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LIMNOLOGICAL EFFECTS OF HEADWATER FERTILIZATION ON THE WEST BRANCH OF THE STURGEON RIVER, MICHIGAN

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LIMNOLOGICAL EFFECTS OF HEADWATER FERTILIZATION ON THE WEST BRANCH OF THE STURGEON RIVER, MICHIGAN

By

PETER JAMES COLBY

A THESIS

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ABSTRACT

During the summer of 1955 two applications of inorganic commercial fertilizer were made to Hoffman Lake, the source of the west branch of the Sturgeon River. Following fertilization there was an increase in total and soluble phosphorus, ammonia nitrogen, and possibly sulfates at Station I only.

Both in 1954 and 1955 there was an obvious increase in aufwuchs flora at Station I following fertilization. Contrary to the 1954 results, in 1955 the 30-day collections showed a decrease in flora at the downstream stations. This is not in agreement with the results of the weekly collections where a statistically significant increase was detected following fertilization. Such factors as limited carrying capacity of the shingles, erosion, predation, et cetera, may cause the shingles left in the stream for 30-day periods to lose their efficiency in accumulation of aufwuchs flora.

There was approximately a 14 percent increase in the volume of bottom organisms from 1954 to 1955. The average wet weight per square foot values show production to be low in the west branch of the Sturgeon River as compared with other similar streams.

There is evidence of longitudinal distribution of trout in the west branch. Starting with brook trout at the headwaters there is a gradual displacement by rainbow and brown trout downstream. The brook trout growth in the west branch is poor, even when compared to unproductive streams.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to: Dr. Robert C. Ball, under whose direction this study was made, and Dr. Frank F. Hooper, for their assistance and guidance; Mr. Nickolas Anton, an associate throughout the major part of this investigation; Dr. Gordon Guyer for his assistance with the identification of bottom fauna; Dr. D. W. Hayne for assistance with the statistical preparation and analysis; Dr. E. W. Roelofs and Dr. G. W. Prescott for their helpful criticisms; and Mr. Edward H. Bacon and Mr. Gerald F. Meyers for assistance in the collections of field data.

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INTRODUCTION

Fishing continues to be a leading attraction in the state's multimillion dollar tourist industry, and according to economists, this industry will continue to grow (Michigan Department of Conservation, 1955). Thus the maintenance and improvement of the existing fisheries becomes important. A means of improving the available recreational fisheries would be the development of practical methods to increase the biological productivity of our less productive lakes and streams.

This dissertation deals with the second-year phase of a four-year project designed to test whether trout fishing can be improved in an unproductive trout stream by the addition of nutrients, and also to determine if it is economically feasible to use this method as a management procedure. The second-year study consists of evaluating the data collected during the summer of 1955 and making comparisons where possible with the information obtained in 1954 by Grzenda (1955). In conjunction with the stream studies, dissertations by Alexander (1956) and Anton (1957) deal with the fertilization of Hoffman Lake.

Fertilization as a management procedure in streams and larger lakes is still in the experimental phase. Hasler and Einsele (1948) pointed out that detrimental effects of fertilization may outweigh biological gains; thus, they strongly emphasized that only experimental fertilization should be undertaken at this stage of our knowledge. They concluded that apart from increasing productivity, addition of nutrients to a lake gives the limnologist an excellent tool for studying lake metabolism experimentally. Almost all of the fertilization projects to date have been limited to lentic environments such as farm ponds and small lakes. A recent review of the literature on artificial fertilization of lakes and ponds is given by Maciolek (1954).

The application of commercial inorganic fertilizer to Hoffman Lake which feeds the west branch of the Sturgeon River is one of the original attempts to enrich a lotic environment. One other attempt has been recorded by Huntsman (1948) who added commercial inorganic fertilizer to a barren Nova Scotia stream and found an increase in the quantity of fish, filamentous algae, and certain insect larvae.

LOCATION AND DESCRIPTION OF STATIONS AND STUDY AREA

The west branch of the Sturgeon River is located in Charlevoix, Otsego, and Cheboygan counties in the northern Lower Peninsula of Michigan. It arises from Hoffman Lake (T.32N,R.4W sec. 26,27,34,and35) and flows in a northeasterly direction for approximately thirteen miles, joining the Sturgeon River at Wolverine. The tributaries are Allen, Berry, and Fulmer creeks.

The west branch receives a large volume of ground-water seepage and spring flow, as can be seen from the discharge measurements (Table I), which probably accounts for the relatively stable water temperature (Figure 1).

The watershed is located in the interlobate area of the Port Huron Morainic System formed during the Mankato substage of Pleistocene glaciation. Whiteside, Schneider, and Cook (1956) classify this area as that of Land Division N of the limy Podzol Region of Michigan. They characterize this division as a rolling to extremely rough land which occupies the morainic areas of the northern part of the Lower Peninsula and the eastern part of the Upper Peninsula. The parent materials from which the soils of this area were

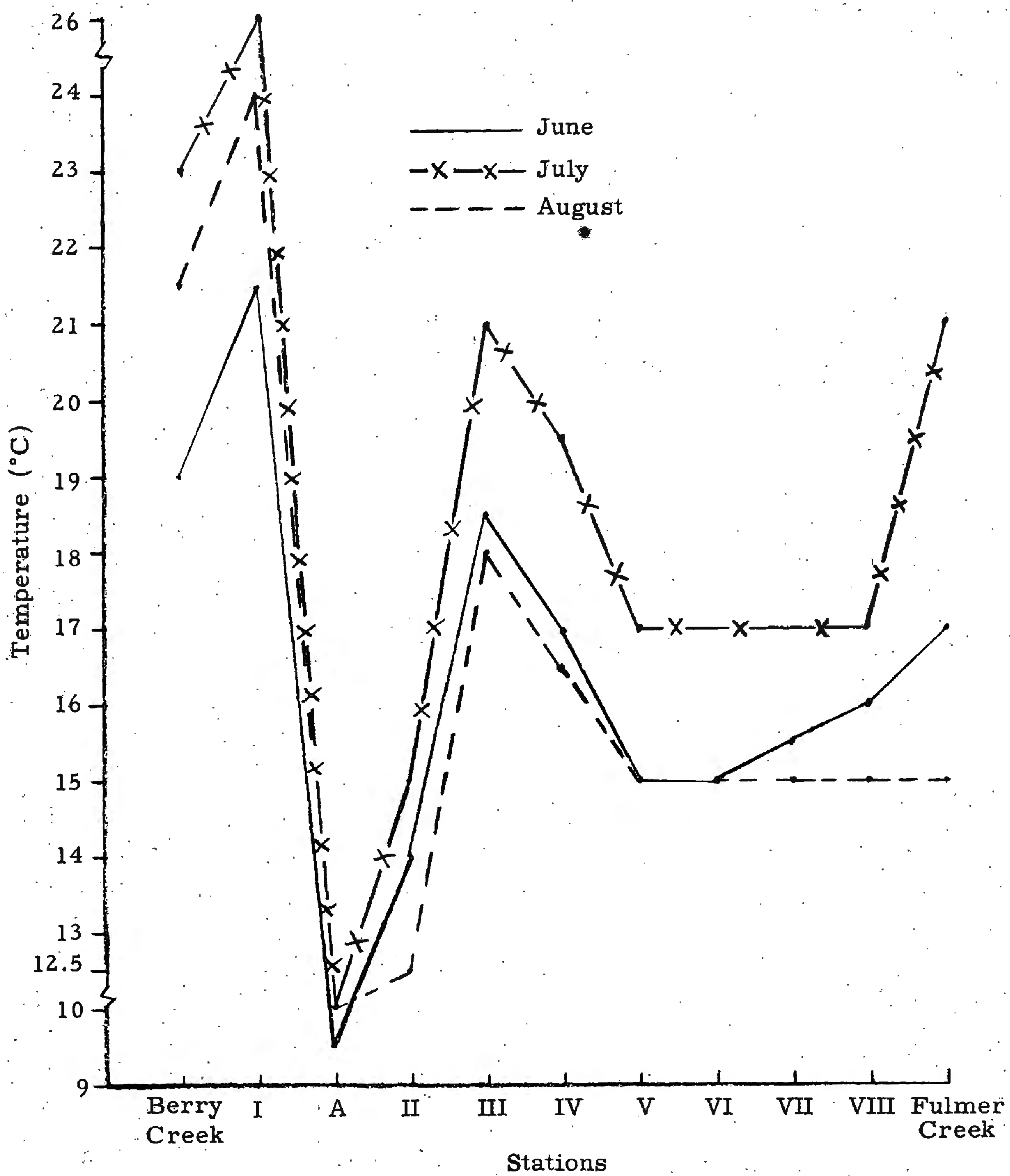
TABLE I

DISCHARGE (VOLUME OF FLOW) MEASUREMENTS TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER ON JULY 23, 1954, AND AUGUST 27, 1955[a]

Station	Discharge (CFS)	
	1954	1955
II	8.76	6.56
III	9.68	---
IV	16.5	---
V	21.0	23.2
VI	29.6	---
VII	45.2	---
VIII	---	68.3

[a]1954 data courtesy of Arlington D. Ash, USGS, Lansing, Michigan.

