A BIOLOGICAL AND CHEMICAL SURVEY OF THE RED CEDAR RIVER IN THE VICINITY OF WILLIAMSTON, MICHIGAN

Thesis for the Degree of M. S.

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Morris Leroy Brehmer

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A BIOLOGICAL AND CHEMICAL SURVEY OF THE RED CEDAR RIVER IN THE VICINITY OF WILLIAMSTON, MICHIGAN

by

MORRIS LEROY BREHMER

AN ABSTRACT

Submitted to the School of Agriculture of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1956

Approved R. C. Ball by P. I. Tack

THESIS

Morris Leroy Brehmer

The Red Cedar River, once a productive smallmouth bass stream, is located within the recreational area of metropolitan Lansing. The aesthetic and recreational value of this stream has been reduced as the result of urbanization and increased agriculture with the resulting fast run-off, erosion, and siltation, and by the introduction of domestic and industrial pollution.

The results of the chemical analyses indicated the ammonia nitrogen content of the water increased from trace amounts upstream from the sewer outfalls to an average of 110 micrograms per liter 0.3 mile downstream from the outfalls. The content varied depending on the dilution rate and stream velocity. The data indicate the ammonia was quickly utilized or oxidized to the more stable nitrites and nitrates. The ammonia content of the water did not approach toxicity levels during the survey period.

The total phosphorus determinations indicate an average of 90 micrograms per liter in the river upstream from the City of Williamston. After the introduction of domestic pollution, the average total phosphorus content was 184 micrograms per liter. The additional phosphorus, through utilization by the aquatic flora or precipitation as complex phosphates, decreased downstream until at the station 6.6 miles from the sewer outfalls, the total phosphorus content approximated that found upstream from the City of Williamston.

The BOD of the water increased as the result of the introduction of the raw sewage and septic tank effluents, but the increase was not sufficient to reduce the dissolved oxygen content below 90% of saturation.

The results of the bottom fauna study indicate a reduction in the number of families of benthic forms at the stations 0.3 and 0.6 miles downstream from the sewer outfalls as compared to the station upstream from the outfalls. At the station 6.6 miles downstream, the mean number of families of benthic forms per square foot increased over the control station located upstream from Williamston. This would appear to indicate that stream fertilization resulting from the nutrients being released by the decomposition and mineralization of the organic material in the domestic sewage is increasing the complexity of the standing crop of the area.

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INTRODUCTION

Stream pollution has long been a subject of public interest. In historical times, before the knowledge of modern water purification was attained, it was essential to keep the streams used for drinking water as bacteriologically pure as possible. Many of the plagues and outbreaks of disease can be traced directly to an impure source of water supply. It has long been the practice to expect a pure supply of water to enter a community from upstream and then to discharge wastes into the stream downstream from the community without regard for others. As areas became more populated, it was necessary to enact laws to protect communities from the pollution of their neighbors upstream.

Pollution as defined by the dictionary is "The act of making foul or unclean; dirty." Stream pollution to the bacteriologist means the discharge of wastes into a river which increases the bacterial count to a degree that the water might be harmful to human welfare, or impossible to use for human consumption even after modern water treatment. The industrial engineer is interested in the quality of the water used by his plant from the standpoint of purification costs, or of mineral and chemical content that might foul condensers or be injurious to the product manufactured. The sanitary engineer considers stream pollution from the standpoint of water chemistry and water quality. The aquatic biologist is interested in stream pollution and its effects on the biodynamics of the vertebrate and invertebrate animal population. The sportsman may interpret stream pollution by its effects on the aesthetic value of the stream or on the fish population in the river. In reality, all of the above factors are interdependent and are methods of determining the presence of or measuring the degree of pollution.

The pollutants that are introduced into a stream and alter its characteristics are diverse and often selective in their biological effects. Probably the best understood are materials that require large amounts of oxygen in the process of stabilization or decomposition. These may lower the dissolved oxygen content of the water sufficiently to eliminate aquatic animals that have a high oxygen demand but, at the same time, not visably affect those forms with lower oxygen requirements. If the amount of oxygen demand exceeds the replacement by dilution, re-aeration, or photosynthetic action of plants, the stream becomes septic and biological life is confined to anaerobic or facultative forms of life.

Industrial wastes may pollute a stream by altering the pH of the water or by directly acting as a poison to aquatic fauna. Often these factors are interrelated. For example: Ammonia nitrogen is more toxic to fish in alkaline water whereas cyanide compounds are more toxic in acid waters.

Pollutants may also affect aquatic organisms by covering spawning areas or burying bottom dwelling invertebrates. Finely divided materials may stay in suspension for long periods and may affect fish life by mechanical clogging of the gill area.

Fresh-water aquatic animals are often very sensitive to saline solutions that may be emptied into a stream. Strong salt water solutions alter the osmotic equilibrium necessary for respiration and elimination.

Solutions of oil in water may also form a covering over the gills of aquatic fauna thus excluding oxygen from these organs.

Domestic pollution usually affects aquatic life primarily by depleting the oxygen supply of the water while industrial pollution may alter conditions by any of the methods mentioned previously or by a combination of several.

Many rivers and streams are alternately used to carry away the wastes from a city upstream and as a source of drinking water farther downstream. This practice would not be possible without the phenomenon of stream self-purification. This process involves many factors and the entire biota of a stream is affected.

Whipple (1948) suggests that the zones of pollution and self-purification of streams be classified as follows:

1. Clean water
2. Zone of degradation
3. Zone of active decomposition
4. Zone of recovery
5. Cleaner water.

Brinley (1942a), describing his work on the Ohio River, describes the various zones as:

1. Zone of active bacterial decomposition
2. Zone of intermediate bacterial decomposition
3. Fertile zone
4. Game fish zone
5. Biologically poor zone.

When raw sewage is emptied into a stream, the heavier particles immediately settle to the bottom. If the rate of flow is adequate, the dissolved oxygen level may be maintained and the area will contain an abundant population of flora and fauna. As decomposition progresses, the available dissolved oxygen is utilized in the stabilization process and the biota is confined to those forms with very high tolerance limits to adverse conditions, or if completely depleted, to facultative or anaerobic bacteria. In the process of anaerobic decomposition, carbon dioxide, methane, hydrogen sulfide, and ammonia nitrogen are released, which produce conditions toxic to most aquatic life.

As decomposition proceeds, oxygen reappears in the lower area of the zone as a result of the combination of plant photosynthesis, surface absorption, and decreased demand. This zone is referred to as the zone of recovery by Whipple or the zone of intermediate bacterial decomposition by Brinley. The number of bottom fauna organisms per unit area is usually high but the species composition limited. The phytoplankton population of the lower part of the zone increases due to the concentration of minerals released from the organic material in the process of decomposition.

For a short distance downstream from the zone of recovery the flora and fauna usually exceed that of the area above the source of pollution due to the dissolved nutrients in the water. The bottom fauna, requiring large amounts of organic material for existence, are usually replaced by those forms omnivorous or carnivorous in their feeding habits. As the dissolved nutrients are utilized by the phytoplankton, many of which are in turn utilized by the fauna of the stream, the environmental conditions are again similar to those upstream from the source of original pollution.

Due to the fact that the density and species of the phytoplankton varies with stream conditions, workers have attempted to correlate water quality and effects of pollution with variations in plankton populations. Brinley (1942b) pointed out in his studies on the White River in Indiana that under conditions of gross pollution the phytoplankton was almost entirely destroyed with the exception of Chlamydomonas sp. The difficulty with this type of study is that many streams have a very low initial phytoplankton population, and, as pointed out later by Brinley (1943), a sudden rain will often flush out plankton. Also high turbidity that often follows a rain will reduce the plankton population or on the other hand, high water may wash out a swamp or oxbow lake into the main stream and cause a sudden increase in the plankton.

Patrick (1954) describes the use of diatoms to evaluate stream conditions. Concerning the use of indicator organisms, she states, "Diatoms seem to be the most logical choice for the following reasons:

1. They need no special treatment for preservation because the cell wall, on which identification is based, is composed of silica.
2. The diatom flora of a normal stream is made up of a great many species and a great many specimens, thus the group lends itself to statistical treatment.
3. A great deal is known about the sensitivity of various species to certain ecological conditions.
4. Some species of this group are very sensitive to environmental changes; others vary all the way to great tolerance."

