THE [illegible] FAUNA OF THE SANKAKEE BASIN

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FIG. 1.—AN UNDREDGED PORTION OF THE KANKAKEE RIVER, FILLED WITH VALUABLE SPECIES OF MUSSELS, SHOWING CONDITIONS UNDER WHICH THEY FLOURISH.

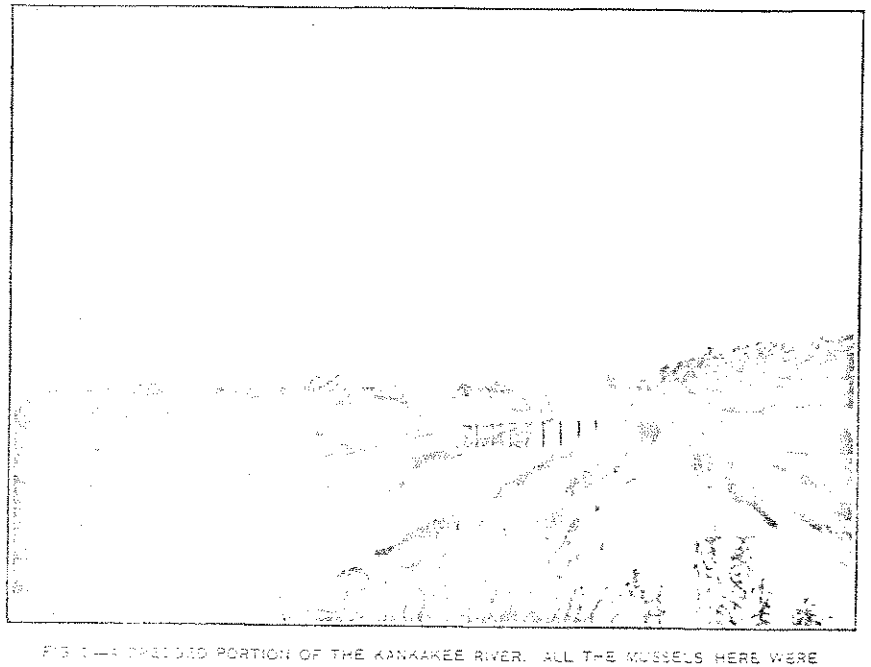


FIG. 2.—A DREDGED PORTION OF THE KANKAKEE RIVER. ALL THE MUSSELS HERE WERE KILLED BY DREDGING AND NOT ONE CAN LIVE UNDER THE ARTIFICIAL CONDITIONS HERE ESTABLISHED.

THE MUSSEL FAUNA OF THE KANKAKEE BASIN.

By Charles B. Wilson and H. Walton Clark.

INTRODUCTION.

The following paper gives the results of fresh-water mussel investigations made by the authors in the Kankakee Basin during the summer of 1909, under the auspices of the United States Bureau of Fisheries.

The mussel fauna of the various localities is recorded in the table on page 38, and forms an important result of the investigations. But careful attention was also given at each of the localities to the kind of bottom on which the mussels were found, the depth of water and rapidity of the current, the relative temperature of the water, the nature of the plankton present and suitable for food, the actual stomach contents of selected samples, the relative size and physical condition of the mussels, the small fish and crawfish found on or near the mussel beds, and the times of spawning of the various mussel species. In particular, most of the species secured alive were examined for parasites, for the color of the nacre and any staining or spotting produced by the parasites, and for pearls or baroques as a result of parasitic infection. The results of these studies are given under the various stations where they were made and constitute by far the most valuable portion of the work.

Samples of the shells were afterwards examined by Mr. J. F. Boepple and others who are experts in the manufacture of pearl buttons. The value per ton of the different marketable species was carefully estimated and is recorded in the table on page 39, giving some idea of the economic importance of the investigation.

The boat was put into the Yellow River at Burr Oak, Ind., and traversed the remainder of that river to its junction with the Kankakee, and the latter river from this junction to the city of Kankakee, Ill.

The river below this city, the upper portions of both the Yellow and Kankakee Rivers, the whole of the Iroquois River, and the various lakes and tributaries, were worked by means of short drive

from the nearest railroad towns. At each of the lakes a boat was secured and the whole of the lake shore and as much of the outlet as was deemed advisable were examined. The fact that quite a portion of the Yellow and Kankakee Rivers has been artificially dredged and the old winding channel converted into a straight cross-country ditch, presented changed conditions of extreme importance in their relation to mussel propagation. These conditions have been accurately recorded, and furnish an instructive contrast to the remainder of the area worked.

While the entire Kankakee Basin was thus more or less completely examined and satisfactory results were obtained, the authors would not regard the work as in any sense final. It is rather initiatory and suggestive, and its value lies in the data and comparisons it furnishes with reference to the natural conditions under which mussels live and thrive in a region which has been as yet scarcely touched by the progress of civilization.

PHYSICAL FEATURES OF THE KANKAKEE BASIN.

The Kankakee Basin embraces the whole of the northwest corner of the State of Indiana south of the narrow Great Lakes drainage, and adjacent portions of Illinois, and is drained by the Kankakee, Yellow, and Iroquois Rivers and their tributaries. These 3 rivers, the principal streams that flow into them, and 12 of the more important lakes lying within the basin were thoroughly examined.

This basin is radically different from that of the Maumee River, previously examined, in that the Indiana portion of it lies wholly within what geologists designate as a plain of accumulation. The origin of the valley can not be stated more concisely than in the words of W. S. Blatchley in the Twenty-second Report of the Geology of Indiana, page 59:

> The valley doubtless owes its origin to the flow of waters which followed the melting of one of the later retreating ice sheets. This flow was at first sufficient in volume and velocity to erode the present valley to quite a depth through the underlying clay. Later, on account of a diminution of the supply of water, as well as the gentleness of the slope, the current became too sluggish to erode much deeper or to carry coarse material, and only the finer sediment was brought down. From a still further diminution of the water supply, as well as by the building up of a sedimentary dam near the western end of the valley, the water for a long period ceased to flow, and a lake of shallow depth resulted. Again by a new accession of water from the northwest, the barrier at the foot of the valley was washed away and the river of the present had its beginning. At first its waters flowed the full width of the valley, but in time their volume decreased, and a portion of the river's bed became bare in summer. Over this a vegetation sprang up and decayed. A soil was thus started above the sands and was added to each year by the decay of the summer's vegetation and the sediment brought down by the overflow in the spring. The main current of the stream was thus gradually narrowed until it reached its present size.

We thus have a basin surrounded by glacial moraines and everywhere covered with a heavy mantle of glacial drift or till, so thick[5] that not a single outcrop of surface rocks is known to occur within its limits,[6] even in the bed of the river or any of its tributaries. Consequently, there are no rocky bottoms with alternating riffles and quiet reaches, but everywhere a uniform current and labyrinthine windings. The river itself is noted for its low banks and the crookedness of its channel. It rises in a marsh about 3 miles southwest of South Bend in St. Joseph County, Ind., flows southwesterly through that county to the Laporte County line, from which point it forms the boundary between the counties of Laporte, Porter, and Lake on the north, and St. Joseph, Starke, Jasper, and Newton on the south. At about the center of the Starke County line it receives the Yellow River as a tributary from the east. Crossing the State line between Lake and Newton Counties, it flows south of west to the town of Waldron, Ill., where it is joined by the Iroquois River from the south. Thence it flows northwesterly to the northeastern corner of Grundy County, where it joins the Des Plaines, coming from the north, and the two form the Illinois River.

The Yellow River, its principal eastern tributary, rises in three forks, north, middle, and south, in the southeastern corner of St. Joseph County, Ind., the southwestern corner of Elkhart County, and the northwestern corner of Kosciuszko County, respectively.

The north and middle forks unite near Bremen in Marshall County, and flow directly south until opposite Plymouth, the county seat. Here they are joined by the south fork, and the river turns westward through Plymouth, then south for about 5 miles, and then westward again through the remainder of Marshall and the whole of Starke County, entering the Kankakee at about the center of what was formerly English Lake.

The Iroquois River, the only other tributary of any size, arises in several creeks in the southeastern portion of Jasper County, Ind., flows a little south of west across Jasper and Newton Counties, cutting the State line 6 miles north of the southern boundary of Newton County. It then flows west through Iroquois County, Ill., as far as Watseka, the county seat, where it receives Sugar Creek from the south. The two then flow northwest about 5 miles to a junction with Spring Creek, also from the south. There the river turns almost due north and crosses the remainder of Iroquois County and into Kankakee County, where it empties into the Kankakee River a mile west of the town of Waldron. The Yellow River is about 65 miles, the Iroquois 100 miles, and the Kankakee 300 miles in length. The banks of the Yellow and Iroquois Rivers, and those of the Kankakee River in Illinois, are high and solid and in many places well wooded, and the adjacent country is of the usual prairie type.

[5] That is, in the State of Indiana.

In Indiana, however, the entire basin of the Kankakee River is marshland, the most extensive body of swamps within the State. On the immediate border of the river there is a strip, from a few rods to a mile or more in width, which is heavily timbered. Then come dense thickets of underbrush, and finally the open marsh, covered with a rank growth of grasses, sedges, reeds, and semi-aquatic vegetation.

There were formerly more than half a million acres of this marshland in the seven Indiana counties drained by the Kankakee, but its area has been recently somewhat reduced by extensive ditching. Enough still remains, however, of this old glacial lake bed to act in the manner of an immense sponge, overflowing and absorbing water during the wet season and slowly oozing it forth during the dry.

There is thus never any real lack of water in the river, the amount of discharge at the State line being considerably over a thousand cubic feet per second even at low water. In general the soil of the marshes is a dark sandy loam, very rich in organic matter, and hence the waters of the river contain an abundance of food material for the mussels they contain. In many places the wild rice, rushes, lily pads, and aquatic grasses fill all except the very channel of the river and contribute their quota of food material. Owing to the fact that the land can not be cultivated, there are few dwellings on or near the river, and repeatedly one may row 15 or 20 miles without seeing a human habitation. The presence of the rich marshes, combined with the absence of human environment, have made this region an ideal breeding ground for waterfowl and aquatic animals of every sort. Fish are also abundant in the river, together with plankton of great variety and richness. Each and all of these conditions have a very important bearing upon mussel life.

And withal the region is one of marvelous beauty and attractiveness, and as radically different in many respects from an ordinary swamp as could well be imagined. In the first place, the river itself, in spite of its intricate windings and rich vegetation, is not sluggish as one would expect, but has everywhere a good current, averaging 3 or 4 miles an hour. Then the river bed is nowhere of the proverbial quagmire type, but is hard sand or fine gravel, mixed with mud to just the right consistency for most mussels. Here, then, we have a region especially favorable in almost every particular for mussel growth, strictly secluded by its environment from all but the hunter, the trapper, and the fisherman, and still maintaining primitive conditions throughout most of its extent. Futhermore, its waters have always drained into the Mississippi Basin as they do now, and the mussel fauna, originally derived from that source, has never undergone any radical changes.

We may be reasonably certain, therefore, that the data here obtained are natural and authentic, and that they have not been to any degree artificially modified.

MUSSEL SURVEY.

LOCALITIES EXAMINED.

Station 1. The middle fork of the Yellow River.—The entire upper portion of this river, down to within 6 miles of Plymouth, has been recently dredged. The result has been a conversion of the winding forks of the river and their tributary streams into a series of straight cross-country ditches, in which the water flows at a uniform rate over an equally uniform and undifferentiated bottom of sandy gravel.

These ditches were examined at several places (the first four stations) in order to ascertain what effect the dredging had upon the mussels and other life in the headwaters of the river. The dredged material, thrown up along the sides of the ditches, everywhere presented abundant evidence that mussels were formerly present in considerable numbers. But the process of dredging, by throwing out the living mollusks upon the land where the ditch coincided with the old channel and by withdrawing the water from such portions of the old channel as did not thus coincide, *completely destroyed the entire mussel fauna.* There has been some restocking of the new channels by ordinary natural methods, but the conditions have been extremely unfavorable for such restoration. Our fresh-water Unionidæ are dependent upon small fish for their distribution and for transportation into new regions like those created by this dredging. At the last rebuilding of the dam at Plymouth no fishway was provided. Consequently, the only fish available, as well as the only supply of glochidia, had to come from the short undredged space of 6 miles above the Plymouth dam and from such specimens as may have escaped destruction during the dredging. Furthermore, the reduction of the water channels to an absolutely uniform grade and depth has proved very unfavorable to the spread of mussel life. The constant shifting of the sand and soil along the bottom of the channel effectually prevents the young mussels from obtaining a stable foothold anywhere. In the presence of such adverse conditions it was remarkable to find any evidence of a restoration of the mussel fauna.

This first station was near the town of Bremen, in the northeastern corner of Marshall County; the ditch representing the middle fork of Yellow River was 6 feet wide and the water was about 8 inches deep at the center. There was no vegetation of any sort present, and no fish or crawfish could be found for the distance of a mile above the town. The bottom of the ditch was gravel or sand, kept

in constant motion by the swift current. The only trace of mussels were the dead shells which had been dredged out of the old channel and left high and dry along the sides of the ditch.

Station 2. Half a mile below (west of) Bremen.—The ditch had been enlarged here to 10 feet in width, and the water was knee-deep (22 inches) at the center, with a current fully 8 miles an hour. The bottom was of sand over firm peat, and there was some vegetation in the form of scattered patches of *Ceratophyllum*. This served to prevent in places the constant motion of sediment along the bottom and gave an opportunity for mussels to establish themselves. The three specimens recorded were found alive and of fair size, and there were more of the dead shells in the piles of clay along the banks than at the previous station.

A number of *Campeloma*, *Sphærium*, *Planorbis*, and *Pisidium* shells were also found, which probably represented the inhabitants of a swale that had been drained by the ditch. No fish or crawfish were seen. The only mussels found were two "fat muckets" (*Lampsilis luteolus*) and one "floater" (*Anodonta grandis*).

Station 3. Junction of north and middle forks.—This junction is about 2 miles west of Bremen and a few rods north of the Baltimore & Ohio Railroad tracks. The north fork is much the larger and its waters were very muddy, in strong contrast to those of the middle fork.

No life at all, animal or vegetable, except a few young pike, *Esox reticulatus*, was found at this station. This was probably due to the fact that the peat over a large area along both sides of the forks and the main stream had been recently burned to a considerable depth, changing the water, for the time being, into a sort of lye.

Station 4. Yellow River, 1 mile below station 3.—The ditch here is 12 to 15 feet in width, and the water is 2 to 3 feet deep at the center; the bottom is gravel and clay, firm and solid, with a slower current, about 6 miles an hour. The ditch has been cut through about 8 feet of blackish alluvial soil, and the water, in consequence, is turbid.

There was no vegetation in the water, but we found a large number of mature crawfishes, *Cambarus propinquus*, and a few small fishes which proved to be young pike. No mussels were found alive, but there was an abundance of dead shells along the sides of the ditch.

A short distance to the west of this station are two other dredged ditches, running approximately parallel with the river. These are known as the Bunch ditches and were dredged several years before the river itself. They run into Bunch Creek, the first outlet of the Lake of the Woods, and this creek empties into Yellow River 2 miles farther south. Both ditches and the creek were examined for considerable distances, but although fishes and crawfish appeared to be abundant no live mussels could be found. The water in the eastern ditch was quite black and there was considerable "ditch moss" (*Philotria*) in scattered patches. A few small minnows, *Notropis whipplii*, were found here, and a number of sunfish, *Eupomotis gibbosus*, were nesting in the crannies of a pile of rocks that had been thrown into the edge of the ditch from the railroad. The western ditch is shallower and cleaner; the water is yellow instead of black, and quite clear. The bottom is a fine gravelly clay, well adapted for mussel life, and many *Cambarus propinquus* were seen.