Figure 1. Average monthly water temperature of the west branch of the Sturgeon River and its tributaries for the summer of 1955.


June
July
August
Temperature (°C)
26
24
23
22
21
20
19
18
17
16
15
14
13
12.5
10
9
Berry Creek
I
A
II
III
IV
V
VI
VII
VIII
Fulmer Creek
Stations

formed range from sands to sandy loams, with loams and clay loams in local areas. The original forest was chiefly hardwood with the sugar maple (Acer sacchrum) the dominant tree. The value of the land for farming is greatly reduced by the associated sandy soils and unfavorable slopes.

Due to the high relief of the adjacent moraines the watershed is rather restricted. Grzenda (1955) approximated the drainage area of the watershed to be 14.0 square miles. The vegetation adjacent to the stream is largely composed of stands of aspen (Populus sp.), red cedar (Juniperus virginiana), black spruce (Picea mariana), and tag alder (Alnus incana).

The following is a brief description of eight collections and the one control station used to study the effects of dilution of the added nutrients and their utilization at varying distances downstream from the lake.

Station I: This station is located at the outlet of Hoffman Lake, the source of the west branch of the Sturgeon River. The outlet is narrow and only a small volume of water leaves the lake. The bottom is composed of marl and the physicochemical and biological conditions are more typical of the lake than the remaining downstream stations. The higher aquatic plants consist of

Potamogeton spp., Typha latifolia, Scirpus sp., Chara sp., and Saggitaria latifolia.

Station II is located approximately one mile downstream from Hoffman Lake. There is greater discharge at this station due to the addition of water of two large springs, one of which served as the control station (Station A). The bottom is a combination of shifting sand and silt.

Station III is located approximately two miles from Hoffman Lake. The current is slow with the bottom consisting of silt due to partial impoundment of the stream by a beaver dam. There is an abundance of higher aquatic at this station. Nasturtium officinale, Ranunculus longirostris, Sparganium sp., Potamogeton spp.

Station IV is approximately four and one-half miles downstream. The stream here is moderately swift and the bottom is composed mostly of shifting sand and stretches of gravel. This section of the stream receives very little direct sunlight due to the tree canopy.

Stations V, VI, and VII are located downstream from the source six and one-half, eight, and nine and one-half miles, respectively. The current is moderately swift at these stations. All have the stream bottom covered with patches of sand and gravel. There is a gradual widening of the river from source to confluence with the Sturgeon River. The lower stations receive much more direct sunlight than the upper ones.

<u>Station VIII</u> is approximately ten and one-half miles downstream. One of the large tributaries (Fulmer Creek) enters the west branch here. The bottom is gravel and rubble.

No stations were established beyond this point because domestic waste from streamside cabins might interfere with the interpretation of results.

METHODS AND PROCEDURES

Application of Fertilizers

During the summer of 1955, two applications of inorganic commercial fertilizer (12-12-12 N-P-K) were made to Hoffman Lake. Nitrogen and phosphorus were in the form of ammonium sulfate and phosphoric acid respectively. The fertilizer was applied from a motorboat along the southwestern perimeter of the lake. The lake is unstratified and has complete circulation; therefore, the adding of fertilizer on the windward side distributes the nutrients throughout the lake, following which, if they remain in solution, they may be discharged into the outlet on the eastern end of the lake. The result: possibly the enrichment of the west branch of the Sturgeon River, thus providing the nutrients necessary for primary production at the lower trophic levels. Six thousand pounds of fertilizer were applied July 31 and 4,000 pounds additional on August 6. This was twice the concentration of that added in the two 1954 applications.

Physicochemical

Analyses of water were made from samples collected at each station to ascertain selected physicochemical properties and to trace any movement of the nutrients downstream. Total and soluble phosphorus determinations were by the molybdate method (Ellis, Westfall, and Ellis, 1948), ammonia nitrogen by direct Nesslerization, and sulfate by the turbidimetric method (Standard Methods, 1955). The colorimetric determinations used in these procedures were made with a Klett-Summerson photoelectric colorimeter. Alkalinity was determined by the methyl orange indicator method according to Standard Methods, pH was determined electrometrically with a Beckman pH meter, and conductivity, with a conductivity bridge manufactured by Industrial Instruments Company. Water and air temperatures were taken directly with a pocket thermometer at the time the samples were collected. The stream flow or discharge in 1955 was determined by use of Embody's formula (Lagler, 1952). Stream flow determinations in 1954 were provided through the courtesy of A. D. Ash, U.S.G.S., Lansing, Michigan

Biological

Aufwuchs. In the literature there are several definitions of "periphyton" (the closest English equivalent to the German term "aufwuchs"). Young (1945) found the periphyton complex to be comprised of organisms with a rather large taxonomic diversity. He describes periphyton as an "assemblage of organisms growing upon the free surface of submerged objects in waters, and covering them with a slimy coating.'' He excludes benthos from his definition. The term ''aufwuchs'' has a much broader connotation than periphyton. ''Aufwuchs comprises all attached organisms (except the macrophytes), including such forms as sponges and Bryozoa, which are usually considered as benthos by American authors; also included are the various forms living free within the mat of sessile forms'' (Ruttner, 1953). The assemblage of organisms that collected on the measuring devices placed in the stream will be referred to in this dissertation as aufwuchs following the definition of Ruttner.

Patrick (1949) found that the measure which uses largely the organisms that are attached to the bottom or edges of the stream, reflects the water conditions which have flowed by a given point for a considerable time before sampling, whereas a chemical analysis can only describe the condition of the water at the exact time it was taken.

A modification of the Harvey (1934) method, rather than the count method, was used to measure quantitative changes in aufwuchs production. The latter method is time-consuming, very difficult, and of doubtful quantitative value.

Aufwuchs production was used as an index of productivity mainly because the sterile characteristics of the stream limits the selection of other indices. The aufwuchs community was also used because it is one of the most stable groups of organisms in the lotic environment. Unlike stream plankton, its sessile characteristics protect it from the flushing action of the stream in times of high water.

Harvey (1934) found that a good correlation existed between colorimetric determinations of pigment extracted with acetone and the actual enumeration of comparable samples of plankton. This method was later used by Tucker (1949) as a means of estimating the abundance of phytoplankton. Tucker concluded that in a single sample the method is of little value because the standard error of estimate is too large to obtain a reliable result. However, because of its high correlation with actual counts when many samples are considered, this method is of value as a means of estimating changes in total abundance of phytoplankton. From the standpoint of statistical analysis it has not been perfected sufficiently to be used other than as a general indicator (Tucker, 1949), even with the use of a photoelectric colorimeter (Tucker, 1956). Tucker (1949) also found that the highest correlation was among the green algae and diatoms, which comprise most of the aufwuchs flora in this study.

To collect aufwuchs and measure trends in its production, five bricks and fifteen shingles were placed in the stream at each station for thirty-day periods before and after fertilization. At the termination of the first thirty-day period (the day before the first application of fertilizer) the bricks and shingles were removed and new ones placed in the same spot and position, thus enabling the samples to be compared statistically.

In addition to the bricks and shingles in the stream, ten shingles were placed upstream from Station IV (Station IVA). The purpose for this procedure was to detect weekly changes in aufwuchs production.