Other methods of detecting and evaluating pollution include a chemical analysis of the suspected effluents or stream below the source of the outfall. This type of study usually includes determinations for dissolved oxygen, free carbon dioxide, biochemical oxygen demand, ammonia nitrogen, suspended solids, etc. Patrick (1949), in her survey of the Conestoga River System, found that "-- of the twenty-three stations which were found to be more or less polluted from the biological standpoint, six showed no signs of pollution except that the carbon dioxide content was somewhat high. --- As to biochemical oxygen demand, ten of the surveys of stations which showed an upset condition from their biological analysis did not indicate such a situation from their BOD. Five biologically healthy stations had high BOD's. Indeed, one station had a BOD of 11.55 p.p.m., which was one of the highest found."

It is generally considered that chemical analyses alone will give a general picture of stream conditions, but will not determine the effects of the pollutants on biological life.

Shelford (1918), Richardson (1921 and 1925) and Baker (1926) in their work on the Illinois streams and bottomland lakes were among the first workers to describe the use of aquatic invertebrate animals to detect and measure stream pollution. The invertebrate bottom fauna are generally accepted as being the most satisfactory indicators of pollution as they are relatively immotile and must be able to survive adverse conditions or they must perish. Many of the insect larvae have life cycles that extend for more than a year; therefore, adverse physical and chemical conditions prior to the sampling period can be detected. Typical insects are the nymphs of the burrowing mayfly (Hexagenia sp.) with a life cycle of two years and the larvae of the dobson fly (Corydalis sp.) with an aquatic larval cycle extending through three years.

Several papers have been published concerning the relative tolerance of the aquatic bottom dwelling invertebrates. Beck (1954), in studies of Florida streams, found many species that were typical of clean waters only, while others are able to survive adverse conditions. Gaufin and Tarzwell (1952) concluded that a single species of organism such as _Tubifex tubifex_ or _Chironomus tentans_ cannot be used safely as indicators of pollution unless their relative abundance is considered. The United States Public Health Service Environmental Health Center located in Cincinnati, Ohio, published a mimeographed form in which the aquatic invertebrates were classified according to their tolerance to adverse conditions as pollutional, facultative or clean water organisms. Wimmer and Surber[1] and others have used this classification in describing stream conditions graphically with pie graphs.

A review of the literature concerning index organisms indicates that seldom is an entire genus characteristic of pollutional conditions. Therefore, the laborious and time-consuming task of identifying the organisms to species is necessary for their use. In addition, the physiological tolerances or median tolerance limits have been evaluated for only a few species.

In this study the benthic organisms shall be identified to family groups, evaluated statistically and presented graphically to show differences in ecological conditions at the sampling stations. If

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[1]Bottom Fauna Studies in Pollution Surveys and Interpretation of the Data. Presented, Fourteenth Midwest Wildlife Conference, Des Moines, Iowa, December 18, 1952. (Mimeographed)

this method for evaluating stream conditions under the influence of sub-lethal pollution is successful, the method should be widely applicable to studies involving gross pollution.

Whipple (1948) and others have demonstrated the relative densities and biological associations of organisms associated with various degrees of pollution. It is recognized that a population of bottom dwelling invertebrates may be completely eliminated under conditions of gross pollution, whereas a zone downstream from the area of active decomposition may be supporting a population greater than otherwise occurs in the stream. This results from the higher concentration of phosphorus, nitrogen and other nutrients released during the stabilization of organic material. As the excess nutrients are utilized by the aquatic flora, which are in turn converted to aquatic animal life, stream conditions approach normal and benthic conditions again are typical of those above the source of pollution.

Very few population centers in the United States are located far from a stream or river. Whereas the original reason for location on a waterway may have been for economics, the recreational value of such a location today is unlimited. Unfortunately, many of the nation's streams that were once capable of providing swimming, fishing and boating facilities have had their aesthetic and recreational value reduced by siltation and pollution.

There are many streams that could be recovered for recreational use by the installation of sewage treatment plants and efficient agricultural practices in the drainage area. Although it appears that often sewage problems are being resolved primarily through the efforts of public health agencies, the ultimate effect is of great benefit to the public from the recreational standpoint.

The Red Cedar River and its tributaries are within the recreational area of metropolitan Lansing and have considerable potential for boating and fishing. Originally considered an excellent smallmouth bass stream, it is typical of many waterways required to carry increasing amounts of silt, and industrial and domestic wastes. In view of its location in an area where urbanization is encroaching on agricultural land, the need for clean water will become more critical as the population of metropolitan Lansing increases.

This study was undertaken in the vicinity of Williamston, Michigan, the source of domestic pollution approximately 15 miles upstream from East Lansing. Sub-lethal amounts of raw sewage and septic tank effluents that enter the stream at this point reduce the aesthetic value and may restrict the aquatic life. This area was chosen because of its proximity to the population centers of Lansing and East Lansing, and because the situation is typical of many warm water streams through the country.

METHODOLOGY

METHODOLOGY

Six sampling stations were designated on the Red Cedar River in the vicinity of Williamston.

Station I was located 30 yards upstream from the Michigan Highway 47 Bridge in Section 33, Township 4 North, Range 2 East of the Michigan Meridian.

The stream width was approximately 45 feet and the maximum depth was 30 inches. The bottom material at this station was composed of a sand bar along the north bank and fine to medium-sized gravel over the remaining area.

Station II was located immediately above the Williamston Reservoir, upstream from the Deitz Road Bridge in Section 32, Township 4 North, Range 2 East of the Michigan Meridian. The stream width was approximately 50 feet with a depth of about 4 feet. The bottom material was composed of large rocks, thus quantitative bottom sampling was impossible.

Total phosphorus, ammonia nitrogen and biochemical oxygen demand determinations were made at this station to ascertain whether these factors increased as a result of inflowing water from the Doan Creek drainage.

Station III, located in Section 35, Township 4 North, Range 2 East of the Michigan Meridian, was approximately 0.3 mile below the Williamston Dam. This sampling area was downstream from six sewer outfalls which delivered a total estimated flow of raw sewage and septic tank effluents of 100 gallons per minute.

The bottom material was composed of gravel and small rocks. A definite sewage odor was apparent and bits of domestic sewage and toilet tissue could be observed in suspension. Luxuriant growths of Vallisneria americana occurred throughout this area of the stream. The river was approximately 50 feet in width and had an average depth of 18 inches.

Station IV, also located in Section 35, was approximately 0.6 mile below the Williamston Dam and below the confluence with the Deer Creek drainage. This area is located immediately below the site of the new sewage treatment plant.

The bottom material was composed of fine gravel and small rocks which produced no surface agitation of the water. The average depth was approximately 18 inches and the stream width was 40 feet. No evidence of domestic waste was observed in this area.

Station V, located in Section 27, Township 4 North, Range 1 East of the Michigan Meridian, immediately above the Zimmer Road Bridge, was designated a chemical analysis station to determine the changes in water quality from the previous sampling area. The bottom material was composed of fine sand and large rocks, making an accurate quantitative sampling of the bottom invertebrate fauna impossible. This area is 3.6 miles downstream from the Williamston Dam and the sources of pollution.

Station VI, 6.6 miles downstream from the Williamston Dam, is in Section 25, Township 4 North, Range 1 West of the Michigan Meridian, 30 yards above the U. S. Route 16 Bridge.

The bottom material is composed of medium-sized gravel and small rocks with an occasional growth of Vallisneria americana. The average depth was approximately 18 inches and the width was 60 feet. No surface agitation was apparent as a result of the bottom type.

Water samples for chemical analyses were collected weekly from April 30, 1955 to June 10, 1955. All samples were collected according to prescribed methods and those intended for ammonia nitrogen and biochemical oxygen demand (BOD) determinations were cooled to approximately 5° C. in a portable ice chest and analyses were made as soon as feasible. The ammonia nitrogen analyses were made within five hours. The BOD samples were adjusted to 20° C., seeded with 1 milliliter of raw sewage that had undergone a 24-hour incubation period, and, if necessary, diluted with phosphate buffered and fortified water, and placed in the 20° C. incubator. The methods for BOD determinations are described in "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes" (1955).

