakes examined. Along the edges of the Mississippi sloughs it is fairly common and reaches a large size, often distinguished with difficulty from *Lampsilis fallaciosa* except for the thinness of the shell and the black epidermis. It is rare in Lake Maxinkuckee, only a few examples having been obtained from the mussel bed near Norris Inlet. It is much more common in Lost Lake in the large bed along shore south of the Bardsley cottage. Mr. Blatchley, in a short report on the mollusks of the lake (25th annual report, Department of Geology and Natural Resources of Indiana, 1900, p. 250), says of this species: "Not common in the main lake; more so in the muck and mud along the margins of Lost Lake, where a well-marked variety, with a larger and broader beak, was taken. A specimen of this was sent, among others, to Mr. Chas. T. Simpson, of the Smithsonian Institution, for verification. In his reply he says: 'The variety of *subrostratus* which you send is, so far as I know, confined to northern Indiana. It is quite remarkable, and would seem to be almost a distinct species. I have seen quite a number of specimens of it, and at first thought it a variety of *U. nasutus*, but there seem to be intermediate forms connecting it with *U. subrostratus*.'"

With the exception of the differences due to sex, all the Maxinkuckee and Lost Lake shells are very uniform in appearance, much more so than *L. luteola*, and are hardly distinguishable from examples from Lake Tippecanoe, Upper Fish Lake, or a specimen collected in the Wabash River at Terre Haute by Dr. J. T. Scovell. They are dark brown in color with very faint rays. The species appears to be rare in the Tippecanoe River at Delong. One example was obtained there, which is somewhat shorter and stouter than those of the lake, and not so badly stained; it shows faint rays posteriorly. The Lost Lake shells are some-

what larger than those found at the other lakes. No young were found, the smallest shell obtained being a half-grown example. One gravid specimen was found at Lost Lake September 7, 1908. The marsupium closely resembles that of *L. iris*, being a kidney shaped mass filling the hinder portion of the outer gill, this mass marked into segments by rather deep radiating furrows. The very edge of the marsupium is white, beyond the dusky submarginal area, the white making a chain-like area at the edge of the gill. Like *L. iris*, this species has a tendency to form pearls, but they are too small to be of any value.

Food of individuals: The following is the result of the examination of the contents of the intestines of *L. subrostrata* from Lost Lake at various dates.

Sample 22. August 20, 1908. A small amount of flocculent bluish-gray material. *Peridinium tabulatum*, abundant; *Microcystis æruginosa*, abundant; *Anuræa cochlearis; Pediastrum boryanum;* Diatoms—*Synedra; Cocconema cymbiforme.*

Sample 23. August 20, 1908. A very small amount of flocculent grayish material. *Peridinium tabulatum*, a few; *Microcystis æruginosa*, a little; *Pediastrum boryanum; Cosmarium; Tetraedron minimum; Scenedesmus; Euglyphia alveolata; Peridinium*, a small, sharp-spined form. Diatoms make up the greater part, including *Cocconema cymbiforme; Navicula; Fragilaria; Coscinodiscus;* and *Epithemia.*

Sample 24. September 7. A large amount of material, black mud below, greenish flocculent material above. The upper portion contains chiefly *Botryococcus braunii* and *Microcystis æruginosa.* Bottom portion—*Microcystis æruginosa*, common; *Botryococcus braunii; Peridinium tabulatum; Peridinium*, a small-spined species; *Scenedesmus*, frequent; *Staurastrum; Pediastrum duplex; Cœlastrum*, a few; *Anuræa cochlearis; Tetraedron; Docidium; Cœlosphærium kuetzingianum;* Sponge spicule; *Lyngbya æstuarii;* Diatoms, *Synedra; Navicula; Gomphonema;* etc.

10. *Lampsilis luteola* (Lamarck). Fat Mucket.

Lampsilis luteola is the most widely distributed of the American *Unionidæ*, its range extending over nearly all of North America east of the Rocky Mountains. It lives and thrives under a great variety of conditions, being frequent in both lakes and rivers.

In Lake Maxinkuckee this is the most common mussel, being found almost everywhere in water from 2 to 5 or 6 feet deep where the bottom is suitable. It prefers a rather solid bottom with some admixture of sand or gravel, but occurs also even where the bottom is of a rather firm peaty nature as in some places in Outlet Bay. It is, however, rather scarce and widely scattered in such localities. The best beds are found at Long Point, at Farrar's, in front of McDonald's, by the old Kruetzberger pier, and in Aubeenaubee Bay off from the Military Academy. In Lost Lake it was abundant in the large mussel bed below the Bardsley cottage, and a few shells were found in the north end of the lake.

