# THE BIOLOGICAL RESPONSE OF A TROUT STREAM TO HEADWATER FERTILIZATION

By

ALFRED RICHARD GRZENDA

A THESIS

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

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MICHIGAN STATE UNIVERSITY
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## ABSTRACT

Inorganic fertilizer was added to a marl lake, which is the source of a trout stream, twice during the summer of 1954. Large quantities of fertilizer left the lake. However, except in one instance none of the nutrients could be traced chemically to a station one mile from the lake. The one exception occurred one day after the second application, when large quantities of ammonia nitrogen ranging in value from 0.11 to 0.20 p.p.m. could be traced downstream to a station three miles from the lake. This movement of nutrients was correlated with inclement weather present at the time of and following fertilization.

An increase in aufwuchs flora was noted at all stations after fertilization. The most distant station was approximately thirteen miles from the lake. The greatest mean increase in aufwuchs flora was noted at the outlet of the lake.

The standing crop of bottom fauna was found to be extremely low. Two peaks in the numerical abundance of bottom fauna were observed; the first and greater in late July, the second in late August.

The fish population was composed almost entirely of brook, brown, and rainbow trout. The species distribution of fish was found to be associated with bottom type. Brook trout were associated with sand and silt bottoms. The other two species were associated with gravel bottoms. The growth of trout was poor compared to other Michigan trout streams.

## ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation and indebtedness to: Dr. Robert C. Ball and Dr. Frank F. Hooper, under whose expert guidance this study was made; Mr. Gaylord Alexander, with whom the field work was carried out; Dr. D. W. Hayne, for his invaluable assistance in the preparation of the statistical analyses; Mr. Edward H. Bacon and Mr. Gerald Meyers, for their assistance in collecting field data; his wife Lois, for her enthusiastic assistance in collecting field data and identifying invertebrates.

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# INTRODUCTION

In recent years the socioeconomic system of the United States has enabled the sportsman to make great demands upon our recreational fisheries. An excellent account of the phenomena together with its anthropological implications is given by Loomis (1955).

Paradoxically, the same system which has created the demand for more and better fisheries has also destroyed recreational areas by urban encroachment and industrial pollution. Thus the fisheries biologist is faced with the formidable task of maintaining and improving the existing fisheries to provide for the future recreational needs of the nation.

To accomplish this end the fisheries biologist must be alert to new methods of increasing the biological productivity of our lakes, ponds, and streams. One of these methods, which has only recently been used in this country, is the enrichment of natural waters by the addition of inorganic fertilizer. The dynamics and management potential of fertilization are not understood. A summary of the more important fertilization experiments, both European and American, is given by Maciolek (1954).

Most fertilization experiments have been limited to lentic environments. To the writer's knowledge only one paper appears in the literature concerning the fertilization of a stream. Huntsman (1948) increased plant and fish production in a barren Nova Scotia stream by the addition of inorganic fertilizer.

In June, 1954, a project was planned and work started on a series of experiments to determine the feasibility of using inorganic fertilizer to increase the productivity of trout streams. Inorganic fertilizer was added to a marl lake which was the source of a trout stream. The productivity of the stream and lake was studied prior to fertilization to form a basis for evaluating changes due to the added nutrients. This information is also to be used in planning and evaluating future experiments on the same lake and stream.

This dissertation deals with the productivity of the stream before fertilization, changes in productivity due to fertilization, the nature of the downstream movement of added nutrients. A similar thesis dealing with the effects of fertilization on the productivity of the lake is being written by Mr. Gaylord Alexander of the Department of Fisheries and Wildlife, Michigan State University.

## Description of the Study Area

The west branch of the Sturgeon River is a cold-water trout stream located in Charlevoix, Otsego, and Cheboygan counties, Michigan. Its source is Hoffman Lake (T.32N, R.4W, Sec. 27, Charlevoix Co.), a marl lake of 128 acres having a methyl orange alkalinity of 128 parts per million. The stream flows in a northeasterly direction for approximately thirteen miles before its confluence with the Sturgeon River at Wolverine.

The West Branch of the Sturgeon River receives a large volume of ground water seepage and spring flow the entire length of its course. This accounts for the cold and relatively stable water temperatures encountered throughout the summer (Table I and Figure 1). The stream has three major tributaries: Fulmer Creek, Allen Creek, and Berry Creek, all of which have higher summer water temperatures than the main stream. These streams are approximately 1.0, 2.0, and 3.0 miles in length, respectively.

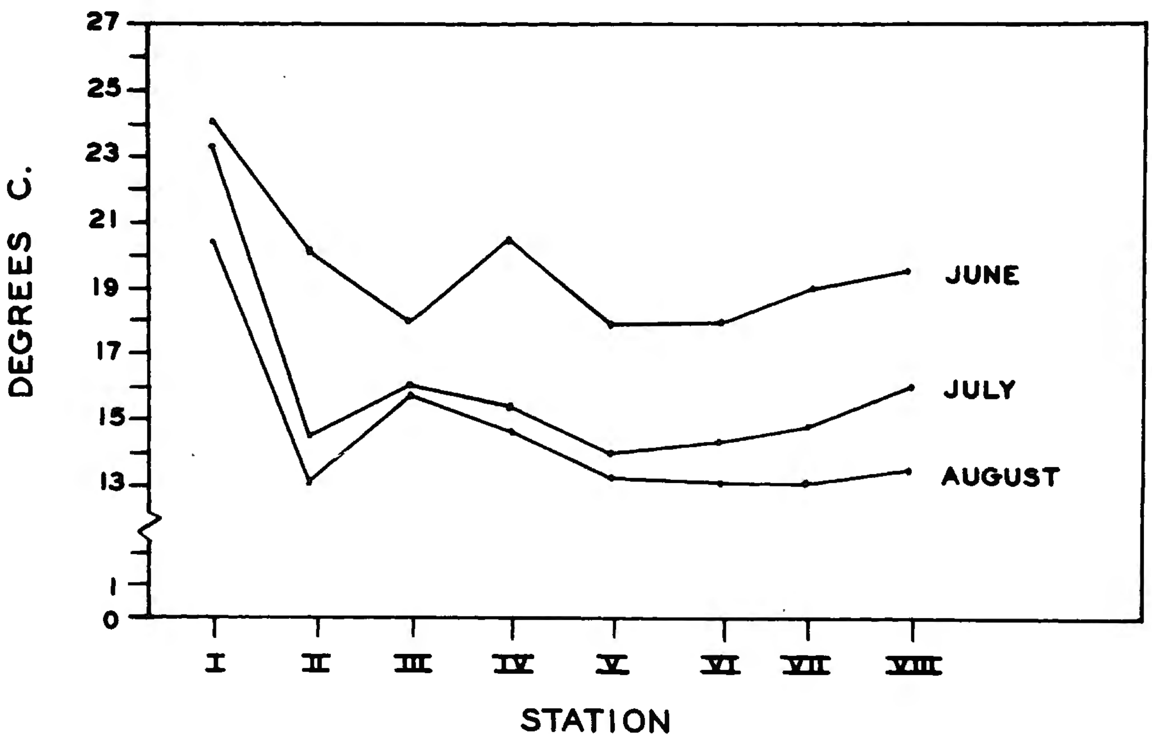
The bottom types present in the West Branch include marl, silt, sand, and gravel. Generally speaking, there is a distinct succession in bottom types in the above order between the stream's origin and its confluence with the Sturgeon River.

TABLE I

WATER TEMPERATURES OF THE WEST BRANCH OF THE STURGEON RIVER, JUNE TO SEPTEMBER, 1954
(temperatures in °C)

| Date | Item | Station | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII |
| June | Water | 26.0 | 20.0 | - | 23.0 | - | - | 20.0 | 20.0 |
| 18 | Air | 27.0 | 27.0 | - | 27.0 | - | - | 27.0 | 27.0 |
| 29 | Water | 22.5 | - | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 19.0 |
| | Air | 20.5 | - | 20.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| July | Water | 23.0 | 15.5 | 16.0 | 16.0 | 16.0 | 16.0 | 16.5 | 16.5 |
| 12 | Air | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.5 | 22.5 | 22.5 |
| 23 | Water | - | 13.5 | 15.0 | 13.5 | 11.2 | 12.0 | 13.0 | - |
| | Air | - | 24.5 | 24.0 | 23.0 | 17.0 | 27.0 | 27.5 | - |
| 26 | Water | 24.0 | 13.5 | 17.5 | 17.0 | 17.0 | 15.0 | 15.5 | 15.5 |
| | Air | 23.5 | 22.0 | 23.0 | 22.0 | 24.0 | 22.0 | 21.0 | 21.0 |
| Aug. | Water | 22.0 | 13.0 | 16.0 | 15.0 | 13.0 | 13.0 | 12.5 | 12.0 |
| 6 | Air | 20.0 | 20.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 |
| 10 | Water | 18.0 | 12.0 | 15.0 | 14.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| | Air | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 15.0 | 15.0 |
| 12 | Water | 18.5 | 14.5 | 15.0 | 13.5 | 12.0 | 12.5 | 12.0 | 12.0 |
| | Air | 14.0 | 13.0 | 15.0 | 14.0 | 14.0 | 14.5 | 14.0 | 15.0 |
| 19 | Water | 23.5 | 13.0 | 19.0 | 17.0 | 14.5 | 14.0 | 14.0 | 17.0 |
| | Air | 20.0 | 20.5 | 19.0 | 19.0 | 19.0 | 19.0 | 18.5 | 18.0 |
| 29 | Water | 20.0 | 13.5 | 14.0 | 14.0 | 14.0 | 13.0 | 13.0 | 13.5 |
| | Air | 19.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.5 | 19.0 |
| Sept. | Water | - | - | - | 13.0 | 12.0 | 13.0 | 13.0 | 13.5 |
| 3 | Air | - | - | - | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |

Figure 1. The mean water temperature at each of the sampling stations for the months of June, July, and August.



27
25
23
21
19
17
15
13
1
0
DEGREES C.
JUNE
JULY
AUGUST
I
II
III
IV
V
VI
VII
VIII
STATION

The first quarter-mile of stream downstream from the source has a marl bottom. The stream then broadens and forms a shallow pondlike area about a quarter-mile in length. This area is formed by the backwater of an abandoned beaver dam. The bottom is composed largely of fine silt and organic material. Higher aquatic plants, notably *Carex* sp., *Nuphar advena*, and *Myrica gale*, are very abundant.

Below the beaver dam the stream bottom is composed of shifting sand for about one and a half miles. This is followed by two more silt-bottomed backwaters, each about a half-mile in length. Below the beaver dams the stream bottom once again becomes composed of shifting sand. As the stream progresses downstream and the gradient increases, patches of fine gravel become increasingly common. Two miles upstream from the confluence with the Sturgeon River the bottom is composed almost entirely of fine and coarse gravels.

The watershed surrounding the stream is composed of moderately steep hills covered with maple forest. The vegetation adjacent to the stream is composed largely of stands of aspen and cedar. The approximate drainage area of the watershed is 14.0 square miles.

The agricultural land use class of the watershed as proposed by Veatch (1953) is largely Class IV (submarginal) with occasional areas of Class III land (marginal) being restricted to such specialized crops as pasture and tree farms.

The entire length of the stream is relatively pristine except for a two-mile area upstream from the confluence where pollution from urban encroachment may occur.

## Description of Sampling Stations

Eight sampling stations were established on the West Branch of the Sturgeon River during the summer of 1954. The following is a synoptic description of the salient features of each station.

Station I. Station I was located at the source of the West Branch of the Sturgeon--the outlet of Hoffman Lake.

The stream flow at this station is sluggish and the bottom composed of marl. The physical, chemical, and biological conditions present at this station are more typical of the lake than of the subsequent downstream stations.

