Ecological Notes on the Mussels of Winona Lake.*

By T. J. Headlee and James Simonton.

In the summer of 1903 the writers, under the direction of C. H. Eigenmann, made observations on the mussel distribution of Winona Lake with a view to determining the reason for the same. We examined the shore line from 4 inches to 4 feet by wading, from 4 to 7 with a clam rake, from 7 to 86 feet with an iron dredge.

The species found were determined by comparison with shells that had been named by Call, Simpson and Baker. The nomenclature is that used by Call in his report on Indiana Mollusca, Geological Report, 1899. They were: Unio luteolus, Unio subrostratus, Unio glans, Unio fabalis, Unio rubiginosus, Anodonta grandis, Anodonta edentula Margaritana marginata.

This is a deep kettle-hole lake. In general the beaches are composed of sand and gravel, which shade off with varying rapidity into marly sand, then into sandy marl, then into coarse white marl, and finally into the fine dark marl that covers the bottom in all the deeper parts of the lake and which is the accumulation of plankton tests. The bottom steadily grows softer as the proportion of dark marl increases. So soft does it become that a small sounding lead sinks into it of its own weight from 6 to 12 inches. In some places, especially the southwest side and in the little lake the shallow part of the beach is formed of muck which shades off into marl without the presence of any sand or gravel.

In general it may be said that the mussel zone extends from the shore line to where the bottom changes to very soft marl. This region will average from 4 inches to 9 feet of water, although in some places the mud comes to within a few feet of the water's edge, while in others the sandy and gravelly bottom runs out into 22 feet of water.

A. grandis is usually found just on the outer edge of the sand and gravel bank, while A. edentula appears most numerously a little farther out. A few specimens of both species were taken closer in shore,

*Contributions from the Zoölogical Laboratory of Indiana University, No. 62.

grandis being sometimes found on sandy bottom, edentula, however, invariably upon a soft bottom. Neither (healthy forms) was ever taken on hard sand or gravel.

U. glans has been taken upon sandy and gravelly bottoms, in from 4 feet out. U. fabalis appeared in about the same region except that it goes out on the soft bottom even farther than edentula.

U. subrostratus appears on the outer edge of the sand and gravel banks in about four feet of water and extends out as far as the light form of U. luteolus.

U. luteolus is the most variable, the most widely distributed and the most abundant species in the lake. It varies from a moderately thin, light straw-colored shell, marked by radiating greenish lines, to an extremely heavy, almost black form. The gradations of form, color, and size are shown in the plate and are very nearly perfect. The straw-colored variety is found in from 4 inches to 22 feet of water; it is, however, dominant inshore, in weed patches (Potomogeton and Ceratophyllum), and on chara-covered bottoms. The dark variety occupies the same region but is dominant upon sand and gravel bottoms in from three and one-half to twenty-two feet of water. The intergrading forms cover the same territory as the straw-colored and dark varieties but can not be said to be dominant anywhere.

U. rubiginosus occupies about the habitat dominated by the dark form of U. luteolus, except that it was not found in deeper water than ten feet.

M. marginata was found so infrequently (only six times) that the writers could tell little of its distribution. The specimens found were taken on sand and gravel, and white marl bottoms in from four to twenty-two feet.

There are a number of conditions in the environment which suggested themselves to us as possible explanations for this distribution —age, sex, light, heat, food supply and oxygen, pressure, wave action, character of the bottom, and enemies. Sex can not be important, for males and females are found together throughout the habitat; light can have but little to do with it, for mussels are absent in places in three feet of water and are abundant in others in fifteen feet, the difference in light being considerable. Further, the light over some of the immense beds in White River is no greater and perhaps even less than in twelve feet of lake water. That heat has little effect, during the summer at

least, is shown by the fact that heavy beds were found in different temperatures, and by the fact that temperature variation in the mussel zone did not amount to more than two degrees; oxygen is not important, for the supply of oxygen throughout the mussel zone varies very little; pressure can have but little to do with it, for we found specimens on a sandy bottom in twenty-two feet of water, while on dark marl bottoms in ten feet none were taken in any case. Food supply can not be effective, for it is about equally abundant throughout the zone. The food consists principally of diatoms; secondarily of low algæ forms, and one-celled animals.

