THE FAUNA OF AN ACID STREAM[1]

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INTRODUCTION AND METHODS

Although it is well known that many streams of our country, including especially the Monongahela and even the Ohio, are becoming acid due to industrial wastes, so far as I know few, if any, studies have yet been made on the biology of a naturally acid stream or of a stream in the early stages of becoming acid. Such a stream is the Big Muddy River of southern Illinois. The author had the opportunity of making two trips to this river and of collecting some data on it while engaged in a study of stream pollution for the Illinois State Water Survey. Although these trips were of a purely preliminary nature, yet, inasmuch as the work has not been continued, and since some of the data are of considerable interest, it has seemed advisable to make the results available to those interested in the same or similar problems.

An essential feature of such a study is that all chemical determinations be made in the field. It is as *impossible* to determine the hydrogen-ion concentration of a river from samples of water transferred to the laboratory as it would be to determine its temperature. The author used the buffer solutions of Clark and Lubbs (1) sealed in non-soluble test tubes with 0.2 c.c. of indicator solution. The water to be tested was added to a corresponding amount of indicator in a similar test tube and comparison was made immediately in the field. The color standards were freshly prepared before leaving the laboratory for each trip and were checked with freshly prepared standards immediately upon returning. The accuracy of this method is about ± P_H 0.1. Without exception, water samples were taken below the surface and from midstream.

DATA

Most of the streams of Illinois are basic. Water from midstream of those upon which the author has made observation, the Mississippi, Illinois, Kaskaskia, Embarras, Vermillion, and Sangamon, showed alkalinities varying from P_H 7.4 to P_H 8.5 or higher. The water of the Big Muddy varied between P_H 5.8 and P_H 7.1.

The larger part of the Big Muddy River and its tributaries lies in the great coal fields of southern Illinois (fig. 1), and in rainy weather receives

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water from at least three distinct sources; (1) rain water and surface run off, probably neutral to weakly basic, (2) ground waters, frequently acid, and (3) waters pumped from the mines, usually strongly acid. During the dry season the only source of water is the ground water.

Two trips were made to the Big Muddy River. At the time of the first, February 27 to March 1, 1919, the stream had but recently returned to its banks following heavy rains, and was still much swollen. Two weeks previously the bottoms had been inundated and large amounts of highly mineral-

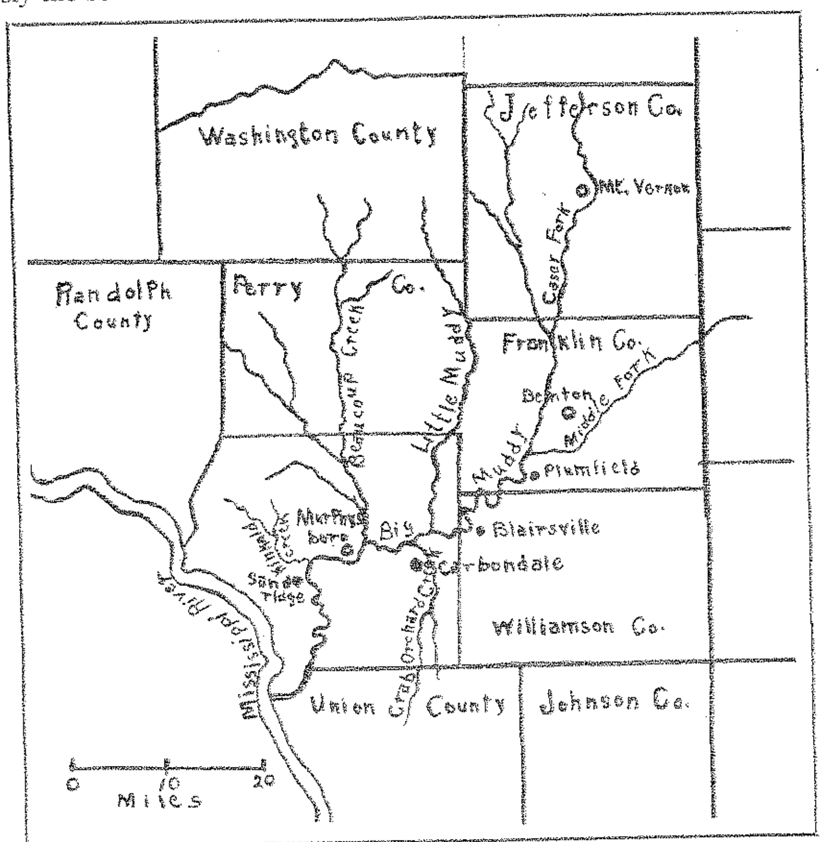

FIG. 1. Map of southeastern Illinois showing the Big Muddy River and its tributaries.