These facts seem to indicate that even after the conditions become again favorable for mussels it still takes a long time to restore them under natural conditions. In all probability the introduction of small fish well infected with glochidia would materially hasten the restoration of the mussel fauna here.

Station A. The Lake of the Woods.—This lake is situated in the northeastern corner of Marshall County, 4 miles southwest of Bremen. It is 1½ miles long and 1¼ miles in extreme breadth; it is oval in shape, with a fairly regular outline, except on the western shore, where a broad bay increases the width by half a mile. It formerly occupied a much larger area than at present, as is evidenced by the distance from the present water's edge of an old shore line, separated by a broad, sandy, level plain, once lake bottom. On the eastern side large peat deposits extend north into St. Joseph County and south to the line between North and Center Townships. This latter southeast corner was the original outlet of the lake into the Yellow River.

Through the drying up of the lake its area was diminished to one-tenth of the original size. This reduced lake was bordered by high and heavily wooded banks, except at the northeast and southeast corners, and must have been a beautiful sheet of water, plentifully supplied with all sorts of life, including mussels. But a ditch was dug 50 or 60 years ago from the northeast corner into the north fork of the Yellow River and the lake level was reduced 4 feet. The original shore, in places a high, picturesque, abrupt bank, covered with large oak and cottonwoods, can still be seen from 500 to 1,000 feet back from the present beach.

Even this outlet, however, did not satisfy the farmers in the vicinity and another ditch was dug 15 or 20 years ago from the southwest corner of the lake, running south for a mile or more, then turning east into the Yellow River. This lowered the lake again from 2½ to 3 feet and the second lake shore is also visible in many places, covered with poplars and yellow birches.

By these two lowerings the lake has become little more than a mud hole, fringed with reeds and rushes which grow far out into the

water. In addition the bottom of the lake, wherever it can be seen, is entirely covered with plants, *Chara* and *Potamogeton*. In following around the entire lake margin only a single spot was found free from this vegetation. Finally the water itself is filled with a suspended plankton which is entirely vegetative, made up mostly of minute algæ (*Clathrocystis* and *Lyngbya*).

All the water plants are covered with a fuzzy growth of *Mesocarpus*, which also forms in floating masses, and with the *Clathrocystis* collected in large curdlike lumps. Such a lake does not afford good conditions for either fish or mussels and both were very scarce. A careful examination of the entire margin of the lake yielded only 7 specimens of the "fat mucket" (*Lampsilis luteolus*), of which 5 were dead, 16 specimens of *Anodonta grandis*, 14 of which were dead, and 1 dead *Anodontoides ferussacianus subcylindraceus*. As it was of interest to know the food and parasites of mussels living under such conditions, the four live specimens were examined, with the following results: In *A. grandis*, *Atax* was abundant, with an occasional *Cotylaspis*. The distomid of Osborn[1] was exceptionally abundant and made the nacre very rough, but gave a dark discoloration instead of the usual salmon tint. The stomachs yielded *Clathrocystis* and *Calospherium* in abundance with some *Pediastrum*. In *L. luteolus* both marginal cysts and the distomid of Kelly were fairly abundant, with no other parasites. Small pearls were found in the margin of one mantle and a small dorsal baroque in the other specimen. The stomachs were filled with *Clathrocystis* and *Cosmarium* well fused into a dark gritty mass.

Station 5. Above the dam at Plymouth.—This dam was built 60 years ago, but has been washed out and rebuilt several times, the last time without any fishway. It backs the water up the river about 4 miles; this dead water and the river for 2 miles above were thoroughly examined, as well as the side lagoons, which are common along the dead water. The center of the dead water was too deep for wading and there were so many snags it was impossible to dredge it. Elsewhere the mussels were widely scattered and not many were found alive. In some places the banks were too soft and miry, in others too hard and solid for mussels, and it was only the infrequent spots between the two that yielded any returns.

On examining the mussels for parasites the following were found: In *L. luteolus* there were many cysts along the mantle margin and the distomid of Kelly was fairly abundant. In many of the specimens there were small pearls and in some of them dorsal baroques. In *A. grandis*, *Atax* was the most common parasite, with a few

[1] This name is applied to a distomid which was found by Prof. Osborn to be the cause of salmon [illegible] in *Anodonta grandis*. [illegible] undertaken since the above was written [illegible] the belief that the distomid in question, which produces a chocolate instead of a [illegible] stain, is of a different species.

Cotylaspis. The distomid of Osborn was abundant, producing a dark discoloration and rough nacre like that found at the Lake of the Woods.

Station 6. Below the dam at Plymouth.—This station offered a pleasing contrast to the preceding. The water was shallow, the maximum depth being 2 feet, the bottom was firm sand and gravel, and the current was about 3 or 4 miles an hour. From the dam to the mill race we found good collecting; below there the river became deeper and there were not as many mussels.

Of the specimens obtained one small *L. ventricosus* had a very thin shell with pink nacre; *A. imbecillis* was quite common and five were obtained that were gravid; one *L. parvus* was also found gravid; a few *L. iris* and large *A. calceola* were found along the shore.

In addition to the mussels collected by the authors here, Mr. Aaron Greenwaldt, who had collected shells from the river for the State Geological Survey, presented the Bureau of Fisheries a beautiful collection of 125 shells very perfectly cleaned and kept with the two valves tied together. For this valuable present the authors here return sincere thanks. The collection included the following species, the number of specimens being given after each: *Q. coccinea*, 16; *Q. rubiginosa*, 6; *Q. pustulosa*, 3; *Q. undulata* (from above the dam), 6; *S. costata*, 12; *S. compressa*, 7; *A. imbecillis*, 1; *S. edentulus*, 2; *A. grandis*, 10; *L. iris*, 6; *L. luteolus*, 20; *L. ventricosus*, 21; *U. gibbosus*, 15.

Of the small fishes obtained at this station the straw-colored minnow (*Notropis blennius*), chub (*Semotilus atromaculatus*), and Johnny darter (*Boleosoma nigrum*) were particularly abundant and many of each species were put back into the river. A considerable number of the young straw bass (*Micropterus salmoides*) and grass pike (*Esox vermiculatus*) were also caught, but only one or two samples were kept. We were told there was a severe attack of the "pearl fever" here during the previous year and that the boys brought out and examined mussels by the barrel without material results. If so, they must have disposed of the shells, since none were found except a single pile, containing about a ton and a half, a short distance below the dam.

Station B. Pretty Lake.—Pretty Lake, situated 3 miles southwest of Plymouth, is a typical glacial kettle hole, nearly circular in outline and about half a mile in diameter. The water is remarkably clear and has a fine greenish tint, like that of Lake Maxinkuckee.

It is fed by springs, the entire northeastern shore being covered with them, and at present has no outlet. There is a single inlet at the northwest corner which is a dry run most of the time, but the presence of a large gravel delta testifies that at times it discharges

considerable water into the lake. There is an old outlet at the southeast corner of the lake, which formerly drained into the Yellow River. Although the mouth is closed by a sand bar, the water in the lake occasionally rises high enough to overflow this and run into the river. The bottom of the lake is firm sand and gravel, and the shores slope off rapidly into deep water, the depth being 40 feet at the center.

It is a very clean lake and in this respect presents a marked contrast to the Lake of the Woods. For vegetation pickerel weed (*Pontederia*) was common around the shores, the largest patch being along the northern margin. The broad-leaved pondweed (*Potamogeton amplifolius*) and Robbins's pondweed (*P. robbinsii*) were found in large patches, and *Chara*, probably *fœtida*, was also common. There were plenty of white water lilies but no spatterdock (*Nymphæa*). Great patches of ditch moss (*Philotria*), considerable wild celery (*Vallisneria*) and hornwort (*Ceratophyllum*), and some *Naias*, *Cladophora*, bladder wort (*Utricularia*), and *Decodon*, and in one place some *Nostoc* were found in shallow water. The water temperature at the surface near the center of the lake was 79° F.; the plankton was very light, containing no vegetation and but a few water fleas (*Cladocera*).

A careful examination of the entire margin of the lake yielded eight specimens of *L. luteolus*, widely scattered, and a half dozen *A. grandis*. The mussels were too far apart to breed well and all were stunted in size and peculiarly fragile at the hinge.

For food the stomachs of the *A. grandis* contained one *Cosmarium*, two or three *Calosphaerium*, a few *Clathrocystis*, and one *Ascaris*. In the *L. luteolus* were found one *Anuræa* and a little *Clathrocystis* mixed in a dark gritty mass. Here where the mussels are nearly starved they seem to digest well. (It is common where food is abundant to find undigested organisms at the posterior end of the mussel's intestine, but such was not the case here.)

Station 7. Yellow River at Hibbard.—The water of the river here was perfectly clear and had a maximum depth of 3 feet. The bottom was of fine sand, coarse gravel, and here and there a mud bar, particularly along the shore. The current was rather slow, not more than 2½ miles an hour, and the temperature was 78° F.

For vegetation there were lodged masses of alga, some *Cladophora*, and patches of the river pondweed (*Potamogeton fluitans*) and aquatic moss. There were also many small sponges scattered over the rocky parts of the bottom. A large number of young black bass, some Johnny darters (*Boleosoma nigrum*), and a few black-sided darters (*Hadropterus aspro*) were found on the mussel beds. Only a few mussels were found in the muddy places, chiefly *L. gibbosus*, *A. grandis*, and *L. ligamentinus*. None occurred in the shifting sand, but where the sand was firmly packed and among the rocks they were placed almost as thick as they could lie. *L. ventricosus* and *U. gibbosus* were most abundant and occurred in about equal numbers. The *ventricosus* were all upright, the tips pointed upstream, and the entire mussel buried with the exception of the large brown siphons. The *gibbosus* were more active, moving about in every direction, and often found lying flat on one side. *S. costata* was also very common and when buried, with only the crinkled edge showing, was easily mistaken for *undulata*. A single *L. rectus* was found lying upon its back and spawning. Nearly all the *costata* also were gravid, and most of them contained one or more dorsal baroques, yellowish in color. The *Q. coccinea* nearly all had pink nacre.

The shells obtained at this station were of large size, particularly the pocketbooks (*L. ventricosus*), and of excellent luster. And it is certain that a qualitative examination would show them to be as valuable as any obtained during the entire summer.

Station 8. Yellow River at Burr Oak.—This is the station where the boat and outfit were launched for the trip down the river. The conditions were identical with those at Hibbard, except that the current was a little swifter—4 miles an hour. *Potamogeton natans*, *Cladophora*, and *Tetraspora* were found in patches on the mussel beds. As before, the mussels were found mostly in the gravel and hard sand and were completely buried, except the siphons. Many of the *ventricosus* and some of the *gibbosus* were spawning and it was noticeable that the small fishes, especially *Notropis blennius*, *Boleosoma*, and *Semotilus*, which were the ones most abundant, kept playing about near the spawning mussels.

Station 9. County Line Bridge, 4 miles west of Burr Oak.—This was a broad, pond-like stretch of river, with a sluggish current, plenty of spatterdock and white water lilies, a bottom of hard mud and fine gravel, and banks of seepy blue clay.

Not many mussels were collected here—just enough to show that they were still scattered plentifully along the river bottom.

Station 10. Zinc Bridge at Ober.—The water was shallower than at the preceding station, with a maximum depth of only 2 feet, and a current of 5 miles an hour; the other conditions were the same.

The mussels were thickly scattered everywhere, with especially dense beds along the shore. The small fish were again noticed playing about in the immediate vicinity of the spawning mussels.

L. ventricosus has a habit of moving its bright yellow siphon fringes, which are much enlarged during spawning, back and forth in the water. This undulatory motion seems to attract the small darters and minnows, particularly *Notropis blennius*, which could

be seen darting in toward the fringes repeatedly. It also probably assists in furnishing fresh water for the respiration of the young mussels.

At intervals during the undulations small numbers of glochidia are discharged from the brood chambers of the mussel and carried out of the excurrent aperture. These glochidia are of the hookless type, and must be taken into the mouth of the fish that is to carry them during their parasitic period. We can thus understand the advantage of attracting these fish and keeping them in the immediate vicinity during the discharge of the glochidia.

Since this is the last station before the dredged portion, which includes all the remainder of the Yellow River, we may summarize the results.

This stretch of river from Plymouth to Ober, a distance of 20 miles or more, forms an ideal breeding ground for mussels. The natural conditions are exactly suited to mussel life; there are the right kinds of river bottom, plenty of lime and food in the water, and a current of fairly uniform velocity; the water is kept reasonably cool by the springs and brooks which flow into the river, and there are plenty of small fish to distribute the glochidia.

The river is already well stocked with mussels whose shells are far above the average in size and quality, as can be readily seen by reference to the table of values given on page 39. Furthermore, these mussels are not irregularly distributed in small patches, but form a single bed which is practically continuous for the entire 20 miles. With such natural resources it would be a very easy matter to keep the river stocked with mussels that would yield the farmers a far better revenue than any of the swamp land found in the immediate vicinity. A judicious use of the supply already at hand, selecting the larger mussels and leaving the smaller ones unharmed for further development, and replenishing the stock regularly by introducing small fish richly infested with glochidia, would insure ample returns for a long series of years.

The new mussel hatchery just started at Fairport, Iowa, will be able to supply the fish carrying glochidia. Furthermore, the proved quality of the mussels, particularly *L. ventricosus* and *L. ligamentinus*, would make of this a profitable region from which to obtain glochidia for supplying that same hatchery. The railroad facilities at Plymouth, Hibbard, Ober, and Knox are all that could be desired, and there is no trouble in navigating the river between these points in an ordinary rowboat, as was proved beyond question by the present expedition.

Station 11. Old bed of Yellow River below Ober.—No greater contrast could well be imagined than that which was actually presented between the strip of river just described and that same river

bed from Ober to where it empties into the Kankakee, all of which has been artificially dredged. The dredged portion begins 1 mile west of Ober, and since the sole aim of the contractors was to cover the greatest possible distance at the least expense, irrespective of natural scenery, animal and vegetable life in the river, or in fact anything else, they did not follow the old winding channel, but cut across country in a straight line, which intersected the old bed at various places. This dredged part is of nearly uniform depth, from 1 to 3 feet, with a flat bottom of sand and gravel, which the swift current washes up into ripple marks, zigzagging across the entire width of the river. The current is uniform from 4½ to 6 miles an hour and keeps the finer sediment in constant motion along the bottom, thus forming an effectual barrier against mussel life. Hence, although this stretch has been dredged eight years, and there was an abundant mussel fauna in the old channel, which was not killed off except in limited areas, and which might easily have established itself in a much shorter time in the new channel if the conditions had been favorable, practically no progress has been made in that direction.

An occasional *L. ventricosus* was found alive in the dredged channel, together with shells of *Q. rubiginosa*, *L. iris*, *L. ligamentinus*, *L. luteolus*, etc., which had recently died (probably washed in from the old channel).

No real restocking can be expected until the bottom gets thoroughly solidified, packed down so that it will not wash along continually, and until at least some breaks in the current are formed similar to those in the old channel.

All the mussels found in this long stretch of 20 miles were obtained from the old channel, and it was very interesting to see how completely they had accommodated themselves to the changed conditions. Instead of a good current running over a sandy or gravelly bottom and keeping everything clear and clean, we now find lagoons and bayous in which the water is practically motionless except during floods.

Consequently, they are rich in algæ and other water plants, and the firm bottom has been covered with soft mud and in many places with fine ooze, 2 feet or more in depth. And yet the mussels have remained, *Q. pustulosa* being the only one killed off to any extent. The others have succeeded in climbing up on top of the mud and ooze as fast as it was deposited. Even the large and heavy *rectus*, *ventricosus*, and *undulata* are found on the very top. How such an unwieldly bulk as a full grown *undulata* can move about and actually lift itself up through mud so soft that it will not hold up an empty shell is difficult to understand. But the undoubted fact remains that they actually accomplish it. A noticeable peculiarity of all these lagoon mussels was the presence of a large tuft of growing

algæ around the siphonal (upper) end of the shell. These would be a manifest aid in oxygenating the stagnant water in which the mussels live, and might also be of assistance in keeping them on top of the mud, just as webs of gossamer keep spiders suspended high in air and enable them to perform aerial journeys.

