THE ATTRACTION OF FISHES BY DISPOSAL PLANT EFFLUENT IN A FRESH WATER LAKE

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In his paper of 1930 on the phytoplankton and pollution in Presque Isle Bay, Lake Erie, Gottschall pointed out the fact that fishes are directly or indirectly dependent upon microplankton, macroplankton, and bacteria for food material; that larger fish live upon the smaller plankton consumers, or, in some cases upon the plankton organisms themselves.

The deleterious effects of sewage pollution upon living organisms in rivers and streams have been described by Richardson (1921) in a paper discussing the changes which occurred in the Illinois River as a result of the addition of great amounts of raw sewage to its water. Agersborg (1929) gives us exactly the reverse picture in his report of great improvement in the condition of the same river below Decatur, Illinois, after the installation of a sewage disposal plant in that city. Previous to the installation raw sewage had been discharged directly into the river.

The effects of domestic sewage, however, upon the open waters of a large lake are bound to differ from those upon the confined waters of a stream. Where there is constant aeration through wave action the chances of depletion of the oxygen supply in a body of water which seldom freezes over its entire surface for long are small indeed. In such a case the addition of purely domestic sewage should tend to make the water more productive. This is partly borne out in the work of Gottschall, who found a rich phytoplankton in Presque Isle Bay. This bay is contaminated with sewage from the city of Erie, Pa., and yet even in this relatively confined body of water there is no evidence of anaerobic respiration.

THE PROBLEM

For many years the writer has observed that each late summer and fall the effluent from the sewage disposal plant of the city of Lakewood, Ohio, on the shore of Lake Erie, attracts large numbers of lake fishes, the most abundant of those attracted being the white bass (*Lepibema chrysops* Raf.) and the small lake minnows. At this time, when the annual run of white bass occurs these fish, although often seen along the shore line of the lake, appear in great abundance in the turbid waters of the disposal plant effluent where it mixes with the lake water, sometimes splashing out of the water after the minnows, and sometimes swimming slowly back and forth through the cloudy effluent. Many fishermen in the vicinity of Lakewood take advantage of this schooling of *Lepibema* and catch quantities of the fish by casting or trolling with small lures, near the outlet.

The question arose as to whether the white bass feed upon small particles of solid matter in the effluent itself, upon plankton organisms numerous in the vicinity of the outlet, or upon lake minnows which may be attracted to the place either by effluent or by plankton organisms. It was thought that a comparison of the water in the region of the effluent outlet with that in the open lake might indicate a difference with respect to the abundance of such plankton forms as serve as food for small fishes.

The effluent from the Lakewood sewage disposal plant is discharged into Lake Erie at a point, under water, about half a mile from shore. The liquid is conveyed to the point of discharge through a three-foot main. At the end of this main

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there is a series of upward-pointing openings so that the effluent is forced toward the surface of the lake in several streams. The lake water here is about four meters deep. The points of effluent discharge as seen from a boat are marked by a series of muddy slicks on the water, each slick being between six and ten feet in diameter depending upon the rate of flow of the effluent and its temperature relative to that of the lake water. The slow currents in Lake Erie which may arise due to wind or to changes in barometric pressure may cause the water to one side of the line of slicks to remain clear while the water on the downcurrent side is turbid, muddy gray, and filled with bits of bacterial slime and such articles as are not digested in the Imhoff tanks of the disposal plant or are not removed by the gratings at the inlet to the plant. The flow of effluent is not constant, its volume being affected considerably by the amount of rainfall in Lakewood, since many of the older parts of the town have storm and sanitary sewage lines combined.

EQUIPMENT AND METHODS

The investigation was divided into two portions. During the summer of 1938 various places along the shore of Lake Erie in the region of Lakewood, Ohio, were visited by boat in order that some one station might be established whose water would be little apt to be affected by surface water and by water from Rocky River, which empties into the lake just west of the city. Finally a point about two miles from shore and almost due north of the effluent outlet was decided upon and designated as *Station A*. The other station, *Station B*, was in the muddy drift of the effluent, sometimes on one side of the outlets, sometimes on the other, depending upon the direction of the current in the lake. All of the recorded hauls and collections were made when the water at *Station A* was clear and clean, and when that at *Station B* could clearly be seen to contain effluent, as revealed by its gray color and high turbidity.

