THE EFFECT OF SEWAGE AND OTHER POLLUTION ON ANIMAL LIFE OF RIVERS AND STREAMS[1]

FRANK COLLINS BAKER, UNIVERSITY OF ILLINOIS

Stream pollution may be broadly divided into two main divisions: contamination by organic sewage from cities and towns and by chemical wastes from factories and mines. Both are inimical to life but the latter is especially fatal to animal life, causing wide stretches of otherwise fertile streams to become veritable deserts. Organic sewage, in a crude or highly concentrated form, is also very injurious, effectually eliminating most forms of life from the polluted body of water.

The importance and seriousness of the problem of stream pollution in its effect on the life of the rivers and streams into which the contaminating material is discharged has not, until very recently, been given the attention that the subject demands. The diminishing fish

[1] Contribution from the Museum of Natural History, University of Illinois, No. 11.

supply, and in many places the very objectionable physical character of the polluted waters, have caused the authorities of several states to pass laws governing the discharge of these wastes into streams and the establishment of penalties for disregarding these laws. New York and Massachusetts have led in the framing of these laws and other states are following the good example set by these two older commonwealths, where the conditions seem to have reached a maximum of harmfulness (see Ward, 1918, 1919).

During recent years stream pollution has enormously increased and the problems arising from this condition have been investigated by many biologists and sanitary engineers. The former have studied the problem from the viewpoint of its effect on the useful animal life, especially fishes and river mussels, and this phase probably bears as close a relation to human welfare as any other. Of course, from the standpoint of health, the pollution problem is of paramount importance because of its bearing on such diseases as typhoid fever which may be caused by a polluted water supply.

Perhaps the worst effect of chemical pollution is to be found in the streams of western Pennsylvania, where mine water heavily loaded with oil or acid water from coal mines is permitted to flow into the rivers and streams of this part of the state. Studies by Ortmann (1909) show that whole stretches of the Allegheny, Ohio, and Monongahela rivers have been made into deserts, as far as the animal life is concerned, by the large amount of poisonous substances discharged into these streams by the mines, oil industries, and chemical and other factories that border these rivers. In the Susquehanna River the same condition prevails in many places (Leighton, 1904). Such pollution causes a complete extermination of the fauna (and largely of the chlorophyl-bearing flora) and leaves the stream in such condition that restocking by either natural or artificial means is practically impossible, and if attempted is a waste of money.

Pollution by sewage, when the polluting material is of small percentage as compared with the pure water of the stream (as 200 to 1), causes little inconvenience to the animal life and is doubtless of some benefit because of the additional food material that is added (Forbes and Richardson, 1919, p. 146). But the streams seldom remain long in this innoxious condition, the sewage becoming more and more concentrated and less diluted until the whole stream may be supersaturated with noxious substances, the amount of oxygen in saturation reduced, and the biota finally driven out or killed.

The Illinois River is one of the most striking examples of the effect of sewage pollution on the life of a stream. Under the direction of Dr. S. A. Forbes, studies of this river have been carried on for more than forty-two years (since 1877) and a mass of reliable data has been gathered. The opening of the Chicago drainage canal in 1890 produced most revolutionary changes in the life of the Illinois River by the discharge into it of the sewage of Chicago, as well as commercial wastes from this city and other places along the river (Forbes and Richardson, 1913, 1919). The effect of this sewage and other pollution has been to cause the animal life to be almost excluded from the upper parts of the river. That the polluted condition is creeping down stream is shown by comparisons of collections made in 1911 with those made in 1918. In the earlier years a foul water fungus disappeared from the river near Starved Rock; in 1918 it was found at Henry and Lacon, 35 and 41 miles farther down the river (Forbes and Richardson, 1919, p. 145). At the present time (1919) optimum conditions and a normal river fauna are not encountered until Peoria is reached, a distance of about 120 miles from the chief source of pollution at Lockport. Sewage from the towns and cities along the river also contribute to the general septic condition and retard the natural purification that occurs in all bodies of water.

A striking example of the deadly effect of sewage pollution on the mussel life of a stream is given by Wilson and Clark (1912, p. 34) in their study of the Kankakee River mussel fauna. "The DesPlaines River, which joins the Kankakee to form the Illinois River, is simply an immense sewer bringing down the Chicago sewage. Both rivers, but especially the DesPlaines, are full of the characteristic algae 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 these old and bleached, but still capable of identification''. This statement, of course, applies only to the lower part of the Kankakee River where the influence of the polluted DesPlaines has worked upstream for some distance. The Kankakee for the most part is a highly productive stream with a high rate of dissolved oxygen, in fact, the water is supersaturated with this life-giving element.

In the Maumee River (Wilson and Clark, 1912, pp. 26, 28) shell beds were found which had probably been killed by the refuse from gas works near the junction of the St. Marys and St. Joseph rivers. ''Spots of tar were found on dead mussels some distance below this point. The water was covered with an oily scum in places and a tarry odor was perceptible for several miles down the river''. Lower in the river the mussels were showing the effect of increased pollution of the stream by sewage.