The bricks were cinder building bricks 7.9 x 3.7 x 2.3 inches, and the shingles were cedar with 12.0 x 13.0 x 0.3 inch dimensions.

The bricks were suspended in the water by means of a wire fastened to a stable object, and the shingles were nailed to logs or other suitable objects in the stream. Care was taken to place the bricks and shingles so that organisms could become attached to all sides, and deep enough that a drop in water level would not leave them exposed to the air. When removed, the bricks were immediately placed in a porcelain pan to avoid any loss of motile organisms. The bricks were then scrubbed with a nylon brush and washed several times to remove all attached materials. The contents of the pan were then poured into a quart glass jar bearing the serial number of the brick. The shingles were placed directly into a plastic bag and the attached materials were later removed in the laboratory.

At the laboratory the invertebrate faunae were picked from the samples and preserved in 10 percent formalin. The water was removed by use of the Foerst plankton centrifuge. The outflow tube of the centrifuge was placed in a quart jar to catch the outflowing water. This was necessary because often the samples had to be centrifuged more than once to clear the water of all suspended material. The mixture of silt and plant material left in the revolving bowl was placed in a bottle, and 95 percent alcohol was added to extract the chlorophyll. The samples at this point contained a supernatant liquid composed of alcohol and extracted chlorophyll, and a residual layer of silt and plant material on the bottom. The mixture was filtered, the filtrate brought to a constant volume, and the density of the extracted pigment was measured colorimetrically with a Klett-Summerson photoelectric colorimeter using a No. 66 (red) filter. This gave readings in Klett units which were converted into Harvey units by a graph prepared as follows: One Harvey unit equals 25 mg. potassium chromate and 430 mg. nickel sulfate dissolved in one liter of water (Harvey, 1934). The Harvey standards were prepared by dissolving 2.5 grams of potassium chromate and

43 grams of nickel sulfate in one liter of water. This gave a standard equal to 100 Harvey units, which was diluted to obtain desired concentrations used in preparing the graph.

Bottom fauna. Bottom samples were collected from relatively uniform riffle areas from June 24 to August 25, 1955, using a Surber square-foot sampler. The sample spots were not randomized but were selected by choosing three transects across the stream and taking four samples at evenly spaced intervals along each transect, thus representing a 12-square-foot sample of stream bottom per week. The invertebrate faunae were picked while alive from the debris and preserved in 10 percent formalin.

Fish samples. Fish samples consisted of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdnerii*). The samples were collected twice during the summer (July 6 and August 30) at stations II, V, and VIII using a 220-volt, direct-current shocker. Scale samples, measurements in length to the nearest tenth of an inch, and weight in grams were taken from all sizes and species of trout collected, to determine the weight-length relationship and average length per year class. The scales were cleaned and mounted on microscope slides using gelatin-glycerine media. A scale projector was used in determining the average length of each year class. The length-weight relationship was computed using the following formula (Rounsefell and Everhart, 1953):

$$W = cL^{n}$$

in which W = weight*
L = length
c and n = constants

or expressed logarithmically,

$$\log W = \log c + n \log L$$

The values of the constants c and n may be determined by fitting a straight line to the logarithms of L and W (Rounsefell and Everhart, op. cit.). Natural logarithms (ln) were used to express the relationship in this study.

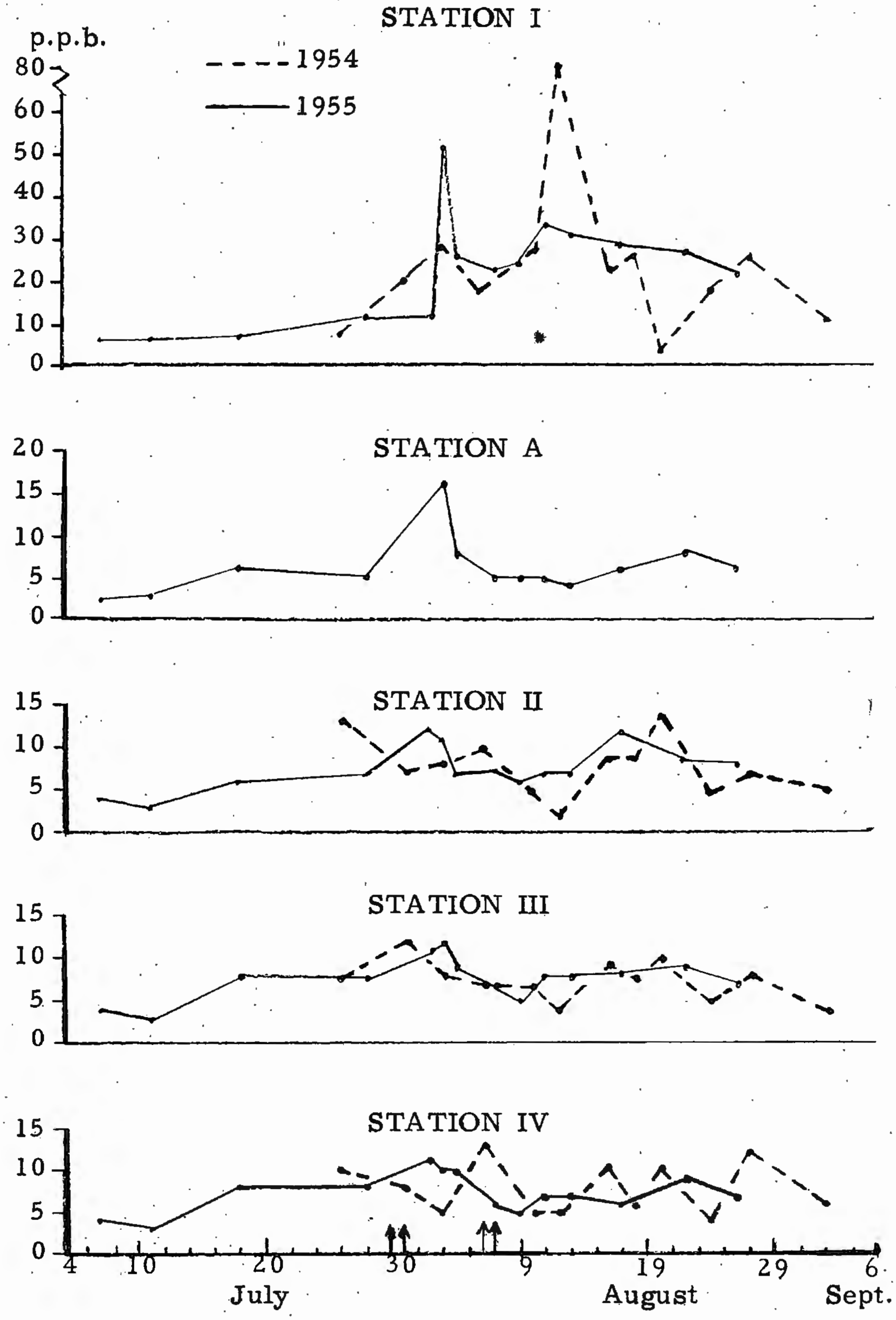
RESULTS AND DISCUSSION

Physicochemical

Phosphorus. Following fertilization there was an increase in total and soluble phosphorus for both 1954 and 1955 (Fig. 2). No significant difference in the concentration was detected at the downstream stations. Although an increase in total phosphorus was detected in the control stream on August 3, it was not of a magnitude as the samples measured at Station I (Table II). Total phosphorus remained at a higher level than the prefertilization concentrations after the second (1955) application. The same situation existed in Hoffman Lake (Anton, 1957). Anton believed that phosphorus became fixed in insoluble precipitates which remained in suspension due to the turbulence of the water caused by wave action and underwater currents. It appears that similar physical forces were responsible for the same effect at Station I in that this station is located at the outlet of Hoffman Lake.