It seems to us that there are three causes which control the distribution of mussels as it appeared in Winona Lake—wave action, character of the bottom and enemies.

The first cause applies only in water less than three feet deep. As U. luteolus and A. grandis appear in this region they are subjected to this agency. Specimens of both A. grandis and the dark form of U. luteolus have been found washed ashore after a storm, and scores of these shells appear along the shore line. Under similar conditions we have seen the light form of U. luteolus moving from the water's edge out into deeper parts; these facts point to the conclusion that the two first mentioned forms are prevented from occupying shallow water by wave action, but that the light form of U. luteolus, being very active and having a thick shell, can well occupy this region. Not only is washing ashore fatal to A. grandis, but wave action quickly action quickly wears away the shell and leaves the animal open to attack. Unio glans, fabalis, edentula, and subrostratus are very light and slow moving; U. rubiginosus is heavy and clumsy, like the dark form of luteolus; the first three, if washed ashore, would be unable to get back, and their shells would be unable to resist the wearing action of the waves, while the last mentioned form could resist wave wearing but would be unable to get back if washed ashore.

The character of the bottom applies throughout the mussel zone. The bottom in the weed patches differs from that in the deeper parts of the lake in being slightly less soft. The sandy and gravelly bottom affords firm foothold and allows the mussel to assume that position which enables it to get the best supply of food and oxygen, while the pure marl allows it to sink so far as to be smothered. Even if the animal does not sink entirely under, the overlying sediment is suf-

ficient to smother it. That there is an overlying sediment is shown by the following experiment: We pumped water from twelve and six inches above the sandy and gravelly bottom in seven, ten, fifteen, twenty-five feet of water; the specimens revealed no sediment that would not settle on standing. Specimens were taken in thirty and thirty-six feet of water over a marl bottom and the twelve-inch samples yielded a small amount of such sediment, while the six-inch samples showed a decided amount. That matter in suspension is fatal to the mussel is shown by the fact that we found in the west side and south end of the lake what were evidently once thriving mussel beds, buried under a thin layer of coarse marl, which had been stirred up by the action of the steam dredge two years before. These mussels were found in the normal position undisturbed in any way. That the mussels were alive five years ago is shown by Dr. Moenkhaus' statement that he and his classes collected an abundance for study in those same regions at that time.

In order to test the ability of the mussel to stand these bottom conditions we made three wire clam baskets, lowered one in twenty-five feet of water, another in thirty-five feet, another in eighty-five feet. We got the following results:

August 5, a basket containing thirteen U. luteolus and one A. grandis was placed in 25 feet of water on a dark marl bottom. On the 10th two examples of U. luteolus were dead; on the 15th one U. luteolus was dead; on the 17th two U. luteolus were dead and four were missing.

August 9, a basket containing five U. luteolus of the light variety and one of the dark, and one A. edentula was lowered in 35 feet of water on a sandy gray marl bottom. On the 15th, one A. grandis and one U. rubiginosus were added. On the 20th one U. luteolus of dark variety was dead; on the 24th five U. luteolus and one U. rubiginosus were found to have the gills badly choked with sediment, while the anodontas were missing.

August 15, a basket containing seven U. luteolus of light and one of dark variety, two A. edentula, and one A. grandis was lowered in 85 feet on a pure dark marl bottom. On the 21st one U. luteolus of dark variety was dead; on the 24th seven U. luteolus and one A. grandis showed gills badly choked with sediment, while the two edentula were in better condition, showing very few patches of marl in gills.