Pollution is worst and usually most deadly to animal life during periods of low water and in winter when the amount of water in the stream is small and the decomposing organic material has less water to deprive of its dissolved oxygen. During times of floods the putrescent material is also carried down stream for many miles and cotaminates areas not previously affected.

While all clean-water forms of animal life are more or less affected by sewage pollution, the decomposition of the organic matter abstracting dissolved oxygen from the water and rendering it unsuitable for aquatic life, the fish, river mussels, and crayfish are particularly affected, most fish being especially sensitive to contaminated water. Some fish (as the brook silversides, *Labidesthes sicculus*) are notably sensitive, while others (as the black bullhead, *Ameiurus melas*) will endure water that perature and evaporation, and temperature and air movement.

Light influences the length of the codlin moth pupal stages as much as ten per cent. Evaporation differences may cause the length of the pupal stage to be doubled under certain conditions and the effects of air movement are often similar. Variability of temperature shortens

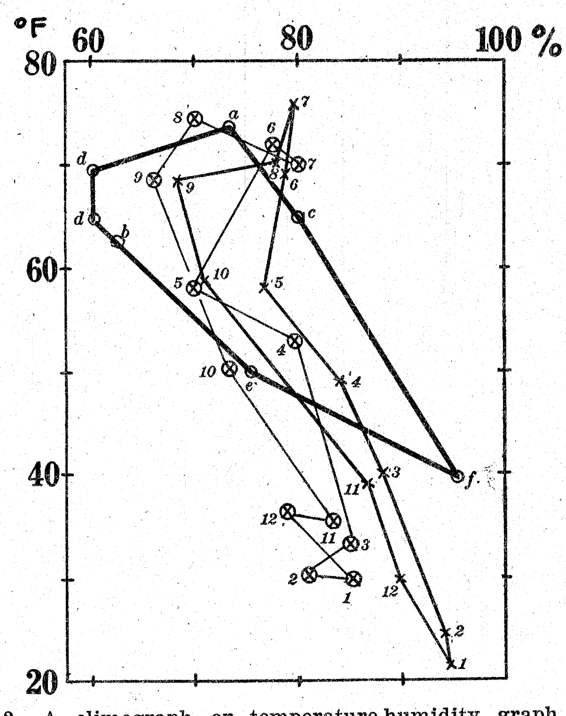

Fig. 2. A climograph or temperature-humidity graph for man and for two years at Urbana, Ill. Horizontal distance represents humidity; vertical temperature in Fahrenheit. The heavy curve with lettered angles connects the following: a, temperature and humidity comfortable for men lightly clothed and making no exertion; b, the same when exercising; c, the lowest death rate; d, high efficiency for factory workers in summer; e, the same in spring and fall; f, the same in winter. The light curve with crosses inside of circles at the angles and numbers adjacent connects the points representing the mean monthly temperature and humidity at Urbana, Ill., for the year 1897 in which the chinch bugs did damage at Urbana and in which the death-rate was high in Chicago. The numbers refer to months. The similar curve with crosses at the angles is for the year 1891 in which there was no chinch bug damage in Champaign county and the death-rate was low in Chicago.

the length of stages and the rate of development. Humidity is one of these; light, variability of temperature, air movement and rate of evaporation are others. On account of these complications it is necessary to express rate of development in more than one dimension. In 1910, Ball writing in the Cairo Scientific Journal used diagrams laid out on section paper in which he represented temperatures on the scale at the left and the humidity on the horizontal scale at the top. He plotted as points on this chart temperature and humidity for each month in the year for various oases in the Sahara and then connected the points so plotted with straight lines. (See Figure 2). Later Griffith Taylor (1914) of Australia followed this same plan plotting the optimum humidity and temperature for man on such a chart accompanied by various similar plots for cities of the various parts of the world. He used wet bulb temperatures which rendered his work not strictly comparable with that of others. In 1916 Pierce applied this same principle to the Mexican Boll Weevil, but since he followed the usual custom of the Bureau of Entomology in not citing any authorities, it is not possible to tell whether he originated the idea independently also.

In the case of humidity and temperature in our work on the codlin moth we have found it possible to plot the length of the pupal period, the pupal mortality, and the failure to pupate in this fashion with advantageous results. The pupal mortality is indicated at certain temperatures and humidities in figure 3. Another type of diagram is being prepared which we believe will prove to be quite helpful in making predictions regarding the time of appearance of the adult codlin moth. On this diagram we are plotting for each temperature the per cent deviation in the length of the pupal period due to humidity, but the work is not complete. On a diagram of this kind it is possible to plot also the march of temperature and humidity for each day and thus determine whether the humidities will have a marked effect on rate of development or only a slight effect. Probably such diagrams could be made for temperature and light, tem-

1913, pp. 179-200). This study was made when pollution was at its maximum and during the period when molluscan life had disappeared from the lower part of the river. The dissolved oxygen in the lower river, below the trunk line sewer, in July and August when the temperature was high and the water low, varied from 5 to 41 per cent of saturation. The water at the bottom of the river almost always contained less oxygen than that at the surface. On one day in August, the percentage of saturation in a distance of three miles did not exceed 5 per cent from the surface to the bottom of the stream, which has a depth of about twenty-six feet. The number of bacteria per cc. for this period was 1,650,000 near the source of pollution and but 67,000 near the mouth of the river where the influence of the pure water from Lake Ontario increased the amount of dissolved oxygen.