One hundred milliliter samples were used in the ammonia nitrogen determinations. The samples were cleared of plankton and foreign material by the addition of 1 milliliter of 50 percent sodium hydroxide solution and 1 milliliter of 10 percent zinc sulfate solution. Fifty milliliters of the cleared sample was treated with 0.5 milliliters of 50 percent potassium-sodium tartrate solution to prevent clouding and 1 milliliter of A.P.H.A. Nessler's Solution according to methods described by Ellis, Westfall, and Ellis (1948). Color values were determined with a Klett-Summerson Colorimeter according to methods described by Snell and Snell (1949) and the ammonia nitrogen content was calculated from a graph prepared by the analysis of known standards.

Total phosphorus, or all phosphorus obtained by the digestion of a non-filtered sample, determinations were made according to methods described by Ellis, Westfall, and Ellis (1948).

Duplicate 100 milliliter samples were treated first with 0.5 milliliters of concentrated sulfuric acid, evaporated to approximately 5 milliliters, and then evaporated to white fumes after the addition of 3 milliliters of concentrated nitric acid. The samples were next treated with 3 milliliters of concentrated hydrochloric acid and 10 milliliters of distilled water and re-evaporated to white fumes. The sample was then made up to 100 milliliters with distilled water, treated with stannous chloride and acidified ammonium molybdate reagent, and the color intensity read in a Klett-Summerson Colorimeter. The color intensity reading was compared with a graph prepared by the analysis of solutions of known concentrations, and the amount of total phosphorus present in the sample computed.

The bottom material was classified according to composition for the purpose of obtaining aquatic invertebrate fauna samples at the various stations from areas of comparable ecological conditions. Areas of bottom containing gravel or small rocks that produced no turbulence on the water surface were designated as Stratum I. Where surface agitation was produced by the flow of water over larger gravel and rocks, the bottom type was designated as Stratum II. Stratum III was the type applied to bottom materials consisting of fine sand of such a consistency as to prevent the rapid flow of water through a Number 30 Standard Sieve. This habitat is usually very infertile in that the sand is continually shifting with the current. Bottom material consisting of mud or silt was designated as Stratum IV.

After a thorough reconnaissance of the stream area above and below the Williamston area, it was found that only Strata I and III, or a combination of the two, could be found at all stations. It was decided that samples taken with the square foot bottom sampler of the type described in detail by Surber (1937), in water 12 to 18 inches in depth from Stratum I would result in the most accurate data from more similar ecological conditions.

All bottom samples were taken at random within an area the width of the stream at the location and 50 feet in length. For the purpose of sampling, a line marked at 2 foot intervals was stretched across the stream at the upper limit of the sampling area. Another line, similarly marked, was attached to the cross line with a snap. The predetermined sampling area was found by moving the snap to the marked point on the cross line, walking on the shore downstream from the area to prevent dislodging of the bottom fauna, and then placing the forward edge of the brass frame of the sampler at the second co-ordinate of the perpendicular line. The bottom material was thoroughly worked over to a depth of approximately 3 inches and the organisms thus dislodged were carried by the current into the bag. All samples taken, except those at Station III where raw sewage presented a danger of infection by pathogenic organisms and the samples were preserved in 10 percent formalin, were refrigerated to prevent cannibalism or disintegration and the bottom fauna were picked from the algae and debris while alive.

The bottom organisms collected were preserved in 70 percent alcohol until identification could be made.

STREAM CHARACTERISTICS

STREAM CHARACTERISTICS

The Red Cedar River is a tributary stream of the Grand River system, draining a portion of the central part of the Lower Peninsula of Michigan. The Cedar River, as it is often referred to, originates as the outflow from Cedar Lake, located in Marion Township, Livingston County, in Sections 28 and 29, Township 1 North, Range 3 East of the Michigan Meridian.

The headwater drainage is principally marsh or wet land areas and in many regions the stream has been channeled and straightened for the purpose of agricultural land reclamation. The Red Cedar River flows through or near the communities of Fowlerville, Webberville, Williamston, and Okemos before entering the East Lansing and Lansing areas and the confluence with the Grand River (Figure 1). The total length of the main channel is 49.25 miles.

The Red Cedar River has a tributary system consisting of several small creeks that drain an area approximately 11 miles on either side of the channel and one large stream, Sycamore Creek, for a total drainage area of approximately 472 square miles. The topography of the drainage basin is principally rolling land with pasture land and small grain farming practice predominant. The agricultural practices and the marsh land drainage normally prevent sudden run-off of rains that result in the stream carrying excessively heavy silt loads. The highest annual water levels and occasionally serious floods usually occur in the spring of the year while the watershed area is still frozen and the snow and ice are melting. The period of lowest flow is usually in the fall of the year before the winter rains and snows.

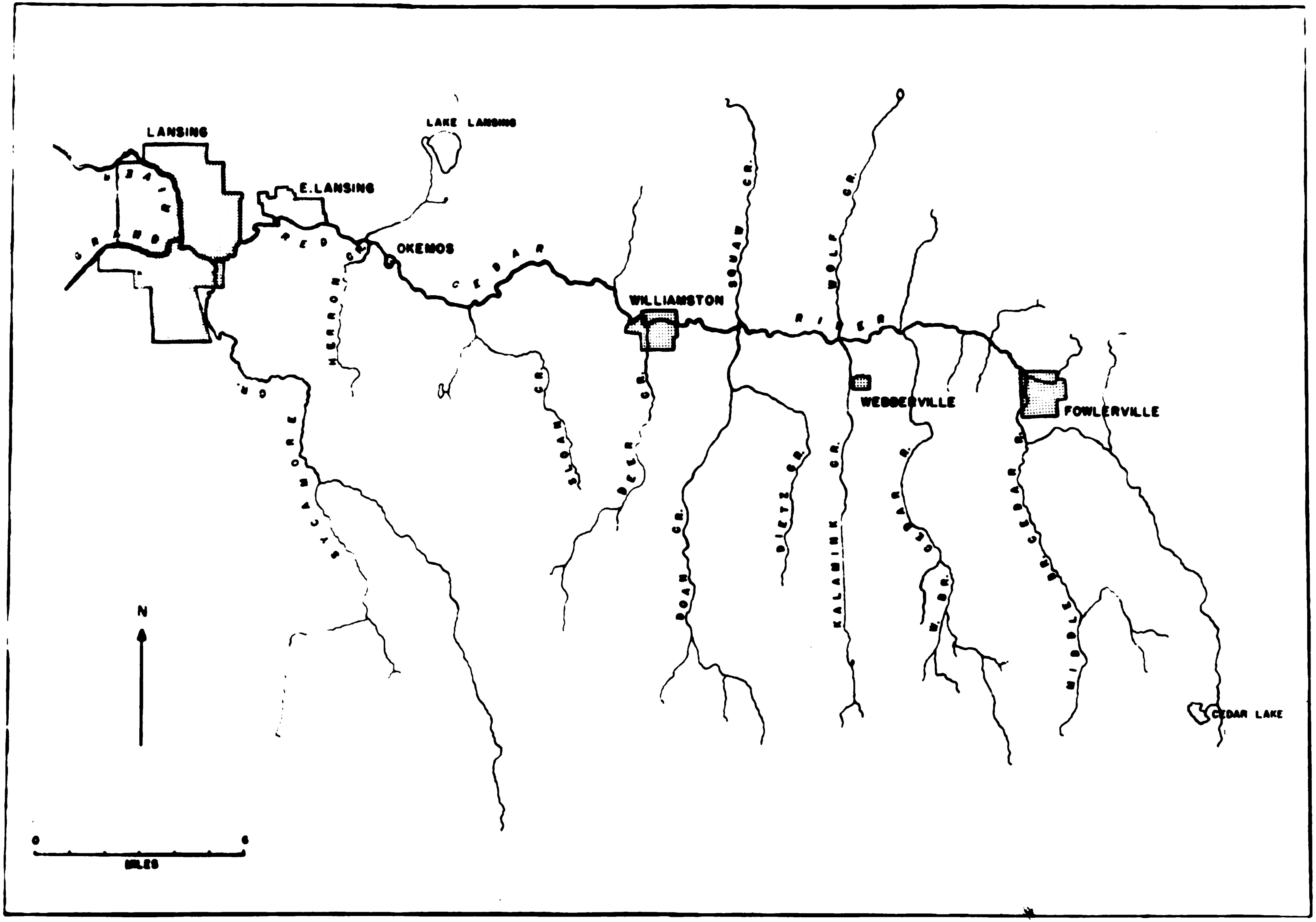

Figure I.- Red Cedar River and Principle Tributaries

Three dams, forming artificial impoundments on the Red Cedar River, are located at Williamston, Okemos, and East Lansing. The Williamston impoundment was created in 1840 for the purpose of running a sawmill. The original dam has been replaced with a new type creating a 13 foot working-head of water. A constant flow generator is still in use at this location providing power for a private refrigeration and frozen food plant. The pool created by the Williamston Dam is narrow, in most cases flooding only the land immediately adjacent to the main channel, and is approximately 2 miles in length.