During the white bass seasons of 1938 and 1939 the stomach contents of a number of white bass and lake minnows were examined in order that their feeding habits might be determined. In this way any plankton organisms which are most important as food for these fishes could be chosen and used as a basis for the study of plankton organisms at the two stations.

The equipment used during the actual collecting trips which were made during the summer of 1939 included an eight-foot wooden dinghy with a small outboard motor; a twelve-inch conical plankton net made of number 8 bolting cloth and equipped with a tubular canvas sleeve at the small end for use with fruit jars; a thermometer and water bottle for determining water temperatures at and below the surface; and a set of wide-mouth cork stoppered bottles for preserving the material taken during the various hauls. Laboratory equipment consisted of a compound microscope and a binocular dissecting microscope used in examining stomach contents of minnows and white bass which were taken in the drift of effluent. In addition to this, a standard 1 ml. Rafter counting cell was used with a ruled ocular disk for counting the catches.

After many trials of different methods of collecting and of keeping the hauls uniform, collections were made on the average of once a week through the latter part of June, through July, August and September of 1939. Those collections in August and September were made at a time when the white bass were abundant in the drift of effluent and could be taken there with a small, shining lure. Collections which were made in July were not recorded because of an uncertainty in the method of handling the counts. The few collections in June are presented in tabular form but are not included in the graphs because of their separation from the later collections with reference to time.

Each collection consisted of a haul with the number 8 net at a level of about three feet below the surface of the water. The haul was made with the outboard motor running very slowly and at a speed that could easily be duplicated for each collection. The haul lasted two minutes. When the wind blew hard enough to affect the path of the boat, hauls were made cross wind. For the sake of convenience in handling each catch only one-half of it was preserved, care being taken that the catch was completely mixed before the partition was made. The portion of each catch to be preserved was placed in a 60 ml. wide-mouthed bottle and enough formalin was added to give an approximately 5% solution. Bottles were given temporary labels on the trip and permanent ones later. During each trip water temperature was taken at the surface and the approximate wind velocity and direction were estimated and recorded, together with the direction of the current of the water.

The number of actual laboratory counts made on each catch was fifteen, and the method of procedure was as follows: Five ml. of the catch were diluted to twenty-five ml. with tap water. Three one ml. samples of this diluted catch were used and five random counts of each were made in the Rafter Cell. All fifteen counts on each catch were averaged and the average number was multiplied by the factor number (109.8) which gives the theoretical number of organisms per liter of water on the basis of the assumption that the net used was one hundred per cent efficient and that all of the water in its one hundred and sixty foot path was filtered through it. In the counting of *Anabaena*, the blue-green alga, complete circlets of cells were counted as one unit, and then the final number was multiplied by 25, the average number of cells per circlet. Similarly, for the diatom *Asterionella*, each whorl of frustules was counted as one unit, and the resulting average multiplied by six, the average number of cells in a whorl. The resulting figures have been plotted against the times at which collections were made. See Figs. 1 through 7.