Of the mussels found *luteolus* was far the most common; then came *ventricosus*, *undulata*, and *rectus*, in the order named. Many of the *luteolus* and *ventricosus* and one *rubiginosa* were gravid. *Atax ypsilophorus* was found in nearly all the species and was especially common in *luteolus*, *ventricosus*, and *edentulus*, and many of the eggs and young were found in the mantle. All of the *rectus* shells had a deep pink nacre, as did also one *ventricosus* and one *ligamentinus*. Both of the *imbecillis* found were gravid and were imbedded perpendicularly in the mud, with the siphons pointing straight upward, a very unusual position for that species.

The minnows and darters were abundant on the mussel beds, as is shown by the list of those obtained. *Notropis blennius* and *Boleosoma nigrum* were most in evidence and could be found everywhere, while the others were more scattered.

Only a few mussels were collected below Knox, and they have been recorded with the others from the old river channel. With the account of the Twin Lakes which follows, this concludes the investigations on the Yellow River.

Station C. The Twin Lakes.—These "twins" are really four in number, grouped near the center of the western third of Marshall County in two pairs, separated by the Vandalia Railroad. The eastern pair are elongated in a northwest and southeast direction and lie in the same straight line. The eastern and smaller one is Lorance Lake, about 80 rods in length and width. It is separated from the larger lake by a stream 50 rods in length. The larger is called Meyer's or East Lake and is a mile in length and about 40 rods wide. The western pair on the other side of the railroad are elongated at right angles to the others, or in a northeast and southwest direction, and they lie side by side with their long diameters parallel. The northern, larger one is Cook or Northwest Lake, and is the same size as Meyer's. The southern one is Holem or Southwest Lake and is about three-quarters of a mile long and 30 rods wide. It is separated from Cook Lake by a narrow ridge of gravel, 15 to 20 feet high and 200 to 300 feet in width.

Lorance Lake empties into Meyer's through the short brook mentioned. Meyer's runs under the Vandalia Railroad track into Cook; Holem also drains into Cook from its southwestern end and Cook delivers the drainage of all four lakes into Eagle Creek, which empties into the Yellow River just above Knox. All the lakes are very shallow, the maximum depth being under 20 feet, and the area

drained into them is limited. In general, they are surrounded by high banks of clay with only a little sand and gravel. They are fed largely by springs, nearly the whole shore line being marshy, with only a few bits of sandy beach.

Three of the lakes, Lorance, Meyer's, and Cook, were carefully examined for mussels; nothing was found in the one first mentioned; the other two yielded returns as follows:

East Lake (Meyer's) is considerably the shallower and warmer of the two; the bottom is a firm sandy marl, with scattered patches of *Chara* and *Potamogeton*, while the shores were fringed with pickerel weed, water lilies, reeds, bulrushes, and similar vegetation. The mussels were rather widely scattered, but formed beds where they did occur. Only two species were found, *Anodonta grandis* and *Lampsilis subrostratus*, the former in far greater abundance than the latter. The *subrostratus* yielded no parasites at all, the *grandis* were fairly loaded with them, every specimen yielding large numbers. They included *Atax* of several species, prominent among which was a rather small, deep-red one, *Cotylaspis*, marginal cysts, and the distomid of Osborn. The cysts of the marginal distomid were especially abundant and number hundreds in many of the specimens, while one must have had fully a thousand. The distomid of Osborn formed great pink patches under the umbo and tinged nearly all the shells with a reddish salmon color.

Northwest Lake (Cook) is deeper and the water was clearer and colder. Like East Lake the bottom is a firm sandy marl, covered in many places with *Chara*. The shallow water along the shore was one solid mass of reeds, bulrushes, and lily pads. The mussels were widely scattered and the same two species were found as in East Lake, with the addition of *L. luteolus*. As before, *grandis* was much the more common; the older examples were found with their shells high out of the sand, just enough being buried to hold them in place. The younger examples were more deeply buried. Many small fishes were seen upon the mussel beds; they included *Notropis blennius*, *Fundulus dispar*, and the young of *Lepomis pallidus* and *Erimyzon sucetta*.

Samples of plankton were secured from the clear water in the center of the lake at a depth of 8 feet. There were found five species of copepods, most of them covered with *Vorticella*, small pink water mites, *Daphnia*, a few nauplii, *Lyngbya*, minute *Spirogyra*, *Anuræa cochlearis*, *Ceratium hirudinella*, *Fragillaria crotonensis*, and *Anabæna*. This was the richest plankton obtained during the summer, and yet the water appeared perfectly clear.

On examining the mussels they were found to be as badly infested with parasites as those of East Lake, but here the *Atax* and *Cotylaspis* were far more numerous, and there were not as many

cysts. Some specimens contained 30 or more of the adult parasites, besides innumerable young swarming over the gills or the mantle.

The bed of mussels along the center of the north shore gave a remarkably fine opportunity to study the activities of the mussels in the natural beds, as the perfectly clear, calm water enabled one plainly to see them carrying on their life processes. The species examined was the *Anodonta grandis* of the lake, a plump, inflated form which probably represents the subspecies *footiana*.

The inhalent aperture was very large, black exteriorly and for some distance in. It was possible to look in far enough to see the gills. Long papillæ in approximately a single row project directly across and nearly to the center of the siphonal opening; most are single, but a few may be forked. The incoming current of the mussel is not nearly as strong as the outgoing, since the latter has a much smaller cross-section for the same amount of water. Minute red water mites ventured to the very orifice of the inhalent aperture but were not swept in, while small objects coming near the exhalent opening would be driven away with some force.

The exhalent opening was black for some distance in, then faded out to white. It was possible to see the posterior opening of the alimentary canal and the water-tubes running down into the gills of the living mussel. These mussels were quite apathetic; they did not close up at near approach, which must have caused both shock of waves and shadow. One, taken from the bed, closed only for a moment, then opened and began feeding while held in the hand. River mussels in general are more sensitive, and sometimes close when simply a shadow passes.

Station 12. Potato Creek, Kankakee River.—Having finished the workable portion of Yellow River, our attention was next directed to the headwaters of the main Kankakee.

At its source this river forks like the Yellow River, the west fork rising in the Fish Lakes, the east fork in the swamp southwest of South Bend. We found conditions here similar to those at the headwaters of Yellow River, but with this difference: While the east fork and the main river have been dredged recently down to the entrance of the Yellow River and about 10 miles beyond, many of the tributary creeks have been left in their original conditions; and since the west fork has been dredged only here and there, the Fish Lakes, at its source, remain practically unchanged. We were thus able to combine in our examination natural with artificial conditions, and we found an even stronger contrast between the two.

This entire section was worked by short drives from Walkerton, in the extreme southwest corner of St. Joseph County, since it was impracticable to row up against the swift current in the dredged Kankakee above its junction with Yellow River.

Naturally we examined first those portions in which the conditions had been least changed. Potato Creek is the southernmost of several large creeks which empty into the east fork of the Kankakee, and lies just north of Walkerton. The bed of the creek is hard sand or gravel, and, being undredged, it still preserves those alternations of swift and sluggish current, deep and shallow water, coarse and fine bottom, which are conducive to mussel life.

We found in it nine species of mussels, nowhere very thickly bedded, but as many, perhaps, as would be expected in a creek of the size, it being 8 or 10 feet wide, with the water nowhere more than a foot or a foot and a half in depth. On examining these mussels, the *Anodontoides* and the *Anodonta* were found infested with *Atax* parasites and the distomid of Osborn; the other mussels were free.

Station 13. Pine and Yellowbanks Creeks.—These are two other creeks of about the same size as Potato Creek and lying to the north of Walkerton. But, although they presented conditions apparently as favorable as those of the last station and were examined for long distances on either side of the highway, not a single mussel could be found in them, nor any dead shells, with the exception of one valve of *Symphynota compressa* in Yellowbanks Creek.

Station D. The Fish Lakes.—These lakes really occupy a single lake basin which is divided by narrow channels into four bodies of water, known as the Upper Mud Lake, Upper Fish Lake, Lower Fish Lake, and Lower Mud Lake, respectively. The two Fish Lakes have each an area of about 100 acres and a maximum depth of 40 feet. The thoroughfare between them is 80 rods long and 15 or 20 feet wide, with a maximum depth of 2 feet, and has a good current. The water in both of the lakes and the thoroughfare was clear and quite warm. The bottom was marl, hard and firm in most places, but very soft in a few spots. The shallow belt along the shore is narrow, as a rule, though wider and more irregular in the Lower Lake than in the Upper. The banks are high about halfway around each of the lakes, but low and swampy for the other half, where in each case it borders on the respective Mud Lake. There was the usual lake vegetation around the shores—reeds, rushes, spatterdocks, and some algæ.

Mussels were found abundantly everywhere. *A. grandis* was the most common and was found everywhere mingled with the other species. Most of the specimens were exceptionally large. Their shells were also thick and strong; in fact, many of them furnished shells of sufficient thickness for the manufacture of buttons.

L. luteolus was fairly abundant, and, instead of the usual dwarfed specimens found in lakes, these were fully as large as any obtained in the Yellow or Kankakee Rivers.

L. subrostratus was sparingly distributed, only 20 specimens being found, but each of these had large shells for the species, with an exceptionally thick white nacre.

A few *Unio gibbosus* were found in shallow water close to the shore.

A large number of dead shells of *Q. undulata* were scattered about over the bottom, and at one spot in the Upper Lake a colony of living examples was found. This is the first instance in our experience of finding this species in a lake, although Call reports it as fairly common in the lakes of northern Indiana. The shells were all fully as large and of as fine quality as those found in the rivers. A single live specimen of *L. iris* was found near the shore, one of *L. glans*, and one of *A. imbecillis*. All these mussels were well incrusted with marl, but the size of the shells and the healthy appearance of most of the specimens indicate that the conditions are at least very favorable.

A. grandis was as plentifully distributed in the thoroughfare between the lakes as over the lake bottom, but the other species were not found there.

The two Mud Lakes, as their names indicate, had a bottom of soft black muck and contained no mussels.

On the way back to Walkerton another Mud Lake on the east fork of the river, and into which Potato Creek empties, was visited. But the lake has been practically all drained by the dredging of the river and what is left was so black and swampy that it was not deemed worth examining.

The mussels from the Fish Lakes yielded an abundance of *Atax* parasites, some *Cotylaspis*, and many of the distomid of Osborn. The exceptional size and thickness of the shells of all the species is worthy of notice.

Station 14. Kankakee River at Davis, Ind.—The old bed of the river was examined close to the bridge of the Pittsburgh Division of the Pennsylvania Railroad. The same conditions were repeated here as in the dredged portion of the Yellow River below Ober. There was too swift a current and too much moving sand for the mussels to obtain a foothold in the dredged channel, but the old bed of the river was full of them. In this latter locality the hard sandy bottom had been overlaid with 1 or 2 feet of soft black mud, brought down during the freshets and deposited in the quiet water of these lagoons.

The mussels were even more numerous than in the old bed of the Yellow River, three or four being often obtained in a single square foot of the mud. These mussels also usually had a large mass of algæ attached to their upper ends and forming a sort of funnel in the water. Whatever may be the effect of the supporting power of the algæ in the mud, the two furnish a good example of symbiosis. The mussel supplies the alga with a place of attachment, otherwise lacking, and in return the alga helps to purify and oxygenate the water for the mussel.

Q. undulata was by far the most common species, there being two of them to every one of all the other kinds. No adult *Atax* parasites were found in this species, but the mantles of many of them contained clusters of the eggs.

Each of the *Q. pustulosa* (75 specimens in all) contained from several to a large number of adult *Atax*, besides clusters of eggs in the mantle, and young in various stages of development, swarming over the gills. *Q. coccinea* contained no parasites at all, and the nacre of all but two of them was white and would make excellent buttons. *L. centricosus* had an abundance of young *Atax* in the mantle and on the gills, and many of them had dorsal baroques.

L. rectus showed anywhere from 10 to 20 adult *Atax* in each specimen, besides plenty of young and an occasional *Cotylaspis*. A marginal baroque was found in one, and the nacre of all was a deep purple. None of the other species contained parasites.

Station 15. Kankakee River at the crossing of the Nickel Plate Railroad.—Just above the railroad bridge is a large island with the old channel to the west of it and the newly dredged one to the east. The water runs through this old channel oftener than at the previous station, so that only a few inches of mud have been deposited. The mussels were very abundant here, forming the largest and most densely populated bed found anywhere in the old channel of either river. There was much driftwood buried in the mud along the west bank of this old channel, and the mussels were clustered around the twigs and branches as thickly as they could stand, seeming to get some support from these solid objects.

Farther up behind the island the water was shallower and there was a perceptible current and no mud. Here the mussels were actively moving about, and as the water was clear they could readily be found.

On examination, none but the *Q. pustulosa* contained any parasites, but these had enough to compensate for any lack in the others. Every specimen was infested, and it was not at all uncommon to find 50 or 60 adult *Atax*, besides the eggs and young, in a single mussel. Many of these mussels contained small pearls and some of them dorsal baroques.

The *Q. coccinea*, again, had white nacre, none of the rosy nacred being found, and being at the same time large and flat, furnished

excellent material for buttons. (See values, p. 39.) The *L. rectus*, on the contrary, were not merely pink, but nearly all of them were deep purple.

The small fishes seined on these mussel beds furnish a good sample of those to be found in the upper part of the Kankakee River. *Boleosoma nigrum* was by far the most common, with *Notropis blennius* second in abundance. *Notropis heterodon* was common and easily recognized by its dark lateral stripe and black chin. We also obtained five examples of *Ericymba buccata*.

Station E. Koontz Lake.—This lake is situated in the extreme northeastern corner of Starke County, Ind. It is shaped like a three-leafed clover, the middle leaflet considerably the largest, and the whole lake covers 200 or more acres. The outlet is at the southwest end, where a stone dam has been built, 10 feet high and wide enough to accommodate a carriage road across its top. This outlet, called at first Cedar Creek, runs west into Robbins ditch, where it is joined by other ditches and becomes 40 or 50 feet wide, or nearly the size of the Kankakee itself, and empties into that river a couple of miles above the mouth of Yellow River and about the same distance below station 15. The outlet was examined for a mile west of the lake but yielded only a single *L. luteolus*.

The lake is in a large measure artificial, being formed by backwater from the dam. It has a hard sandy or gravel bottom and the shallow water around the shore is filled with rushes and lily pads, while the bottom itself is covered with *Chara* and *Potamogeton*, and so does not afford good localities for mussels. In a few places, however, the bottom is of clear sand and here *A. grandis* and *L. luteolus* were found in considerable abundance, and a few *Q. rubiginosa*.

These mussels were all of good size and quality for lake shells. No adult *Atax* were found in the *A. grandis*, but the eggs and young were abundant. Adult *Atax* species were found in all the *luteolus*, in addition to eggs and young. No parasites were present in *rubiginosa*.

Station 16. Kankakee at mouth of Yellow River.—Since being dredged this part of the Kankakee is called the Sisbro ditch. The old channel of the river crosses the ditch here and is available on both sides.

To the north we found a rather deep pool with a solid bottom and only a little mud and containing a large number of minnows and darters. Here we obtained only a few shells, chiefly *undulata* and *luteolus* with some *coccinea* and *pustulosa*. Farther down where the old channel crossed to the south there was running water, shallow in depth, with a firm sandy bottom in places and mud elsewhere. Here the mussels were exceedingly active, and nearly all were found at the end of long tracks that looped and turned upon themselves. Some *Oscillatoria* was found growing on the quieter shells.