To sum up: In the basket in twenty-five feet, lowered on dark marl, in nineteen days five were found dead and four missing; in the basket in thirty-five feet, lowered near Sandy Point on a sandy gray marl bottom, in fifteen days one was dead, all showed gills partly filled with sediment; in the basket in eighty-five feet, lowered on pure dark marl, in nine days two were found dead and the gills of all but A. edentula badly choked with sediment. U. fabalis, U. glans and U. subrostratus were not included in this experiment because the first two would have slipped out through the meshes and the third could not be obtained at the time. However, it seems reasonable to suppose that they would have proven not unlike the others. It seems, therefore, that those forms possessing light weight in proportion to surface exposed and close-fitting valves are best able to resist the soft marl and the overlying sediment.

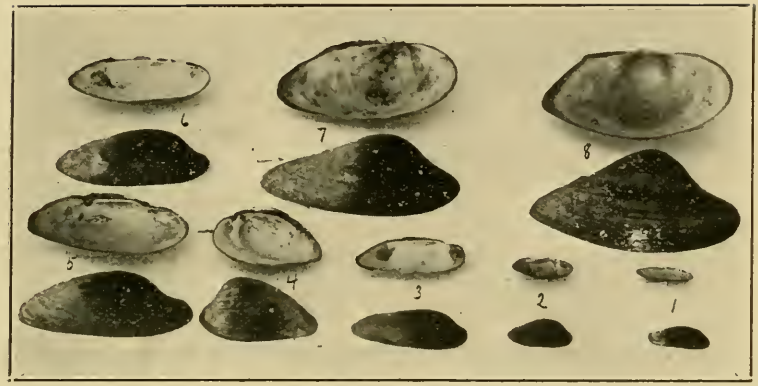
A. grandis and edentula, having light and close-fitting valves, are found accordingly on the outer edge of the sandy marl bank; the edentula, being better fitted to withstand the bottom conditions, is found out in the edge of the dark marl. U. glans and fabalis, owing to lightness and close-fitting valves, occupy about the same situation, the fabalis having much the lighter shell, being found out as far or farther than the edentula. They are also found inshore, where not subjected to wave action. U. subrostratus, having medium weight valves, which are also close-fitting, is confined to the gravel and sand banks, weed patches and chara-covered beds. U. rubiginosis, having very heavy and rather loose-fitting valves, is confined to clear sand and gravel banks. The dark form of luteolus, having extremely heavy and rather loose-fitting valves, is confined to hard sand and gravel banks. The straw-colored form by its medium weight and tight-fitting valves is able to live on sand, gravel, in mud patches and on chara-covered bottoms. Owing to the fact that so few specimens of M. marginata were found we were unable to draw any conclusions as to its ecology.

The muskrat is the principal enemy of the mussels; around his house many mussel shells are found, but no live mussels. Shells of all the species in the lake except the smaller ones are found, the Anodonta shells being in much greater evidence than is proportionate to their total number. They do not appear so on first examination, for they are broken up by the animal and worn by the waves. The conditions on the sand banks beyond reach of wave action are very favor-

able for Anodonta life, except for the presence of the muskrat. Anodontas are absolutely absent from water some distance from his home, where we found Unios rather abundantly. This points to the fact that the muskrat confines the Anodonta to the deeper waters at the edge of the sandy and gravelly banks.

It seems to us that the foregoing facts give basis for the following conclusions: First, that the mussel zone lies mainly upon sandy and gravelly banks, and on the outer edge of the same; second, that wave action and the muskrat determine the limit of the distribution shoreward, and that the character of the bottom is the principal factor determining the outer boundary of the zone.

PLATE I.



1—Unio fabalis; 2—Unio glans; 3—Unio subrostratus; 4—Unio rubiginosus; 5—Margaritana marginata; 6—Unio luteolus; 7—Anodonta grandis; 8—Anodonta edentulus.

PLATE II.

1, 2, 3, and 4 are pairs of U. luteolus, which exhibit gradations of form, color and size from the light straw-colored forms to the almost black variety.

a, b, c, d, e, f, g, and h exhibit the gradations of color and markings found, from white to dark varieties, without regard to sex.