The original dam in Okemos that was used to provide water power to operate a grist mill has been replaced with a small stone ballast type that creates a small pool for recreational purposes. The East Lansing dam, located within the campus of Michigan State University, is constructed of concrete and maintains a constant depth of water for recreational and aesthetic purposes and power plant supply.

The bottom material of the Red Cedar River consists of fine sand in the upper regions to rocks and gravel with small areas containing silt deposition in the middle and lower stretches. In general, the bottom gradient is even with long pools rarely exceeding 6 feet in depth divided by shallow riffle areas. The profile of the stream bottom (Figure 2) indicates the gradient of the bottom is relatively gradual from its source at Cedar Lake at an elevation of 934 feet above sea level to 817 feet at the confluence with the Grand River, for an average fall of 2.5 feet per mile. The shoreline slope is generally gradual with very little erosion or cutting above the normal water line.

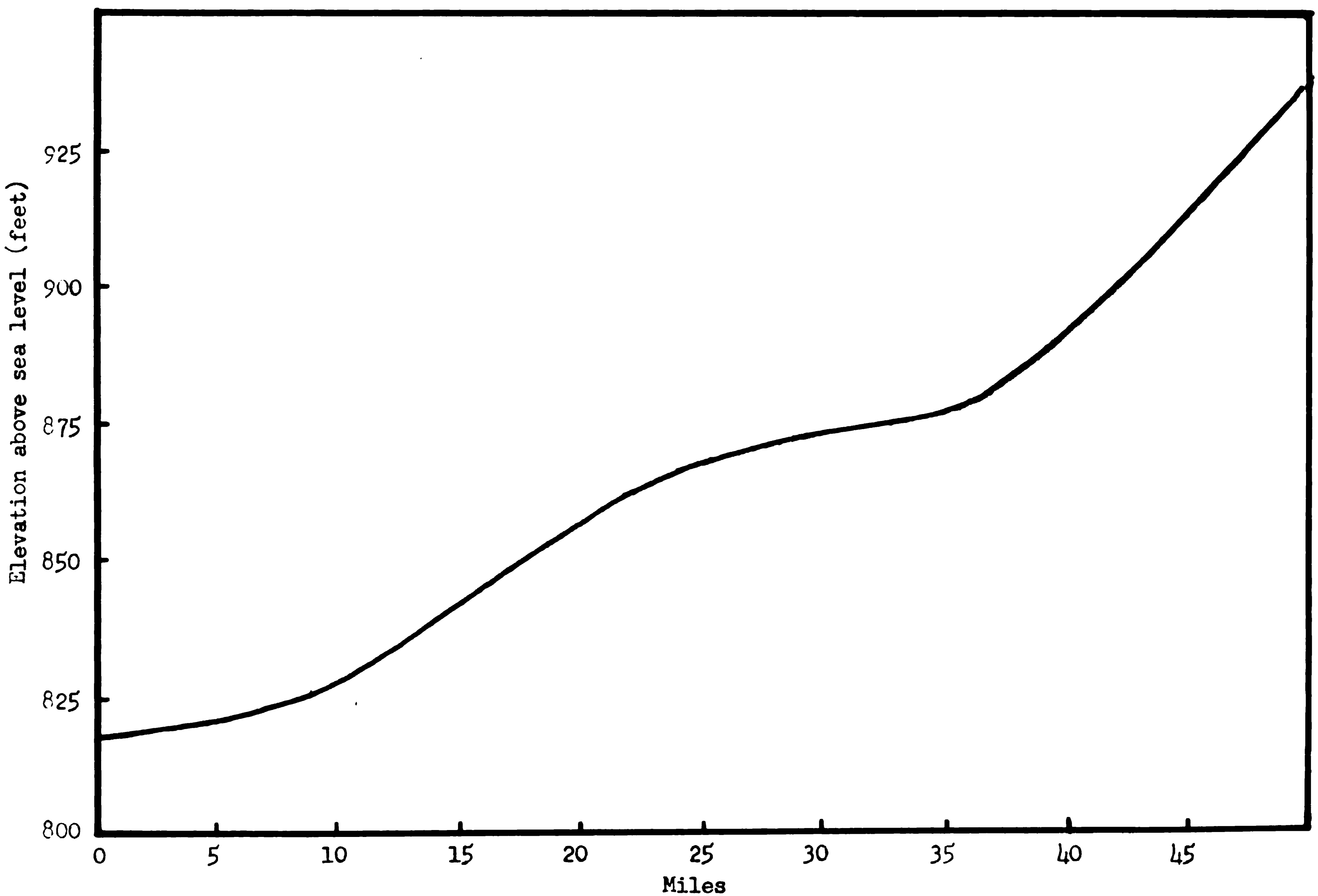

Fig. 2. Profile of Red Cedar River (Data from United States Geological Survey Topographic Maps).

A gauging station is maintained by the United States Geological Survey in East Lansing, seven miles upstream from the mouth. This station is 6 miles upstream from the Sycamore Creek confluence and the data represent a drainage area of 355 square miles.

The maximum discharge recorded at the East Lansing station during the 20-year period from 1931 to 1951 occurred during April, 1946, when a flow of 5,510 cubic feet per second was measured. The minimum flow recorded during the same period was 3 cubic feet per second on July 31, 1931.

The amount of precipitation on the watershed area of the Red Cedar River was below average during the period of study. The data given in Table I, based on information received from the U. S. Geological Survey Office in Lansing, Michigan, represent stream conditions from January 1 to May 31, 1955.

TABLE I

RED CEDAR RIVER FLOW DATA
FOR THE PERIOD JANUARY 1 - MAY 31, 1955
EAST LANSING U. S. GEOLOGICAL GAUGING STATION

	January	February	March	April	May
Total Flow (Second-feet)	9,704.	8,794.	17,725.	6,191.	2,937.
Mean Flow (Second-feet)	313.	314.	572.	206.	94.7
Second-feet Per Square Mile	0.882	0.885	1.61	0.580	0.267
Run-off in Inches	1.02	0.92	1.86	0.65	0.31
Maximum Flow (Second-feet)	1,080.	1,230.	1,320.	363.	139.
Minimum Flow (Second-feet)	89.	83.	314.	139.	66.

CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF THE RED CEDAR RIVER

CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF THE RED CEDAR RIVER

The Red Cedar River is a warm-water stream having chemical and biological characteristics generally associated with such bodies of water.

The river is slightly alkaline with the pH of the water ranging between 7.2 and 7.8. The water is highly buffered, with the methyl orange alkalinity varying from 100 to 300 p.p.m. No phenolphthalein alkalinity was observed during the survey period at the East Lansing Gauging Station in the spring of 1951 or 1955 (Tables II and III). The free carbon dioxide content of the water ranged between 4 and 7 p.p.m. during the survey period. This higher value is the result of low photosynthetic action during the late winter months and the high solubility constant in water at low temperatures.

Periodic afternoon dissolved oxygen determinations at the sampling station locations in the Williamston area revealed that the oxygen content of the water midway between the surface and the bottom ranged above 90 percent of saturation. The photosynthetic action of the stream flora and the agitation incurred as the water flows over the Williamston Dam and over shallow areas more than compensated for the demand of the organic materials in the process of stabilization. During the survey period the water temperature increased from 12° C. to 22° C.