The Lake Maxinkuckee shells are smaller and thinner than those of the rivers; they closely resemble those of most of the neighboring lakes with which they were compared, such as Twin Lakes, Pretty Lake, Bass Lake, etc. The *L. luteola* of Upper Fish Lake are much larger and more like river shells. Compared with specimens of more remote lakes, those of Lake Erie are much smaller, more solid and not stained, the rays being quite distinct. The *L. luteola* of Lake Pokegama, Minn. are unlike any of those above cited, being large, thick and heavy, furnishing excellent button material.

Lampsilis luteola is represented in Lake Maxinkuckee and Lost Lake by two forms; although these forms are well connected by intergrades the extremes are pretty markedly distinct.

The colony in Lost Lake is composed of compressed, elongate shells, almost as large as those found in rivers, but considerably thinner. It is in the females of this group, and only in part of them, that the greatest variation occurs. The males are not much unlike the ordinary well-known form of the neighboring rivers. The most strongly aberrant females are markedly compressed, and flare out broadly in the post-basal region. The umbones are far forward and they remind one somewhat in contour of the marine species, *Modiola plicatula*. Some of them closely resemble *Lampsilis radiata* of the Atlantic drainage. The Lost Lake mussels of this species are stained a peculiar attractive ash-gray which does not greatly obscure the rays. They are not so heavily encrusted with marl as are those in the Lake Maxinkuckee beds. Typical Lake Maxinkuckee specimens are dwarfed and stained a deep brown, which obscures the rays. Most of them are thickly-coated posteriorly

with incrustations of marl. It is principally this species which has associated with it the little water-beetle, *Stenelmis sulcatus* Blatchley. At Long Point, where *L. luteola* is the most common mussel, examples of the peculiar Lost Lake form are rather frequent. In comparing sets of shells from the various mussel beds of the lake, Long Point, Farrar's and the Norris Inlet beds, it was noted that the mussels of each bed, as one approached the upper portions of the lake, averaged somewhat smaller.

As regards food, movements, reproduction, etc., *L. luteola* does not differ greatly from the other mussels of the lake with the exception that it appears to be considerably the most active species in the lake. A few more were observed moving about during the winter of 1900-1901. The deep water individuals rarely move about at all. In the autumn of 1913 the migration of those near shore into deep water was strikingly shown in a series of numerous furrows, with a mussel at the deep water end and extending from shore outward near Long Point.

As with the other mussels of the Lake, reproduction is a rather inconspicuous phenomenon, not attended with the marked display common in the larger river examples. Of 252 examples collected at Long Point, October 17, 1907, 25 contained glochidia in the gills, some being very full and much distended. One was found gravid May 24, 1901, and on August 22, 1906, some in Lost Lake appeared to be about ready to spawn.

The young of this species were found rather frequently in the lake, much more frequently, indeed, than any other kind. The smallest examples were obtained while seiving sand for Sphæriums at Long Point. These young mussels live buried in the fine sand near shore. Specimens up to about a half-inch long are very crinkly, being covered with narrow elevated parallel ridges, generally five in number, each consisting of two open loops placed end to end, the sides of the loops being roughly parallel with the ventral margin of the shell; the ends where they join form a sharp curve upward toward the umbone. These double loops are followed by a number of broken irregular ridges. The markings just described persist on the umbones of the older shells until eroded away. The half grown shells are beautifully rayed with green on a whitish background. As the shells grow older they become gradually stained a deep uniform brown, obscuring the rays.

Most of the mussels of the lake are slightly parasitized, none abundantly; they contain a few examples of a small reddish *Atax*, and a few *Cotylaspis insignis*. A small round worm, somewhat like a vinegar eel, was found very active in the intestine of one specimen; it was probably parasitic.

Small irregular pearls or slugs are produced but they are of no value. In some rivers this species produces an abundance of small round pearls. Some of the pearl-bearing river specimens were planted in the lake in 1912 to see if they would infect the lake shells.