The most abundant higher aquatic plants at this station are the cattail (*Typha latifolia*), the bullrush (*Scirpus* sp.), the stonewort (*Chara* sp.), and the arrowhead (*Saggittaria latifolia*).

*Station II.* Station II was located approximately one mile downstream from Hoffman Lake.

Two large springs maintaining water temperatures between 8° and 10°C. throughout the summer flow into the West Branch at this station. The section of stream upstream from Station II was not considered trout water because of its high summer temperatures. All of the water downstream from Station II was exceptionally cold throughout the summer (see Table I).

The bottom type at Station II is shifting sand. The only abundant higher aquatic plant present is the Mare's tail (*Hippuris vulgaris*).

*Station III.* Station III was approximately two miles downstream from the source of the stream. It was located in the backwater of an abandoned beaver dam.

The bottom type is silt with intermittent patches of sand. The current is sluggish and a continuous downstream movement of organic detritus was observed.

Higher aquatic plants are very abundant at this station. Large stands of water cress (*Nasturium officinale*) are very common. Several species of pondweed (*Potamogeton* sp.) are fairly abundant, with the burrweed (*Sparganium* sp.) being less common.

Station IV. Station IV was approximately four and a half miles downstream from Hoffman Lake.

The bottom is composed of shifting sand. The stream flow is moderately swift. The canopy of the trees adjacent to the stream covers the stream so completely that very little direct sunlight reaches the water.

Station V. Station V was approximately six and a quarter miles downstream from the source of the stream.

The stream flow is swift, the bottom being composed of sand with intermittent patches of fine gravel. Like Station IV, very little or no direct sunlight reaches the stream.

Stream improvement structures (i.e., deflectors) erected by the Fish Division of the Conservation Department were present at Station V and at all subsequent downstream stations.

Station VI. Station VI was located approximately eight miles downstream from the source of the stream.

The stream flow is moderately swift with the bottom being composed of sand and intermittent patches of fine gravel. The stream above this station was fished very little.

Station VII. Station VII was located approximately nine and a half miles downstream from Hoffman Lake.

The stream flow is moderately swift with the bottom being composed of fine gravel and intermittent patches of sand. This station received more fishing pressure than Station VI.

Station VIII. Station VIII was located approximately ten and a half miles downstream from the source of the stream.

The stream flow is moderately swift. The bottom is composed of fine and coarse gravel with intermittent patches of sand. Fulmer Creek, one of the larger tributaries, has its confluence with the West Branch of the Sturgeon River at this station.

Encroachment by cottages begins at this station. No sampling stations were established below Station VIII to avoid the effects of any pollution which might originate from these cottages.

Of all the established stations, VIII had the heaviest fishing pressure. Downstream from Station VIII the West Branch receives an even greater fishing pressure because of its proximity to U. S. Highway 27 and the town of Wolverine.

TABLE II

DISCHARGE MEASUREMENTS TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER ON JULY 23, 1954

| Station | Area (sq. ft.) | Mean Velocity (ft./sec.) | Discharge (cfs.) |
|---|---|---|---|
| II | 26.0 | 0.34 | 8.76 |
| III | 18.6 | 0.52 | 9.68 |
| IV | 17.3 | 0.95 | 16.5 |
| V | 15.3 | 1.37 | 21.0 |
| VI | 30.1 | 0.98 | 29.6 |
| VII | 25.4 | 1.78 | 45.2 |

Data courtesy of Mr. Arlington D. Ash, USGS, Lansing, Mich.

Figure 2. The West Branch of the Sturgeon River--Station VI.

Figure 3. The West Branch of the Sturgeon River--Station VIII.

# METHODS AND MATERIALS

## Biological

Aufwuchs. The aufwuchs community is a unique group of organisms containing elements of both the benthos and plankton. It is defined in the European literature as all attached organisms including those free living forms found living within the sessile mat (Ruttner, 1953). Its closest equivalent in the English terminology is periphyton, as defined by Young (1945). The term "periphyton" as used by other workers is usually taken to mean only those organisms found living on plant stems.

The organisms found in the aufwuchs community cover a wide taxonomic range, but the algal forms dominate (Young, op. cit.). The aufwuchs community is perhaps the most stable group of organisms in a stream environment. Unlike stream plankton, it is not as subject to the flushing action of high water levels. For this reason Patrick (1949) states that a study of the attached materials in a stream will reflect the water conditions that flowed by a given point in a stream for a considerable time before sampling.

Because of the kinds of organisms composing the aufwuchs community and its stability, it seems ideal to measure stream productivity at the trophic level where nutrients are synthesized into protoplasm. Newcombe (1950) attempted to measure lake productivity by the production rate of organisms becoming attached to an artificial substrate (microscope slides). This was accomplished by weighing the amount of material (both living organisms and nonliving particulate matter) which became attached to a known area in a given length of time. This is in principle what was done in this experiment.

Aufwuchs organisms were collected by placing bricks and shingles of a uniform size and shape in the stream. Two sets of bricks and shingles were placed at each station; the first before fertilization, the second at the time of fertilization. Each set was allowed to remain in the stream for thirty days and consisted of ten shingles and five bricks. The bricks used were cinder building bricks measuring 2-1/4 x 3-1/2 x 7-3/4 inches. The shingles were cedar, cut to measure 3 x 12 inches.

The bricks were suspended with wire from stable objects found in the stream. The shingles were nailed to submerged logs. In both cases the substrates were placed in such a manner that organisms could become attached on all sides. The first set of bricks and shingles was removed a day before the application of fertilizer. It was also at this time that the second set of bricks and shingles was placed in the stream. When replacing bricks and shingles, care was taken to place them in the same spot and position as those removed. This was done so that the two samples could later be analyzed statistically to evaluate the effects of fertilization.

The aufwuchs organisms were removed from the substrate with a nylon brush. The animals present in the sample were picked out and preserved in 10 percent formalin and later identified and counted. The remaining portion of the sample consisted of a mixture of living plant material, water, and nonliving particulate matter. The water was then removed from the sample with a Foerst plankton centrifuge.

Weighing the residue to evaluate the amount of living plant material found in the sample was not a satisfactory method because of the large and varying amounts of nonliving particulate matter present. Therefore, a technique was devised to measure plant material alone. This was accomplished by extracting the chlorophyll from the sample and using the density of the extracted pigment as a measure of the chlorophyll-bearing organisms present.

This technique was previously used by Tucker (1949) to estimate phytoplankton abundance. Tucker found there was a good correlation between actual counts and pigment density. The best results were obtained from the green algae and the diatoms. In conclusion,

Figure 4. The method of collecting aufwuchs with a shingle.

Figure 5. The method used to collect aufwuchs samples with a brick, showing the way bricks were removed from the stream.

Tucker (op. cit.) states that the density of the extracted pigment is extremely useful to measure trends and general abundance of phytoplankton providing many samples are taken.

Basically, all methods of chlorophyll extraction embrace the following procedures. First, the chlorophyll must be extracted by means of some solvent. After the pigment has been extracted it must be separated from the residue. This is usually done by the use of a centrifuge or a filter. The sample is then photometrically compared with a standard that has been prepared. Refinements may be made in the photometric technique by using filters to cut down on absorption by other pigments (Manning and Juday, 1941).

In this experiment 95 percent ethyl alcohol was used as a solvent. The liquid was separated from the residue by decanting. In some cases the sample had to be filtered because of a suspension of plant material that was present in the liquid. The value of the density of the extracted pigment was then determined by using a Klett-Summerson photoelectric colorimeter with a number 66 filter (red). The Harvey Standard was used to express the density of the pigment. A Harvey unit is defined as 25 mg. of potassium chromate and 430 mg. of nickel sulphate dissolved in one liter of water (Harvey, 1939).

No attempt was made to convert these units into numbers or weights of organisms present. They were taken to be figures indicating the abundance of chlorophyll-bearing organisms found in the aufwuchs community before and after fertilization.

Bottom samples. Bottom samples were collected at weekly intervals from June 29 to September 7 at Station VIII. They were taken from a relatively uniform riffle using a Surber square foot sampler.

No attempt was made to randomize the sampling spots. Instead, a transect was made across the stream taking samples at the following spots: near the right bank, one-third the distance across the stream, two-thirds the distance across the stream, and near the left bank. Three such transects were made at each collection, making a total of 12 square feet of bottom sampled.

Fish samples. Fish samples were collected twice during the summer at Stations II, V, and VIII. The fish were captured using a 220 volt direct current shocker. Scale samples were taken from the captured fish. The following measurements were also taken: total length measured to the nearest tenth of an inch, and weight in grams. The captured fish were then marked and released.

The scale samples were cleaned and then mounted in a gelatin media on microscope slides. The average length of each year class was determined by reading the scales on a projector. The weight-length relationship of the three species of trout was computed by using the formula given by Lagler (1952).

## Chemical

Application of fertilizer. Hoffman Lake, the source of the West Branch of the Sturgeon River, was fertilized twice during the summer of 1954. An inorganic commercial fertilizer having a guaranteed analysis of 10-10-10 NPK was used. The sources of available nitrogen and phosphorus were ammonium sulphate and phosphoric acid, respectively.

Three thousand two hundred pounds of fertilizer was applied on July 30; a second application of 2,720 pounds was made on August 9.

Chemical procedures. The movement of fertilizer from the lake was traced by the analysis of water samples taken from the downstream sampling stations. Soluble and total phosphorus determinations were made using the molybate method. Ammonia nitrogen was determined by direct Nesslerization. The colorimetric determinations necessary for both procedures were made on a Klett-Summerson Colorimeter.

The actual procedures used were essentially those described by Ellis, Westfall, and Ellis (1948).

# RESULTS

## Biological

*Aufwuchs flora.* A quantitative difference in the amount of aufwuchs present at Station I after fertilization could be observed by eye. Large amounts of the green alga *Spirogyra* became attached to the substrate giving the appearance of a green blanket covering the bottom. No such change could be observed at any of the downstream stations.

A qualitative difference in aufwuchs composition was also noted between bricks and shingles at Station I after fertilization. The shingles, like the natural substrate, became covered with long strands of *Spirogyra*. This type of growth was almost lacking on the bricks. Instead, the bricks supported a floclike growth of diatoms. Bricks and shingles at downstream stations had about the same floral components.

The total amount of aufwuchs on bricks and shingles, measured quantitatively by the density of the extracted chlorophyll, was greater at all stations after fertilization. However, when inspecting measurements obtained from individual bricks and shingles considerable variation was noted. Six of the fifty-six measurements obtained after fertilization were lower than those obtained before fertilization (Table III). Statistical analysis was used to determine if there was a likely difference between samples, or if the increase could have resulted from sampling variation.

Analysis of variance was used to test the null hypothesis that there was no change in aufwuchs abundance after fertilization. The values used in these analyses were obtained by subtracting the density of chlorophyll extracted from a particular brick (or shingle) from the value obtained from a brick placed in the same spot after fertilization. In this manner a set of fifty-six differences was obtained.

Before using analysis of variance, the data were tested with Bartlett's test for homogeneity of variance (Snedecor, 1946). No significant evidence of heterogeneity of variance was found. Preliminary examination of the data failed to show any correlation between the mean and mean square. On the basis of these two tests it was decided that it would be statistically sound to use analysis of variance.