TABLE II

PHYSICAL AND CHEMICAL CHARACTERISTICS
OF THE RED CEDAR RIVER AT THE EAST LANSING GAUGING STATION
FEBRUARY-MAY, 1951

Date	Mean flow	Water temperature	Dissolved oxygen	Carbon dioxide	Alkalinity: Phenolphthalein	Alkalinity: Methyl orange	pH
February 20	1,840	1.0°	12.8 ppm	6. ppm	0	90	7.2
February 22	1,660	2.0°	12.2	5.	0	120	7.2
February 27	797	3.5°	11.8	7.	0	178	7.4
March 2	616	3.5°	--	5.	0	210	7.6
March 6	744	4.5°	8.2	5.	0	195	7.4
March 8	559	6.5°	--	3.	0	200	7.6
March 13	301	3.5°	14.3	4.	0	230	7.8
April 3	851	3.5°	12.0	4.	0	195	7.6
April 5	661	4.5°	12.2	4.	0	220	7.2
April 7	499	5.0°	12.0	4.	0	190	7.2
April 10	744	9.0°	10.2	4.	0	210	---
April 14	467	7.0°	10.0	4.	0	220	7.8
April 17	450	5.0°	12.2	6.	0	210	7.6
April 19	368	5.0°	9.8	5.	0	240	---
April 24	616	8.5°	10.7	4.	0	210	7.6
April 28	636	14.0°	7.4	4.	0	225	7.6
May 1	508	18.0°	8.6	4.	0	250	7.6
May 8	242	16.0°	9.0	5.	0	255	7.6
May 15	352	15.5°	7.2	5.	0	240	7.6
May 31	157	19.0°	7.0	4.	0	285	---

TABLE III

PHYSICAL AND CHEMICAL CHARACTERISTICS
OF THE RED CEDAR RIVER AT THE EAST LANSING GAUGING STATION
FEBRUARY-MARCH, 1955

Date	Mean flow	Water temperature	Carbon dioxide	Alkalinity		pH
				Phenolphthalein	Methyl orange	
February 2	86	0.0°	6.0 ppm	0	285	7.52
February 4	86	0.0°	6.0	0	287	7.58
February 7	83	0.0°	7.0	0	278	7.58
February 9	83	0.0°	6.0	0	280	7.72
February 11	89	0.0°	7.0	0	250	7.85
February 14	97	0.0°	5.0	0	275	7.70
February 16	92	0.0°	---	0	260	--
February 18	92	0.0°	---	0	277	7.72
February 21	770	----	4.0	0	92	7.50
February 23	1,140	0.0°	5.0	0	84	7.48
February 25	646	0.0°	6.0	0	103	7.37
February 28	1,050	0.0°	4.5	0	79	7.6
March 2	824	0.0°	4.5	0	103	7.3
March 4	1,230	0.0°	5.5	0	92	7.35
March 7	666	----	3.2	0	117	7.6
March 9	421	----	3.0	-	148	7.7
March 11	473	6.5°	---	-	---	--

Total Phosphorus

The phosphorus content of a stream is primarily dependent upon the leaching action of natural phosphates in the soil, on the erosion of inorganic fertilizers applied to agricultural lands, and on the decomposition of plant material. The natural phosphorus content of streams varies considerably depending on the water source. Grzenda (1956) reports the total phosphorus content of the West Branch of the Sturgeon River, a spring-fed stream, to consistently be less than 15 micrograms per liter. This is extremely low when compared to the 9.4-16.6 p.p.m. maxima reported for the Missouri River between Sioux City, Iowa and Council Bluffs, Iowa by Damann (1951). In polluted streams, the total phosphorus content is increased by nutrients released during the decomposition of organic material introduced into the stream. In recent years, the increased use of synthetic household detergents containing complex phosphate compounds has greatly added to the phosphorus content of raw sewage and treated effluents, thereby increasing the content in streams receiving these discharges.

Total phosphorus determinations were made at Stations I and II, located above the City of Williamston and at Stations III, IV, V, and VI below the city.

Although the results of the total phosphorus determinations were variable on two of the testing periods, the data indicate a definite increase in total phosphorus in the stations located below the Williamston sewage outfalls (Table 4). The discrepancies in the total phosphorus determinations undoubtedly occurred as a result of the method of

TABLE IV

TOTAL PHOSPHORUS CONTENT IN MICROGRAMS PER LITER
OF THE RED CEDAR RIVER
IN THE VICINITY OF WILLIAMSTON, MICHIGAN

Date	Station						
	I	II		III	IV	V	VI
April 30, 1955	37	28		52	33	27	31
May 10, 1955	88	33		54	67	48	34
Method of transferring samples				changed.			
May 20, 1955	76	75	Sewer outfalls	182	120	88	70
May 27, 1955	76	60		156	122	82	60
June 3, 1955	87	98		87[1]	172	115	76
June 10, 1955	130	127		214	194	135	123

[1]Difficulty experienced during digestion of sample.

transferring the water samples from the original collection bottles to the flasks used in the digestion and addition of the reagents. The method of pipetting the sample to the flask was discontinued after erratic results were observed and the remaining transfers were made by measuring in a graduated cylinder after violently shaking the original sample bottle.

The results of the total phosphorus determinations indicate an increase after the addition of the raw sewage and septic tank effluent. The highest total phosphorus values were noted at Station III, 0.3 mile downstream from the sewer outfalls. The phosphorus content of the water decreased as the stream flow progressed downstream with the deposition of suspended solids on the stream bottom and the utilization of the nutrients by the phytoplankton and higher aquatic plants.

The phosphorus content at Station VI is slightly less than that at the stations upstream from the City of Williamston. This phenomenon might possibly result from an increased phytoplankton and rooted aquatic flora population below the outfall utilizing the available phosphorus to such a degree that a lower dissolved phosphorus content occurs farther downstream. Flaigg and Reid (1954) reported that higher concentrations of nitrogen compounds will tend to accelerate the growth of algae so that it is concentrated in a shorter length of stream; therefore, it is likely that the increased population resulting from the ammonia nitrogen and other nitrogen compounds contained in domestic pollution would also tend to reduce the phosphorus content of a stream at the lower stations.

In summary, the increase in the total phosphorus content of the Red Cedar River below the City of Williamston is significant, but not as high as might be expected in an area receiving raw sewage and septic tank effluent. In explanation, the mean flow of the river during the month of May, 1955, was 94.7 second-feet. The estimated discharge of sewage and septic tank effluent was 0.2 second-feet. This dilution factor of 1:4700 was sufficient to minimize the effects of the pollution.

Ammonia Nitrogen

Ammonia nitrogen or ammonium salts, the first stage in the mineralization of organic nitrogen, is present in natural waters in low concentrations as a result of the decomposition of plant materials. The ammonia nitrogen content of a stream is increased significantly by the introduction of domestic or organic pollution due to its high organic nitrogen content. In the highly polluted Blackstone River, the Massachusetts State Board of Health (1913) reported 11.7 p.p.m. of ammonia.

The ammonia nitrogen content of the water in the Red Cedar River was determined weekly during the latter part of May and the first two weeks of June, 1955. The results of the analyses as given in Table V indicate that under normal conditions only a trace of ammonia nitrogen is found in the Red Cedar River. The highest ammonia nitrogen content was found at Station III, located 0.3 mile below the sewer outfalls. The highest value of 147 micrograms per liter found on May 27, 1955, is well below the toxicity level for this compound (Ellis, 1937). The free ammonia was rapidly lost by oxidation or by direct utilization by the aquatic flora as indicated by a reduction of 50 percent or more only 0.3 mile downstream from Station III.

In all samples, except those taken on May 27, 1955, after a heavy rainfall, the ammonia nitrogen content was reduced to a trace at Station V.