The *Lampsilis luteola* of the rivers is a fair button shell, but the Lake Maxinkuckee shells are too small and thin to have much value. It is a remarkable fact that in Lake Pokegama, Minn., *L. luteola* grows abundantly in shallow bottom among the weeds, and there produces a handsome thick heavy shell, one, indeed, concerning which the pearl button manufacturers are very enthusiastic, so much so that the shells at that distant point from the market brought $22.00 per ton; in the summer of 1912, two carloads of these shells were shipped to Europe.

Just why the Lake Maxinkuckee shells are not like the excellent ones of Lake Pokegama remains as yet unanswered, but seems to be largely a question of breed. It would certainly be worth while to introduce the Lake Pokegama breed into Lake Maxinkuckee.

Following is the results of the examination of various individuals of the Maxinkuckee and Lost Lake shells:

Sample 25. *L. luteola*. Lost Lake, September 7, 1908. Mussel gravid. Length 100 mm., altitude 62 mm.; diameter 33 mm. Live weight 2½ oz.; shell 1¾ oz. Parasites: 7 free *Atax* among gills, young *Atax* in gills and numerous *Atax* eggs on interior surface of mantle. Food chiefly *Microcystis æruginosa; Botryococcus braunii, Lyngbya æsturaii; Melosira; Navicula.*

Sample 26. *L. luteola*. Lost Lake, September 7, 1908: Mussel gravid: Length 95 mm., alt. 60 mm., diam. 38 mm. Live weight 3¾ oz.; shell 1¾ oz. Parasites: 7 free *Atax* in gills, and *Atax* eggs in the mantle. Food, chiefly *Microcystis æruginosa;* also *Botryococcus braunii; Navicula; Lyngbya æstuarii;* and *Anuræa cochlearis.*

Sample 27. *L. luteola*. Lost Lake by Bardsley's September 7, 1908. Live weight 3¼ oz.; shell 1½ oz., length 97 mm., alt. 54 mm., diam. 33

mm. Parasites: 7 free *Atax* among gills. Many small red eggs of *Atax* on inner surface of mantle. Food chiefly *Microcystis æruginosa; Botryococcus braunii;* and *Navicula.*

Sample 28. *Lampsilis luteola.* Lost Lake, September 7, 1908. Live weight 3¾ oz.; length 104 mm., alt. 54 mm., diameter 33 mm. Parasites: *Atax* 6, free among gills, eggs of *Atax* on inner side of mantle, young in pits on side of foot. Food, *Microcystis æruginosa*, most common; *Lyngbya æstuarii; Navicula; Melosira; Anuræa;* and *Cocconema.*

Intestinal contents of two examples of *L. luteola* obtained in Lake Maxinkuckee August 27, 1908, near the shore just north of the ice office gave the following results:

Sample 29. *Microcystis æruginosa*, main mass; *Anuræa cochlearis*, a few; *Botryococcus braunii*, rather common; *Cocconema cymbiforme*, one; *Lyngbya æstuarii*, 1 filament; *Navicula*, 2 examples; *Synedra*, a few.

Sample 30. *Microcystis æruginosa*, main mass; *Botryococcus braunii*, very common; *Lyngbya æstuarii*, several filaments; *Anuræa cochlearis*, a few; *Synedra*, some; *Navicula*, one example very lively; *Cosmarium*, one; Round worm like vinegar eel, very lively.

Sample 31. Lost Lake, 1908. A good mass of material, blackish below, flocculent greenish above. *Lyngbya aestuarii*, a few filaments, *Microcystis æruginosa*, quite abundant; *Anuræa cochlearis;* sponge spicule; *Pediastrum duplex; Staurastrum; Botryococcus braunii; Peridinium tabulatum*, a few; *Peridinium*, a small spiny species 1; *Pediastrum boryanum;* several diatoms—*Navicula; Coscinodiscus; Melosira; Cocconema cymbiforme; Microcystis*, is the most abundant element; *Peridinium* is rather scarce.

Sample 32. Lake Maxinkuckee, August 27, 1908: A small amount of brownish green flocculent material. *Anuræa cochlearis*, quite frequent; *Lyngbya æstuarii*, short filament; *Peridinium tabulatum*, a few; *Cœlastrum microporum; Cœlosphærium knetzingianum; Pediastrum boryanum; Scenedesmus*, very few; *Chydorus*, fragment. Diatoms, *Epithemia turgida; Navicula; Cocconema cymbiforme; Gomphonema; Coscinodiscus.*

Sample 33. Lake Maxinkuckee, August 27, 1908: A fair amount of brownish green material, muddy below, flocculent green above. The

green top material consisting chiefly of *Microcystis æruginosa;* with some *Anuræa cochlearis; Lyngbya æstuarii, Microsystis æruginosa; Bulbochæte,* bristle; *Cœlastrum microporum; Merismopœdia glauca; Pediastrum boryanum;* Diatoms—*Navicula, Coscinodiscus;* etc.