Analysis of variance indicated there was a statistically significant gain in aufwuchs after fertilization on both bricks and shingles. A statistically significant difference was also noted in the magnitude of gains occurring among the eight stations. However, when testing Station I against Stations II to VIII it was found that

TABLE III

INCREASE IN THE DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS SAMPLES AFTER FERTILIZATION

| Station | Sample Size | | Total Increase After Fertilization (Harvey units) | | Mean Increase After Fertilization (Harvey units) | |
|---|---|---|---|---|---|---|
| | B | S | B | S | B | S |
| I | 3 | 4 | 160 | 334 | 53.3 | 83.5 |
| II | 5 | 6 | 49 | 113 | 9.8 | 18.8 |
| III | 4 | 3 | 19 | 47 | 4.8 | 15.6 |
| IV | 4 | 5 | 47 | 113 | 11.8 | 26.5 |
| V | 4 | 4 | 33 | 92 | 8.3 | 23.0 |
| VI | 5 | 5 | 27 | 19 | 6.8 | 19.0 |
| VII | 3 | 4 | - 6 | 38 | -2.0 | 9.5 |
| VIII | 5 | 8 | 24 | 181 | 4.8 | 20.1 |

B = bricks; S = shingles.

the difference in gains among the stations was due to the magnitude of change occurring at Station I (Tables IV and V).

This particular analysis was not the best available for comparing the conditions at Stations II to VIII. First it was decided to eliminate Station I from any further analysis. This procedure seemed valid because Station I is typical of the lake and clearly differs from the seven downstream stations. Further, data from bricks and shingles showed the same trend from station to station, suggesting consistent differences not revealed in the separate analyses. Data from the two sources were therefore pooled, using the mean values as variates because of disproportionate subclass numbers resulting from loss of bricks and shingles.

The analysis of variance using the pooled data indicated there was a statistically significant gain in aufwuchs after fertilization. Statistically significant differences in gains were noted among the seven downstream stations (Table VI).

The mean increase in the density of chlorophyll extracted from aufwuchs samples at each station is shown in Figure 6. Disregarding Station I the greatest mean increase was observed at Station IV. In spite of the similarity in physical characteristics between Stations VII and VIII the gain in aufwuchs at these two stations after fertilization was quite different. Therefore, it is felt that the

TABLE IV

ANALYSIS OF VARIANCE OF CHANGES IN DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO SHINGLES

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | "F" |
|---|---|---|---|---|
| Mean . . . . . . . . . . . . . . | 1 | 25,654.2 | 25,654.2 | 255.3** |
| Total . . . . . . . . . . . . . . | 39 | 19,110.8 | | |
| Among stations . . . . . . . | 7 | 15,575.2 | 2,225.0 | 20.1** |
| I vs. rest . . . . . . . . . . | (1) | (15,041.5) | (15,041.5) | 136.1** |
| Among rest . . . . . . . . . | (6) | (533.7) | (88.9) | 0.8 |
| Within stations . . . . . . . | 32 | 3,535.6 | 110.5 | |

** Significant at the 1 percent level.

TABLE V

ANALYSIS OF VARIANCE OF CHANGES IN DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO BRICKS

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | "F" |
|---|---|---|---|---|
| Mean . . . . . . . . . . . . . . | 1 | 3,894.0 | 3,894.0 | 27.3** |
| Total . . . . . . . . . . . . . . | 31 | 9,762.2 | | |
| Among stations . . . . . . . | 7 | 6,343.9 | 906.3 | 6.4** |
| I vs. rest . . . . . . . . . . | (1) | (5,923.7) | (5,923.7) | 41.6** |
| Among rest . . . . . . . . . | (6) | (420.2) | (70.0) | 0.5 |
| Within stations . . . . . . . | 24 | 3,418.1 | 142.4 | |

** Significant at the 1 percent level.

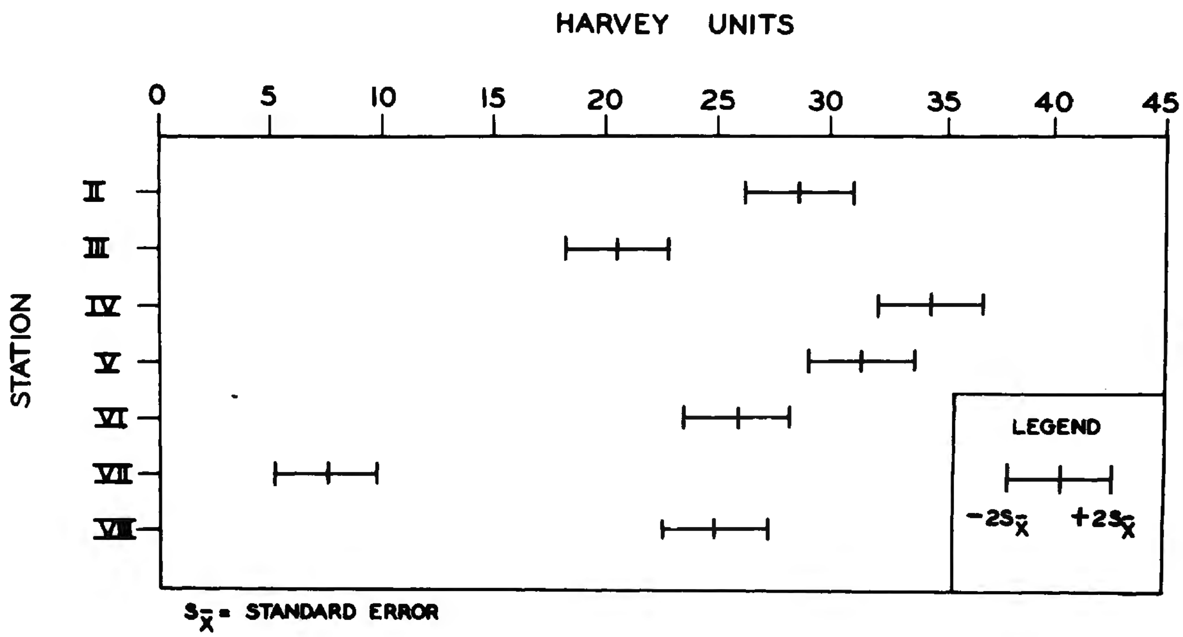
TABLE VI

ANALYSIS OF VARIANCE OF CHANGES IN DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO BRICKS AND SHINGLES
(pooled data, computed from mean values)

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | "F" |
|---|---|---|---|---|
| Mean . . . . . . . . . . . . . . | 1 | 2,137.8 | 2,137.8 | 137.0** |
| Among stations (II-VIII) . | 6 | 508.8 | 84.8 | 32.5** |
| Between kinds . . . . . . . | 1 | 233.8 | 233.8 | 89.6** |
| Stations x kinds . . . . . . | 6 | 15.6 | 2.61 | |

** Significant at the 1 percent level.

Figure 6. The mean increase in the density of pigments extracted from aufwuchs samples.


HARVEY UNITS
0
5
10
15
20
25
30
35
40
45
STATION
II
III
IV
V
VI
VII
VIII
LEGEND
$-2S_{\bar{X}}$
$+2S_{\bar{X}}$
$S_{\bar{X}}$ = STANDARD ERROR

real value of the chlorophyll method, in this particular instance, was in evaluating changes which occurred within stations rather than comparing changes among stations.

Gumtow (1955) made a study of aufwuchs in a Montana stream. It was found that the floral components of the aufwuchs community remain constant throughout the year. However, an extreme seasonal periodicity in the abundance of these organisms was noted. These cycles of paucity and abundance were found to be associated with environmental changes such as high water temperatures, floods, and high turbidity. The water temperatures and other environmental conditions present in the West Branch of the Sturgeon River remained relatively constant throughout the study period. Therefore, it is believed that any gain in aufwuchs after fertilization was due directly to fertilization even though the added nutrients could not be chemically traced at all of the downstream stations.

Aufwuchs fauna. Four families of two-winged flies (Diptera), five families of caddis flies (Trichoptera), two families of May flies (Ephemeroptera), two families of stone flies (Plecoptera), and other miscellaneous groups such as planarians and snails were found to be present in the aufwuchs fauna. However, the black fly *Simulium*, the net-spinning caddis fly Hydropsyche, and the May fly Baetis comprised over 95 percent of the total number of animals collected.

Each station had a distinct faunal composition (Figure 7). At Stations I, II, VII, and VIII the composition of the fauna remained about the same for the two collections. At Stations IV, V, and VI there was a decrease in the proportion of May flies present in the second collection. Stations VII and VIII, which are very similar in their physical characteristics, had almost identical faunal assemblages.

Bottom fauna. The numerical abundance of bottom fauna during the summer of 1954 approximates a fairly smooth bimodal curve (Figure 8). The first and greater peak of abundance was observed on July 27. A second peak was observed on August 31.

Analysis of variance was used to test for a statistical difference among collections (Tables VII and VIII). A set of 132 items, each representing the total number of organisms found in a square foot of bottom, was used in this analysis.

Preliminary analysis of the data revealed there was a linear relationship between the mean and the mean square. Such a condition is contrary to the basic assumptions behind analysis of variance (Bartlett, 1947). Therefore, a logarithmic transformation was used to overcome this difficulty.

Figure 7. The percentage composition of the various orders found in the aufwuchs community.