TABLE V

AMMONIA NITROGEN CONTENT, EXPRESSED IN MICROGRAMS PER LITER, OF THE RED CEDAR RIVER AT THE SIX SAMPLING STATIONS IN THE VICINITY OF WILLIAMSTON, MICHIGAN

Date	Station						
	I	II		III	IV	V	VI
May 20, 1955	t[1]	t	Sewer outfalls	30	t	t	t
May 27, 1955	35	33		147	70	120	33
June 3, 1955	t	t		100	25	t	t
June 10, 1955	t	t		162	77	t	t

[1]t - trace amount

Biochemical Oxygen Demand

The biochemical oxygen demand of water is defined as the amount of oxygen, expressed in p.p.m., required for the stabilization of organic material during a five day incubation period at 20° C. Although this figure represents only 68 percent of the oxygen required for complete stabilization, the results are more typical of stream conditions in that only the dissolved oxygen in the sample is utilized without affecting the intermolecular oxygen exchange with the nitrites, nitrates, and sulfates.

The author (unpublished reports) has found natural BOD's ranging from less than 0.5 p.p.m. in a clear stream free from suspended materials to 9.8 p.p.m. in a stream feeding from a plankton-rich lake. The introduction of raw sewage having a BOD of approximately 300 p.p.m. affects the stream according to the dilution rate, rate of sedimentation of solids, natural aeration, and water temperature.

The results of the biochemical oxygen demand determinations on the Red Cedar River indicate a definite increase below the City of Williamston (Table VI). This increased oxygen demand of from approximately 2 p.p.m. above the sewer outfalls to from 4.6 to 8.8 p.p.m. below is due to a greater amount of suspended and dissolved organic material carried by the stream. On May 27, 1955, the highest B.O.D. value of the survey was recorded. Heavy rains had just fallen on the watershed area and the increased stream velocity kept the solid material in suspension.

At no time during the survey did the B.O.D. seriously reduce the dissolved oxygen content of the water. Reaeration by dilution, photosynthetic action of the aquatic flora, and agitation was sufficient to compensate for the oxygen demand of the organic material in the process of stabilization.

TABLE VI

BIOCHEMICAL OXYGEN DEMAND OF THE RED CEDAR RIVER
IN THE VICINITY OF WILLIAMSTON, MICHIGAN
AS EXPRESSED IN PARTS PER MILLION

Date	Station						
	I	II		III	IV	V	VI
May 20, 1955	1.8	---	Sewer outfalls	6.8	---	2.3	1.4
May 27, 1955	2.9	---		8.8	5.6	3.2	2.1
June 3, 1955	2.1	1.3		4.6	4.4	1.6	0.6

Bottom Fauna

The invertebrate bottom fauna of the Red Cedar River was sampled at stations located above and below the City of Williamston in an attempt to obtain a correlation between ecological conditions as indicated by the chemical analysis and the invertebrate population present. All samples were taken with the square foot Surber sampler from Stratum I in water 18 inches or less in depth.

The bottom fauna of the Red Cedar River presents a complex biota with 33 families of organisms represented in the samples (Table VII). With the exception of the ubiquitous Tendipedidae larvae, the taxonomic composition, and the relative number of individuals representing each family varied considerably from station to station.

The phylum Mollusca was represented at all stations sampled. The family Lymnaeidae or the pond snails were found at all stations except VI. This species, as the common name implies, is usually found in lakes, or streams of low velocity. The families Sphaeridae and Unionidae were collected at all stations with the sphaerids the most abundant at Station III, located 0.3 mile below the sewage outfalls. Only two individuals of the family Ancylidae or limpet snails were collected and these were found at Station IV.

One turbellarian or flatworm was collected during the sampling period and this was found at Station IV.

The Oligochaeta or tubificid worms are generally recognized as the most tolerant of all aquatic organisms. These Annelida or sludge

TABLE VII

PERCENT FREQUENCY OF OCCURRENCE IN THE SAMPLES AND AVERAGE NUMBER PER SAMPLE OF BOTTOM ORGANISMS RECORDED FROM STRATUM I AT THE SAMPLING STATIONS IN THE VICINITY OF WILLIAMSTON

	Station I Stratum I		Station III Stratum I		Station IV Stratum I		Station VI Stratum I	
	% Frequency in samples	Av. No.	% Frequency in samples	Av. No.	% Frequency in samples	Av. No.	% Frequency in samples	Av. No.
Mollusca								
Lymnaeidae	20	*	26.7	*	45.5	*		
Sphaeridae	80	4.4	66.7	7.3	45.5	*	88.9	3.4
Unionidae	20	*	13.3	*	9.1	*	66.7	2.0
Ancylidae					18.2	*	11.1	*
Platyhelminthes								
Turbellaria					9.1	*		
Annelida								
Oligochaeta	100	3.4	80.0	19.8	90.1	5.1	33.3	*
Hirudinae			6.7	*			11.1	*
Amphipoda								
Talitridae	20	*	6.7	*	18.2	*	88.9	2.3
Gammaridae							11.1	*
Arachnoidea								
Hydracarina					18.2	*		
Plecoptera								
Perlidae	80	1.4			27.3	*	100.0	5.1

Ephemeroptera								
Caenidae			20.0	*	27.3	*	22.3	*
Ephemeridae							88.9	3.0
Heptageniidae	80	1.6	6.7	*	18.2	*	88.9	3.4
Baetidae	60	1.2	33.3	*	54.6	1.4	100.0	11.4
Hemiptera								
Notonectidae							11.1	*
Corixidae					9.1	*		
Trichoptera								
Hydroptilidae	20	*	6.7	*	9.1	*	44.4	*
Hydropsychidae			26.7	*	27.3	*	33.3	*
Psychomyiidae					9.1	*	100.0	3.0
Leptoceridae	60	2.2			9.1	*	66.7	3.1
Coleoptera								
Elmidae	100	10.2	86.7	5.6	72.8	2.2	77.8	2.8
Dytiscidae	40	*	6.7	*				
Halipidae			6.7	*				
Curculionidae	20	*						
Diptera								
Tipulidae	40	*			18.2	*	33.3	*
Simuliidae			60.0	3.3	45.5	1.2	55.6	4.9
Tendipedidae	100	92.4	100.0	29.5	100.0	27.3	100.0	19.3
Rhagionidae	20	*						
Heleidae	80	*	46.7	1.1	45.5	*	11.1	*
Ephyridae	40	*					33.3	*
Culicidae			6.7	*				
Odonata								
Coenagrionidae							11.1	*

*Less than one individual/sq. ft.

worms appear to prefer a habitat rich in organic material and conditions bordering on septicity are not a deterrent to their existance (Ellis, 1937). This organism was found at all stations with the largest number appearing at Stations III and IV.

The class Crustaceae was represented by the amphipod, Hyallela azteca of the family Talitridae, and by a member of the family Gammaridae. The greatest number of these organisms were found at Station VI although Hyallela azteca appeared in the samples from all stations. An occasional crayfish was collected in the samples, but due to the ineffectiveness of the sampling method on organisms so motile, they were not recorded in the data.

Other non-insect aquatic invertebrates found in the samples in small numbers included leeches of the family Hirudinae and water mites or Hydracarina.

The aquatic Diptera were the most prevalent of the insects found in the samples. Members of the family Tendipedidae or true midge larvae were found in all samples at all of the sampling stations. This family contains many genera and several hundred species and their habitat preference and tolerance to adverse conditions is extremely varied. The largest number of these organisms was found at Station I where the mean number per square foot of the bottom sampled was 92. Other aquatic Diptera families represented were Tipulidae, Simuliidae, Rhagionidae, Heleidae, Ephyridae, and Culicidae. The larvae or pupae of the Tipulidae or crane flies were found at all stations except III but the culicid or mosquito larvae were found only at this station.

Only one family of the Plecoptera or "stoneflies" was present in the sampling areas. This was Perlidae with *Perlesta placida* being the most common. This organism was found at all stations except III.

Ephemeropteran or mayfly nymphs of either the families Caenidae, Ephemeridae, Heptageniidae, or Baetidae were represented at all of the stations sampled, but only the Heptageniidae were found at all locations. The ecological requirements of this group of insects are quite diverse with the members of certain families found in silt or soft mud and others found only in fast moving water.

Four families of the Trichoptera or "stonefly" group were found during the sampling on the Red Cedar River. Of these families, Hydroptilidae, Hydropsychidae, Psychomyiidae, and Leptoceridae, all were found at Stations IV and VI, but the greatest total number of the order was found at Stations I and VI. Members of this group are generally considered as having a narrow range of tolerance and are not found in waters subjected to pollution.