Three or four miles farther down the river the old channel crossed the ditch again. Here in the deeper parts of the pools the mussels fairly touched one another. A pearler had been working on these mussels and had left a couple of large piles of freshly killed shells on the bank.

Along this stretch of river we obtained the first good evidence that the mussels are reestablishing themselves in the dredged channels. Living specimens were fairly common near the shore.

This part of the river was once the bottom of English Lake, a marshy overflow from the Kankakee, 10 or 12 miles long, 2 or 3 in width, and of shallow depth. It was filled with algæ of all kinds, reeds, rushes, water lilies, and an abundance of wild rice, and formed a natural breeding ground for thousands of waterfowl. It must have fairly swarmed with mussels, to judge from the dead shells of those thrown out by the dredge and the large numbers still found alive in every portion of the old channel that contains water. The dredging has entirely drained the lake and it is now a straight cross-country ditch, with the mussels gradually repopulating it. The conditions here are much more favorable than in the Yellow River, and a little artificial restocking would restore the mussel fauna in a few years.

On cleaning the mussel shells we found them an interesting lot. The *L. luteolus* were all more or less blistered and steel-colored at the tips of the valves, and frequently the whole shell was curiously roughened. They yielded many small pearls, all located near the tip of the mantle in the region of the siphons. And they usually had a number of young *Atax* crowded around the exhalent orifice. So far as our experience goes this is a rather unusual position for young *Atax*. Their ordinary situation is along the lips of the inhalent aperture. *Q. pustulosa* also contained many *Atax*, but they were not as numerous as at station 15. Four of the *Q. coccinea* had white nacre and all the *L. rectus* were pink instead of the deep purple of those farther up the river. Parasites were also found occasionally in *L. ventricosus*, *L. ligamentinus*, and *Q. undulata*. A few of the *ventricosus* and *luteolus* were gravid or beginning to become so.

Station F. Bass Lake, Starke County, Ind.—This lake is fourth in size among the Indiana lakes and covers an area of 2¼ square miles. It lies in the southeastern part of the county, about 6 miles south of Knox. It is somewhat boot-shaped, the leg portion elongated northeast and southwest, the foot portion at right angles to this. It occupies a shallow basin on the top of a morainic ridge and more than half of its area is 5 feet or under in depth; the maximum

depth is 32 feet. The greater part of the shore line is low and marshy, and the water is filled with a dense growth of reeds and rushes. The bottom is sand or blue and sticky clay, interspersed with extensive muck beds, the latter giving rise to a luxuriant growth of aquatic vegetation. The sand and clay are also covered with algæ, among which is *Chara*. *Potamogeton* is also common. In fact the lake flora is richly developed at the expense of the fauna. At present the lake has no outlet or natural inlet, but is fed entirely by springs. The old outlet, however, now so filled that water runs through it only occasionally, was to the west, emptying into the Kankakee about 3 miles below station 16. Dwarfed *L. luteolus* were fairly common in the gravelly sand close to the shore, and there was a large bed of them around a point which juts out into the lake from the eastern shore, Cranberry Point. A few *A. grandis* were also found. Both species were infested with *Atax* parasites, but not in large numbers, and in addition *Cotylaspis* and the distomid of Osborn were present in *A. grandis*. This lake had been examined in 1906, and a number of *Anodontas* obtained near the ice houses and *Lampsilis luteolus* on the opposite shore.

Station 17. Kankakee River, Riverside, Ind.—On the way down from English Lake to Riverside small piles of mussel shells that had been left by pearlers were frequently found. Here the mussels have fully reestablished themselves in the dredged portion of the river, and the steep banks just under the water were well lined with *L. luteolus*.

Just above Riverside the dredged ridge along the north bank of the river held back a small pond covered with *Euglena* in a portion of the old channel. This was nearly filled with soft mud and contained but few mussels, though there were plenty of dead shells along the bank. On this stretch of river there was a marked increase in the number of *ligamentinus* and *ventricosus*. All the shells found were large and of excellent quality.

Station 18. Burrow's Camp to Baum's Bridge.—The dredged portion of the river stopped at the last station and we now entered the genuine Kankakee swamps. The sides of the river were low and boggy but heavily wooded for a short distance back from shore. The bottom we found to be firmly packed sand, admirable for wading, and there was a current of 4 miles an hour.

Mussels were plentiful along the shore wherever the bottom could be seen, and we waded often enough to show that they continued into the deeper water. There were occasional piles on the banks, left by fishermen and pearlers, and in one of the shells thus left a small pearl was found. But only one of the live *luteolus* yielded pearls, a much smaller percentage than further up the river.

Every specimen of *pustulosa* was infested with *Atax* parasites and most of them contained dorsal baroques. The *ventricosus* specimens contained both *Atax* and *Cotylaspis*; two of them were gravid and one had two dorsal baroques. The single *A. grandis* was the first one found in the Kankakee River.

Station 19. Baum's Bridge.—Just below the bridge is a clubhouse belonging to the Crawfordsville Club. We stopped over night with Mr. George Wilcox, the keeper of the clubhouse, who, besides entertaining us hospitably, gave us much valuable information in regard to the river. He told us of a mussel fisherman who had gone down the river two years before and who had obtained several hundred shells from a bed in front of the clubhouse. We had also been informed that button manufacturers had sent out circulars along the river offering $20 per ton for good shells, and that people along the river who had sent in samples had been offered from $5 to $8 and $12. We tried our dredge in the same place, a sort of eddy in the current. The water was 8 to 10 feet deep and the bottom of hard sand and fine gravel with some lumpy blue clay. The mussels were abundant both in the sand and at the edge of the clay. Most of the specimens were *undulata*, but there were many *luteolus* near the shore and some fine *ligamentinus*, *rectus*, and *coccinea*. Several of the *ligamentinus* were gravid, and most of the *coccinea* had white nacre. Nearly all the *luteolus* contained *Atax* and *Cotylaspis* parasites and 5 out of the 32 had small pearls in the mantle edge.

Station 20. Hebron Bridge, Kankakee River.—The river widens out into a sort of lake about 3 miles above this bridge. The bottom was firm sand and nearly uniform, not more than 4 feet deep at the maximum, with large patches of water lilies and smartweed, and plenty of *Potamogeton fluitans* along the banks.

Mussels were found all over the bottom, but were most plentiful among the roots of the *Potamogeton* along the shore. Nearly all the *L. luteolus* were found there, while the *ventricosus* and *ligamentinus* were in midstream and proved exceptionally large and fine. *Q. undulata* was also common in the deeper water, but there were almost no *Q. pustulosa*. The three specimens of *S. complanata* were the first found in this river.

Most of the *luteolus* and *ventricosus* were either gravid or becoming so, and, together with the *undulata*, were each infested with a few adult *Atax*, and often with eggs and young parasites; and many contained also *Cotylaspis*. The *luteolus* averaged about one pearl apiece in the edge of the mantle, while the *ventricosus* contained dorsal baroques. The other species were free from parasites.

Station 21. Water Valley, Kankakee River.—The collection here was obtained from three different localities: (1) Hog Wallow Slough,

a marshy lagoon on the north bank of the river with water 2 or 3 feet deep and a hard bottom of sand; (2) the south bank of the river, which is in the town of Thayer and where some pearlers had left a pile of about 100 shells all freshly killed; and (3) the middle of the river between the two places, where we used the dredge in water about 6 feet deep, with a hard sandy bottom and very little current.

At the slough the mussels were scattering, but of excellent size and quality. In the pearlers' pile, which were all *luteolus*, we found many pearls of small size in the edges of the mantles. From the deep water of the midriver were obtained *coccinea* (in deep water only), *undulata*, and *pustulosa*. Shells are said to be easily obtained in large numbers here at low water. Many of the *ventricosus* were nearly gravid, and the *luteolus* were all infested with *Atax* and *Cotylaspis* parasites, though the other species were free.

During our stay in Water Valley we stopped with Mr. John Phelps, a fisherman who is thoroughly acquainted with the Kankakee River, and who gave us much valuable information in reference to the mussels as well as the fishes. Through his courtesy we had an opportunity to examine many of the fish caught in the river.

The redeye, *Ambloplites rupestris*, yielded a few specimens of *Ergasilus centrarchidarum* attached to the gill filaments. Another specimen had mussel glochidia on its gills, while a third one was covered with bloody spots over the outside surface of the body, most common near the anal fin. Attached to one of these spots was a *Lernæocera cruciata*, which Mr. Phelps told us were quite abundant on this fish in the early spring. These redeyes, together with the large and small mouthed black bass and the sunfish, all of which are plentiful in this portion of the Kankakee, have proved to be the most satisfactory species for carrying glochidia (Bulletin of the Bureau of Fisheries, vol. XXVIII, p. 624.) Their presence, therefore, insures one of the most important conditions for the success of artificial mussel propagation.

Station G. Cedar Lake, Lake County.—This must have been a favorite name with the early settlers, judging from the fact that there are at least six "Cedar" lakes in the State of Indiana. This particular one is in the center of Lake County and covers 1.17 square miles, being a little over 2 miles in greatest length and about three-quarters of a mile in greatest breadth. It is shaped like a kidney or bean, and owes its origin to irregularities in the deposition of the drift material. It is surrounded on all sides except the south by heavily wooded ridges, which formerly were its shores. It is another case of artificial drainage, like the Lake of the Woods.

In order to reclaim 200 acres of comparatively worthless marsh land at the southern end of the lake, a ditch was cut on its eastern side which lowered the level of the lake 10 or 12 feet. This artificial

ditch is the present source of Cedar Creek, which flows south into the Kankakee River.

The present shores are hard and firm and the bottom is sandy along the north and east sides and muddy along the west and south sides. Both sand and mud are covered in many places with *Chara* and *Potamogeton pusillus*, mixed with some *Vallisneria*, *Philotria*, and *Cladophora*, the latter on the pebbles. Along the shores are reeds and rushes, forming a thick fringe.

The water of the lake was remarkably green, due to the presence of minute suspended algæ, mostly *Clathrocystis*, with some *Lyngbya* and *Anabæna*. A tow taken at the surface near the center of the lake yielded a wineglassful of Entomostraca, chiefly copepods and *Daphnia*, much the richest haul of any taken during the summer.

In front of the Siegler Hotel, on the west shore, is a broad sand bar used for bathing. Here, just outside the bathing rope, in 6 feet of water, was a thick bed of mussels, nearly all *A. grandis*, with a few dwarfed *L. luteolus*.

Mr. Siegler kindly furnished us with a boat and a long-handled rake with which to secure our specimens.

We were told at the hotel that formerly the people about the lake were accustomed to cook and eat the *Anodontas* with much relish, but had gotten out of the habit in late years. An examination of the eastern shore showed that the *A. grandis* was very plentiful there, but *L. luteolus* was scarce.

A seine haul just south of Cedar Point gave us the largest number of small fishes obtained during the season, mostly *Labidesthes sicculus* and *Boleosoma nigrum*. Evidently the abundance of Entomostraca produced its legitimate effect.

On examining the mussels, all the female *luteolus* were found to be gravid and infested with a small red *Atax*. Only one or two of the *grandis* were gravid, but they were all badly parasitized, containing from 5 or 6 to 30 *Atax*, chiefly *A. ypsilophorus*, and a few *Cotylaspis*. No pearls were found in any of our specimens, though we were told many had been obtained from the *Anodontas*.

Station 22. Burtons Landing, Kankakee River.—This station was on the south bank of the river just above where the dredged ditch empties in.

The bank was very steep, giving 4 or 5 feet of water close to the shore: the bottom was mixed sand and mud; the current was slow and there was no vegetation present. The mussels proved to be abundant, both along the shore and in the deeper water of the midriver. *Q. undulata* being the most common species. It was noticeable that there were no mussels in the sand brought down by the ditch. A broad delta had been formed, reaching far out into the river, but the mussels carefully shunned its shifting sands. Furthermore, all

those on the down-river side, which had been caught by these same sands, were dead, another striking testimony of the effect of a shifting bottom on the mussel fauna.

All the *luteolus* and *pustulosa* were infested with *Atax*, one *pustulosa* yielding 61 of the adult parasites. The *luteolus* also contained a few *Cotylaspis;* the other species were free.

The two *A. gracilis* and the single *S. complanata* are worthy of note in view of the rarity of the species in the river.

This is the last station in the swamp region of the Kankakee, and it may be well to give a brief summary of the conditions prevalent there.

This length of the undredged portion of the river from English Lake to the State line is variously estimated by different authorities. A conservative estimate would make it at least 100 miles, and it is practically one continuous mussel bed for the entire distance. There are places where the mussels are thicker than elsewhere, but there is hardly a spot where search will not reveal at least some species.

We have here again an ideal breeding ground for mussels, similar to the Yellow River from Plymouth to Ober, but at least five times as large. The natural conditions are even better here than they were in the Yellow River; there is the same kind of a bottom, lime and food enough in the water, a good current the whole distance, and plenty of small fish to distribute the glochidia.

Then there is in addition the great swamp reservoir to regulate the supply of water, the organic material derived from the swamp vegetation to serve as food, and the enforced seclusion of the region to obviate any disturbing influences. There are several valuable species of mussels, like *rectus*, *pustulosa*, and *coccinea*, which were not common in the Yellow River, but which would add greatly to the value of the mussel product; and finally we find the mussels here infested with the same pearl and baroque producing parasites.

Instead, therefore, of expending large sums of money in an artificial drainage system, thereby entirely destroying the natural resources of the region, making it of no possible use as a game or fishing resort, and annihilating its rich mussel fauna, all for the sake of reclaiming a few hundred acres of land that have not proved to be worth much, it would seem to be far more profitable to cultivate the resources already in existence.

Nature has herself clearly indicated the kind of products suited to the region. Now that man has learned how to handle one of the most valuable of those products, mussel shells, it would require very little effort or expense to convert the native mussel fauna into a rich source of revenue. The *L. rectus*, which has white nacre, called the "white sand shell" by the mussel fishermen, could be easily introduced, and would produce shells that bring large sums of money in the market. The hunting and fishing would not be injured, but rather benefited by the increase of the mussels.

Here is an ideal chance for the breeding of mussels on a large scale; it only needs to be once started to prove its value. Furthermore, the mussels are infested with the same kinds of parasites as those of the Yellow River, while pearls and baroques are even more plentiful. Consequently, the prospects of a reasonable bonus from this source are exceptionally good.

Station 23. Kankakee River between the State line and Momence, Ill.—Just across the State line occurs the first limestone outcrop in the bed of the river. This is the ledge which has acted as a natural dam and prevented the wearing down of the river bed. Were it not for this ledge the river would have long since drained the immense swamp region. But just as it is responsible for the character of the channel above it in Indiana, so it marks the beginning of a very different kind of channel below it in Illinois. In the 50 miles of river from the State line to the head of the Illinois, the Kankakee falls 130 feet, or nearly 3 feet per mile. From a deep and smoothly moving river, without a break between its source and the State line, it is suddenly converted, on passing this ledge, into a succession of broad and shallow rapids difficult to navigate. The old bed of sand and fine gravel ceases and in its place we find shelving rocks, coarse gravel, and bowlders.

Such radical changes in the surrounding conditions would suggest that the mussel fauna must change also, and such we find to be the case. Several additional species appear all at once and are common down to the mouth of the river. We no longer find a continuous bed of mussels, but they are scattered wherever they can find a foothold. For long distances the solid rocky bottom prohibits them from remaining; then come favorable localities where they are packed as closely together as they can lie. In general, the conditions are not as favorable in Illinois as in Indiana; it is certainly very much more difficult to gather the mussels. Our first collection within the State, however, was made rather easy by the fact that pearlers had been at work along the river and had left small piles of shells scattered here and there on the banks. We selected from these and supplemented them with living specimens of other species. Near the State line some *undulata* were found with a yellowish epidermis instead of black.