ized mine waters were still being received. The acidity of the water samples taken ranged from P_H 6.2 to P_H 5.8. Upon standing a few minutes these values changed from P_H 6.6 to P_H 6.4, although the water did not become neutral after twelve hours' exposure to the air, showing that the acidity was not due, or was due only in part, to carbonic acid. The second trip was taken by canoe during the dry season, July 29 to August 22, 1919, starting in the upper part of the river (opposite Benton), where it was so shallow that the canoe containing the apparatus had to be dragged most of the time, and continuing to a point shortly above the river's mouth and below the entrance of the last important tributary. At this time, except locally, the water was weakly acid to neutral, P_H 6.8 to P_H 7.1 or 7.2, the acidity being higher in the upper part of the stream, in the heart of the coal country where even the springs are acid, and decreasing toward the mouth where the tributary ground waters become basic.

It is the finding of these acid springs which is the basis for calling the Big Muddy a "Naturally Acid Stream," admitting, however, that the acidity is, at times, greatly increased by human agencies. These springs bubbled or seeped up through a layer of fine white sand at a temperature much below that of the river, which would indicate a deep origin; thus spring No. 1 had a temperature of 14.6 degrees Centigrade on a hot August afternoon when the temperature of the river was about ten degrees higher. Although the water itself was clear and sparkling, the sand around was stained a bright red with iron oxide precipitated upon contact with air. The hydrogen-ion concentration of the water was about P_H 5.5 and was not materially altered by exposure to air for two hours with frequent shaking, showing that the acidity was not due to carbonic acid. The high acidity of mine waters is usually due to sulfurous acid produced by the oxidation of iron pyrites present in coal. Although the bottle of water from this spring collected for mineral analysis was unfortunately broken in transit to the laboratory, the precipitate of iron oxide around the spring, the inky appearance of tea and coffee made from the water, and the characteristic taste, all point to a similar source of acidity.

Table 1 gives the hydrogen-ion concentrations and methyl orange titrations (alkalinity as ppm. $CaCO_3$) characteristic of various parts of the stream. In this table distances, where given, were estimated as following the course of the stream.

It is probably not without significance to the inhabitants of the stream that the highest acidities occurred at low temperatures, and that during the heat of the summer the water was almost neutral, since it has been repeatedly shown (Gail, 2; Powers, 4; Stickney, unpublished) that the effects of acids or toxic substances increase rapidly with an increase in temperature.

The biological survey was made during the summer trip. The stagnant character of the stream makes it especially favorable for abundant algal growths, which do not appear to be in the least inhibited by the acidity. The felt-like masses of oscillaria which covered the surface and bottom of the pools were the heaviest the author has ever seen. Thick scums of euglena were common, while desmids, tabellarian diatoms, and colonial phytoflagellates were also abundant. Of the zooplankton forms the most characteristic were the ostracoda, copepoda, and bryozoon statoblasts (*Pectinatella*).

The bottom fauna of a stream is always of interest because its forms, being unable to migrate with a changing environment, are limited by the