Gaufin and Tarzwell (1952) report that on their work on Lytle Creek no members of the Ephemeroptera or Trichoptera were found in the septic zone and only *Caenis sp.* was found in the zone of recovery.

The adult members of the families Notonectidae and Corixidae of the Order Hemiptera are active swimmers; therefore, they seldom are collected in a sampling device such as a Surber net. Two adult members of this group were collected at Stations IV and VI, but these probably do not represent the actual population present.

One damsel fly nymph of the family Coenagrionidae, Order Odonata, was found during the sampling, this being at Station VI. These organisms are usually found in habitats consisting of soft mud or natural organic material such as decaying leaves or plant material.

The aquatic Coleoptera or beetles were represented by four families, the Elmidae, Dytiscidae, Haliplidae, and Curculionidae. The members of the family Elmidae, both adults and larvae, were found at all stations, but the largest number was found at Station III. This would suggest that this group prefers conditions rich in suspended organic material and a thin deposition on the bottom. Representatives of the other families were found only at Stations I and III.

A great variation in the total number of organisms per square foot was noted at all sampling areas. These differences in carrying capacity of areas that appear very similar are often due to small pockets of organic matter lodged in a crevice between rocks or the presence of algae capable of supporting a large number of organisms. For this reason, a larger number of samples than possible under most conditions would be necessary to estimate true differences in populations at the 95% confidence level. In this study, the number of organisms shall be considered and presented but the statistical evaluations shall be based on the taxonomic composition of the population. The mean and associated variation will be presented according to the standard form $\bar{X} \pm s$.

Station I, located upstream from the City of Williamston, contained a total of 18 families of bottom fauna with 12 families represented in 30 percent or more of the samples taken. The mean number per square foot was 9.8 with a standard error of 0.35. A graphic comparison of the mean number of families, plus-and-minus two standard errors, found at the sampling stations located above and below the sewer outfalls is given in Figure 3.

This station had the greatest variation in total number of organisms per square foot of the stations sampled. The highest number found was 216 and the lowest 78. The mean was 120 ± 57.3. Many of the rocks on the bottom were covered with periphyton, thus presenting conditions favorable to large populations of midge larvae.

The bottom faunal population at Station I shall be considered characteristic for the midsection of the Red Cedar River. The biota of the area is not under the direct influence of domestic or industrial pollution and the nutrient content of the water is derived from the decomposition of phosphate bearing parent material and the leaching of the watershed area.

Station III, located 0.3 mile downstream from the Williamston Dam, supported a total of 18 families of bottom organisms, but only 7 were found in 30 percent or more of the samples. The mean number per sample was 6.3 with a standard error of 0.3. Family Perlidae of the stonefly group was not represented in this area. The average number of Oligochaeta per square foot increased considerably over the number found at Station I. This group of organisms is usually more abundant in areas containing large amounts of organic material and a visible increase in bottom deposition was noted in this area during the sampling period. A brown colored material having a fetid odor would become dislodged during the agitation of the rocks while sampling and would appear to remain in suspension for a considerable distance downstream from the area. It is supposed that this material is of sewage and bacterial origin.

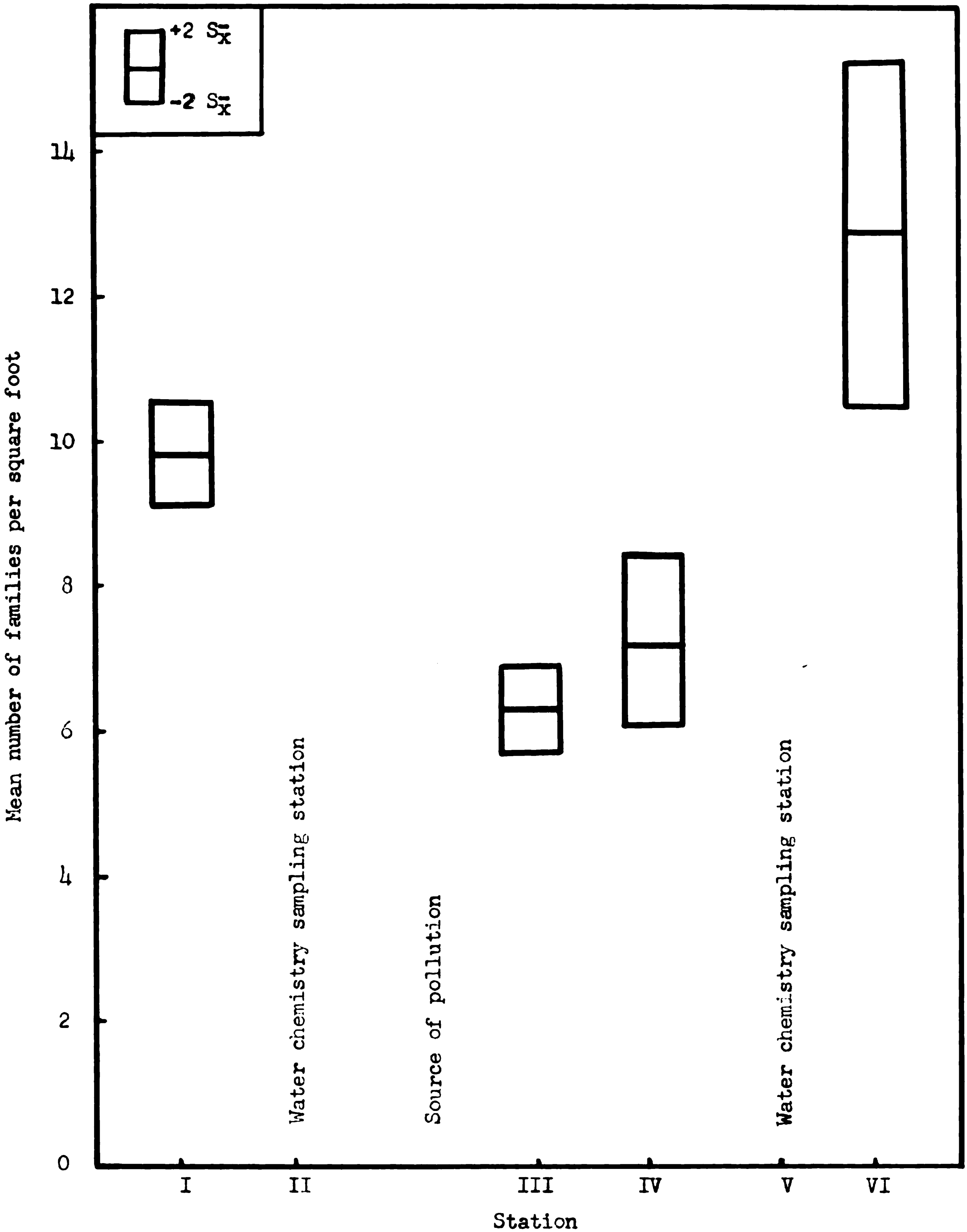

Figure 3. Mean number of families of bottom organisms per square foot from the sampling stations on the Red Cedar River in the vicinity of Williamston, Michigan.

The largest number of organisms found per square foot from Station III was 160 and the lowest was 20. The mean number found was 66 ± 39.0.

The results of the chemical analyses indicate that the river at this location contains a greater phosphorus content than upstream from Williamston, and that the ammonia nitrogen content is high enough to be measured by the standard procedures. Other conditions being equal, the increased nutrient content of the water should result in an increase in the production of bottom fauna. Patriarche and Ball (1949) found an increase of 16 and 136 percent in the standing crop of bottom fauna in two fertilized ponds over two very similar control ponds that were not fertilized. This would indicate that other factors such as mechanical interference by the suspended material or chemical conditions not detected during the survey period are presenting adverse conditions to certain groups of benthic organisms.

Twenty-two families of bottom organisms were recorded for Station IV located 0.6 mile downstream from the Williamston Dam. Eight of these families were represented in 30 percent or more of the samples. The mean number of families represented was 7.2 with a standard error of 0.58.

The composition of the benthic fauna was slightly more complex than at the previous station. The average number of Oligochaeta per square foot was 5.20 ± 3.7 as compared to 19.8 ± 18.0 per square foot at Station III. The previously mentioned four families of caddis flies were recorded from this area although the average number was less than 1 per square foot.