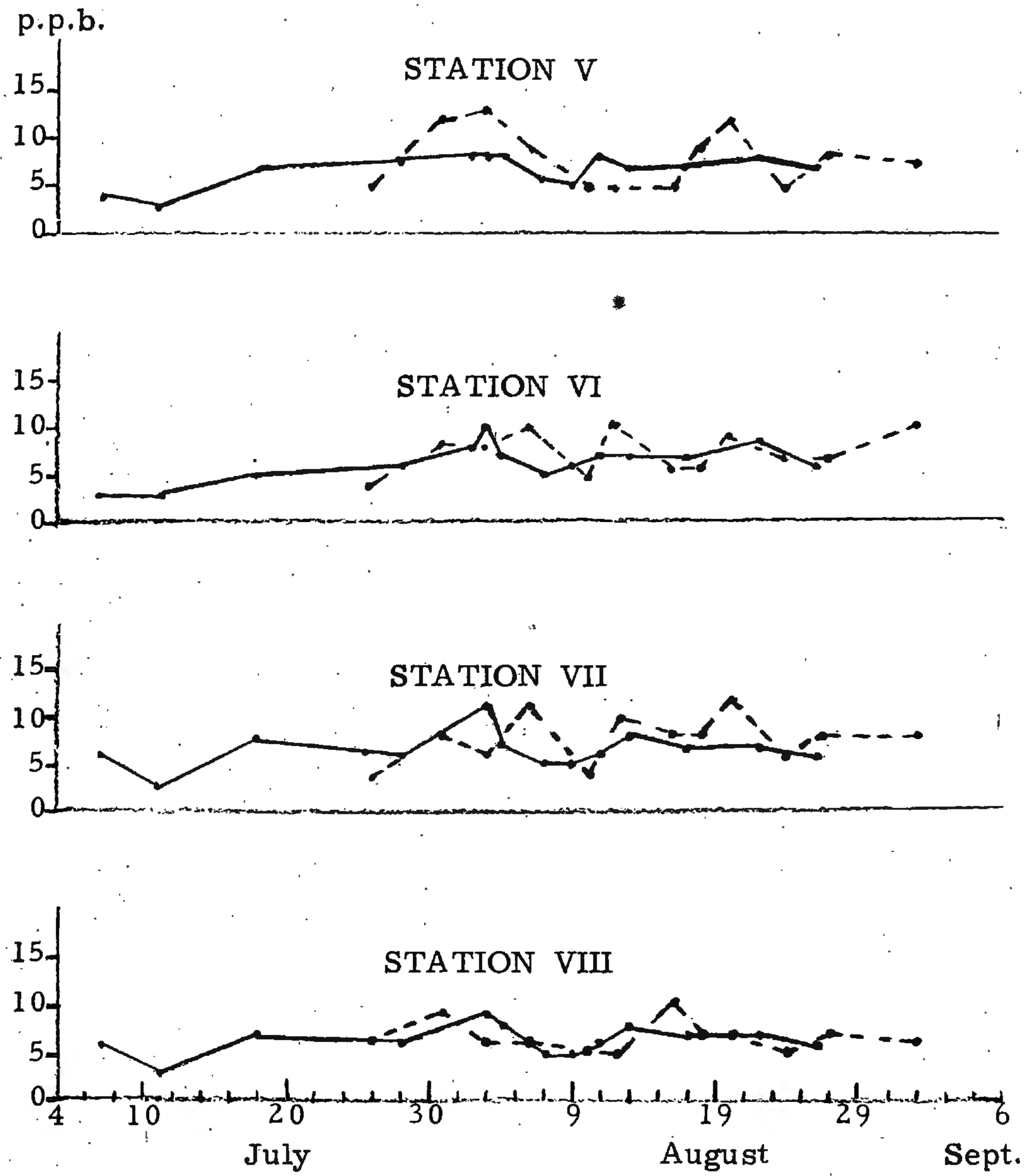
Soluble phosphorus increased to 21 p.p.b. on August 3, but rapidly returned to prefertilization concentrations (Table II). This is not unusual for phosphorus may be lost to bottom deposits (Welch,

Figure 2. Comparison of the total phosphorus content of water samples taken from the west branch of the Sturgeon River during the summers of 1954 and 1955.



Dates of Fertilization: July 30 and August 9, 1954
July 31 and August 6, 1955

Figure 2 (Continued)



Dates of Fertilization: July 30 and August 9, 1954
July 31 and August 6, 1955

TABLE II

PARTS PER BILLION OF PHOSPHORUS IN WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER DURING THE SUMMER OF 1955[a]

Date	Item	Station								
		I	A	II	III	IV	V	VI	VII	VIII
July 7	Soluble	1	1	1	1	1	1	1	1	1
	Total	6	3	4	4	4	4	3	6	6
11	Soluble	2	t[b]	1	1	1	1	1	1	1
	Total	6	3	3	3	3	3	3	3	3
18	Soluble	t	t	t	t	t	t	t	t	t
	Total	7	6	6	8	8	7	5	8	7
28	Soluble	1	5	1	1	1	1	1	1	1
	Total	11	5	7	8	8	8	6	6	6
Aug. 3	Soluble	21	1	t	t	3	2	1	t	1
	Total	51	8	7	12	7	8	10	11	9
7	Soluble	10	..	..	..	..	..	..	..	..
	Total	22	5	7	7	6	6	5	5	5
9	Soluble	..	..	..	..	..	..	..	..	..
	Total	24	5	6	5	5	5	6	5	5
11	Soluble	3	0	t	1	1	2	t	t	1
	Total	33	5	7	8	7	8	7	6	6
13	Soluble	2	1	1	3	1	1	1	t	t
	Total	30	4	7	8	7	7	7	8	8
17	Soluble	1	t	1	t	0	t	0	t	t
	Total	28	6	12	8	6	7	7	7	7
22	Soluble	2	2	2	2	2	2	1	2	1
	Total	26	8	8	9	9	8	9	7	7
26	Soluble	1	1	1	1	1	1	1	1	1
	Total	21	6	8	7	7	7	6	6	6

[a]Dates of fertilization: July 31 and August 6.

[b]t = trace amounts below 1 p.p.b.

1952), taken up by plants (Ruttner, 1953), or precipitated out in some chemical compound such as tricalcium phosphate (Neess, 1949). It was discovered that radioactive phosphorus (P^{32}) is taken up by plants and zooplankton in a matter of minutes or hours, not days or weeks (Coffin et al., 1949).

Moyle (1954) describes the phosphorus optimum for lake trout (in Minnesota waters) to be 0.02 p.p.m. A comparison of his value with those measured in the west branch indicates that the concentration of phosphorus in the stream is too low for a very successful salmonoid environment.

At the time of fertilization it was estimated that less than 1 cu. ft./sec. of water left Hoffman Lake at Station I as compared to 6.6 cu. ft./sec. leaving Station II. Since the greatest source of waters at Station II are the springs and ground water seepage, it is assumed that the phosphorus concentration was greatly reduced by dilution.

Ammonia nitrogen. A temporary increase in ammonia nitrogen was detected at Station I on August 3 (Table III). This may have been the result of fertilization due to peak concentrations being measured in Hoffman Lake on that date (Anton, 1957). No quantitative increase that could be attributed to fertilization occurred

TABLE III

PARTS PER MILLION OF AMMONIA NITROGEN IN WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER DURING THE SUMMER OF 1955[a]

Date		Station								
		I	A	II	III	IV	V	VI	VII	VIII
June	29	.04	.02	.02	.02	.00	.07	.11	.02	.04
July	7	.02	.02	.02	.02	.02	.02	.04	.02	.02
	11	.04	.01	.01	.07	.04	.05	.15	.03	.04
	18	.14	.06	.03	.07	.09	.08	.07	.06	.06
	28	.07	.02	.03	.05	.05	.04	.04	.03	.03
August	2	t[b]	t	t	t	t	t	t	t	t
	3	.28	t	t	t	t	t	t	t	t
	7	0	0	0	0	0	0	0	0	0
	11	.10	.10	.15	.15	.10	.20	.20	.15	.20
	17	.02	.02	.02	.03	.02	.02	.02	.02	.03
	22	.01	.01	.01	.01	.01	.01	.01	.01	.01
	26	t	t	t	t	t	t	t	t	t

[a]Dates of fertilization: July 31 and August 6.

[b]t = trace amounts.

downstream. Although increases in ammonia nitrogen were detected downstream on August 11, a similar trend was observed in the control stream. It is also conceivable that a concentration of .20 p.p.m. may occur naturally in the west branch. This reasoning is based on the concentrations which approached .20 p.p.m. prior to fertilization (Table III).