Station 24. Momence, Ill.—Just above the town was the camp of three mussel fishermen who had been collecting shells from the immediate vicinity for the market. They had secured about 15 tons, the only culls from which were a few *U. gibbosus*. They told us the shells from this locality were not as tough as those in the Wabash

River, and hence did not bring quite as much per ton. They showed us a good collection of pearls and baroques obtained from their mussels, and just as we landed they picked a large spherical pearl the size of a pea out of the mantle of an *L. ligamentinus*. We looked over their pile of shells and took samples of the different species; the great bulk of the pile was *ligamentinus* and *ventricosus*.

We secured the following species which had not been found in the river above: *L. ellipsiformis*, common; *Q. tuberculata*, several; *Q. metanevra*, rather common; *A. truncata*, frequent; *S. edentulus*, two; *S. costata*, common and large; *O. ellipsis*, two. Some of the *L. rectus* had white nacre, but most were pink; the *U. gibbosus* showed purple, pink, and white nacre, with considerable difference in shape and size of shells.

Station 25. Waldron, Ill.—The river was shallow and rocky and very difficult to navigate below Momence, but the water was fairly clear, so the shells could be seen on the bottom. There was considerable *Potamogeton lonchites* and water willow along the water's edge. Beds of mussels could be seen in various places, especially near the riffles; but as the mussel fishermen at Momence had worked this part of the river thoroughly, no stop was made until we were close to Waldron. Here was found a pile of freshly cleaned shells, about one-quarter of a ton, which had been left by pearlers. Samples of the different species were selected and kept; the pile was nearly all *L. ligamentinus*, with some *L. ventricosus* and *U. gibbosus;* the other species listed occurred in small numbers. One of the *L. rectus* had white nacre, the first white-nacred one seen; the rest were pink. Both the *ligamentinus* and the *ventricosus* had been gravid in considerable numbers when captured.

At Waldron an 8-foot dam prevents all intercourse with the river farther down.

Station 26. Watseka, Iroquois River.—This river is the chief tributary of the Kankakee in Illinois as was the Yellow River in Indiana. Like the main river, the character of this tributary changes radically at Watseka. Nearly half the river basin, 800 square miles, lies in Indiana, and is of the same type as the Kankakee Basin in that State, marshy and sandy.

Just before reaching Watseka, Ill., it crosses the so-called Iroquois moraine and afterwards traverses an old lake bed. There is much more fall in the river, but it is never as rapid as the Kankakee. The great amount of dry prairie land it drains makes it a "flashy" river, subject to rapid rise and fall, and hence the upper portions of it are not very rich in mussels. Furthermore, in the vicinity of Watseka the banks of the main river and of Sugar Creek, a large tributary from the south, are so steep and slimy with clay that it was practically impossible to do any wading. The collection of shells from this station, therefore, includes simply what could be picked up along the shore.

About a dozen years ago a Mr. Hill started a woolen factory in Watseka for the manufacture of woolen goods, and, as an adjunct to employ the surplus water power and to furnish the buttons for the goods he turned out, operated a button factory. The farmers along the Iroquois River and Sugar Creek kept him supplied with shells, which they gathered and carried to the factory. A flourishing business was done for six or eight years until hard times came and caused the shutting down of both factories. Enough was accomplished to prove that these two streams contain a plentiful supply of shells—enough to run such a factory for a long time.

Station 27. L'Erable, Iroquois River.—This is about 10 miles below Watseka, but the river widens in that distance from about 40 feet to fully 175 or 200. It was about 3 feet deep at the center, with a bottom of fine gravel along the channel bordered on each side by sand, while the banks were soft clay mud. The current was almost imperceptible and the water very muddy. The mussel fauna was rich and varied, as the list given amply proves, and the species were fairly well sorted according to the kind of bottom.

In the soft mud were found *luteolus* and the first *fallaciosus* we had seen, with an occasional *ventricosus*. In the sand were a few *lachrymosa*, also the first found in the Kankakee Basin, *pustulosa*, *undulata*, *complanata*, *costata*, and *rubiginosa*. In the gravel was the great majority of the *lachrymosa* and *undulata*, with an occasional *ventricosus* and *complanata*. *Q. lachrymosa* was more abundant than all the other species taken together, and in many places were so thick one could hardly get a foothold without standing on them. The shells were exceptionally large and of fine luster and quality.

On examining the mussels for parasites, nearly all the *complanata*, *luteolus*, *pustulosa*, *trigona*, and *lachrymosa* were found to be infested with *Atax*, the distomid of Kelly, and marginal cysts. A few of the shells contained pearls and dorsal baroques, but in much smaller numbers than were found in the mussels of the Kankakee River. A small number of each of the species just named were gravid, the others were free from parasites, and in none of them had the eggs passed down into the gills. While most of the *rubiginosa* had the characteristic reddish orange meat, a few were found almost white.

The Iroquois is a river of *Quadrulas*, with comparatively few *Lampsilis*, in marked contrast to the Yellow and Kankakee Rivers, which are nearly all *Lampsilis*, with comparatively few *Quadrulas*.

Station 28. Iroquois River 3 miles above its junction with the Kankakee.—The change in the bed of the river already noted was

even more apparent here; the river was shallow and full of riffles and the bottom was almost continuous rocks, with little sand or mud between them. But the shores still showed the obnoxious black clay mud.

Fortunately, the muskrats had been busily at work eating the smaller mussels with some of the large ones, and had collected large piles in many places. The mud on shore was nearly a solid network of muskrat tracks, with here and there the long groove where they had dragged a shell too large to lift and carry. They evidently had no trouble in finding plenty of mussels, although we could not locate the live ones among the rocks. The 15 species listed were all obtained from the muskrat piles, and, as will be seen, include *Q. metanevra*, which evidently prefers localities with a very rocky bottom.

Station 29. Mouth of the Iroquois River.—Where the Iroquois joins the Kankakee, there are two or three small islands, raised but little above the level of the water, but giving support to a mass of dense underbrush.

Here again the muskrats had nearly covered the mud around the roots of the bushes with nicely cleaned mussel shells of many species—probably all that can be found in the vicinity. Two *Q. lachrymosa* were found alive at the water's edge; all the others collected were the shells from the muskrat piles.

Station 30. Kankakee, Ill.—Several pearlers had been at work on this portion of the river and about 1 mile above the city of Kankakee were two large piles of shells close to the water's edge on the south bank. The first pearler, and evidently the more experienced one, had collected only *L. luteolus*, but his pile of shells did not show proof of having yielded many pearls. The other party had collected all species indiscriminately, and 14 different kinds were found in the pile. None of these shells gave evidence of having been much parasitized and probably did not yield very large returns. They gave us a fine collection from the locality, however, without the trouble of wading and hunting for them.

The selection of *luteolus* as a pearl producer is worthy of notice, since it coincides exactly with our own experience in the whole Kankakee Basin. The pearl problem is quite possibly different in each river. In some rivers *Q. undulata* or *plicata* are regarded as the pearl-bearing shells; in others, *L. ligamentinus*, and so on. In the Kankakee *L. luteolus* was the most prolific, and indeed the only species that one could count on to yield them, but the pearls were all, though perfectly spherical and of good luster, of very small size, called by the pearlers "mustard-seed pearls."

Station 31. Custer Park, Ill.—Just below the city of Kankakee there are five large dams across the river within a few miles, while at Aroma and Wilmington there are rapids with a sudden descent of 20 feet in the river. These make this part of the river unnavigable. Accordingly, the boat and outfit were shipped from Kankakee, and the remaining portion of the river was worked from the railroad.

From Wilmington, the nearest station, we drove to the house of Mr. Jesse Fairchild, on the north bank of the river. He kindly lent us his boat and told us where to find a mussel bed, which he said was the only one for some distance up and down the river.

It lay along the edge of a riffle where the water was about 2 feet deep and the current 5 or 6 miles an hour. The bottom was entirely covered with stones of all sizes and shapes, mostly well rounded, and thrown together with small pockets between them. These pockets were filled with sand or fine gravel, and in them the mussels were found. The stones, the gravel or sand, and the mussels were all covered with a dense coating of dark green algæ.

All the mussel specimens obtained were small, for large ones can not crowd in among the rocks, and many of the females were gravid. *L. ligamentinus* was the most common species, and every specimen showed clearly the radiating rays on the external surface.

Marginal cysts were found in some of the *S. edentulus* and *L. ligamentinus*, and a few *Atax* in one *L. ventricosus*, but as a whole this lot of mussels was remarkably free from parasites. The number of species at this station was only equalled by those which were obtained from the 15 tons collected at Momence by the mussel fishermen.

Station 32. Wilmington, Ill.—This station was just below the road bridge across the Kankakee River, between the second and third dams. The river here has a rocky bottom and is practically one continuous riffle with a very swift current. There was a large outcrop of limestone on the shore and more appeared in the bed of the river.

The collecting was very difficult, but the few live mussels found were supplemented by a large pile of freshly cleaned shells on the shore, probably left by a pearler. All the shells were large and well developed, particularly the *L. ligamentinus* and *S. costata*. The *L. ventricosus* and *rectus* had an exceptionally good luster and were of excellent quality; the other species were about average.

Station 33. Forked Creek, Wilmington, Ill.—This is a rather small creek that runs into the Kankakee from the north, and is made up of alternating pools and riffles. In the riffles the bottom is rocky, with many gravel and sand bars; in the pools there is more or less mud. The main vegetation is water willows, with occasional yellow water lilies and *Philotria*, and everywhere an abundance of tough algæ. Most of the shells were dead and seemed to have been killed by muskrats. The live specimens of *A. calceola*, *S. edentulus*, and *L. ellipsiformis* were all gravid. The *L. ventricosus* and *ligamentinus* and the *Q. undulata* were all small in size, but otherwise normal.

Station 34. Mazon Creek, Ga dore, Ill.—This is another tributary of the Kankakee from the north and in its general features closely resembles Forked Creek. It consists mainly of rather shallow pools connected by slender threads of water, with numerous sand and gravel bars. The bottom is practically all pebbles and sand, with almost no mud. Water willows are thickly distributed, with large patches of spatterdock, but there were not many algæ.

The mussels were found mostly along the edges of the sand bars and were usually small in size. Many of them were actively crawling about and lay at the ends of long furrows. Pearlers had been at work here also, and many recently killed shells were seen along the banks, mostly *Q. undulata*, with some *L. luteolus*. The muskrats were evidently abundant and had left many dead shells scattered along the water's edge, chiefly the small *L. ellipsiformis* and young specimens of *Q. undulata*, *S. complanata*, and *S. edentulus*.

The *L. ellipsiformis* was particularly abundant and an excellent lot was obtained. The young *S. edentulus* and *S. complanata* were all bright-rayed. One *edentulus* and most of the *ellipsiformis* were gravid, and in the former was a single large *Atax ingens*, the only parasite found. The dead shells of *luteolus*, however, looked as if they had been well parasitized and had contained many pearls. One pearl about the size of a small buckshot was obtained from a living specimen, which contained many marginal cysts. This pearl was perfectly spherical, and though fresh, was of rather poor luster.

Station 35. Mouth of the Kankakee River.—The Des Plaines River, which joins the Kankakee to form the Illinois River, is simply an immense sewer bringing down the Chicago drainage. Both rivers, but especially the Des Plaines, are full of the characteristic algæ and other vegetation which grow in such waters, and the combination of a copious vegetation with the sewage has effectually killed off all the mussels in the vicinity. Not a single living specimen could be found in either river, but there were hundreds of dead shells along the banks, most of them old and well bleached, but still capable of identification. The species listed from this station are all such dead shells.

Since this finishes the examination of the Kankakee Basin, it will be well to sum up the general results of the work in the form of brief statements:

SUMMARY OF MUSSEL DISTRIBUTION.

1. The Kankakee River and its two principal tributaries, the Yellow and Iroquois Rivers, present a very rich and varied mussel fauna throughout their entire lengths, except in those portions which have been artificially dredged.

2. The 32 mussel species obtained in the Kankakee Basin produce shells of exceptional size, luster, and quality, and many of them are of high commercial value. (See table, p. 39.)

3. The basin is divided at the State line into two regions, radically different in the conditions which they present, and harboring consequently different mussel faunas. These regions may be designated as the Indiana and Illinois portions of the basin.

4. The Indiana part of the basin is a region of swamps, smooth sandy bottoms, a uniform current, and abundant vegetation. It is the home of *Lampsilis* and *Anodonta*, with relatively few *Quadrula* species. It contains seven species not found in the Illinois part of the basin, viz, *S. compressa*, *A. f. subcylindraceus*, *A. imbecillis*, *L. glans*, *L. iris*, *L. subrostratus*, and *L. parvus*.

5. The Illinois part of the basin is a region of rolling prairie land, rough rocky bottoms, alternating riffles and dead water, with almost no vegetation. It abounds in *Quadrula*, *U. gibbosus*, and *Symphynota*, with comparatively few species of *Lampsilis*. It contains eight species not found in the Indiana part of the basin, viz, *Q. trigona*, *Q. lachrymosa*, *Q. metanevra*, *P. æsopa*, *S. complanata*, *O. ellipsis*, *L. ellipsiformis*, and *L. fallaciosus*.

6. There are seven species universally distributed throughout both regions, viz, *Q. coccinea*, *Q. undulata*, *U. gibbosus*, *A. grandis*, *L. ligamentinus*, *L. luteolus*, and *L. ventricosus*. Five of these possess shells which are in constant demand for the manufacture of buttons, and the table of values given on page 39 shows that they are of exceptionally good quality.

7. Most of the species are richly infested wherever they occur with an interesting variety of parasites, and some of these furnish the requisite incentive for the production of pearls and baroques. Both these products are common throughout the entire basin and would undoubtedly become a valuable revenue if the mussels were properly cultivated. Pearling might not pay here now, as the pearls are quite small. It is, however, the best place the authors have ever seen from which to attack the pearl problem.

8. The most valuable species are all good breeders throughout the basin. This, taken in connection with the excellent quality of the shells they produce and the good railroad facilities everywhere available, makes this basin one of the best yet examined for the supply of glochidia to be used in artificial mussel propagation.

9. The fishes which have proved to be the most satisfactory hosts of glochidia are abundant in all three of the principal rivers of this basin. Their presence insures one of the most essential conditions necessary for the success of mussel culture.

10. The undredged portions of the Yellow River, a distance of 20 miles from Plymouth to Ober, and of the Kankakee, a distance

of at least 100 miles from Riverside to the State line, furnish an ideal breeding ground for the artificial propagation of mussels on a large scale. The swamp reservoirs keep the supply of water uniform, there is just the requisite amount of current, a suitable variety of hard bottom, plenty of lime and natural food in the water, and the region is well protected by its environment from outside molestation and disturbance. For this, as well as many other reasons, it well deserves to be protected from future dredging syndicates.

11. Dredging entirely annihilates the mussel fauna of such a basin throughout the portions operated upon, no matter how prolific and varied that fauna may have been previously. And it establishes artificial conditions, every one of which is antagonistic to any re-establishing of the fauna. The most fatal condition is the constant movement of the fine sand and silt along the bottom of the dredged channels. Until that has ceased there can be no chance for mussels to live.

Portions of the basin which were dredged 15 or 20 years ago show no signs of restocking with mussels, though there are thousands of them close at hand in the old channels.

12. The mussel fauna of the lakes is almost entirely composed of *Anodonta* and *L. luteolus*. With the exception of those found in the Fish Lakes all the lacustrine mussels were practically worthless from a commercial standpoint. The shells were either too thin and brittle or they were dwarfed below a workable size. The excellent quality of those found in the Fish Lakes, however, suggests strongly that under favorable conditions lake mussels may become as valuable as those from a river. The presence in the lake of such a flourishing colony of *Q. undulata* shows that some, at least, of the thick-shelled species can thrive in a lake, a fact experimentally proved for other species by the authors. Why not stock some of the lakes, then, along with the rivers, selecting those species best suited for such conditions?