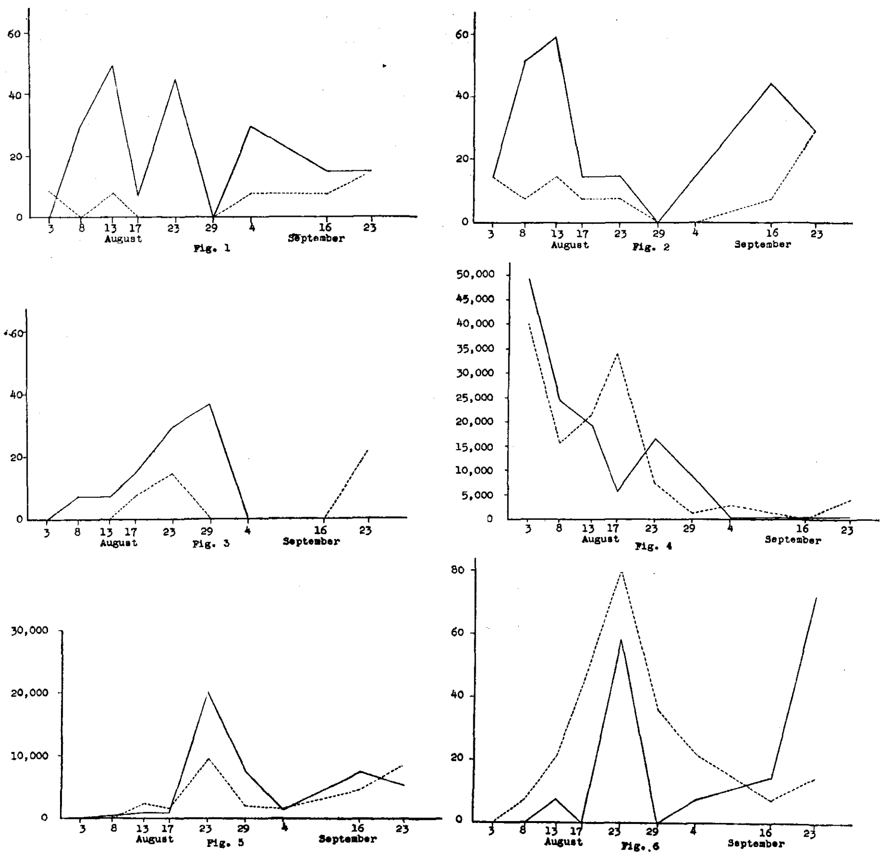
RESULTS

The examination of fish stomach contents which was carried out during the summer revealed (a) that although certain algae are apparently taken by minnows swimming in the region of the effluent outlet, more often the food of these fishes is composed of Entomostraca, and (b) that although the white bass takes the spinning lure readily and many times is found to contain only lake minnows, there appears in about half of the fish examined a granular, brownish mush. Microscopic examination shows this mush to be made up of enormous numbers of cladoceran skeletons.

Because of these findings it was decided that the actual comparison of the plankton populations at stations *A* and *B* should be made with reference to a few particular organisms or organism types. For this comparison the phytoplanktonts *Anabaena*, *Asterionella*, *Ceratium* and *Dinobryon* were chosen, and likewise the zooplankton groups Cladocera, Copepoda, and Rotifera. With reference to the algae considered no attempt was made to determine the species, and in the case of the animals, the organisms were noted only with respect to their groups.

In the table and graphs expressing the results of the counts the figures stand for the number of organisms per liter of lake water, based on the assumption that the net was one hundred percent efficient. Although it is known that this was certainly not the case, since the hauls were all made as nearly alike as possible the inefficiency of the net can be treated as constant error.

From Figs 1, 2, and 3, it will be seen that the Cladocera, Copepoda, and Rotifera were more numerous in the region of effluent discharge than they were in the open lake at a distance from this region. In the graphs the solid lines indicate organism counts at *Station B*, broken lines indicate organism counts at *Station A*. Figures for the Cladocera and Copepoda were tested and found to be statistically significant according to the method presented by Fisher (1930) for appraising small samples. Probable errors for these two groups were found to be 3.7% and 4%



FIGS. 1–6. (1) Graph expressing numbers of Cladocera per liter of water plotted against collection dates. (2) Graph expressing numbers of Copepoda per liter of water plotted against collection dates. (3) Graph expressing numbers of Rotifera per liter of water plotted against collection dates. (4) Graph expressing numbers of *Anabaena* per liter of water plotted against collection dates. (5) Graph expressing numbers of *Asterionella* per liter of water plotted against collection dates. (6) Graph expressing numbers of *Ceratium* per liter of water plotted against collection dates.

All figures calculated on basis that the net used was 100 per cent efficient. In all graphs broken lines refer to counts from *Station A;* solid lines in all graphs refer to counts from *Station B.*

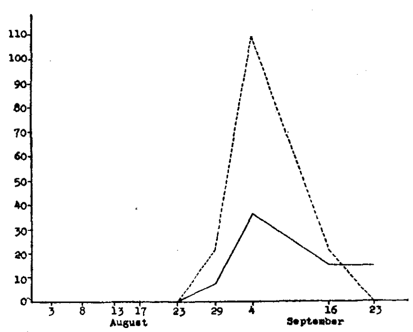


FIG. 7. Graph expressing numbers of *Dinobryon* per liter of water plotted against collection dates. Figures calculated on basis that the net used was 100 per cent efficient. Broken lines refer to counts from *Station A;* solid lines refer to counts from *Station B.*

respectively. Although the probable error for the figures on Rotifera is too high (80%) to allow for confidence, during the entire month of August and the first part of September the individuals appear much more numerous at *Station B* than at *Station A*.