The rapid decrease of ammonia may have been the result of oxidation of ammonia nitrogen into the nitrite and nitrate forms. Barnes (1955) states there is strong evidence that ammonia is oxidized to nitrite and subsequently to nitrate. He states further that the nitrate form is largely taken up by the diatoms.

Ammonia salts in excess are reported as poisonous to fishes if present with carbonates (Welch, 1952). Amounts exceeding 2.5 p.p.m. are generally detrimental or lethal, and quantities of more than 1.0 p.p.m. usually indicate organic pollution (Ellis et al., 1948). Table III shows the values for ammonia nitrogen to be low, indicating little organic production in the west branch of the Sturgeon River.

Sulfates. There were slight variations in the amount of sulfate present at all stations. The highest concentration of 17 p.p.m. was observed at Station I on August 3 and 9 (Table IV). The

TABLE IV

PARTS PER MILLION OF SULFATES IN WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER DURING THE SUMMER OF 1955[a]

Date		Station								
		I	A	II	III	IV	V	VI	VII	VIII
June	20	14	..	13	13	13	12	11	11	11
	22	15	10	13	13	12	12	11	10	10
	27	13	10	12	11	11	11	10	9	10
	29	14	10	12	12	12	12	10	10	9
July	5	13	8	11	11	9	9	8	8	9
	11	14	10	12	12	11	11	10	10	10
	18	14	10	11	13	13	13	12	10	10
	25	14	10	13	12	13	12	11	11	12
August	2	13	9	12	11	11	11	10	9	9
	3	17	10	12	12	12	11	10	10	10
	7	13	9	10	12	13	11	12	11	10
	9	17	9	13	12	12	11	10	11	11
	11	15	9	12	11	11	10	11	10	11
	13	15	11	12	12	12	12	11	9	10
	17	14	10	12	12	13	11	9	9	9
	22	16	9	12	13	12	12	11	11	11
	26	16	8	10	11	11	11	10	9	9

[a]Dates of fertilization: July 31 and August 6.

August 3 high may have been the result of fertilization in that a concentration of 26 p.p.m. was present in Hoffman Lake on that date (Anton, 1957). It is also quite conceivable that the quantity (17 p.p.m.) could occur naturally in the stream.

Other than to follow the dispersal of fertilizer, sulfate determinations provide an index to measure productivity. Studies in Minnesota show a paucity of higher aquatic plants below 50 p.p.m., and the best growth occurs where the sulfate-ion concentration exceeds 200 p.p.m. (Moyle, 1954). Comparing Moyle's values with those in Table III affords further evidence that production is low in the west branch of the Sturgeon River.

Alkalinity. There was no alkalinity as shown by phenolphthalein. Therefore, the methyl orange alkalinity is representative of the total alkalinity. Under such conditions the alkalinity is all bicarbonate (Theroux et al., 1943). Alkalinity in the west branch is probably present as calcium and magnesium bicarbonate, making the stream an efficient buffer system. Table V shows no change as a result of fertilization. This provides further evidence that the stream is well buffered.

The lower bicarbonate values obtained at Station I are typical of Hoffman Lake rather than the downstream stations. This is true

TABLE V

PARTS PER MILLION OF METHYL ORANGE ALKALINITY IN WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER FOR THE SUMMER OF 1955[a]

Date		Station								
		I	A	II	III	IV	V	VI	VII	VIII
June	20	150	. .	180	180	180	184	182	180	182
	22	155	200	179	182	182	187	185	183	186
	27	153	192	178	180	183	185	183	181	186
	29	155	187	180	180	180	181	175	177	182
July	7	145	185	160	160	165	165	163	164	169
	11	145	187	180	183	180	186	182	181	185
	18	142	182	175	168	160	166	161	165	166
	25	140	185	176	166	170	175	172	175	179
August	7	130	187	178	177	177	179	177	176	177
	9	135	188	176	178	179	180	179	180	182
	13	136	185	174	173	176	188	187	183	188
	17	136	188	184	183	184	188	186	187	188
	22	133	187	182	182	183	184	184	182	186
	26	134	189	187	187	186	188	187	188	189

[a]Dates of fertilization: July 31 and August 6.

due to the stream receiving the major portion of its volume from springs and ground water seepage which are rich in bicarbonates (example, the control stream).

Hydrogen-ion concentration. Variations in pH were small at any one station (Table VI). Because bicarbonates (acting as buffers) react in such a way as to maintain equilibrium, it is conceivable that the effects of fertilization would not be detected by the hydrogen-ion concentration. It is the writer's opinion that this situation existed at Station I where values for pH show no significant change, although the effects of fertilization are apparent.

It may be of interest to note that by applying the values obtained for pH and bicarbonate alkalinity to a carbon dioxide, alkalinity-pH conversion chart (Theroux et al., 1943) the quantity of free carbon dioxide in the west branch is negligible.

Conductivity. The application of fertilizer had no effect on this measurement. At first it may appear that the decrease in conductivity was brought about by fertilization, but the control stream also shows the trend (Fig. 3., Table VII). The variations in concentration of electrolytes may have been the result of dilution caused by runoff from rainfall.

TABLE VI

THE HYDROGEN-ION CONCENTRATION OF WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER DURING THE SUMMER OF 1955[a]

Date		Station								
		I	A	II	III	IV	V	VI	VII	VIII
June	21	8.5	. .	8.1	8.5	8.5	8.4	8.4	8.4	8.3
	22	8.1	7.8	7.9	8.1	8.1	8.1	8.1	8.1	8.0
	27	8.2	7.8	8.0	8.4	8.3	8.3	8.4	8.2	8.2
	29	7.6	8.0	8.1	8.4	8.4	8.4	8.4	8.4	8.3
July	7	8.2	7.9	8.1	8.2	8.3	8.2	8.2	8.2	8.2
	11	8.1	8.0	8.0	8.1	8.2	8.1	8.1	8.1	8.2
	18	7.8	8.0	8.0	8.2	8.2	8.1	8.2	8.1	8.2
	28	8.3	8.0	8.2	8.4	8.4	8.4	8.4	8.4	8.3
August	7	8.0	7.7	7.9	8.0	8.0	8.1	8.2	8.2	8.2
	13	8.4	7.8	8.2	8.3	8.4	8.3	8.3	8.3	8.3
	17	8.2	7.8	8.1	8.2	8.3	8.2	8.3	8.3	8.3

[a]Dates of fertilization: July 31 and August 6.