Station II. Tippecanoe Lake, Kosciusko County, Ind.—This lake does not properly belong to the Kankakee Basin, but drains into the Tippecanoe River and thence into the Wabash. For this reason it has been placed here at the end of the list after the finishing of the Kankakee Basin. The lake lies a little north of the center of the eastern boundary of the county and covers 1.6 square miles, being the fifth largest lake in the State. It is divided into three basins—the eastern, known as James Lake; the central; and the western, called Oswego Lake. Tippecanoe River enters the eastern end of James Basin and flows through the entire length of the lake, maintaining a good current throughout the year. Grassy Creek, the outlet of a chain of four small lakes (Maybe, Sawmill, and the two Barbees) to the south, enters the middle basin near its southwest corner.

The two upper basins are remarkably free from aquatic vegetation, while Oswego basin is packed with *Potamogeton*, *Utricularia*, *Philotria*, and many species of rushes, spatter-dock, water arum, pickerel weed, cat-tails, etc.

The entire lake is surrounded by high and steep banks except in one or two places, and promontories run out into it from both sides. At the southernmost of these promontories on the east side the lake has the remarkable depth of 178 feet, making it probably the deepest fresh-water lake of its size in America. And this is true of the whole lake, the only shallow-water areas of any size being the delta brought in by the Tippecanoe River and a small area along the north side of the east shore. Furthermore, the lake is to-day more nearly in its natural state than any of the others examined. It was a genuine relief to find such a body of water unaffected by damming or draining.

Owing to its great depth, the water is always cool, even in the hottest weather, and is very clear and free from vegetable débris. The bottom is hard and marly in most places except the Oswego Basin, where it is soft black muck. The entire margin of the lake and Tippecanoe River for a mile and a half below the outlet were examined, and mussels were everywhere abundant. At Government Point, over the shallow-water area on the eastern margin already mentioned, they were especially plentiful. Here the marly bottom was softer and the mussels had dug circular cavities 2 or 3 inches deep into the marl. In the bottom of the excavation were sometimes one mussel, sometimes a whole nest of them of varying sizes. *Anodonta*, *Strophitus*, and *Lampsilis* were thus found.

This and other portions of the eastern shore were the only places where *L. glans* and *M. fabale* were found during the entire summer, with one exception for each species.

In the Tippecanoe River the sand and gravel of the swifter current and the marl of the quieter water were found thickly covered everywhere with living mussels and dead shells. *Q. undulata* was the most common species and most of the specimens were exceptionally large and plump. In several of them there was a decided breaking up of the ridges on the outside surface into pustules similar to those on *pustulosa*, making a sort of nondescript shell that was difficult to classify at first.

As would be expected, there were a few species in this fauna not found in the Kankakee Basin. These include *Micromya fabale*, *L. multiradiatus*, *T. sulcata*, and *P. phaseolus*.

The *Quadrulæ* have been searched strenuously for pearls and several good ones are reported to have been found, but none of the other species contain either pearls or baroques.

DISTRIBUTION OF MUSSEL SPECIES.

Stations.

Mussel species.	1	2	3	4	A	5	6	B	7	8	9	10	11	C	12	13	D	14	15	E	16	F	17	18	19	20	21	G	22	23	24	25	26	27	28	29	30	31	32	33	34	35	H
Quadrula tuberculata (purple warty-back)																															X				X		X	X	X			X	
Quadrula coccinea	X		X	X			X		X	X	X	X	X		X			X	X		X			X	X	X	X		X		X	X			X				X				X
Quadrula trigona (pig-toe)																																		X	X				X				
Quadrula rubiginosa							X		X	X		X	X						X	X			X	X	X				X	X	X	X	X		X		X	X	X	X			X
Quadrula pustulosa (warty-back)							X		X			X	X					X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X				
Quadrula lachrymosa (maple-leaf)																																X	X	X	X	X	X	X					
Quadrula metanevra (monkey-face)																															X	X			X		X	X				X	
Quadrula undulata (three ridge)	X		X	X		X	X					X	X				X	X	X		X		X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X		X
Quadrula ebena (niggerhead)																																											X
Pleurobema aesopus (bullhead)																											X				X												
Pleurobema clava																																											X
Unio gibbosus (lady-finger, spike)	X		X	X			X		X	X		X			X		X	X	X		X		X	X	X	X	X		X		X	X	X	X	X	X	X		X	X			X
Alasmidonta truncata (elk-toe)									X	X		X																			X	X			X			X	X	X			
Alasmidonta calceola									X		X	X			X																												X
Symphynota complanata (heel-splitter, hatchet-back)																										X			X		X	X		X	X		X				X		
Symphynota costata (squaw-foot)							X		X	X		X	X					X			X				X				X		X	X		X	X			X	X	X			
Symphynota compressa							X					X			X	X		X																									
[illegible]					X		X					X			X																												
[illegible]	X	X	X	X	X	X	X	X	X			X	X	X	X		X			X		X		X				X	X	X													
[illegible]						X	X					X	X	X			X		X																								
[illegible]	X		X	X			X		X	X		X	X		X			X													X								X	X			
Obovaria ellipsis (Missouri niggerhead)																															X												
[illegible] (pancake)																																						X					
[illegible]																	X																										X
Lampsilis ellipsiformis																															X								X	X	X		
Lampsilis iris							X		X	X		X					X	X																				X					X
Lampsilis subrostratus														X			X																										
Lampsilis rectus (black sand-shell)								X				X					X	X		X		X	X	X	X			X		X	X			X	X	X	X	X					
Lampsilis fallaciosus (slough sand-shell)																																		X									
Lampsilis ligamentinus (mucket)	X		X	X					X		X	X	X					X	X		X		X	X	X				X	X	X	X	X	X	X	X	X	X	X	X		X	X
Lampsilis luteolus (fat mucket)	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lampsilis ventricosus (pocketbook)	X		X	X			X		X	X	X	X	X		X			X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X			X
Lampsilis multiradiatus																																											X
Micromya fabalis																																											X
Truncilla sulcata																																											
Ptychobranchus phaseolus																																											

COMMERCIAL VALUE OF THE SHELLS OBTAINED.

The relative values of the mussel shells from the Kankakee Basin were determined by Mr. J. F. Boepple, lately deceased, a mussel expert of wide experience and high authority, then stationed at Fairport, Iowa.

Average lots of the different species were weighed, blanks of various diameters were stamped upon the inside of the shells and counted, the number of similar blanks which could be obtained from a ton of shells was computed, and from these data, together with the quality of the pearl, the value per ton was calculated. In many instances the results of these computations were verified by sending the stamped shells to a button factory, where the blanks were actually sawed out, and their value given.

These values are expressed in the following table, each value quoted being an average from several lots of the same species. The diameter of the blanks is measured in "lines" ($=\frac{1}{40}$ of an inch), 16, 18, etc. "F." and "M." denote first and medium quality. "T." indicates that more than half of the blanks are "tips," that is, uneven in thickness and of poor quality; "t." indicates that considerably less than half are tips. The numerals "1," "2," and "3" indicate different grades of shells, including size, color, luster, etc. Thus, reading the second line, 1 ton of second quality *L. ligamentinus* shells would yield 1,119 gross of 20-line blanks, more than half of which would be "tips." The value of blanks and tips together would be $33.57.

TABLE OF SHELL VALUES.

Locality and species.	Gross of blanks per ton of shells. 16 line.	18 line.	20 line.	24 line.	30 line.	35 line.	40 line.	Value per ton.
YELLOW RIVER.								
L. ligamentinus, 1			F. 1.009			F. 173		$60.54
L. ligamentinus, 2			T. 1.119					33.57
L. ventricosus, 1			M. 833					50.94
L. ventricosus, 2				M. 588				23.52
L. luteolus			t. 607			M. 78		12.14
Q. undulata			T. 573					15.09
KANKAKEE IN INDIANA.								
L. ligamentinus, 1			M. 673			F. 104		38.91
L. ligamentinus, 2			t. 1.285					52.15
L. ventricosus, 1			F. 578		F. 347			64.76
L. ventricosus, 2			t. 1.166					29.15
Q. pustulosa, 1		M. 1,297						38.91
Q. pustulosa, 2			t. 803					32.36
Q. pustulosa, 3		t. 1.011						30.33
Q. coccinea, 1		t. 1.255						27.65
Q. coccinea, 2			t. 833					[illegible]
Q. coccinea, 3		T. 1,404						28.08
IROQUOIS RIVER.								
Q. rubiginosa		t. 1,198				F. 32	F. 31	[illegible]
Q. lachrymosa	t. 1,098							[illegible]
KANKAKEE IN ILLINOIS.								
L. ligamentinus, 1			T. 771			F. 111		[illegible]
L. ligamentinus, 2	T. 1,219	F. 406	T. 1,130					[illegible]
L. ventricosus, 1			T. 711		F. 278			[illegible]
L. ventricosus, 2								[illegible]
L. luteolus	T. 1,294							[illegible]
Q. pustulosa		t. 1,142			F. 119			[illegible]
Q. undulata								

SMALL FISHES FOUND ON THE MUSSEL BEDS.

KEY TO TABLE.—I, the unchecked portion of the Yellow River from Plymouth to Ober; II, the unchecked portion of the Kankakee River from Riverside to the State line; III, the Iroquois River; IV, the Kankakee River in Illinois; V, the lakes.

Species.	I.	II.	III.	IV.	V.
Catostomus commersonii	×	×		×	
Catostomus nigricans		×			×
Schilbeodes gyrinus	×	×			
Cottus ictalops	×				
Lucius lucius	×	×		×	
Lucius reticulatus	×	×			
Pimephales notatus		×	×	×	×
Semotilus atromaculatus	×	×	×		×
Abramis chrysoleucas	×		×		
Cliola vigilax			×		
Fundulus diaphanus					×
Perrina caprodes		×		×	
Notropis blennius	×	×	×	×	
Notropis whipplii	×	×	×	×	×
Notropis cornutus		×	×	×	×
Notropis umbratilis stripes			×		
Notropis heterodon	×	×			×
Etheostoma iowæ			×		
Phenacobius mirabilis			×		
Hybopsis amblops			×		
Hybopsis kentuckiensis		×		×	
Labidesthes sicculus	×	×	×	×	×
Pomoxis annularis			×		
Perca flavescens	×				×
Micropterus punctulata	×				
Micropterus dolomieu		×	×	×	
Micropterus salmoides	×	×	×		×
Chænobryttus gulosus	×				×
Ambloplites rupestris	×	×		×	×
Lepomis pallidus		×			×
Pogonomus gibbosus		×			×
Hadropterus phoxocephalus			×	×	
Hadropterus aspro	×	×	×	×	
Boleosoma nigrum	×	×	×	×	×
Etheostoma cæruleum			×	×	
Etheostoma iowæ	×				×
Maxostoma aureolum		×			

DISCUSSION OF MUSSEL SPECIES.

1. *Quadrula tuberculata* (*Rafinesque*). *Purple warty-back.*—This mussel, although it attains considerable size and weight, rivaling or exceeding the common warty-back (*Q. pustulosa*) in this respect, is of no value whatever to the button industry on account of the dull purple nacre. It nowhere forms large beds and wherever found usually constitutes a small per cent of the mussel fauna.

Of all the heavy-shelled species examined anywhere, however, this is the most liable to infection by distomids, perhaps on account of its immense inhalent aperture, which allows a larger and greater variety of objects to enter than is the case of other strong-shelled mussels. This makes it among the greatest producers of dorsal baroques and, generally speaking, it is the species most likely to produce genuine pearls. The baroques may be either purple or pale, almost white, and generally are rather lusterless and of low value. The pearls are always purple, sometimes almost black, and, when formed near the iridescent tip of the mussel, may have a very good luster. The clammer cleans all shells he obtains, whether valuable for buttons or not, in the hope of finding pearls.

Viewed in this light, *Q. tuberculata* is not altogether unimportant as a commercial species. Its shell is the package that may contain a prize—usually a worthless trinket, but always arousing expectancy. *Q. tuberculata* adds more markedly than any other species to the size, but hardly to the value, of the clammer's pile of slugs or "chicken feed" which furnishes, in some cases a small, in others a considerable addition to the revenue derived from the sale of his shells, and it is indeed one of the strongest incentives to persistence in the clammer's trade, as it furnishes not so much in actual cash as the element of luck or chance, and keeps him in constant expectancy of a possible great discovery.

Accordingly, it is not improbable that clamming operations the country over depend in no inconsiderable degree on the presence of this and similar species, not directly useful of themselves, but appealing to the instincts of the treasure seeker, the nomad, and adventurer, who can not endure the monotony of a steady, uneventful trade and who require some special incentive or stimulus to persistency.

This species is of value as furnishing in almost any part of the country readily available material for the study of the natural causes and phenomena of pearl production and will probably prove in the end one of the gateways through which our knowledge in that direction, and its practical applications, will come.

We did not find this species in the headwaters of the Kankakee or Yellow Rivers, though it is common in the Tippecanoe, not far distant. The first found in the Kankakee was at Momence, Ill., and in the lower stretches of the river. It was also found in the Iroquois.

The systematic position of this species is doubtful. We have never found it gravid, and it is, apparently, but rarely found in that condition. It is reported to bear glochidia in only the outer gills. When ground and polished for ornament, this is one of the most attractive of shells.

2. *Quadrula ebena* (*Lea*). *Niggerhead.*—This, the most valuable of button shells, does not occur within the Kankakee Basin, though it is fairly common in parts of the Illinois River, below. We found one specimen of what appeared to be this shell at Tippecanoe Lake, where its occurrence is difficult to account for.

3. *Quadrula coccinea* (*Conrad*).—*Q. coccinea* is, at its best, a very good, if not excellent, button shell. The assemblage of forms that pass under this name exhibit so much variation, however, that no general statement can be made concerning it. It has no trade name, probably because it has not been found in great quantities in regions exploited by the button industry and partly because of its lack of distinctive characters. But it is found throughout the length of the Kankakee and Yellow River systems wherever shells thrive at all, being represented by specimens in 22 of the 35 river stations

investigated. It occurs occasionally in lakes, but is essentially a river shell. A few were found in Tippecanoe Lake.

In the upper parts of the Yellow River, from Plymouth down to Ober, and in places in the upper Kankakee this species reaches great perfection and is represented by a well-defined type not easily confused with any other species—a large flat shell of pretty uniform thickness and very good luster. The majority of the shells of the upper part of the river are of a delicate pink color, very pleasing to the ordinary eye, but not to the maker of buttons. Farther down stream the majority are white-nacred and serviceable in the commercial sense. We were unable to obtain any gravid specimens of this flat, highly characteristic form. *Q. coccinea* was fairly common in the clammer's pile at Momence.

In some of the lower parts of the Kankakee system, and especially in the Iroquois River, what appears to be this species loses its distinctive character and is represented by a much more inflated form, closely approaching *Quadrula solida* or some other member of the perplexing *obliqua-trigona-plena-solida* group. A gravid specimen of this inflated form was obtained in the Iroquois River. Only the outer gills contained the glochidia. These filled the entire gill, which was padlike and white in color. According to Simpson's classification this would place it in the genus *Pleurobema;* but more examples are desired and the whole subject requires investigation. Dr. A. E. Ortmann is of the opinion that *Q. coccinea* is identical with *Q. obliqua*, which usually bears its glochidia in only two gills and which he considers a *Pleurobema*. All the examples of *Q. coccinea* we have ever seen, however, even the inflated ones, have lacked the peculiar sulcus that is to be found in *Q. obliqua*.

4. Quadrula trigona (*Lea*). *Pig-toe.*—This species is one of the staple button shells. Its size is usually rather small, and a furrow on the valve makes it difficult to cut to advantage, but its excellent luster and whiteness compensate to some extent for its deficiencies and it is excellent for small buttons. Its occurrence in the Kankakee area is exceptional; one was found in the Iroquois at L'Erable and one in that stream 3 miles above its mouth. Another was found in the Kankakee at Wilmington. These are not exactly typical shells. It is somewhat surprising that it is not more common, as it could easily come up from the Illinois River.