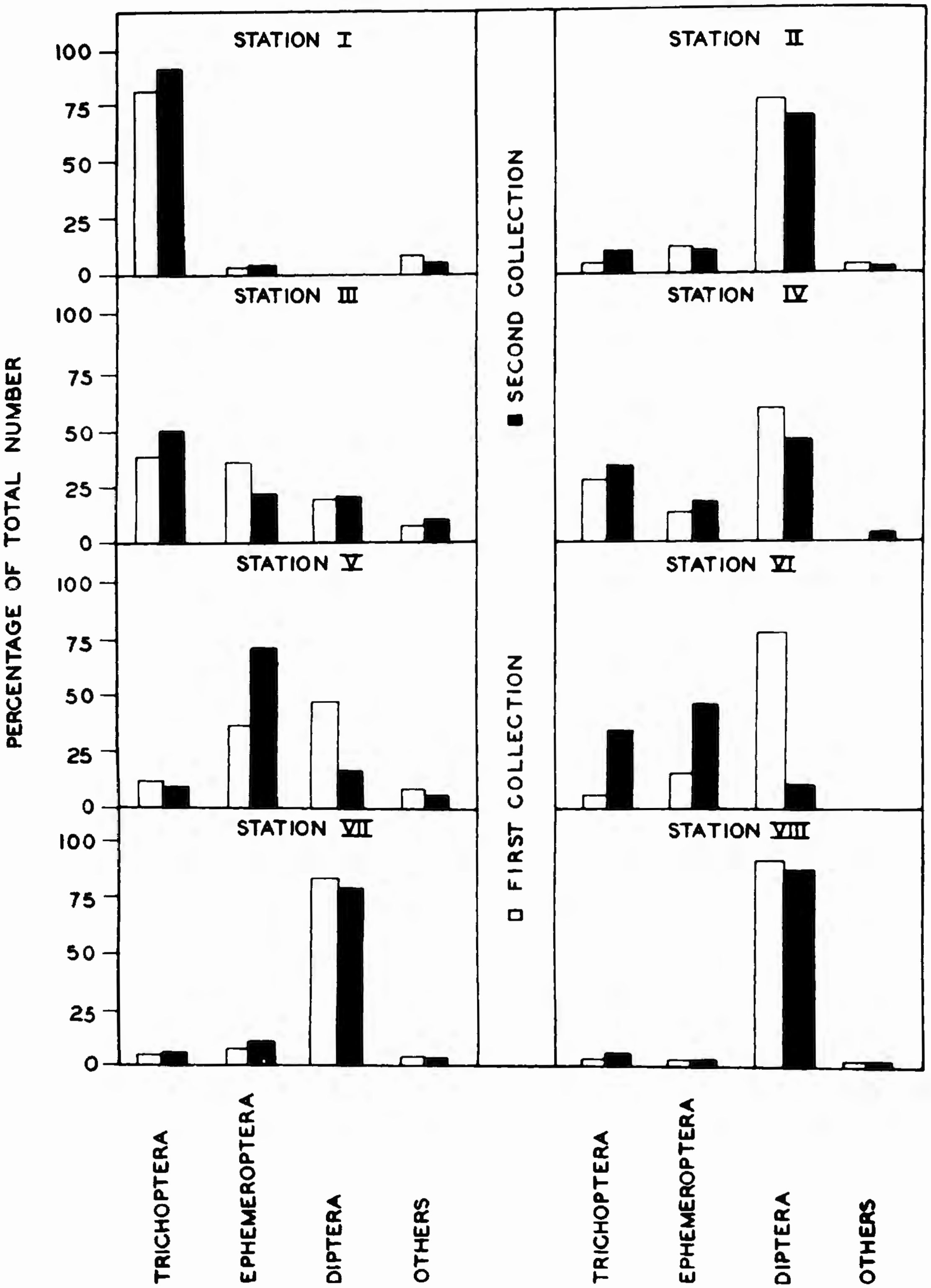
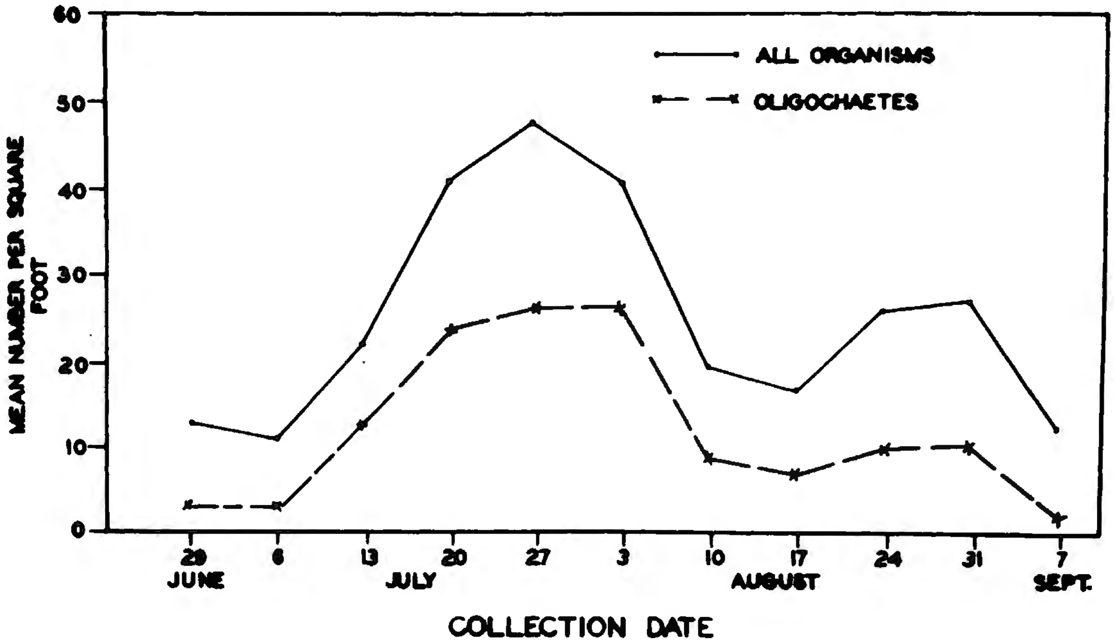

STATION I
STATION II
STATION III
STATION IV
STATION V
STATION VI
STATION VII
STATION VIII
100
75
50
25
0
PERCENTAGE OF TOTAL NUMBER
■ SECOND COLLECTION
□ FIRST COLLECTION
TRICHOPTERA
EPHEMEROPTERA
DIPTERA
OTHERS

Figure 8. The numerical abundance of bottom fauna throughout the summer of 1954.



60
50
40
30
20
10
0
MEAN NUMBER PER SQUARE FOOT
ALL ORGANISMS
OLIGOCHAETES
29
JUNE
6
13
20
27
JULY
3
10
17
24
31
AUGUST
7
SEPT.
COLLECTION DATE

TABLE VII

ANALYSIS OF VARIANCE OF ENUMERATION OF TOTAL BOTTOM FAUNA TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | "F" |
|---|---|---|---|---|
| Total . . . . . . . . . . . . . . | 131 | 22.05466 | | |
| Among collections . . . . . | 11 | 4.33074 | 0.39370 | 2.666* |
| Within collections . . . . . | 120 | 17.72392 | 0.14769 | |

* Significant at the 5 percent level.

TABLE VIII

ANALYSIS OF VARIANCE OF ENUMERATION OF BOTTOM FAUNA TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, EXCLUDING OLIGOCHAETES

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | "F" |
|---|---|---|---|---|
| Total . . . . . . . . . . . . . . | 131 | 17.63734 | | |
| Among collections . . . . . | 11 | 0.75374 | 0.06852 | 0.487 |
| Within collections . . . . . | 120 | 16.88360 | 0.14069 | |

The value obtained from this analysis was significant at the 5 percent confidence level, indicating a statistically significant difference among the weekly collections.

It was observed that by numbers the oligochaetes were the most abundant organism (Tables IX and X). Analysis of variance was used to test for a statistical difference among weekly collections when the oligochaetes were excluded from the population. The values used in this analysis were the totals used above, minus the number of oligochaetes present in each sample. A logarithmic transformation was also used here.

This test revealed that the differences among the weekly collections were not statistically significant after the removal of the oligochaetes.

The bottom fauna present in the West Branch of the Sturgeon River showed considerable taxonomic diversity. Despite this diversity a relatively small number of groups consistently comprised the bulk of the standing crop of bottom fauna.

The oligochaetes were the largest component of the bottom fauna, making up 48 percent of the total number of organisms collected during the entire summer. One family of May flies (Baetidae), one family of beetles (Elmidae), one family of caddis flies (Brachycentridae), one family of two-winged flies (Tendipedidae), and the

TABLE IX

PERCENTAGE COMPOSITION BY NUMBER OF BOTTOM FAUNA COLLECTED FROM THE WEST BRANCH OF THE STURGEON RIVER, JUNE TO SEPTEMBER, 1954

| Collection Date | Taxonomic Group | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ephemeroptera | Trichoptera | Plecoptera | Coleoptera | Diptera | Oligochaeta | Others |
| June | | | | | | | |
| 29 | 40.0 | 14.8 | 0 | 1.9 | 18.7 | 21.9 | 2.6 |
| July | | | | | | | |
| 6 | 32.8 | 3.3 | 0 | 6.3 | 27.3 | 25.0 | 5.5 |
| 13 | 14.7 | 4.3 | 0.4 | 6.9 | 13.1 | 59.9 | 0.8 |
| 20 | 7.4 | 20.0 | 0.5 | 3.3 | 8.8 | 57.9 | 0.2 |
| 27 | 6.5 | 25.8 | 0.7 | 3.9 | 7.6 | 54.8 | 0.4 |
| Aug. | | | | | | | |
| 3 | 13.7 | 4.9 | 0.6 | 2.9 | 7.1 | 63.9 | 1.2 |
| 10 | 17.0 | 15.2 | 2.2 | 5.2 | 13.9 | 40.1 | 0.4 |
| 17 | 18.1 | 19.6 | 3.5 | 5.0 | 14.6 | 38.7 | 0.5 |
| 24 | 24.8 | 14.7 | 2.6 | 3.3 | 17.7 | 36.6 | 0.3 |
| 31 | 10.6 | 29.8 | 2.5 | 7.5 | 10.9 | 36.5 | 0.6 |
| Sept. | | | | | | | |
| 7 | 19.3 | 42.5 | 4.8 | 7.6 | 8.9 | 15.5 | 0.7 |

TABLE X

SUMMARY OF THE TOTAL NUMBER AND TOTAL VOLUME OF BOTTOM FAUNA TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER

| Collection Date | Total Number | Total Volume (c.c.) | Number per Square Foot | Volume per Square Foot (c.c.) |
|---|---|---|---|---|
| June 29 . . . . . . | 155 | 3.35 | 12.9 | 0.28 |
| July 6 . . . . . . | 128 | 1.80 | 10.7 | 0.15 |
| 13 . . . . . . | 259 | 1.95 | 21.6 | 0.16 |
| 20 . . . . . . | 490 | 2.90 | 40.8 | 0.24 |
| 27 . . . . . . | 569 | 3.70 | 47.4 | 0.31 |
| August 3 . . . . | 459 | 4.05 | 38.3 | 0.34 |
| 10 . . . . | 230 | 5.30 | 19.2 | 0.44 |
| 17 . . . . | 199 | 1.30 | 16.6 | 0.11 |
| 24 . . . . | 306 | 2.45 | 25.5 | 0.20 |
| 31 . . . . | 322 | 3.40 | 26.8 | 0.28 |
| September 7 . . . | 145 | 1.60 | 12.0 | 0.13 |

oligochaetes comprised 79 percent of the total number of bottom organisms collected during the entire summer. The percentage composition of bottom fauna with regard to order may be seen in Table IX.

The volume of bottom fauna collected in any given collection was so small that no detailed study was made. The total volume and mean volume of bottom fauna taken at each weekly collection is shown in Table X.

Surber (1951) made a study of bottom fauna in a trout stream having what he termed "average richness." It was found that the average wet weights of square foot samples collected during the months of June, July, August, and September were 1.65, 1.18, 1.96, and 1.28 grams, respectively. Similar values obtained from the West Branch of the Sturgeon River, using a conversion of one cubic centimeter equaling one gram (Ball, 1948), were 0.28, 0.22, 0.28, and 0.13 grams, respectively. Thus, on the basis of Surber's figures it appears that the level of bottom fauna production in the west branch is very low.

Fish samples. The fish population of the West Branch of the Sturgeon River was found to be composed largely of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdnerii*). Tarzwell (1936), in a previous study of this stream,

TABLE XI

ENUMERATION OF BOTTOM FAUNA TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER

| Taxonomic Groups | Collection Date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | July | | | | August | | | | | Sept. |
| | 29 | 6 | 13 | 20 | 27 | 3 | 10 | 17 | 24 | 31 | 7 |
| Plecoptera | | | | | | | | | | | |
| Perlidae . . . . . . . | | | 1 | 2 | 3 | 1 | 2 | 4 | 5 | 6 | 5 |
| Pteronarcidae . . . | | | | | 1 | 1 | 3 | 1 | 3 | 2 | 2 |
| Nemouridae . . . . | | | | | | | | 1 | | | |
| Perlodidae . . . . . | | | | | | 1 | | 1 | | | |
| Subtotals . . . . . . | 0 | 0 | 1 | 2 | 4 | 3 | 5 | 7 | 8 | 8 | 7 |
| Ephemeroptera | | | | | | | | | | | |
| Ephemeridae . . . . | 2 | 2 | | | | | | | | | |
| Baetidae . . . . . . . | 27 | 13 | 18 | 11 | 23 | 41 | 28 | 30 | 63 | 28 | 14 |
| Heptageniidae . . . | 10 | 7 | 10 | 6 | 4 | 14 | 11 | 6 | 11 | 5 | 8 |
| Ephemerellidae . . | 25 | 20 | 10 | 19 | 10 | 12 | | | 2 | 1 | 6 |
| Subtotals . . . . . . | 62 | 42 | 38 | 36 | 37 | 67 | 39 | 36 | 76 | 34 | 28 |
| Trichoptera | | | | | | | | | | | |
| Rhyacophilidae . . | 8 | 1 | | | 3 | 3 | 2 | 8 | 3 | 12 | 17 |
| Brachycentridae . | 13 | 1 | 11 | 97 | 141 | 18 | 30 | 30 | 29 | 21 | 25 |
| Hydropsychidae . . | 1 | 1 | | | | 1 | | 1 | 10 | 58 | 16 |
| Philoptamidae . . . | 1 | | | | 2 | | | | | | |
| Psycomyiidae . . . | | | | | 1 | 1 | | | | 5 | |
| Lepidostomatidae . | | | | | | 1 | 1 | | 3 | | |
| Leptoceridae . . . . | | 1 | | 1 | | | 2 | | | | 5 |
| Subtotals . . . . . . | 23 | 4 | 11 | 98 | 147 | 24 | 35 | 39 | 45 | 96 | 63 |
| Megaloptera | | | | | | | | | | | |
| Corydalidae . . . . | 3 | 4 | 1 | | 1 | 1 | | | | 1 | 1 |
| Subtotals . . . . . . | 3 | 4 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| Odonata | | | | | | | | | | | |
| Libellulidae . . . . . | | | | | | 1 | | 1 | | 1 | |
| Gomphidae . . . . . | | | | | | 1 | 1 | | | | |
| Subtotals . . . . . . | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 1 | 0 |