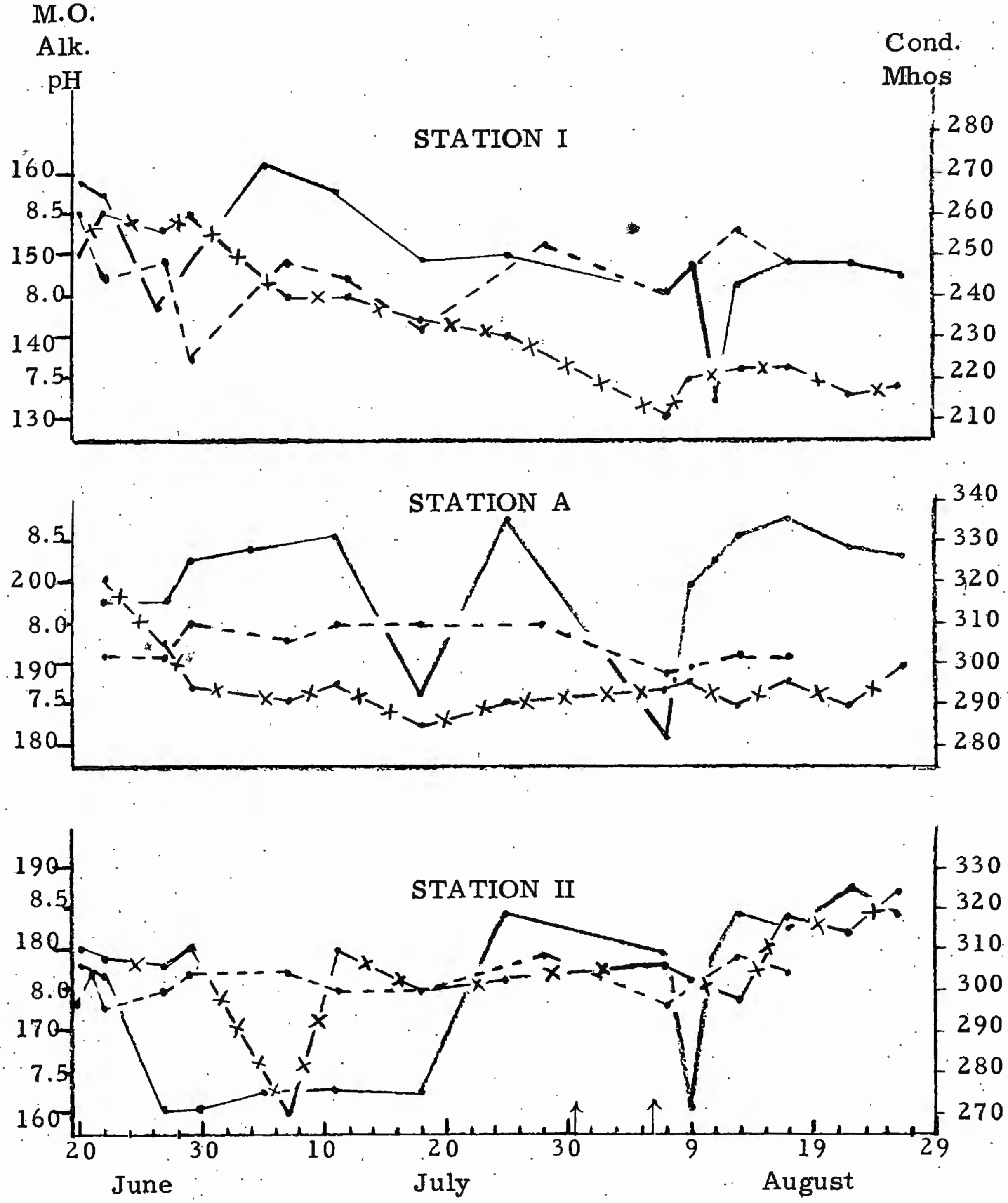
TABLE VII

CONDUCTIVITY (IN Mhos x 10^{-6} AT 18°C) OF WATER SAMPLES TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER DURING THE SUMMER OF 1955[a]

Date		Station								
		I	A	II	III	IV	V	VI	VII	VIII
June	20	267	. .	306	306	306	257	306	306	306
	22	265	316	303	302	305	312	306	303	300
	27	237	316	271	273	284	279	268	269	275
	29	246	325	271	276	276	309	272	266	309
July	5	272	328	275	271	288	263	279	295	298
	11	266	331	276	314	303	319	309	314	319
	18	249	292	275	313	303	311	303	298	305
	25	250	334	319	313	308	325	313	292	325
August	7	241	281	309	309	309	299	289	285	289
	9	247	319	271	303	283	314	314	314	319
	11	214	325	308	325	267	284	289	309	278
	13	242	331	319	295	305	316	309	309	314
	17	248	337	315	325	276	325	299	315	319
	22	248	328	325	319	307	325	319	319	315
	26	245	326	319	309	314	325	316	313	311

[a]Dates of fertilization: July 31 and August 6.

Figure 3. Graphic representation of the hydrogen-ion concentration, methyl orange alkalinity, and conductivity of water samples taken from the west branch of the Sturgeon River during the summer of 1955.



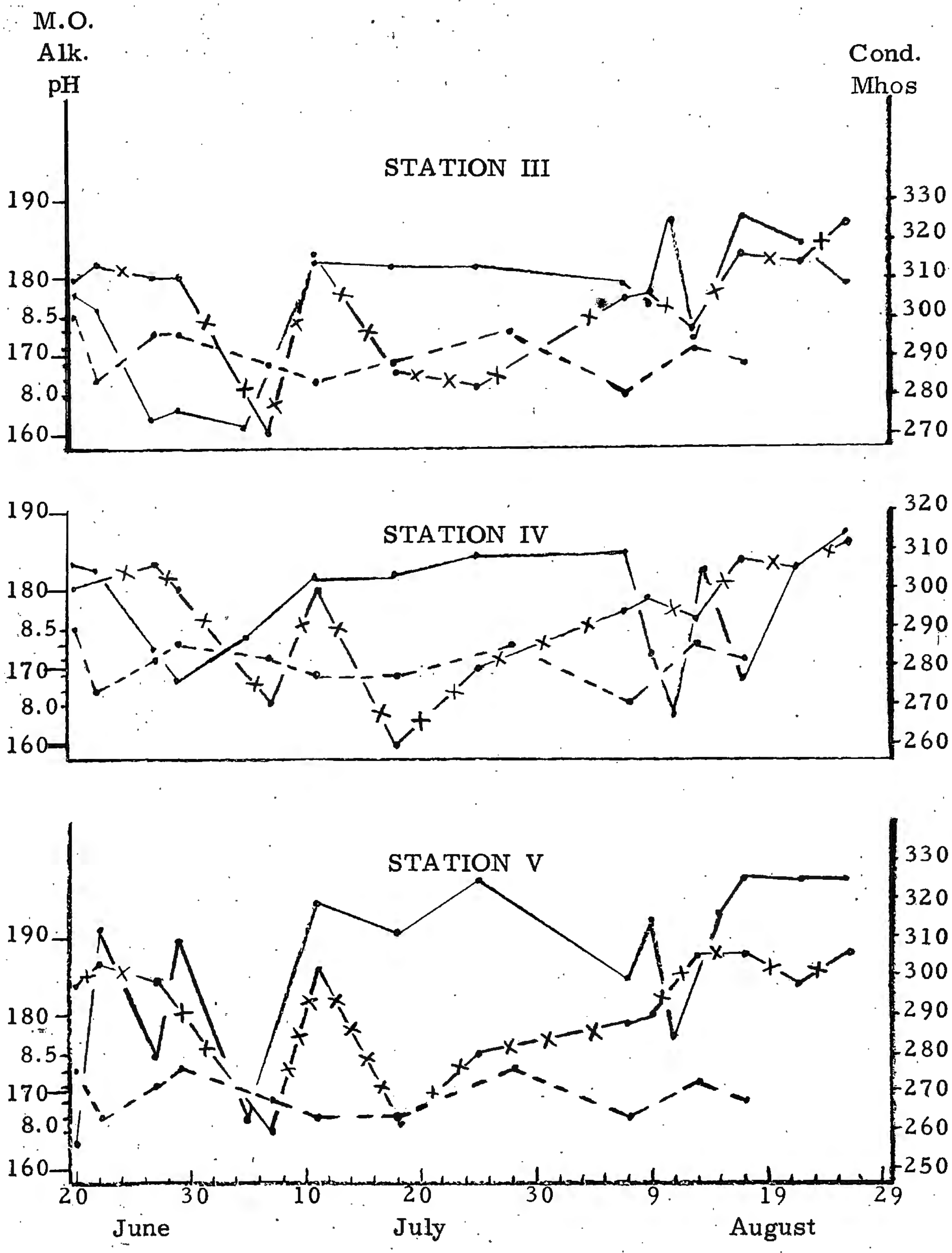
Dates of Fertilization: July 31 and August 6, 1955

—— Conductivity (Mhos X 10^{-6} at 18°C)

– – – Hydrogen-Ion Concentration (pH)

–x–x– Methyl Orange Alkalinity (p.p.m.)