In the upper Mississippi, where the species is abundant, it is very constant in form, and well marked from any other species, but outside of this range it is quite variable in form. It is very frequently infested by a distomid which forms cysts in the mantle, and it occasionally produces beautiful pearls.

5. Quadrula rubiginosa (*Lea*).—This shell is quite similar to *Q. coccinea*, from which it is somewhat difficult to separate it. It

is usually a smaller shell and has a more distinct posterior ridge, which is the chief distinguishing characteristic. The nacre is never pink, but may in rare instances have a yellowish cast. The species has about the same value for buttons as *Q. coccinea*. In the button makers' category it would be classed with the pig-toe group, but it has received no regular trade name.

Q. rubiginosa was found almost the entire length of the Yellow and Kankakee Basins, but was more common in the lower river. It was common in the clammer's shell pile at Momence and in the Iroquois. It is one of the few *Quadrulas* found fairly common in the lakes. We found it in both Tippecanoe and Koontz Lakes. In lakes it is represented by a peculiar dwarfed form with a satiny epidermis. It was difficult to distinguish between the peculiar inflated form found at L'Erable and *trigona*. Some of these were gravid, all four gills being filled, and of a reddish color. The flesh of some of the examples was white, of others reddish. Distomid cysts were very abundant in the margins of the mantle.

6. Quadrula pustulosa (*Lea*). *Warty-back.*—This is a well-known shell among the clammers and button cutters. It is exceedingly variable, sometimes being small and much inflated, and at other places flattish. In some localities it is exceedingly rough and warty and in other places almost smooth. It therefore varies considerably in value, the flatter shells being of more value than the inflated and the smooth better than the rough. In the Kankakee Basin this species has about the same distribution as *Q. rubiginosa*, but is never found in lakes, and is more common in the lower stretches of the river. The examples obtained at Nickelplate were unusually flattish; those about Momence had some of the tubercles developed into long ribs elongate along the lines of growth. It was common in the clammer's pile at Momence and at the pearler's camp below Momence. It was also found in the Iroquois at Watseka and L'Erable.

7. Quadrula lachrymosa (*Lea*). *Maple-leaf.*—This is a well-known shell among button manufacturers, hardly so much on account of its excellence as of the fact that it occurs in considerable abundance in regions where clamming is carried on and the shells can be made good use of. In quality they are about the same as *Q. pustulosa*, the warty-back, but the sulcus or groove along the middle of the shell prevents it from being used to so good an advantage.

In the Kankakee Basin this species is found only in the lower stretches of the Kankakee River and in the Iroquois, and then only in small numbers. At L'Erable on the Iroquois (Aug. 21) they were beginning to become gravid.

8. Quadrula metanevra (*Rafinesque*). *Monkey-face.*—This species, which has about the same commercial value as the preceding, was

found only in the lower stretches of the Kankakee. The first we saw were in the clammer's pile at Momence, where it was fairly abundant. A few were found in the mouth of the Kankakee.

9. Quadrula undulata (*Barnes*). *Three-ridge.*—Two closely related shells, *Q. undulata* and *Q. plicata*, are known to the shell trade as "three ridge" and "blue-point," both names being applied indiscriminately to either species. The extreme forms of these two species are well marked and easily recognizable, and where this is the case it is better to apply the term "three-ridge" to *Q. undulata* and "blue point" to the other shell. Generally, one does not find well-marked examples of both species in the same stream; where the well-marked flatter form (*Q. undulata*) is common, the fuller form (*Q. plicata*) is usually, if not always, absent. All the shells in the Feeder Canal, at Fort Wayne, Ind., seem to be *Q. undulata*, and all noted from the Illinois River seem to be *Q. plicata*. The shells of White River, Ind., seem to be intermediate.

Q. plicata is a fairly valuable button shell and is usually regarded among pearl hunters as a fruitful source of pearls. *Q. undulata*, on account of its thinness, is not quite so valuable as *plicata*. It is a variable shell and differs considerably in value, according to which of its many forms is encountered. The *Q. undulata* of the Kankakee is of low value on account of its roughness and the great depth of its furrows, which interfere with cutting and polishing. It was found abundantly and quite large in Fish Lake, as well as throughout the course of the Yellow and Kankakee Rivers, where it was one of the most widely distributed shells. It was fairly common in the Iroquois as well as in the Yellow and Kankakee and was found in Mazon Creek near Gardiner, Ill. In the old Kankakee Channel at the Nickel Plate Railroad bridge, also at Davis, Ind., and at Kouts and Burton's camp it was the most abundant shell. At Peterson's camp we found some with a yellow epidermis, and at Tippecanoe Lake (July 28) we obtained three gravid examples.

10. Pleurobema coccinea (*Green*). *Bullhead.*—The bullhead is a well-known shell among button manufacturers. Its quality and value differ considerably in different rivers, but it is always a rather inferior shell on account of its brittleness, and in some of the southern rivers it is so hard and flinty that it breaks the teeth out of the saws and the button cutters do not attempt to cut it at all. Among the clammers of the Cumberland it is known as the "clear profit," as the clammer is the only one who gets anything out of it.

In the Kankakee this is a very rare shell. The only ones we saw during the entire trip were three in the clammer's pile at Momence and one at Wilmington Valley.

11. Plagiola elegans (*Leonard*).—This is a handsome shell, too small to be of any use in the manufacture of buttons. It does not occur at all in the Kankakee Basin, but is common in the Tippecanoe River. We found a few in Tippecanoe Lake.

12. Unio gibbosus (*Barnes*). *Lady-finger, spike.—Unio gibbosus* is a common, widely distributed shell, found in all sorts of situations; being one of the common shells of lakes, as well as rivers. The nacre is usually a rather dull purple, which unfits it for the button industry. A white-nacred form is not altogether uncommon. It has a soft satiny luster and can be used commercially. The shells vary in form as well as in color, some being short and humped, more or less closely resembling *P. phaseolus*, and others long and sharp, and at times difficult to separate from *L. rectus*.

U. gibbosus was one of the most widely distributed shells within the Kankakee Basin, being found at nearly all the stations in the Yellow and Kankakee as well as in the Iroquois and in Fish Lake. It was also found in Tippecanoe Lake. It formed most of the culls in the pearler's pile at Momence.

Marginal cysts caused by distomids, dorsal baroques, and small round pearls are common in this species.

One white-nacred shell was found at Plymouth, but as a rule all the shells of the upper parts of the river were deep purple. At Momence these shells exhibited peculiar and interesting phenomena. They seemed to be passing here from the purple-nacred form to the white, and one had all intermediate stages; many were of a beautiful rosy hue throughout, others shaded from blue about the margin through rosy to pale rose. Investigations on other streams have shown similar peculiarities of the color distribution in this shell.

It is worthy of note that both *U. gibbosus* and *L. rectus* become more nearly, or a greater per cent, white-nacred as we go down the Kankakee system, and a careful study here may throw light on the cause of the color in these shells. It may be that the softer waters and amount of humic acid in the upper waters may favor the purplish deposit, while the colorless forms which occur shortly after the limestone river bed is reached may be favored by an excess or abundance of lime.

13. Alasmidonta truncata (*B. H. Wright*). *Elk-toe.—Alasmidonta truncata* is a handsome, beautifully rayed shell, attractive to the collector, but too thin to be of any service in the manufacture of buttons. It is not common in the Kankakee Basin. There was a fair number of shells in the clammer's shell pile at Momence and a few were collected at the mouth of the Iroquois River.

14. Alasmidonta calceola (*Lea*).—This shell is too small to have any commercial value. It is a shell of small streams, and is occasionally found in lakes. It was quite common in the Yellow River at Plymouth and some examples there reached a very large size for the species. It was found at Forked Creek, near Wilmington, and was there noted as becoming gravid (Aug. 27).

15. Symphynota complanata (*Barnes*). *Heel-splitter, lead-back.*—At its very best, this species, offering a broad, flat expanse of satiny white nacre, is an excellent button shell, furnishing more blanks per shell than any other species. In many cases, however, it is too thin for use. This species is found only in the lower half of the river; the first seen were at Hebron Bridge, where we found three. In the clammer's shell pile at Momence it was common and large. It was also found at the mouth of the Iroquois, some fine ones were seen at Kankakee, Ill., and a few at Wilmington. Small ones, cleaned out by muskrats, were found in Mazon Creek.

16. Symphynota costata (*Rafinesque*). *Squaw-foot.*—This species is rarely used for buttons, the nacre being too yellow, and frequently too thin. It is well distributed throughout both the Yellow and Kankakee Rivers, and is fairly common at Plymouth below the dam; 26 were obtained there in a shell pile left by pearlers. In the clammer's pile at Momence it was common and large, although not so immense and thick as found in some rivers. It was also found in the Iroquois River at L'Erable. This species in some rivers is especially subject to distomid infection and occasionally bears pearls.

17. Symphynota compressa (*Lea*).—Compared with the *Symphynotas* just mentioned, this is a small shell. It is always too thin to have any commercial value. It was found in the Yellow River from Plymouth just below the dam to the Zinc Bridge at Ober, in Potato Creek at Walkerton, in Yellowbanks Creek, and the Kankakee at Davis. It is a species belonging to small streams. It was beginning to be gravid at Plymouth September 20, with the embryos orange red, in the outer gills of the parent.

18. Anodontoides ferussacianus (*Lea*).—This is a small thin shell of no economic importance. Like *Symphynota compressa* it is usually confined to small streams, and occasionally lakes. It was rather common at Plymouth; one was found dead in Lake of the Woods, and a few in Yellowbanks Creek. The form found in this area appears to be the subspecies *subcylindraceus*.

19. Anodonta grandis (*Say*).—This species, although it reaches large size, is usually thin-shelled, and only exceptionally attains sufficient thickness to have any commercial value. It was found at the majority of stations throughout the Yellow and Kankakee Rivers, and in the Iroquois. In the lakes (except Fish Lakes, where the river form occurred) this species was represented by a dwarfed somewhat inflated form, the variety *footiana*. Particular attention was paid to the shells above the dam at Plymouth, where the water had been pond-like or lake-like for many years, to observe whether the shells were beginning to approximate in appearance the dwarfed form of the neighboring lakes; but they were all the large, elongate river form.

Anodontas are always more subject to attacks of parasites than any other of our fresh-water mussels, and those of the Kankakee Basin were no exceptions to this rule. Common among the parasites is a distomid which usually is found on the surface of the mantle in the dorsal region of the mussel next to the hinge and causing the nacre to become brick red in color. As this distomid has never received a scientific name, the adult form being up to the present unknown, in our reference to it we have spoken of this form as the distomid of Osborn, after its discoverer. Others of the infected shells were of a dark chocolate color and the distomids, which were plentiful, were smaller in size and probably belonged to a different species.

Other parasites frequently found were *Aspidogaster conchicola* in the pericardial cavity, *Cotylaspis insignis* in the axils of the gills, and numerous species of *Atax* inhabiting the branchial cavity. All the *Anodontas* found in the streams corresponded pretty closely to one type, in no case departing so far as to raise any doubts as to identity; in the lakes, however, it was different; each lake seemed to have a more or less pronounced type of its own. The *Anodontas* of Twin Lakes resemble those of Bass Lake and Cedar Lake pretty closely, but those of Lake of the Woods differ considerably, being larger and thinner. At Tippecanoe Lake, where the dead *Anodonta* shells were so abundant that in places we would frequently find them nested sometimes three in a nest, they presented a different, more inflated type. They very closely, indeed, approached the form known as *Anodonta corpulenta*, generally considered a distinct species from *grandis*. We also found two broken dead shells at Tippecanoe Lake which very closely resembled *A. suborbiculata*, and may, indeed, have been that species; more material would be desirable before deciding.

The *Anodontas* from one of the Twin Lakes, as has already been remarked, were infected in great numbers by a distomid forming clear spherical cysts in the margin of the mantle. Sporocysts and peculiar large white areas like blisters were common on the *Anodontas* of Tippecanoe Lake.

20. Anodonta imbecillis (*Say*).—This dainty, fragile *Anodonta* is of no commercial value. It is a shell of ponds and small streams. The only shell found in Millpond Lake of the Twin Lakes was one example of this species. In the Yellow River at Plymouth below the dam it was fairly common. On July 14 several were obtained here, all gravid, the entire outer gills being thick and padlike, and, when the gills were fully ripe, dark brown. The glochidia have a brown shell, shield-shaped in profile, and have long, coiled threads. One found in Tippecanoe Lake was unusually elongate. A large one was found in the Yellow River at Zinc Bridge, another was found in the outlet of Fish Lakes, and a gravid example was found in the Kankakee bed at Davis (Aug. 9).

21. Strophitus edentulus (*Say*).—This is an exceedingly variable shell, considerably resembling *Anodonta*, and in none of its forms of any commercial importance. It is found in a great variety of situations, in lakes and ponds and both in rather small creeks and large rivers. It is never found in great abundance anywhere. In the Kankakee Basin we found only a few, but these were widely distributed. A dead shell was found at the first station made, on the banks of the Yellow River at Bremen. Some were found at the pearler's pile below the dam at Plymouth, some in Tippecanoe Lake, dwarfed and mostly dead, one valve in the old bed of the Kankakee at Davis, Ind., two at Momence, one at Custer Park with distomid cysts, some at Wilmington, and a gravid example in Forked Creek (Aug. 27). In Mazon Creek at Gardiner, Ill., occurred a brightly rayed form, *pavonia*.

The question of rays appears to be closely related to clearness of water; in turbid streams mussels are usually dull colored, while in clear streams they are usually more brightly rayed.

22. Ptychobranchus phaseolus (*Hildreth*). *Kidney-shell.*—This species, which at its best is a very good button shell, having a white nacre of soft satiny luster, was found only in Tippecanoe Lake. It is also fairly common in the Tippecanoe River, but was not found in the Kankakee River or any of its tributaries.

23. Obovaria ellipsis (*Lea*). *Missouri niggerhead.*—This is a first-class button shell and well known among clammers and button manufacturers. It is of rare occurrence in the Kankakee. We saw it only at the clammer's shell pile at Momence.

24. Lampsilis alatus (*Say*). *Pancake.*—This shell, on account of its thinness and purple color, is of no value to the button trade. It is rare in the Kankakee. We found only one decayed dead shell above Nickel Plate crossing and another dead shell at Custer Park.

25. Lampsilis glans (*Lea*).—This is a shell of lakes and small streams. Its small size and purple color prevent its being of any commercial value. *L. glans* was found only at Plymouth below the dam and in Tippecanoe Lake. At Plymouth it was found gravid (July 27). The glochidia were in a kidney-shaped mass in the posterior part of the outer gill, and are apron-shaped in outline, as is usual in *Lampsilis*. The edge of the gravid portion of the gill has a deposition of black pigment, as in *L. ventricosus* and related forms.

26. Lampsilis ellipsiformis (*Conrad*).—This small shell (too small to be of any value commercially) was found only in the lower part of the river and in the tributary streams. The first we saw were in the clammer's pile at Momence, where it was fairly common. We got 20 there. It was also common in Forked Creek near Wilmington, where all but one were gravid (Aug. 27). Shells opened by muskrats were quite common in Mazon Creek near Gardiner, Ill.

27. Lampsilis ovata (*Lea*).—This very pretty shell is of no commercial importance on account of its small size. It was fairly common and reached an unusual size in the stretch of Yellow River from Plymouth to below Burr Oak. Two were obtained in Tippecanoe Lake, one of them gravid (July 28). A gravid one was obtained above Zinc Bridge (Aug. 3). One was found dead in the Kankakee at Davis, Ind.