TABLE XI (Continued)

| Taxonomic Groups | Collection Date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | July | | | | August | | | | | Sept. |
| | 29 | 6 | 13 | 20 | 27 | 3 | 10 | 17 | 24 | 31 | 7 |
| Coleoptera | | | | | | | | | | | |
| Elmidae . . . . . . . | 3 | 8 | 18 | 16 | 22 | 14 | 12 | 10 | 10 | 24 | 11 |
| Subtotals . . . . . . | 3 | 8 | 18 | 16 | 22 | 14 | 12 | 10 | 10 | 24 | 11 |
| Diptera | | | | | | | | | | | |
| Rhagionidae . . . . | 13 | 9 | 6 | 13 | 9 | 2 | 14 | 6 | 7 | 7 | 5 |
| Tendipedidae . . . . | 12 | 19 | 15 | 13 | 22 | 22 | 7 | 12 | 9 | 6 | 3 |
| Simulidae . . . . . . | 4 | 4 | 5 | 7 | 5 | 9 | 7 | 1 | 31 | 8 | 2 |
| Empididae . . . . . | | 2 | 8 | 10 | 6 | 1 | 3 | 5 | 7 | 11 | 2 |
| Heleidae . . . . . . . | | 1 | | | 1 | 1 | | 5 | | 3 | 1 |
| Tipulidae . . . . . . | | | | | | | 1 | | | | |
| Subtotals . . . . . . | 29 | 35 | 34 | 43 | 43 | 35 | 32 | 29 | 54 | 35 | 13 |
| Oligochaeta . . . . . | 34 | 32 | 155 | 284 | 312 | 313 | 106 | 77 | 112 | 118 | 21 |
| Subtotals . . . . . . | 34 | 32 | 155 | 284 | 312 | 313 | 106 | 77 | 112 | 118 | 21 |
| Gastropoda . . . . . . | 1 | 3 | 1 | 1 | 1 | 3 | | | | | |
| Subtotals . . . . . . | 1 | 3 | 1 | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| Hydocarina . . . . . . | | | | | | | | | 1 | | 1 |
| Subtotals . . . . . . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Totals . . . . . . . . . | 155 | 128 | 259 | 490 | 569 | 490 | 230 | 199 | 306 | 322 | 145 |
| No./sq.ft. . . . . . . . | 12.8 | 10.7 | 21.6 | 40.8 | 47.4 | 40.8 | 19.2 | 16.5 | 25.5 | 26.8 | 12.1 |

states that trout comprised from 93.8 to 98.7 percent of the number of fish present, and over 99 percent of the weight of the population.

The collection data (Table XII) indicate there was a gradual transition in the species composition of the population between the headwaters and the stream's confluence with the Sturgeon River. At Station II the population was composed entirely of brook trout. Downstream, at Station V, fewer brook trout were present, and brown and rainbow trout appeared. Further downstream at Station VIII the two latter species comprised over 90 percent of the fish collected.

The transition in species composition was closely paralleled by a change in bottom types. Generally speaking, the silts and sands were associated with brook trout and the gravels with the other two species.

All of the rainbow trout taken were in year classes 0, I, and II. Therefore, it is assumed these fish migrate downstream to the Sturgeon River before entering year class III. Because of the lack of larger rainbow trout it is thought those present are progeny of a population originating from the Sturgeon River. Residents of the area report the presence of large rainbow trout in the West Branch during the early spring months. Presumably these fish are spawners from the Sturgeon River. However, these reports were not verified during the course of this study.

TABLE XII

SPECIES COMPOSITION OF TROUT SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER USING AN ELECTRIC SHOCKER

| Station | No. of Fish | Brook Trout | | Brown Trout | | Rainbow Trout | |
|---|---|---|---|---|---|---|---|
| | | No. | Pct. | No. | Pct. | No. | Pct. |
| | | | Sample Collected July 6, 1954 | | | | |
| II | 232 | 232 | 100 | | | | |
| V | 160 | 98 | 61.2 | 13 | 8.1 | 49 | 30.6 |
| VIII | 123 | 5 | 4.1 | 60 | 48.8 | 58 | 47.2 |
| | | | Sample Collected August 31, 1954 | | | | |
| II | 280 | 280 | 100 | | | | |
| V | 181 | 87 | 48.0 | 37 | 20.4 | 57 | 31.5 |
| VIII | 159 | 7 | 4.4 | 70 | 44.0 | 82 | 51.6 |

The mean length of each year class of trout is shown in Table XIII. The length-weight relationship for the three species is given in Figures 9, 10, and 11.

Cooper (1951) made a study of the growth of brook trout in three Michigan trout streams. They were the North Branch of the Au Sable, the Pigeon River, and Hunt Creek. By the middle of June the mean lengths of brook trout in year class I were 6.9, 5.7, and 5.1 inches, respectively, in each of these streams. The mean length of brook trout of the same age collected from the West Branch of the Sturgeon River was only 4.7 inches.

The Pigeon River has average productivity, and Hunt Creek is considered to be very unproductive. Both of these streams have better brook trout growth than the West Branch of the Sturgeon River.

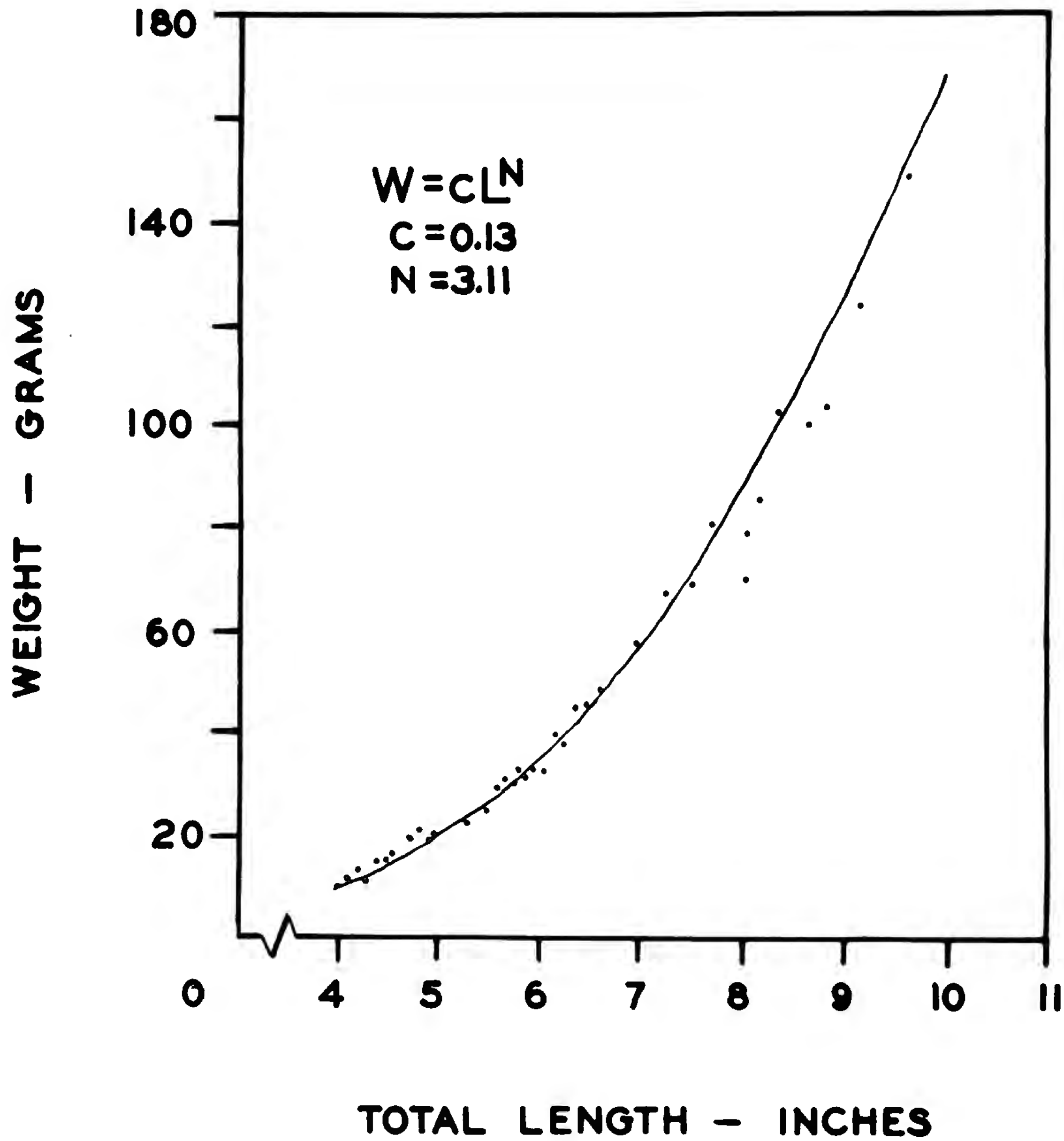
According to Davis (1929) and Embody (1936), the optimum temperature for the growth and feeding of brook and rainbow trout is between 12.8 and 15.6 degrees centigrade. The late spring and summer water temperatures in the West Branch of the Sturgeon River were always close to or within this optimum range. Therefore, it is believed that the poor growth is due directly to the paucity of bottom fauna mentioned earlier in this dissertation. Allen (1951) strongly suggests that a significant relationship exists between trout growth and numbers and bottom fauna abundance.

TABLE XIII

MEAN LENGTH IN INCHES OF TROUT SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, JULY 6, 1954

| Species | Mean Length | Standard Error of Mean | Sample Size |
|---|---|---|---|
| | Year Class I | | |
| Rainbow . . . . . . . . . . . . . . . . . . | 4.5 | 0.09 | 46 |
| Brook . . . . . . . . . . . . . . . . . . . | 4.7 | 0.07 | 88 |
| Brown . . . . . . . . . . . . . . . . . . . | 5.4 | 0.11 | 23 |
| | Year Class II | | |
| Rainbow . . . . . . . . . . . . . . . . . . | 7.2 | 0.16 | 30 |
| Brook . . . . . . . . . . . . . . . . . . . | 6.5 | 0.15 | 48 |
| Brown . . . . . . . . . . . . . . . . . . . | 8.4 | 0.51 | 7 |
| | Year Class III | | |
| Rainbow . . . . . . . . . . . . . . . . . . | - | - | - |
| Brook . . . . . . . . . . . . . . . . . . . | 9.3 | 0.27 | 9 |
| Brown . . . . . . . . . . . . . . . . . . . | 10.4 | 0.26 | 9 |
| | Year Class IV | | |
| Rainbow . . . . . . . . . . . . . . . . . . | - | - | - |
| Brook . . . . . . . . . . . . . . . . . . . | - | - | - |
| Brown . . . . . . . . . . . . . . . . . . . | 11.7 | 0.60 | 5 |

Figure 9. The length-weight relationship of brook trout taken from the west branch of the Sturgeon River, July 6, 1954. Dots represent the empirical mean weight of each size class.