Figure 3 (Continued)



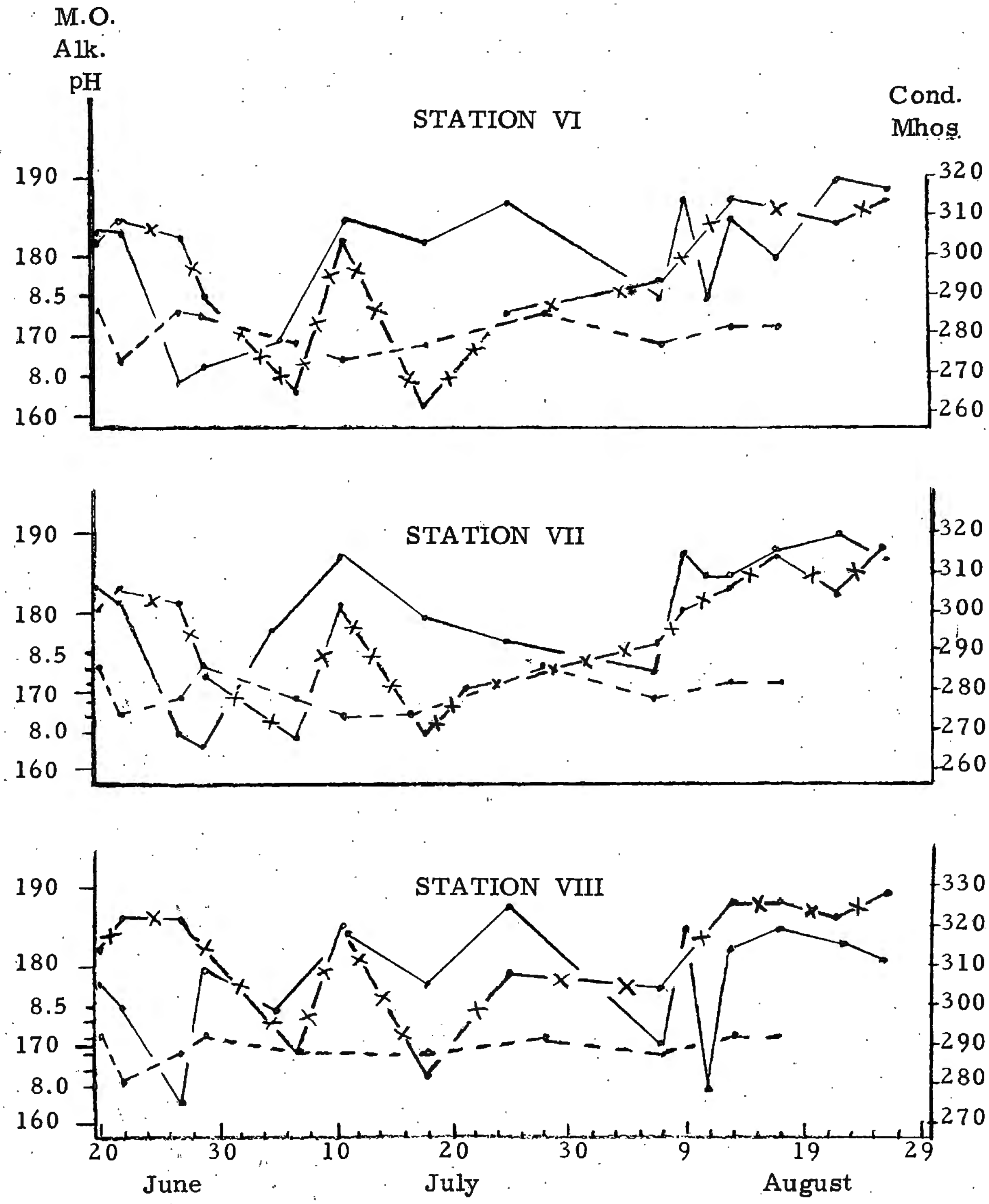
Dates of Fertilization: July 31 and August 6, 1955

——————Conductivity (Mhos X 10^{-6} at 18°C)

— — — —Hydrogen-Ion Concentration (pH)

—X—X— Methyl Orange Alkalinity (p.p.m.)

Figure 3 (Continued)



Dates of Fertilization: July 31 and August 6, 1955

Biological

Aufwuchs flora. For both 1954 and 1955 an obvious increase of aufwuchs flora was observed at Station I following fertilization; also, a difference was noted in the type of flora accumulated on the bricks and shingles. Strands of filamentous algae, mostly *Spirogyra* and *Anabaena*, were found on the shingles, while the bricks were mainly encrusted with diatoms of the genera *Navicula* and *Pinnularia*. Although there was a visible increase in quantity of aufwuchs on the bricks and shingles at Station I after fertilization, no change of this magnitude was observed at the downstream stations.

The "null hypothesis" that no change in quantity of aufwuchs on bricks and shingles occurred, other than that attributed to sample variation, was tested by analysis of variance. The values used in this test were obtained by subtracting the pigment density (in Harvey units) of the flora from a certain brick or shingle before fertilization from the pigment density of the flora of a brick or shingle that was placed in the same location after fertilization. Therefore, the resultant value is a difference from zero, being either positive or negative, depending on an increase or decrease of pigment production after fertilization. Due to the great variation in pigment production between Station I and other downstream stations, Station I was excluded and stations II through VIII were considered in the analysis of variance.

The 1954 results showed that there was a similar trend in production on both the bricks and shingles after fertilization. Therefore, Grzenda (1955) pooled his data, with the results of analysis of variance showing a highly significant difference from zero at the 99 percent level. The mean difference from zero at each station was positive except for the bricks at Station VII. This indicated an increase in chlorophyll production at all stations except for the bricks at Station VII.

Contrary to the results of 1954, a difference was observed between the mean differences from zero of the bricks and those of the shingles. Therefore, they were treated separately. Analysis of variance for the bricks showed no significant difference from zero, at the 95 percent level, after fertilization, but a significant difference at the 95 percent level between stations (Table VIII). The analysis of variance test for the shingles (Table IX) showed a highly significant difference from zero at the 99 percent level. The mean difference from zero for the shingles was a negative value, indicating a decrease in flora production as shown by the decrease in the extracted pigment density.

TABLE VIII

ANALYSIS OF VARIANCE OF CHANGES IN THE DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO THE BRICKS, EXCLUDING STATIONS I AND A

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	"F"
Difference from zero . . .	1	19.5	19.5	3.30
Total	31	241.3	7.78	
Between stations	6	93.54	15.59	2.64*
Error	25	147.8	5.91	

*Significant at the 95 percent level.

TABLE IX

ANALYSIS OF VARIANCE OF CHANGES IN THE DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO THE SHINGLES, EXCLUDING STATIONS I AND A

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	"F"
Difference from zero . . .	1	391.5	391.5	15.66**
Total	85	2226.0		
Between stations	6	276.4	46.1	1.84
Error	79	1949.6	24.99	

**Highly significant at the 99 percent level.

The results of the weekly collections were not in agreement with the 30-day collections. The analysis of variance test showed a highly significant difference at the 99 percent level between weeks (Table X). The total of eight weeks were divided into four-week periods. No significant difference was found within each of these two periods. The mean weekly values (Harvey units) were greater during the second four-week period, indicating an increase in the production of aufwuchs flora after fertilization. The statistical procedure for the weekly collection was not the same as the procedure used for the 30-day collections in that the values were not ascertained by subtracting the pigment density of a certain brick or shingle placed in the same location the previous week. Therefore, the resultant value was not a difference from zero.

The contradictory results regarding the shingles for the weekly and 30-day collections raises the question expressed by Newcombe (1949)(while measuring productivity by the accumulation of attachment materials on microscope slides) on how long slides (bricks and shingles in this case) should be submerged to assure most satisfactory results. Newcombe (1949) further adds that "the time element depends a great deal on the purpose of the experiment and the season of the year." The time element may be of prime importance in that the shingles may have a limited

TABLE X

ANALYSIS OF VARIANCE OF CHANGES IN THE DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO THE SHINGLES AT STATION IVA

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	"F"
Total	76	617.02		
Between weeks	7	365.81	52.26	14.36**
Before vs. after fertilization	1	341.63	341.63	93.85**
Within	6	24.18	4.03	1.11
Within weeks	69	251.21	3.64	

**Highly significant at the 99 percent level.

TABLE XI

ANALYSIS OF VARIANCE OF CHANGES IN THE DENSITY OF CHLOROPHYLL EXTRACTED FROM AUFWUCHS ATTACHED TO THE SHINGLES AT STATION A

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	"F"
Total	21	885.8	42.2	
Between collections . . .	1	72.7	72.7	2.1
Among pairs	10	460.3	46.0	1.3
Error	10	352.8	35.3	

accumulative capacity and this limit is reached within several days. Beyond this point the shingles possibly lose their efficiency in the accumulation of aufwuchs flora, either by one or a combination of the following factors: the limited carrying capacity of the shingle; loss of flora by erosion, such as molar action; or predation on the flora by aquatic fauna. Studies of the relationship between the aquatic fauna and the algal flora show that the larvae of tube dwelling chironomids, Trichoptera and Ephemeroptera, are algal feeders, and that their food consisted primarily of the filamentous diatoms and Chlorophyceae (Brook, 1955). Brook also found that a drastic reduction in the amount of algae can be correlated with the increasing efforts of the browsing fauna.