Measurements:—

The following is a series of measurements of Lost Lake examples:

Measurements in mm.

No.	Date, 1908.	Length.	Alt.	Diam.	Remarks.
1189	Aug. 20.	85.	54.	32.	Fanshaped female.
1260	Sept. 7.	97.4	55.	31.	Fanshaped female gravid.
1215	Aug. 20.	87.	46.	35.6	Fanshaped female.
1224	Aug. 20.	98.	56.	26.	Fanshaped female.
1245	Aug. 20.	90.	51.	32.8	Fanshaped female.
1235	Aug. 20.	98.	48.9	36.3	Male.
1188	Aug. 20.	102.	53.	36.	Male.
1221	Aug. 20.	100.	51.	37.	Male.
1223	Aug. 20.	96.	51.4	34.8	Male.
1228	Aug. 20.	102.3	53.7	33.	Male.
					Most of these shells. blistered posteriorly.

The males are fairly like those of river examples; the females are more fan-shaped. Weight of the 10 shells, 15 oz.; only a few are rayed

11. *Lampsilis ventricosa* (Barnes). Pocket-book.

Rather common at the Long Point mussel bed; a few found in the bed by Farrar's and a few in Lost Lake. The species as found in the lake is markedly dwarfed and quite different in appearance from the usual river form. There are two types in the Long Point bed, one consisting of females and having the post-basal inflation of the shell characteristic of that sex, not exactly as in the river form, however, but somewhat more restricted; this feature, along with a peculiar stain of the epidermis which conceals the normal coloring of the shell, causes them to resemble very closely a short female *L. luteola.* The other type, an oval shell without the post-basal inflation, was at first taken to represent the males, but some of them were found to contain glochidia. These, too, bear a marked resemblance to *L. luteola,* and the only way

to distinguish the two species, as they occur in the lake, was by an examination of the umbonal sculpture. This in *ventricosa* consists of a a few coarse parallel ridges; in *luteola* the sculpture is of numerous fine wavy lines.

The lake *L. ventricosa* was so markedly different from the species as usually known that it was compared with a large series of both lake and river forms. Of river shells only a few from the central part of the Maumee, where for some reason the shells are markedly dwarfed, bore any close resemblance to it. None was found in any of the neighboring lakes with which to compare them. In some of the small lakes of Michigan where Dr. Robert E. Coker had collected he had experienced a similar difficulty in distinguishing between *L. ventricosa* and *L. luteola* and had sent sets of critical specimens to Mr. Bryant Walker of Detroit, Mich., who identified the shells with a few coarse straight undulations on the beaks as *Lampsilis ventricosa canadensis* and the others as *L. luteola.*

The Maxinkuckee specimens were also compared with *L. ventricosa* from Lake Champlain, and were found to be much like them. The Champlain examples which were free from staining of the epidermis more closely resembled in color the *ventricosa* of the rivers.

The specimens of *L. ventricosa* differed considerably in the different beds. Lost Lake examples are usually rather small, and are stained a peculiar ashy-gray. Those from the beds near Farrar's are mostly small and apparently young and are rather well rayed; they resemble river forms more closely than any others in the lake.

The large oval *L. ventricosa* of Long Point are the heaviest shells of the lake. A peculiarity of several of these shells is a conspicuous rib-like thickening on the inside, extending from near the umbonal cavity postero-ventrally. The nacre is soft satiny in luster, and not very iridescent. This oval form of *ventricosa* found at Long Point furnishes the only shell in the lake that could be used to any advantage in the manufacture of buttons, and even it produces rather inferior material. Some of these shells were sent away to a button factory at Davenport and buttons were made of them. The following is a set of measurements of these large shells:

No.	Date, 1907.	Lgth. mm.	Alt. mm.	Dia. mm.	Remarks.
1	Sept. 24.	114.	74.8	53.	Female gravid.
2	Oct. 30.	107.6	65.5	54.8	
3	Oct. 2.	105.2	63.7	52.5	
4	Oct. 30.	92.5	60.4	53.7	Female gravid.
5	Oct. 30.	103.7	67.3	49.3	Dorsal baroques.
6	Oct. 17.	98.6	60.2	55.5	Arcuate, baroque found.
7	Oct. 20.	101.7	63.6	52.2	
8	Oct. 30.	94.6	58.4	53.2	Nacre diseased and blistered.
9	Oct. 17.	95.6	55.7	49.	
10	Oct. 17.	91.5	60.4	49.5	

Although the reproductive phase of *L. ventricosa* of the Lake is much less conspicuous than in the river mussels, most of them apparently succeed in reproducing themselves. Most of the females found later in autumn have more or less numerous glochidia in the gills. No infected fishes or very young mussels of this species were seen.

The most common parasite is *Atax*, and it is not particularly abundant. Of 6 examples collected near Farrar's July 24, 1909, the first contained 9 of the mites, the second 4, the third 15, with *Atax* eggs in mantle and body, the fourth 12 *Atax* and numerous eggs of the mite on the inner surface of the mantle, the fifth 3 *Atax* with eggs, and the sixth 7 *Atax* with eggs and egg scars. No other parasites were noted. No pearls were found, only a few irregular slugs.

In 1906 some of the immense *L. ventricosa* of Yellow River were planted in the lake near shore not far from the old ice office. A few died shortly after planting but near the same place two years later some of the mussels were found alive and apparently thriving. Two of the large females were killed and examined. Although this was at a time when this species is usually gravid, one of these individuals was sterile, apparently having failed to become impregnated. The influence of its residence in the lake was marked by a dark stain which covered the exposed portion of the shell. The other had a few eggs in the gills, and numerous marginal cysts in the mantle. About 10 *Atax* among the gills, and numerous distomids on the outside surface of the mantle in the umbonal cavity.

12. *Lampsilis multiradiata* (Lea).

Not abundant in the lake; occasional shells are found along shore, and now and then they are encountered in the piles of shells where muskrats have been feeding. A few living examples were found in the mussel bed near the mouth of Norris Inlet and a few at Long Point bed. In all hardly a dozen living examples were secured; of 563 shells taken from a pile left by a muskrat at Long Point in 1907, only one was of this species. This mussel, as it occurs in the lake, is not nearly so attractive as river specimens, being dwarfed, and so deeply stained that the rays are inconspicuous, being usually black or dull brown instead of green.

This species was found in unusual abundance in the Tippecanoe River at Delong, and a considerable number was observed spawning during the autumn of 1908. While spawning, this mussel is very conspicuous in its habits. It lies either on its back, or more usually with the posterior end directly upward, and the showy edges of the mantle, which are of a yellowish brown color, and cross-barred with narrow lines which are continuous with the fine rays of the epidermis, look a good deal like a small darter lying on the bottom. Long waving pennant-like flaps, with showy black spots at the base of each are developed, and this portion of the mussel is made still more conspicuous by reason of periodic violent spasmodic contractions.

In the Tippecanoe River near Delong this is one of the favorite foods of the muskrat, and it must be difficult for them to hold their own against that rodent.

13. *Micromya fabalis* (Lea).

Rare; previous to 1913 only one shell had been found; this was picked up on the north shore of the lake in 1907. In 1913 several shells, recently cleaned out by some animal, probably a muskrat, were found at the wagon bridge. This species is fairly common in Tippecanoe Lake and still more so in the Tippecanoe River at Delong, where it was collected in shallow water near shore in rather stiff blue clay. It is the smallest of our Unionidæ. The white or bluish white nacre has an exceedingly brilliant luster.

Several other species of mussels have been recorded for the lake, among them *Quadrula lachrymosa* (Lea), *Margaritana marginata* Say,

Unio pressus Lea, *Anodonta subcylindracea* Lea, *Anodonta imbecillis* Say, *Unio phaseolus* Hildreth, *Unio circulus* Lea, *Unio parvus* Barnes, and *Lampsilis gracilis* (Barnes). We have seen representatives of none of these species from the lake, and while some, such as *Anodonta imbecillis** and *A. subcylindracea* are very probably present, the presence of the others is very improbable.

* Since the above was written a single specimen of *Anodonta imbecillis*, from Lost Lake, has been seen.