180
140
100
60
20
0
4
5
6
7
8
9
10
11
WEIGHT - GRAMS
TOTAL LENGTH - INCHES
$W=cL^N$
C =0.13
N =3.11

Figure 10. The length-weight relationship of brown trout taken from the west branch of the Sturgeon River, July 6, 1954. Dots represent the empirical mean weight of each size class.

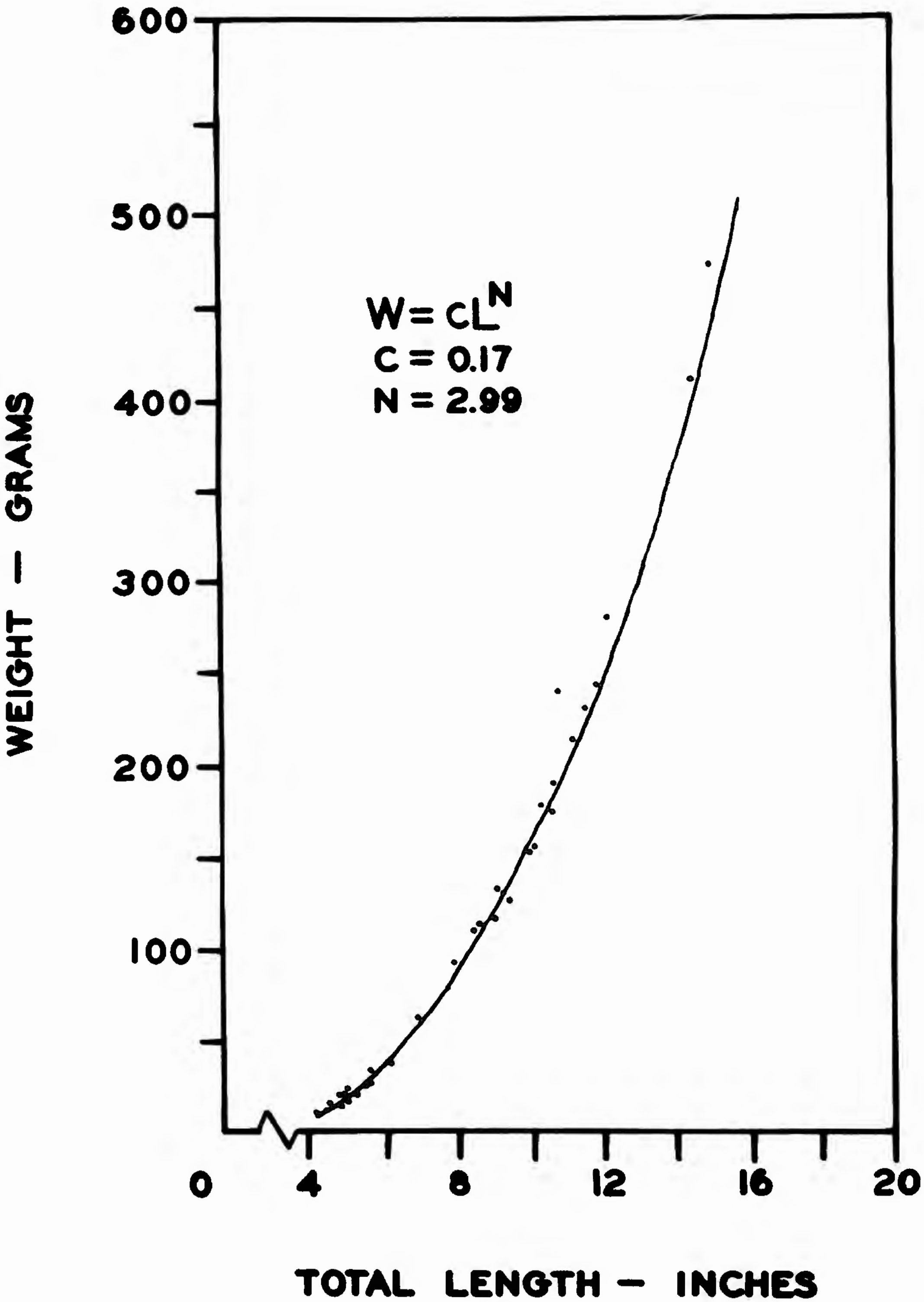
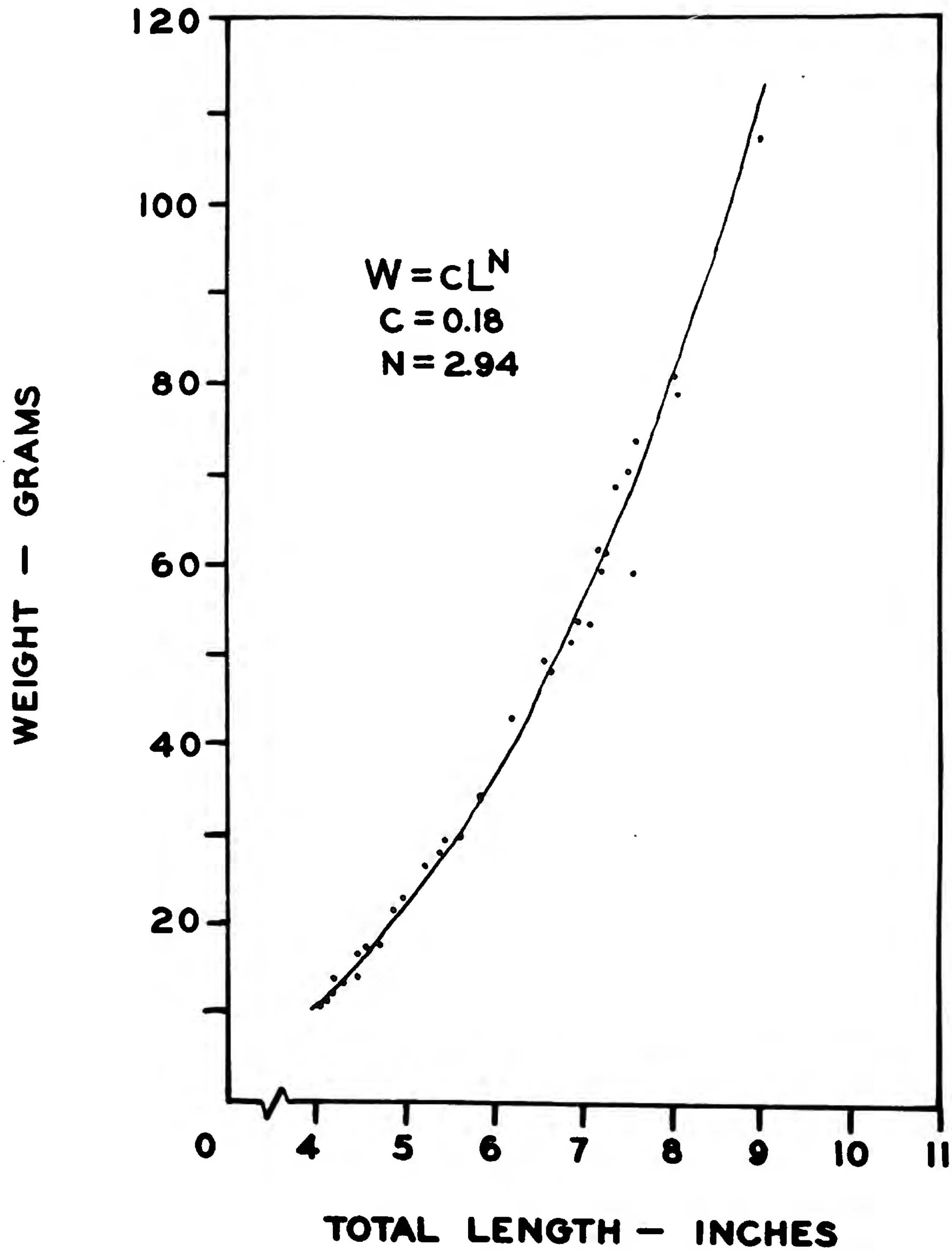

600
500
400
300
200
100
WEIGHT — GRAMS
W= CL^N
C = 0.17
N = 2.99
0
4
8
12
16
20
TOTAL LENGTH — INCHES

Figure 11. The length-weight relationship of rainbow trout taken from the west branch of the Sturgeon River, July 6, 1954. Dots represent the empirical mean weight of each size class.


120
100
80
60
40
20
WEIGHT - GRAMS
$W = cL^N$
C = 0.18
N = 2.94
0
4
5
6
7
8
9
10
11
TOTAL LENGTH - INCHES

## Chemical

Phosphorus. The data indicate that very little, if any, phosphorus moved downstream beyond the immediate vicinity of the outlet of the lake. Station I, which is located at the outlet of the lake, received large amounts of phosphorus immediately after fertilization (Table XIV and Figure 12). No significant increase in phosphorus was noted at Station II, which is a mile downstream from the lake, at any time after fertilization.

Two days after the first application of fertilizer, 28 micrograms per liter of total phosphorus, 2 of which were soluble, were recorded at Station I. This indicates the bulk of the available phosphorus had already been converted to organic matter. Three days after the second application 79 micrograms per liter of total phosphorus were recorded at Station I, representing a threefold increase over the highest concentration leaving the lake after the first application.

Ammonia nitrogen. Following the first application of fertilizer, no measurable amount of ammonia nitrogen could be found at any station except Station I (Table XV and Figure 13). However, appreciable amounts of ammonia nitrogen ranging in value from 0.20 to 0.11 p.p.m. were present at Stations I through III one day after the