Calculations of significance for the data on the algae indicate that the probable error is much too large to permit us to depend on the figures, possibly because of the enormous variation which occurred from collection to collection. The graphs are included, however, to indicate that variation. (Figs. 4, 5, 6, and 7.) It will be seen that the figures for the diatom *Asterionella* and the blue-green alga *Anabaena* are close together at the two stations, whereas *Ceratium* and *Dinobryon* gave higher counts at the open water station.

TABLE I

In this table are presented the data for those collections made on dates not included in the graphs. Three dates of collection are recorded, the 17th, 19th, and 25th of June, 1939. Figures in the column marked *Station A* represent organisms per liter of water in the open lake. Those in the column marked *Station B* indicate organisms per liter of water in the drift of effluent. As explained in the text, the figures are calculated on the assumption that the net used is 100 per cent efficient.

Organisms	Date (1939)	Station A	Station B
Cladocera	6/17	21.960	7.247
	6/19	7.247	40.187
	6/25	219.600	197.640
Copepoda	6/17	73.126	951.526
	6/19	43.920	7.247
	6/25	87.840	51.167
Rotifera	6/17	505.080	95.087
	6/19	397.080	36.563
	6/25	1024.434	329.400
Anabaena	6/17	0.000	0.000
	6/19	0.000	0.000
	6/25	0.000	0.000
Asterionella	6/17	9045.324	435.466
	6/19	435.467	1139.724
	6/25	0.000	0.000
Ceratium	6/17	14.603	0.000
	6/19	0.000	0.000
	6/25	0.000	0.000
Dinobryon	6/17	124.034	0.000
	6/19	7.247	0.000
	6/25	0.000	0.000

Since records of the approximate velocity and direction of the wind and the direction of current were made at each haul, later compared and checked with those published by the Weather Bureau at Cleveland, Ohio, an attempt was made to find some correlation between wind and drift direction and the abundance of organisms at the two stations. Such a correlation could not be found. Inasmuch as the water temperature varied only slightly during the period at which collections were made, it is not believed that there is any correlation to be made with reference to temperature.

From the graphs and table presented it will be noted that only those organisms which live on particulate food appear to be effected by disposal plant effluent in the water. It may be said that the bacteria which undoubtedly exist in large numbers in this effluent, together with numerous protozoa (Agersborg, 1929) are capable of supporting a large population of entomostracans and rotifers. Plant nourishing materials are doubtless discharged into the lake water as well by the disposal plant, but for some reason the plant life is unable to take immediate advantage of this food supply. It is suggested that similar comparative experiments be made on the waters of the effluent drift both near and at a distance from the actual outlet. Such investigations might indicate an increase in the phytoplankton in the water bearing more diluted effluent.

From Table I it will be noticed that the figures for June, 1939, as regards Rotifera, Cladocera, and Copepoda do not exactly follow those for the latter part of the season. No attempt is made to explain this discrepancy. It is suggested, however, that this abundance of organisms may have been washed out away from shore as a result of spring rains. Also, it would be only reasonable to expect that the bacterial count of the entire lake, both in deep and in shore waters, is high in early summer, and is capable of supporting a large population of those forms dependent upon particulate food.

SUMMARY

1. An attempt is made to explain the apparent attraction of white bass by the disposal plant effluent emptied into Lake Erie by the city of Lakewood, Ohio.

2. A comparison of the plankton population in the region of the effluent outlet is made with that at a point in the open lake which is believed to be unpolluted by effluent.

3. Four genera of algae and three groups of zooplankton organisms are used as bases for this comparison.

4. Although the numbers of algae and of Rotifera are not found to be significantly greater at the effluent outlet than in the open lake, the numbers of Cladocera and Copepoda were found, during the months of August and September, to be significantly greater around the effluent outlet.

5. It is concluded that these forms which live on particulate food are supported in abundance by the numerous bacteria and protozoa discharged into the lake in disposal plant effluent. These plankton forms attract fishes.

6. Although an attempt is made to correlate the relative abundance of the organisms considered at the two stations at which collections were made, with wind and current directions, no correlation is found.

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