In 1917 a large part of the city sewage was diverted to a disposal plant situated near the shore of Lake Ontario. Here an average of 32 million gallons of sewage are treated daily and the treated sewage discharged into Lake Ontario in deep water at some distance from the shore. It is at once apparent that when this large amount of sewage was discharged into the Genesee River in a crude condition, it could not but render the water totally unfit for animal life and a menace even to the inhabitants who visited the beautiful parks bordering both sides of the lower Genesee River.

The result of the diminution in the amount of sewage discharged into this river has been that the molluscan fauna, as well as other forms of animal life, have returned and are rapidly taking possession of the favorable environments which were in use previous to the maximum period of pollution. Collections made in September, 1919, contained six species, two being water-breathers and four air-breathers:

Musculium transversum	*Planorbis trivolvis*
Bythinia tentaculata	*Physa integra*
Galba catascopium	*Physa oneida*

It will be noted that of the returned species, one is different *(P. integra)* while four are missing, *Galba caparta, Physa gyrina* and *P. sayii,* and *Musculium partumeium.* It frequently happens that when a fauna returns to a habitat from which it has previously been driven, it is made up of a different aggregation of species (See Ortmann, 1909, for additional notes on this subject).

In the case of the Genesee River we have a striking example of the history of a polluted stream and its effect on one group of the animal life. Previous to the stage of great pollution there is a varied fauna of mollusks very numerous in individuals. In the course of eleven years the gill-bearing species are forced out and after a lapse of fourteen years all molluscan life ceases to live in this part of the river. Seven years later the greater amount of sewage is diverted to another outlet. Two years after this change we find that the mullusks have returned in as great numbers as before the maximum stage of pollution. The significance of all this lies in the fact of the early return of this life, and strikingly indicates that streams may become restocked with life in a short period after pollution has ceased to be of an unfavorable character. At the present time the sturgeon, which formerly resorted to the river to feed and breed, and had been driven out by the polluted condition of the stream, has returned, which is another indication of improved conditions. It is quite probable that the large fall in the river, some 60 feet in height, has had a marked effect in the return of these favorable conditions.

A study of the Salt Fork of the Big Vermilion River, now in progress, indicates that all clean water life, including mussels and crayfishes, has been excluded from this stream for a distance of fourteen miles, and a normal fauna of these animals is not encountered until a distance of twenty miles has been traversed. The shallowness of this stream has evidently provided a sufficient supply of dissolved oxygen and it is apparent that in a deeper stream the ill effects of sewage pollution would be experienced for a much greater distance.

Wherever stream pollution occurs it is evident that the clean-water animals will sooner or later be driven out or killed. Such a condition seriously effects our food and game fishes, which form so large a part of the meat of our population, and the situation demands immediate attention and early remedy. It is a matter of great satisfaction to scientific men that the authorities are awakened to the seriousness of such conditions and that they are providing adequate remedies in many places.

LIST OF REFERENCES IN THE TEXT

Forbes, S. A. and Richardson, R. E.

1913. Studies on the Biology of the Upper Illinois River. Bull. Ill. State Lab. Nat. Hist., IX, pp. 481-574.

1919. Some recent changes in Illinois River Biology. Bull. Ill. Nat. Hist. Survey, XIII, pp. 137-156.

Leighton, Marshall O.

1904. Quality of Water in the Susquehanna River Drainage Basin. Water Supply and Irrigation Paper, No. 108, U. S. Geol. Surv., pp. 1-76.

Ortmann, Arnold E.

1909. The Destruction of the Fresh-water Fauna in Western Pennsylvania. Proc. Amer. Phil. Soc., XLVIII, pp. 90-110.

Shelford, Victor E.

1918. Ways and Means of Measuring the Dangers of Pollution to Fisheries. Bull. Ill. Nat. Hist. Surv., XIII, pp. 23-42.

Ward, Henry B.

1918. The Elimination of Stream Pollution in New York State. Trans. Amer. Fisheries Soc., XLVIII, pp. 1-25.

1919. Stream Pollution in New York State. A Preliminary Investigation of the Problem from the Standpoint of a Biologist. Report to N. Y. Conservation Commission, pp. 1-79.

Wells, Morris M.

1918. The Reactions and Resistance of Fishes to Carbon Dioxide and Carbon Monoxide. Bull. Ill. State Lab. Nat. Hist., XI, pp. 557-571.

Whipple, George C.

1913. Report on the Sewage Disposal System of Rochester, N. Y. By Edwin A. Fisher, City Engineer. pp. 179-200.

Wilson, Charles B. and Clark, H. Walton.

1912. The Mussel Fauna of the Maumee River. Bureau of Fisheries, Document No. 757.

1912. The Mussel Fauna of the Kankakee River. Bureau of Fisheries, Document No. 758.