TABLE 1. *Results of field tests on the water of the Big Muddy River*

Locality	Date	Temp. degrees C.	Alkalinity as ppm. $CaCO_3$	PH
1. Casey Fork at Mt. Vernon	Feb. 27	3	43	6.9
	July 29	29.6	57	7
2. Big Muddy near Benton	Feb. 28	7	19	6.2
	July 30	28.7	78	7
3. Three miles below Benton				
River,	Aug. 1	24	96	6.8
Spring No. 1	Aug. 1	14.6	43	5.5
4. Ten miles below Benton				
River,	Aug. 2	24	90	6.8
Spring No. 2	Aug. 2	16.6	58	5.6
5. Thirteen miles below Benton				
River,	Aug. 13	25	82	7.1
Spring No. 3	Aug. 13	18	58	5.6
6. Above Junction of Middle Fork	Aug. 14	25	79	7.0
7. Middle Fork	Feb. 28	5	18	5.9
	Aug. 14	25	90	7.1
8. Plumfield	Aug. 14	25	78	7.0
9. Blairsville River, Spring No. 4	Aug. 18	26	50	7.0
	Aug. 18	22	428	7.6
10. Above junction of Little Muddy	Aug. 19	22.5	124	7.2
11. Little Muddy	Aug. 19	22	100	6.8
12. Below Little Muddy	Aug. 19	22	115	7.1
13. *Carbondale below Crab-Orchard Creek	Mch. 1	5	15	5.8
Surface Sample	Aug. 20	24	90	6.8
Bottom Sample	Aug. 20	24	90	6.6
14. Spring Fed Creek, 6 miles below Carbondale	Aug. 20	20	516	8.0
15. Above Beaucoup Creek				
Surface	Aug. 20	24	140	7.1
Bottom	Aug. 20	24	142	7.0
16. Beaucoup Creek	Aug. 20	24	146	7.1
17. Murphysboro	Mch. 1	5.2	16	5.8
	Aug. 22	24.3	108	7.0
18. Sand Ridge	Aug. 22	24.5	106	7.0

* Crab-Orchard Creek itself was too turbid to allow colorimetric work. Its effect upon the river indicates a high acidity. A heavy rain fell Aug. 20-21, which probably accounts for the decrease in alkalinity between this sample and the samples taken at the entrance of Beaucoup Creek.

worst conditions to which the locality is subjected. The most characteristic animals of this group were the fresh-water shrimp, *Palaemonetes,* and the Unionidae. Shrimp were found in abundance in almost every part of the stream, as well as in the Little Muddy and Beaucoup Creek, sometimes as many as ten being taken in one scoop of the dredge net. They were found not only during the summer trip, but also in February in the more strongly acid water. The idea that this delicate little animal, said to be highly susceptible to many forms of contamination, may be quite resistant to acid is further substantiated by observations made by the author during the summer of 1918 on Lake Depue, Illinois, where it was found in acid waters near the inlet of waste from a zinc and sulphuric acid plant.

Of the Unionidae the following nine species were identified:

Quadrula pustulosa (Lea)
Amblema undulata (Barnes)
Tritigonia tuberculata (Barnes)
Eurynia luteola (Lamarck)
Anadonta grandis (Say)
Proptera purpurata (Lamarck)
Megalonias heros (Say)
Lampsilis anadontoides (Lea)
Elliptio gibbosus (Barnes)

The distribution of the various species appeared to be influenced by the character of the bottom rather than of the water, since the heavy-shelled forms were invariably found in the upper part of the stream where the bottom is coarse gravel, and the thin-shelled forms nearer the mouth where the bottom is clay and fine sand. A careful survey for about three fourths of a mile revealed no living mussels in the Little Muddy, although apparently recent shells of *Lampsilis anadontoides* were common. One very striking characteristic of the mussels of the Muddy River was the corrosion of their shells, due, no doubt, to the acidity of the water. Although clams were strikingly abundant, no perfect specimens were found, for, even in the very young ones, the umbonal markings had entirely disappeared, while older specimens were extensively corroded.

Abundant as were the mussels in the Big Muddy River, only two snails (individuals) were found; one a living *Pleurocera elevatum* taken opposite Benton (fig. 1), the other a *Campeloma subsolidum* taken near Murphysboro. No dead shells were found to indicate that snails had ever been present. This is in striking contrast to the other streams of Illinois, most of which are rich in gill-breathing snails. Equally conspicuous for their absence were the nymphs of the burrowing may fly, *Hexagenia*. In late summers this form literally honeycombs the muddy sides of pools in the Vermillion and Sangamon rivers. Not one was seen in the Muddy. Nymphs of the dragon flies were also lacking, although two larvae of *Corydalis cornuta* and any number of chironomid and mosquito larvae were taken.