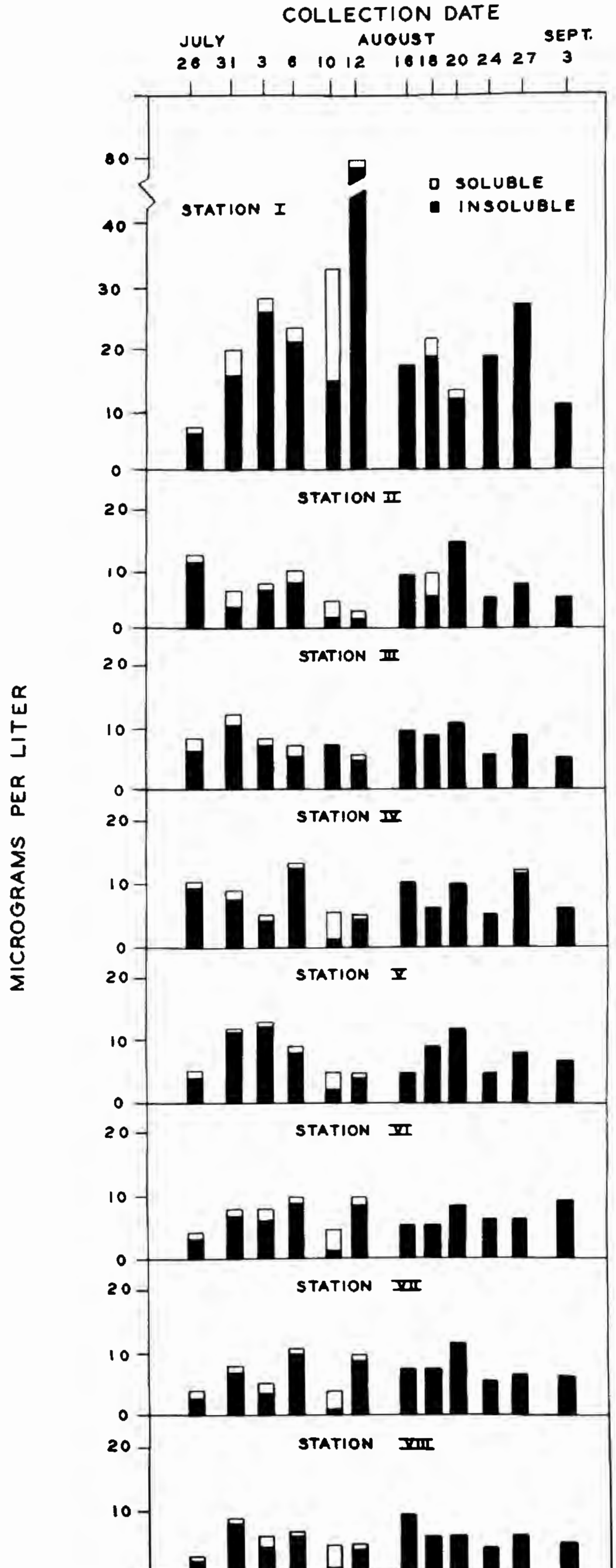
TABLE XIV

MICROGRAMS PER LITER OF PHOSPHORUS IN WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, JUNE TO SEPTEMBER, 1954

| Date | Item | Station I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| July 26 . . . . | Soluble | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |
| | Total | 8 | 13 | 8 | 10 | 5 | 4 | 4 | 6 |
| 31 . . . | Soluble | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| | Total | 20 | 7 | 12 | 8 | 12 | 8 | 8 | 9 |
| August 3 . . | Soluble | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 |
| | Total | 28 | 8 | 8 | 5 | 13 | 8 | 6 | 6 |
| 6 . . | Soluble | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| | Total | 18 | 10 | 7 | 13 | 9 | 10 | 11 | 6 |
| 10 . . | Soluble | 12 | 3 | 4 | 4 | 3 | 4 | 3 | 4 |
| | Total | 27 | 5 | 7 | 5 | 5 | 5 | 4 | 5 |
| 12 . . | Soluble | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Total | 79 | 2 | 4 | 5 | 5 | 10 | 10 | 5 |
| 16 . . | Soluble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 22 | 9 | 9 | 10 | 5 | 6 | 8 | 10 |
| 18 . . | Soluble | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 26 | 9 | 8 | 6 | 9 | 6 | 8 | 7 |
| 20 . . | Soluble | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 3 | 14 | 10 | 10 | 12 | 9 | 12 | 7 |
| 24 . . | Soluble | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 18 | 5 | 5 | 4 | 5 | 7 | 6 | 5 |
| 27 . . | Soluble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 26 | 7 | 8 | 12 | 8 | 7 | 7 | 7 |
| September 3. | Soluble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 10 | 5 | 4 | 6 | 7 | 10 | 7 | 6 |
| 10. | Soluble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | - | - | - | - | - | - | - | - |

Dates of fertilization. July 30 and August 9.

Figure 12. Phosphorus content of water samples taken from the West Branch of the Sturgeon River, June to September, 1954.




DATES OF FERTILIZATION: July 30 and August 9

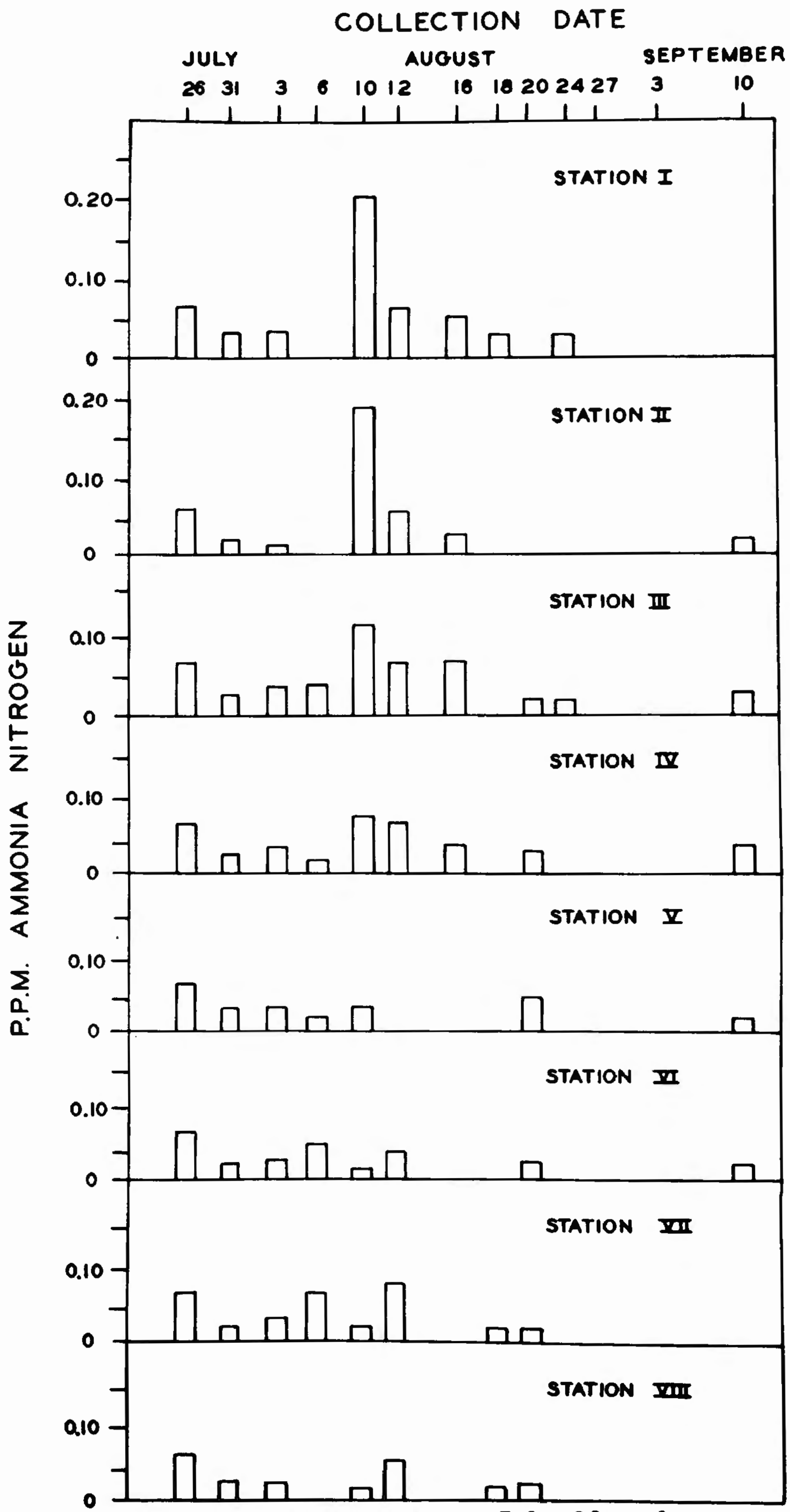
TABLE XV

PARTS PER MILLION OF AMMONIA NITROGEN IN WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, JUNE TO SEPTEMBER, 1954

| Date | Station | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII |
| July 26 . . | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 31 . . | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 |
| Aug. 3 . . | 0.03 | 0.01 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 |
| 6 . . | 0 | 0 | 0.03 | 0.01 | 0.01 | 0.05 | 0.06 | 0 |
| 10 . . | 0.20 | 0.19 | 0.11 | 0.07 | 0.03 | 0.01 | 0.05 | 0.01 |
| 12 . . | 0.06 | 0.06 | 0.06 | 0.06 | 0 | 0.03 | 0.07 | 0.05 |
| 16 . . | 0.05 | 0.03 | 0.06 | 0.03 | 0 | 0 | 0 | 0 |
| 18 . . | 0.03 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 |
| 20 . . | 0 | 0 | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 | 0.02 |
| 24 . . | 0.03 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| 27 . . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sept. 3 . . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 . . | 0 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.01 | 0 |

Dates of fertilization: July 30 and August 9.

Figure 13. The ammonia nitrogen content of water samples taken from the West Branch of the Sturgeon River, June to September, 1954.




DATES OF FERTILIZATION: July 30 and August 9 second application. Station III is approximately three miles downstream from the lake.

It is thought the physical characteristics of the stream between Stations I and II were responsible for the small quantity of added nutrients reaching Station II. Approximately a half-mile downstream from the lake an old beaver dam causes the stream to spread--thus forming a shallow backwater.

The backwater is about a quarter-mile in length and has an organic bottom supporting a luxuriant stand of aquatic plants, notably *Carex* sp., *Myrica gale*, and *Nuphar advena*. Therefore, it is speculated that much of the added nutrients were utilized by the higher aquatic plants, or removed from the system by chemical combination with the organic bottom materials.

The data also indicate there is a relationship between the downstream movement of fertilizer and the weather at the time of fertilization. The second application was followed by three days of rain and nearly a week of overcast skies. Winds, strong enough to form whitecaps, blew in the direction of the outlet for several days following fertilization. It was at this time that large amounts of ammonia nitrogen could be chemically traced downstream to Station III. There was also a threefold increase in the amount of phosphorus present at Station I.

Therefore, it is thought that the inclement weather had the dual effect of "flushing out" the lake and stream and retarding plant activity. Thus the over-all effect would be to have greater concentrations of fertilizer moving downstream.

Moyle (1954) states that within a given range (up to 0.13 p.p.m.) the total phosphorus content of summer surface water shows a straight-line relationship to the size and growth of a fish population. He also found that fish associations are generally distributed in a pattern similar to the distribution of phosphorus and nitrogen. In other words a fish population will adjust itself until it is composed of those species which can best utilize the degree of fertility present and the environmental conditions associated with it. Salmonids are associated with low nutrient content; carp and other rough fish are associated with high nutrient content.

An optimum phosphorus content was also noted for any particular association of fish. Deviations from the optimum phosphorus content have associated changes in environment and food production, thus making the environment less favorable for that fish association.

Moyle (op. cit.) found that the optimum phosphorus content with lake trout is around 0.02 parts per million. Disregarding the phosphorus content at the source of fertilization, the West Branch of the Sturgeon River had a mean summer phosphorus content of 0.007

parts per million. While this figure is not strictly comparable to Moyle's figure for lake trout, nevertheless it suggests insufficient phosphorus for the development of an optimum salmonid environment.

SUMMARY

1. The West Branch of the Sturgeon River is a trout stream located in the northern portion of the Lower Peninsula of Michigan. The surrounding watershed is infertile and unsuitable for agriculture. The stream is relatively pristine except for the lower reaches where some encroachment by cottages occurs.

2. The physical and chemical features of the stream were found to be conducive to low productivity. The water appears to have a low nutrient content. Large areas of the stream receive little or no direct sunlight because of shading by stream bank vegetation. Large stretches of the stream bottom are composed of unproductive sand.

3. Inorganic fertilizer was added to Hoffman Lake, which is the source of the west branch of the Sturgeon River, twice during the summer of 1954. Large quantities of phosphorus and ammonia nitrogen were found to leave the lake. However, with one exception none of the added nutrients could be found at a sampling station one mile from the lake. The one exception occurred one day after the second application when ammonia nitrogen could be traced downstream three miles from the lake. The data indicate this movement of

nutrients was correlated with inclement weather present at the time of and following fertilization.

4. An increase in aufwuchs flora was observed at all stations after fertilization. It is believed this increase was due directly to fertilization. The greatest mean increase in aufwuchs was observed at the outlet of the lake (Station I). Among the downstream stations (II to VIII) the greatest mean increase in aufwuchs was noted at Station IV, which is approximately three miles from the lake.

5. The level of bottom fauna production in the West Branch of the Sturgeon River was found to be extremely low compared to another trout stream having "average richness."