The average number of organisms per square foot was less than recorded for the previous station. The mean was 46 ± 39.2.

The results of the chemical analyses indicated a decrease in total phosphorus content at this station of approximately 30 percent over Station III, located only 0.3 mile upstream. The decrease in ammonia nitrogen was approximately 50 percent.

The data indicate that Station IV is the transition zone between the area in which the biota is adversely affected by the pollution and the zone of natural recovery. Undoubtedly, during certain periods of the year such as during low stream velocities or warm water conditions, adverse conditions extend through this area.

The largest number of families of any of the areas sampled was recorded from Station VI, located 6.6 miles downstream from the City of Williamston. Ecologically, this area appeared to be similar to that of the previous stations, but the area supported a more complex biota. The average number of families of aquatic invertebrates found in the samples was 14 with a standard error of 1.22.

The total number of organisms recorded per square foot was not significantly greater than found at the upstream areas, but it was capable of supporting the larger bottom organisms such as the Trichoptera and Ephemeroptera. The mean number of organisms found was 66 ± 14.8, the same as at Station III.

The results of the chemical analyses indicated that the ammonia nitrogen content of the water at Station VI had decreased to only trace amounts. Ammonia is quickly converted to nitrites and nitrates in well oxygenated water. The latter form is readily utilized by phytoplankton.

The total phosphorus content was lower than found at Station I located above the sources of pollution. This would indicate that the phosphorus concentration found at the upstream areas is converted through phytoplankton into higher forms of aquatic life.

Analysis of the mean number of families per square foot can be made on the basis of the "t" test as outlined by Snedecor (1946). The results of all tests are given in Table VIII.

TABLE VIII

COMPARISON OF THE MEAN NUMBER OF FAMILIES OF BENTHIC ORGANISMS PER SQUARE FOOT AT THE SAMPLING STATIONS AND RESULTS OF THE "t" TEST OF SIGNIFICANCE

Stations	Degrees of freedom	"t" value
I & III	18	7.45**
I & IV	14	3.82**
I & VI	13	2.44*
III & IV	24	1.36
III & VI	23	5.24**
IV & VI	19	4.22**

In summarizing, the data indicate that the composition of the benthic forms is more complex at Station VI as a result of the pollution upstream. The nutrients found in domestic pollution are converted to the available form, and after the area adversely affected is passed and mineralization of the organic material is completed, the production of the stream is high. The presence of the larger mayflies and caddis flies also increase the standing crop of the aquatic vertebrates. Since the latter forms are essential for a stream to be a valuable recreational area, low levels of pollution might be considered beneficial if the area adjacent to the outfall is not adversely affected or health endangered by high bacterial counts or by the presence of pathogenic organisms.

CONCLUSIONS

CONCLUSIONS

1. The data presented indicate that domestic wastes from the City of Williamston alter the chemical characteristics of the Red Cedar River by increasing the total phosphorus and ammonia nitrogen content of the water. The concentration of the latter compound did not approach the toxicity level during the survey period.

2. An increase in the biochemical oxygen demand of the water was noted downstream from the sewer outfalls. During the period of the survey, reaeration by photosynthetic action of the aquatic flora and absorption of atmospheric oxygen maintained the dissolved oxygen content of the water at 90 percent or more of saturation.

3. A mean of 9.8 families of benthic forms per square foot was found in Stratum I at Station I located upstream from the City of Williamston.

4. A decrease, significant at the 99% level, in the mean number of families per square foot to 6.3 and 7.2, respectively, was found at Stations III and IV, located 0.3 and 0.6 miles downstream from the sewer outfalls.

5. No significant change in the mean number of families per square foot was found in comparing Station III with Station IV.

6. At the sampling station located 6.6 miles downstream from the sewer outfalls, an increase in the mean number of families of benthic forms per square foot significant at the 99% level was found when compared to the mean numbers at stations 0.3 and 0.6 miles from the sewer outfalls. The computed mean was 12.9. This increase, significant at the 95% level

over the control station located upstream from the City of Williamston, would appear to indicate that stream fertilization resulting from the nutrients being released by the decomposition and mineralization of the organic material in the domestic sewage is increasing the complexity of the standing crop of the area.

LITERATURE CITED

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American Public Health Association
1955 Standard methods for the examination of water, sewage, and industrial wastes. American Public Health Association, Inc., New York, lvii + 522 pp.

Baker, Fred C.
1926 Changes in the bottom fauna of the Illinois River due to pollutional causes. Ecology, Vol. VII, No. 2, pp. 229-230.

Beck, William M., Jr.
1954 A simplified ecological classification of organisms. Quarterly Journal, Fla. Acad. Sci., 17 (4).

Brinley, Floyd J.
1942a Biological studies, Ohio River pollution. I. Biological zones in a polluted stream. Sewage Works Jour., Vol. 14, No. 1, pp. 147-152.

1942b The effect of pollution upon the plankton population of the White River, Indiana. Investigations of Indiana lakes and streams, Vol. 2, pp. 137-143.

1943 Ohio River pollution control. Report of the U. S. Ohio River Committee, Part 2, Supplement.

Damann, Kenneth E.
1951 Missouri River Basin plankton study (1950). Federal Security Agency, Public Health Service Report, 100 pp.

Ellis, M. M.
1937 Detection and measurement of stream pollution. Bull. U. S. Bur. Fish., Vol. 22, pp. 365-437.

Ellis, M. M., B. A. Westfall, and Marion D. Ellis
1948 Determination of water quality. U. S. Dept. Inter., Fish and Wildlife Serv., Research Rept. No. 9, 122 pp.

Flaigg, N. G. and G. W. Reid
1954 Effects of nitrogenous compounds on stream conditions. Sewage and Ind. Wastes, Vol. 26, No. 9, pp. 1145-1154.

Gaufin, Arden R. and Clarence M. Tarzwell
1952 Aquatic invertebrates as indicators of stream pollution. Pub. Health Rep., Vol. 67, No. 1, pp. 57-64.

Grzenda, Alfred R.
1956 The biological response of a trout stream to headwater fertilization. M.S. thesis, Department of Fisheries and Wildlife, Michigan State University.

Massachusetts State Board of Health
1913 Forty-fourth annual report of the State Board of Health of Massachusetts, 1912 (1913). Public Document No. 34, Massachusetts State Board of Health, Vol. 6, pp. 1-779. Boston.

Patrick, Ruth
1949 A proposed biological measure of stream conditions. Proc. 5th Ind. Waste Conf., Purdue Univ. Eng. Bull., Series No. 72, pp. 379-399.

1954 Diatoms as an indication of river change. Proc. 9th Ind. Waste Conf., Purdue Univ. Eng. Bull., Series No. 87, pp. 325-330.

Patriarche, Mercer H. and Robert C. Ball
1949 An analysis of the bottom fauna production in fertilized and unfertilized ponds and its utilization by young-of-the-year fish. Mich. State Coll., Agr. Exp. Sta., Tech. Bull. 207.

Richardson, R. E.
1921 Changes in the bottom and shore fauna of the middle Illinois River and its connecting lakes since 1913 to 1915 as a result of increase, southward, of sewage pollution. Bull., Ill. Nat. His. Surv., Vol. XIV, Art. IV, pp. 33-75.

1925 Changes in the small bottom fauna of Peoria Lake, 1920-1922. Bull., Ill. Nat. His. Surv., Vol. XXV, pp. 391-422.

Shelford, V. E.
1918 Ways and means of measuring the dangers of pollution to fisheries. Bull., Ill. Nat. His. Surv., Vol. XIII, Art. II, pp. 25-42.

Snedecor, George W.
1955 Statistical methods. Iowa State College Press, Ames, Iowa, 485 pp.

Snell, C. T. and F. D. Snell
1949 Colorimetric methods of analysis. 3rd Ed., Vol. II, D. Van Nostrand Co., Inc., New York, 950 pp.

Surber, E. W.
1937 Rainbow trout and bottom fauna production in one mile of stream. Trans. Am. Fish. Soc., Vol. 66, pp. 193-202.

Whipple, G. S.
1948 The microscopy of drinking water. 4th Ed., John Wiley and Sons, New York, xix + 585 pp.