28. Lampsilis subrostratus (*Say*).—This shell, like *L. iris*, which it in some respects resembles, is too small to have any commercial value. Although occasionally occurring in rivers, it is essentially a lake or slough shell. All we obtained within the Kankakee Basin were found in lakes. Four were obtained in Twin Lakes (July 2), of which one was gravid, the young being contained in a kidney or bean shaped mass in the posterior part of the outer gill, the mass being deeply gibbed, dusky near the margin, and white along the very margin. Some were obtained in Tippecanoe Lake and some in Fish Lake, where it was fairly common. Fragments were found at Round Lake, a small lake near Knox, Ind.

29. Lampsilis rectus (*Lamarck*). *Black sand-shell.*—This species, when it has white nacre, as it sometimes does, is an excellent shell for both buttons and knife handles, approaching in value the yellow sand shell. In some rivers the majority of shells are white, in others colored. This shell is rare in Yellow River. Some were found at the pearler's pile below the dam at Plymouth, Ind., and in 1906 a few were found at Knox. A few were found also in the Kankakee above Nickel Plate crossing, some at Davis, and near Kouts and Hebron Bridge. It was not common in the clammer's pile at Momence, and some young shells were found at Wilmington. It was also in the Iroquois at L'Erable and at the mouth.

The shells of the upper portion of the Kankakee were all colored, some of them a deep purple. Lower down this color faded to a pink. In a pearler's pile at Momence we found the first white-nacred one. The color of this shell seems to be about the same as that of *U. gibbosus* and seems to respond to the same conditions. It is not, however, distributed the same in the shell, but seems to be most marked in the umbonal cavity or teeth. Shells of *L. rectus* which are perfectly white otherwise often are pink or amethystine purple on the teeth or umbonal cavity. The rosy hue of *Q. coccinea* seems to be of a somewhat different nature and notably differs as one proceeds down the river.

30. Lampsilis fallaciosus (*Smith*). *Smooth sand-shell.*—This species, valuable for small buttons, is rare in the Kankakee Basin. The only ones found were in the Iroquois at L'Erable. Most of these contained distomid cysts in the mantle.

31. Lampsilis luteolus (*Lamarck*). *Mucket.* This market is one of the best known of the button shells and probably more tons of

this species are used in the button-making industry than any other single species. It is not so good a shell as the niggerhead and a few others, but is one of the commonest and most widely distributed and the material is very good.

This species is not found in lakes and is not common in the smaller streams. It occurs throughout the length of the Yellow and Kankakee Rivers, but is rather scattered in the Yellow and upper Kankakee. In the lower Kankakee it is found at every station, and began markedly increasing in numbers about Sheldon, Ind. It formed the main mass of shells in the pearler's pile at Momence, Ill., and fine examples were seen in a pile of shells left by a pearler below Momence. It was also found in considerable numbers at Custer Park, Wilmington, and at the mouth of the Kankakee. In the Iroquois River it was found at L'Erable and near the mouth. A large number were gravid at Momence, August 23.

32. Lampsilis luteolus (*Lamarck*). *Fat mucket.—Lampsilis luteolus* is a quite variable shell. It is inferior to the mucket on account of being smaller and more cylindrical, and the greater curvature of the valves makes it harder to work up satisfactorily. Such large fine specimens as occur in some rivers, e. g., the St. Joseph River at Fort Wayne, Ind., would make excellent buttons, but these are not common.

It is one of the most abundant and widely distributed shells and is usually found in lakes and in small rivers. In the Kankakee Basin it occurred at almost every station, in lakes, rivers, and streams alike.

In parts of the Kankakee Basin this species is of especial interest, as many of the examples found are infested with a parasite which leads to the formation of perfect spherical pearls. The pearls are all of small size and on this account not of enough value to justify working them. They are, however, of great scientific interest, as they offer unusual opportunities for the study of pearl formation. In places a single mussel will contain as many as a half dozen or more pearls, and the average will run more than a pearl per mussel. A lot of material was collected which furnished fine sections showing the epithelial sac in which pearls are formed. It also indicated the cause of pearl formation to be probably a small distomid which formed cysts in the mantle of the mussels. It was greatly hoped that opportunities would be given to follow up this subject further, but this hope has not been realized. This field offers excellent opportunities to the investigator.

33. Lampsilis multiradiatus (*Lea*).—This very pretty, much-rayed shell resembles *Lampsilis ventricosus* in general form, but is too small and thin to be of any service in the manufacture of buttons. It was not found in the Kankakee Basin at all, but was not rare in Tippecanoe Lake and River.

34. Lampsilis ventricosus (*Barnes*). *Pocketbook.—Lampsilis ventricosus* is a widely distributed and exceedingly variable shell, occurring in both lakes and streams. Its commercial value varies greatly in different situations. In some locations it is too thin to be of any value whatever. The nacre is usually white and of good luster, though pink or reddish ones are occasionally found.

In the Yellow and Kankakee Rivers this species reaches unusual size and thickness: indeed, in 1906 was obtained, in the Yellow River near Plymouth, what at that time was the record shell for this species, exceeding in size any in the National Museum collection. In the active collecting that has been going on since, it is possible, of course, that larger shells have been found. It was fairly abundant in the Yellow River below Plymouth and became more common in the Kankakee, until below Burton's camp it was present at every station. We did not find it in the Iroquois or in any of the lakes within the Kankakee Basin, though it is fairly common in Lake Maxinkuckee. The form found in the Yellow and Kankakee is the large oval form, either plain or, in some cases, beautifully rayed (*occidens*); near the city of Kankakee, Ill., however, we obtained some specimens with a pretty well-marked posterior ridge (*subovatus*). It was represented by numerous large shells in the clammer's camp at Momence. They were found becoming gravid at Plymouth July 15, spawning in the Tippecanoe River July 28, gravid at Zinc Bridge August 4, and at Custer Park August 27. In Yellow River this species bears numerous small dorsal baroques.

35. Micromya fabale (*Lea*).—This dainty little shell was found at Tippecanoe Lake and is fairly common in the Tippecanoe River, but was not found in the Kankakee Basin. It has no commercial value.

36. Truncilla sulcata (*Lea*).—This little shell was found at Tippecanoe Lake, but was absent from the Kankakee Basin. It is interesting as the representative of the most highly differentiated genus of mussels, a genus mostly southern in distribution. It has no commercial value.

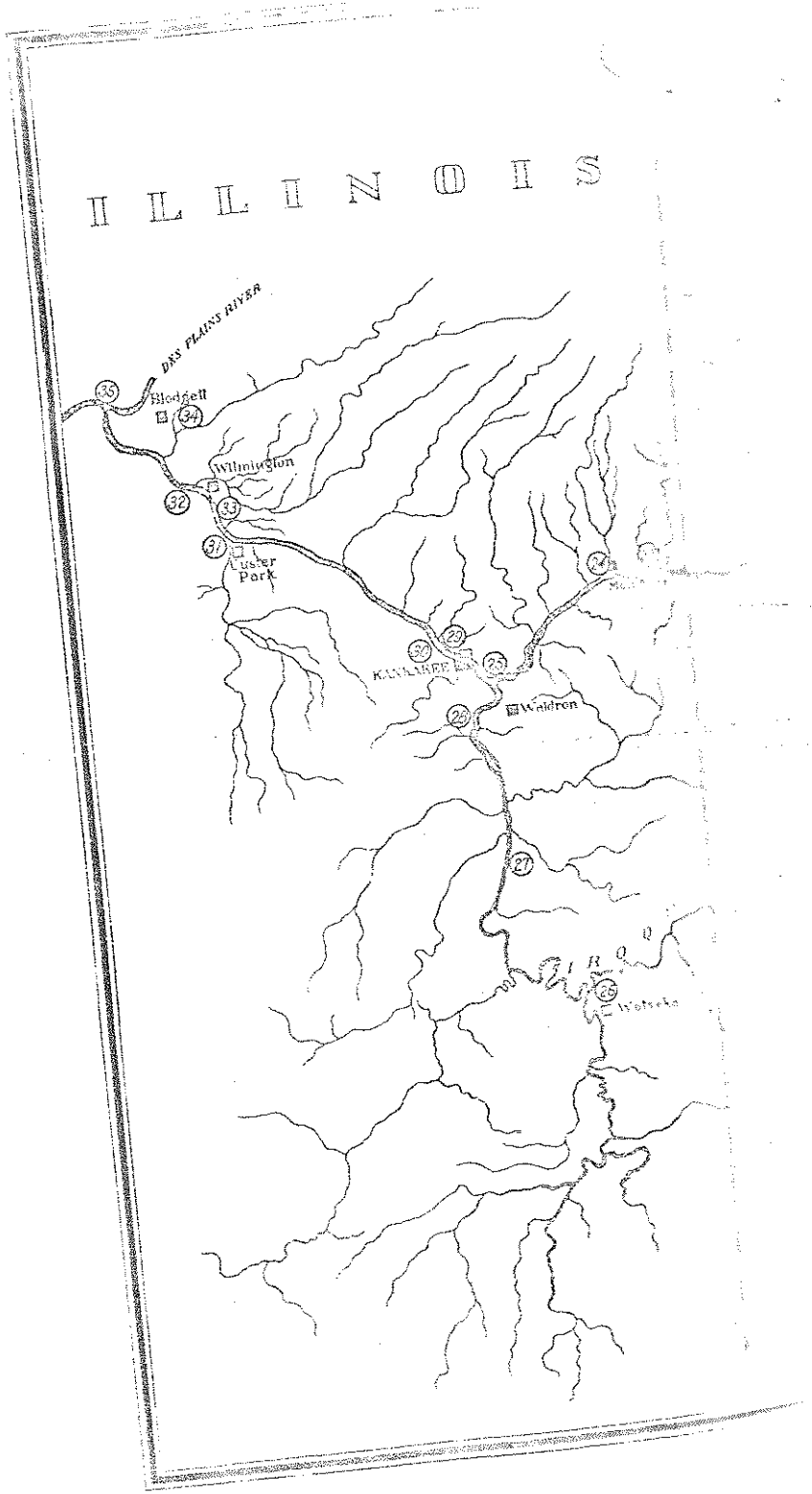
ECONOMIC CONSIDERATIONS.

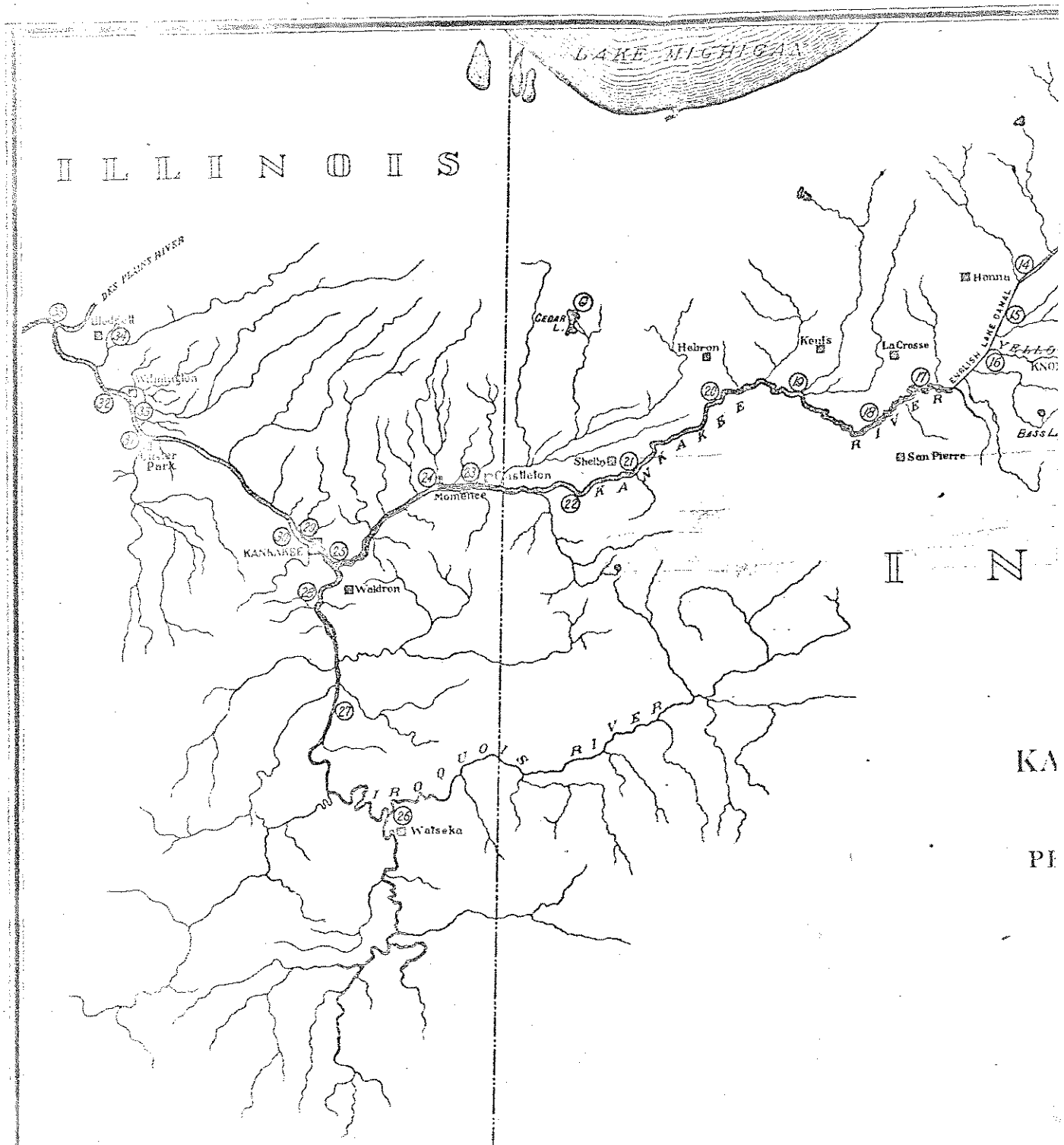
Although the upper portion of the Yellow River is fairly well populated with mussels, it is a small stream and the distance is short, so that commerical operations would soon deplete it. It is, however, a region of especially large and fine *L. ventricosus*. Many of the finest shells of this part of the river have been killed by pearlers, and to gather up and market the cleaned shells might be worth while to some resident of the vicinity. It would hardly be profitable for a professional clammer to construct gear and work this region. Whether it would be a good plan to procure spawn of the remarkably fine *ventricosus* found here for planting elsewhere can not be deter-

mined until it is known that their excellence was hereditary rather than produced by exceptionally favorable conditions.

The dredged portion of the Yellow River, extending from Ober to its mouth, and the dredged part of the Kankakee, so far as the bottom is still unsettled, extending from its source to below the Hebron Bridge, would be hardly workable, for though there is a fair number of mussels, these are all in the old bed, which lies now on this, now on that side of the main navigable channel in the form of crescent-shaped bayous, in many cases extending miles back from the present (artificial) channel. Even in this new channel clamming operations would be neither wise nor profitable until the mussel fauna becomes more firmly established. The clammers at Momence worked upstream as far as they found it profitable, and were getting ready to leave for more promising regions at the time of our visit.

The most profitable region commercially is the stretch of river between Momence and Wilmington, Ill., and this is now (1911) being exploited. A shell dealer of Muscatine (Mr. W. S. Berry) furnished the information (October, 1911) that between Waldron and the Kankakee Dam (5½ miles by water) he had obtained nine carloads of shells, and three below Kankakee, 90 per cent of which were muckets, with a few razorbacks, three-ridges, and big pink pocketbooks. The three-ridges were of little value on account of the deep furrows between the ridges. Below the Kankakee Bridge 200 tons were obtained within 1,000 yards by means of the fork.




LAKE MICHIGAN
ILLINOIS
DES PLAINS RIVER
Wilmington
Gebhard Woods State Park
CEDAR L.
Momence
KANKAKEE
Shelby
Hebron
Kouts
LaCrosse
Hanna
ENGLISH LAKE CANAL
San Pierre
KANKAKEE RIVER
Waldron
IROQUOIS RIVER
Watseka