Fish were everywhere abundant. Dog fish, sun fish, and native carp were taken with the hook and line, while large numbers of minnows, cat fingerlings (at one time a school of several hundred), and unidentified fry were seen in the shallow pools and riffles. There were also numerous swarms of top minnows, while gar, fifteen to eighteen inches in length, were seen in ever-increasing numbers toward the mouth of the river.

Discussion

The study of an acid stream, such as the Big Muddy, is of twofold significance: first, in determining the relative susceptibility of different forms of animals at different stages of their development to hydrogen-ion concentrations, and, second, in assisting in the interpretation of experimental data. While no conclusions can be drawn from a single examination of one stream, it would be of great interest to know, for example, whether branchiate snails and may-fly nymphs are universally absent from acid waters.

The large number of fish fry and fingerlings observed in the upper waters of the stream furnish another problem of interest. These fish must have hatched and undergone the earliest most susceptible stages of their life histories during the period of spring rains while the stream was still receiving strongly acid mine waters. It is improbable that they could have migrated up from the Mississippi since then. At the same time it is possible that the waters of the river were less acid in April and May than when tested in February. In the absence of data on this point no conclusions can be drawn, but this is cited as one of the problems to be solved only after a continuous study of an acid stream with water analyses at frequent intervals throughout at least an entire year.

Six years ago M. M. Wells (5) concluded, from the behavior of fish in gradients of acid and basic waters, that the optimum reaction of water for fish is alkaline and near the turning point of phenolphthalein. (This would be about P_H 8.) Since then others have gotten similar results. But Wells was working with fish from the Vermillion River, a basic stream, P_H about 8. Had he been working with fish from the Big Muddy River, it is probable his findings would have been different. The results of Wells and of those who followed him are good, but they apply not to fish in general, but to fish from a particular alkaline stream. When fish from acid streams have also been studied, it may appear that fish can readily become acclimated to hydrogen-ion concentrations within a considerable range (say P_H 6 to P_H 8.5 at ordinary temperatures), but are exceedingly sensitive in avoiding a change from the hydrogen-ion concentration to which they are accustomed.

Again, it has been suggested that the sensitivity of fish to domestic sewage is a sensitivity to the increased acidity of the water due to the carbon dioxide liberated by organic decomposition. Samples of water from the bottom of the Illinois River between Depue and Henry, Illinois (foul-smelling water from which free oxygen had been entirely absorbed by decomposing sewage, and in which only bacteria and sludge worms could live), showed a P_H value about 7.5, while water from the Big Muddy, in which were delicate young fish, had a P_H value of 6.8. Are hydrogen-ion concentrations in this range a controlling factor in fish distribution? The author has shown in a previous paper (3) that at room temperatures variations in the hydrogen-ion concentration of water between about P_H 6.7 and 7.5 have no detectable effects upon the rate or amount of regeneration in tadpoles, but that greater fluctuations in the direction of either acidity or basicity produce marked decreases in regeneration. A careful study of our acid streams might discover similar ranges of hydrogen-ion concentration to which the various species may become accustomed, but beyond which their continued existence in the stream becomes impossible.

While this study of the Big Muddy River was interrupted before anything more than a hurried preliminary survey had been made, it does serve to emphasize the necessity of close cooperation between field and laboratory studies. At present our knowledge of the rôle in development and distribution of fresh-water animals played by the hydrogen-ion concentration of the water is based almost entirely upon laboratory studies, and stands in need of a careful detailed study at all seasons and all water levels of a few of our acid streams.

Conclusions

1. The hydrogen-ion concentration of the water of the Big Muddy River was found to vary between P_H 5.8 and P_H 6.8 to 7.2, the higher acidity occurring during the winter.

2. The bottom fauna was characterized by the abundance of clams and shrimp, and by the absence of branchiate snails and ephemerid nymphs.

3. Fish fry and fingerlings were found in large numbers during the summer in weakly acid water, P_H 6.8.

4. Observations on our acid streams, continued over a considerable period of time, would tell us much concerning the adaptability of various species to different hydrogen-ion concentrations and are greatly needed in the interpretation of experimental data.

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