6. The fish population was found to be composed almost entirely of brook, brown, and rainbow trout. A gradual transition in the species composition was noted between the headwaters of the stream and its confluence with the Sturgeon River. Brook trout were very abundant in the headwaters and were gradually displaced by brown and rainbow trout in the lower reaches of the stream. The transition in species composition was closely paralleled by a change in bottom types. Generally speaking, the brook trout were associated with silt and sand bottoms and the other two species with gravel bottoms.

7. The growth of trout in the West Branch of the Sturgeon River was poor even when compared to unproductive Michigan streams.

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APPENDIX

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station I)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae . . . . . . . | 0 | 6 | 0 | 1 |
| Simuliidae . . . . . . . . | 0 | 2 | 0 | 1 |
| Subtotals . . . . . . . . . | 0 | 8 | 0 | 2 |
| Trichoptera | | | | |
| Hydropsychidae . . . . . | 41 | 208 | 8 | 202 |
| Psychomyiidae . . . . . | 0 | 1 | 0 | 14 |
| Subtotals . . . . . . . . . | 41 | 209 | 8 | 216 |
| Ephemeroptera | | | | |
| Baetidae . . . . . . . . . . | 4 | 0 | 0 | 0 |
| Heptageniidae . . . . . . | 0 | 0 | 0 | 1 |
| Subtotals . . . . . . . . . | 4 | 0 | 0 | 1 |
| Coleoptera | | | | |
| Elmidae . . . . . . . . . . | 0 | 2 | 0 | 3 |
| Subtotals . . . . . . . . . | 0 | 2 | 0 | 3 |
| Turbellaria . . . . . . . . | 2 | 3 | 0 | 6 |
| Crustaceae . . . . . . . . . | 22 | 0 | 3 | 1 |
| Subtotals . . . . . . . . . | 24 | 3 | 3 | 7 |
| Totals . . . . . . . . . . . . | 69 | 222 | 11 | 229 |
| Mean no./substrate . . . | 23.0 | 55.0 | 3.7 | 57.2 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station II)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae . . . . . . . | 32 | 63 | 0 | 2 |
| Simuliidae . . . . . . . . | 527 | 9 | 163 | 27 |
| Rhagionidae . . . . . . . | 0 | 2 | 0 | 0 |
| Culicidae . . . . . . . . . | 0 | 4 | 0 | 0 |
| Subtotals . . . . . . . . . | 559 | 78 | 163 | 39 |
| Trichoptera | | | | |
| Hydropsychidae . . . . . | 13 | 15 | 11 | 7 |
| Brachycentridae . . . . | 3 | 7 | 7 | 6 |
| Psychomyiidae . . . . . | 0 | 1 | 2 | 1 |
| Rhyacophilidae . . . . . | 0 | 1 | 0 | 0 |
| Subtotals . . . . . . . . . | 16 | 24 | 20 | 14 |
| Ephemeroptera | | | | |
| Baetidae . . . . . . . . . . | 64 | 36 | 32 | 2 |
| Heptageniidae . . . . . . | 0 | 11 | 0 | 0 |
| Subtotals . . . . . . . . . | 64 | 47 | 32 | 2 |
| Plecoptera | | | | |
| Perlidae . . . . . . . . . . | 0 | 1 | 0 | 1 |
| Subtotals . . . . . . . . . | 0 | 1 | 0 | 1 |
| Crustaceae . . . . . . . . . | 1 | 0 | 0 | 1 |
| Subtotals . . . . . . . . . | 1 | 0 | 0 | 1 |
| Totals . . . . . . . . . . . . | 640 | 150 | 215 | 52 |
| Mean no./substrate . . . | 128.0 | 25.0 | 43.0 | 8.7 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station III)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae . . . . . . . | 4 | 12 | 1 | 5 |
| Simuliidae . . . . . . . . | 1 | 1 | 12 | 3 |
| Subtotals . . . . . . . . . | 5 | 13 | 13 | 8 |
| Trichoptera | | | | |
| Hydropsychidae . . . . . | 29 | 8 | 46 | 3 |
| Psychomyiidae . . . . . | 0 | 0 | 1 | 0 |
| Subtotals . . . . . . . . . | 29 | 8 | 47 | 3 |
| Ephemeroptera | | | | |
| Baetidae . . . . . . . . . . | 29 | 6 | 20 | 3 |
| Subtotals . . . . . . . . . | 29 | 6 | 20 | 3 |
| Gastropoda . . . . . . . . . | 0 | 0 | 2 | 1 |
| Nematoda . . . . . . . . . . | 0 | 0 | 0 | 4 |
| Crustaceae . . . . . . . . . | 4 | 2 | 3 | 0 |
| Subtotals . . . . . . . . . | 4 | 2 | 5 | 5 |
| Totals . . . . . . . . . . . . | 67 | 29 | 85 | 19 |
| Mean no./substrate . . . | 14.8 | 9.7 | 21.3 | 6.3 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station IV)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae . . . . . . . | 3 | 59 | 0 | 12 |
| Simuliidae . . . . . . . . | 1 | 0 | 22 | 2 |
| Culicidae . . . . . . . . . | 0 | 1 | 0 | 0 |
| Subtotals . . . . . . . . . | 4 | 60 | 22 | 14 |
| Trichoptera | | | | |
| Hydropsychidae . . . . . | 25 | 3 | 21 | 0 |
| Psychomyiidae . . . . . | 0 | 1 | 6 | 1 |
| Subtotals . . . . . . . . . | 25 | 4 | 27 | 1 |
| Ephemeroptera | | | | |
| Baetidae . . . . . . . . . . | 11 | 1 | 13 | 3 |
| Heptageniidae . . . . . . | 1 | 1 | 0 | 1 |
| Subtotals . . . . . . . . . | 12 | 2 | 13 | 4 |
| Plecoptera | | | | |
| Perlidae . . . . . . . . . . | 0 | 0 | 0 | 1 |
| Subtotals . . . . . . . . . | 0 | 0 | 0 | 1 |
| Coleoptera | | | | |
| Elmidae . . . . . . . . . . | 0 | 0 | 0 | 1 |
| Subtotals . . . . . . . . . | 0 | 0 | 0 | 1 |
| Totals . . . . . . . . . . . . | 41 | 66 | 62 | 21 |
| Mean no./substrate . . . | 10.2 | 13.2 | 15.5 | 4.2 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station V)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae | 5 | 8 | 0 | 0 |
| Simuliidae | 59 | 2 | 13 | 0 |
| Subtotals | 64 | 10 | 13 | 0 |
| Trichoptera | | | | |
| Hydropsychidae | 8 | 10 | 8 | 0 |
| Rhyacophilidae | 1 | 0 | 1 | 0 |
| Psychomyiidae | 1 | 0 | 0 | 0 |
| Subtotals | 10 | 10 | 9 | 0 |
| Ephemeroptera | | | | |
| Baetidae | 31 | 26 | 52 | 10 |
| Heptageniidae | 0 | 4 | 2 | 0 |
| Ephemeridae | 0 | 1 | 0 | 0 |
| Subtotals | 31 | 31 | 54 | 10 |
| Totals | 105 | 51 | 76 | 10 |
| Mean no./substrate | 26.2 | 12.8 | 19.0 | 2.5 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station VI)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae . . . . . . . | 93 | 21 | 1 | 0 |
| Simuliidae . . . . . . . . | 169 | 86 | 5 | 1 |
| Rhagionidae . . . . . . . | 0 | 3 | 0 | 0 |
| Culicidae . . . . . . . . . | 8 | 0 | 0 | 0 |
| Ceratopogonidae . . . . | 1 | 0 | 0 | 0 |
| Subtotals . . . . . . . . . | 264 | 110 | 6 | 1 |
| Trichoptera | | | | |
| Hydropsychidae . . . . . | 9 | 1 | 11 | 0 |
| Brachycentridae . . . . | 7 | 1 | 8 | 0 |
| Rhyacophilidae . . . . . | 1 | 1 | 9 | 0 |
| Psychomyiidae . . . . . | 0 | 0 | 1 | 0 |
| Subtotals . . . . . . . . . | 17 | 3 | 29 | 0 |
| Ephemeroptera | | | | |
| Baetidae . . . . . . . . . . | 63 | 18 | 26 | 2 |
| Heptageniidae . . . . . . | 2 | 2 | 8 | 2 |
| Subtotals . . . . . . . . . | 65 | 20 | 34 | 4 |
| Plecoptera | | | | |
| Perlidae . . . . . . . . . . | 0 | 1 | 0 | 0 |
| Perlodidae . . . . . . . . | 1 | 0 | 0 | 0 |
| Subtotals . . . . . . . . . | 1 | 1 | 0 | 0 |
| Totals . . . . . . . . . . . . | 346 | 134 | 69 | 5 |
| Mean no./substrate . . . | 86.5 | 26.8 | 17.2 | 1.0 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station VII)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae | 23 | 16 | 0 | 4 |
| Simuliidae | 611 | 31 | 52 | 255 |
| Rhagionidae | 4 | 1 | 0 | 0 |
| Subtotals | 638 | 48 | 52 | 259 |
| Trichoptera | | | | |
| Hydropsychidae | 28 | 0 | 5 | 7 |
| Brachycentridae | 6 | 0 | 3 | 0 |
| Psychomyiidae | 0 | 0 | 0 | 1 |
| Subtotals | 34 | 0 | 8 | 8 |
| Ephemeroptera | | | | |
| Baetidae | 40 | 26 | 9 | 28 |
| Heptageniidae | 2 | 4 | 3 | 6 |
| Subtotals | 42 | 30 | 12 | 34 |
| Plecoptera | | | | |
| Perlidae | 1 | 1 | 0 | 0 |
| Subtotals | 1 | 1 | 0 | 0 |
| Arachnida | 1 | 0 | 1 | 0 |
| Subtotals | 1 | 0 | 1 | 0 |
| Totals | 716 | 79 | 73 | 301 |
| Mean no./substrate | 238.7 | 15.8 | 24.3 | 60.2 |

ENUMERATION OF AUFWUCHS FAUNA SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station VIII)

| Taxonomic Groups | First Collection | | Second Collection | |
|---|---|---|---|---|
| | Bricks | Shingles | Bricks | Shingles |
| Diptera | | | | |
| Tendipedidae . . . . . . . | 8 | 34 | 0 | 2 |
| Simuliidae . . . . . . . . | 1123 | 1343 | 175 | 209 |
| Rhagionidae . . . . . . . | 0 | 1 | 0 | 1 |
| Subtotals . . . . . . . . . | 1131 | 1378 | 175 | 210 |
| Trichoptera | | | | |
| Hydropsychidae . . . . . | 16 | 11 | 15 | 10 |
| Brachycentridae . . . . | 6 | 2 | 1 | 0 |
| Subtotals . . . . . . . . . | 22 | 13 | 16 | 10 |
| Ephemeroptera | | | | |
| Baetidae . . . . . . . . . . | 10 | 55 | 2 | 8 |
| Heptageniidae . . . . . . | 0 | 3 | 0 | 3 |
| Subtotals . . . . . . . . . | 10 | 58 | 2 | 11 |
| Plecoptera | | | | |
| Pteronarcidae . . . . . . | 0 | 0 | 1 | 1 |
| Subtotals . . . . . . . . . | 0 | 0 | 1 | 1 |
| Nematoda . . . . . . . . . . | 0 | 2 | 0 | 0 |
| Arachnida . . . . . . . . . | 4 | 3 | 0 | 0 |
| Subtotals . . . . . . . . . | 4 | 5 | 0 | 0 |
| Totals . . . . . . . . . . . . | 1167 | 1454 | 194 | 232 |
| Mean no./substrate . . . | 233.4 | 161.5 | 38.8 | 25.7 |