The reason for these explanations is that after seven days the shingles at Station IVA accumulated nearly the same quantity of aufwuchs flora as those shingles left in the stream for 30-day intervals.

It is known that solar radiation and water temperature are two imporant environmental factors in the production and growth of aufwuchs flora. This was confirmed by Gumtow (1955), who found that qualitatively the floral components of the Periphyton (aufwuchs) complex remain constant but a quantitative difference was associated with environmental changes such as high water temperatures, floods, and high turbidity. In comparing the first four-week period (June 3-July 30) with the second (July 30-August 27), certain environmental differences occurred. During the first four-week period there is a larger quantity of radiant energy reaching the stream and the water temperature is higher because the stream did not reach base level and its summer average minimum temperature until August. Other environmental factors appeared to remain constant; there were no signs of high turbidity or floods. Therefore, all other factors being equal, there should be greater production and growth of aufwuchs flora during the first four-week period as shown by the 30-day collections, or at least no significant change illustrated by "Station A," located on the control stream (Table XI).

If the weekly collections show the true trend and there is an increase in aufwuchs, then it is quite probable that the increase was due to fertilization. If we eliminate light and temperature as possible causes for the increase during the second four-week period, the remaining influence appears to be the addition of nutrients. Even though phosphorus, nitrogen, and sulfates were not traced beyond Station I, there is the possibility that they reached Station IV in concentrations that could not be detected using our chemical procedures.

An explanation for the difference in taxonomic composition and results obtained by analysis of variance between the bricks and shingles is given by Ruttner (1953), who states, "The physical characteristics of the substrate to which these organisms are attached are of the greatest significance in the formation of the Aufwuchs." It might also be added that the filamentous algae (characteristic of the shingles) would seem to be exposed more to the forces of erosion than are the diatoms encrusted on the bricks.

Aufwuchs faunae. The aufwuchs fauna is comprised mostly of Amphipoda (at Station I), two families of Ephemeroptera, Trichoptera, and Diptera. The families Hydropsychidae, Heptageniidae, Baetidae, Tendipedidae, and Simuliidae were present at all stations (see appendix).

Although the sampling stations were qualitatively similar in taxonomic composition of the aufwuchs fauna, a quantitative difference was observed between stations. "Studies made on the insect fauna of northern and southern Michigan trout streams since 1933 have shown that certain characteristics of bottoms, temperatures, pH and other factors, determine the numbers and kinds of insects present" (Morofsky, 1940). In that pH and temperature were rather stable during the sampling period the difference in abundance of fauna between stations appears to be the result of differences in bottom composition and stream flow. Stations V, VI, and VIII were quite similar in composition and abundance; this may be correlated with the similar physical characteristics of the stream at these stations.

The second collection shows a noticeable increase in the percent of Ephemeroptera at all stations except Station I. In contrast to the Ephemeroptera, there was a decrease in the Dipterans at all stations during the second collection (Figure 4). An abundance of amphipods at Station I and Brachycentridae at Station II was observed during the second collection.

In 1954 over 95 percent of the aufwuchs fauna consisted of Hydropsychidae and Baetidae. The family Tendipedidae must be added to include 95 percent of the fauna collected in 1955. A qualitative comparison shows that thirteen families comprised the bulk of the total collection in 1954 as compared to only seven families in 1955.

A comparison of the mean number per substrate for both 1954 and 1955 (Table XII) show great variation in the abundance of organisms between stations and variation at the same stations between years. There was a greater number of organisms at Station VII and VIII in 1954 than in 1955. There was also a greater abundance of amphipods at Station I during 1955. The mean number per substrate also shows a general trend in abundance downstream for both years. The low quantity of organisms per substrate at Station

Figure 4. The percentage composition of the aufwuchs fauna.

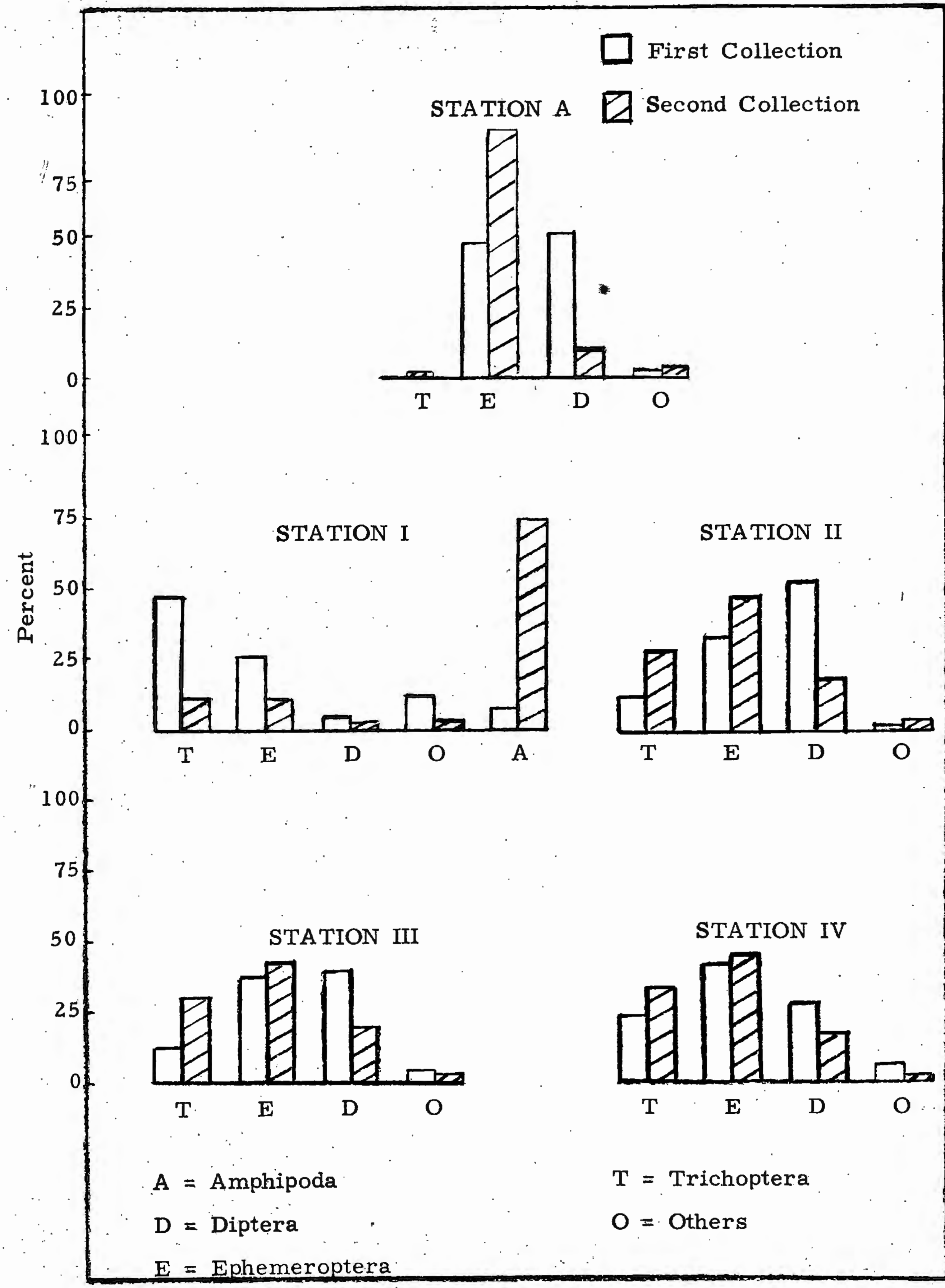
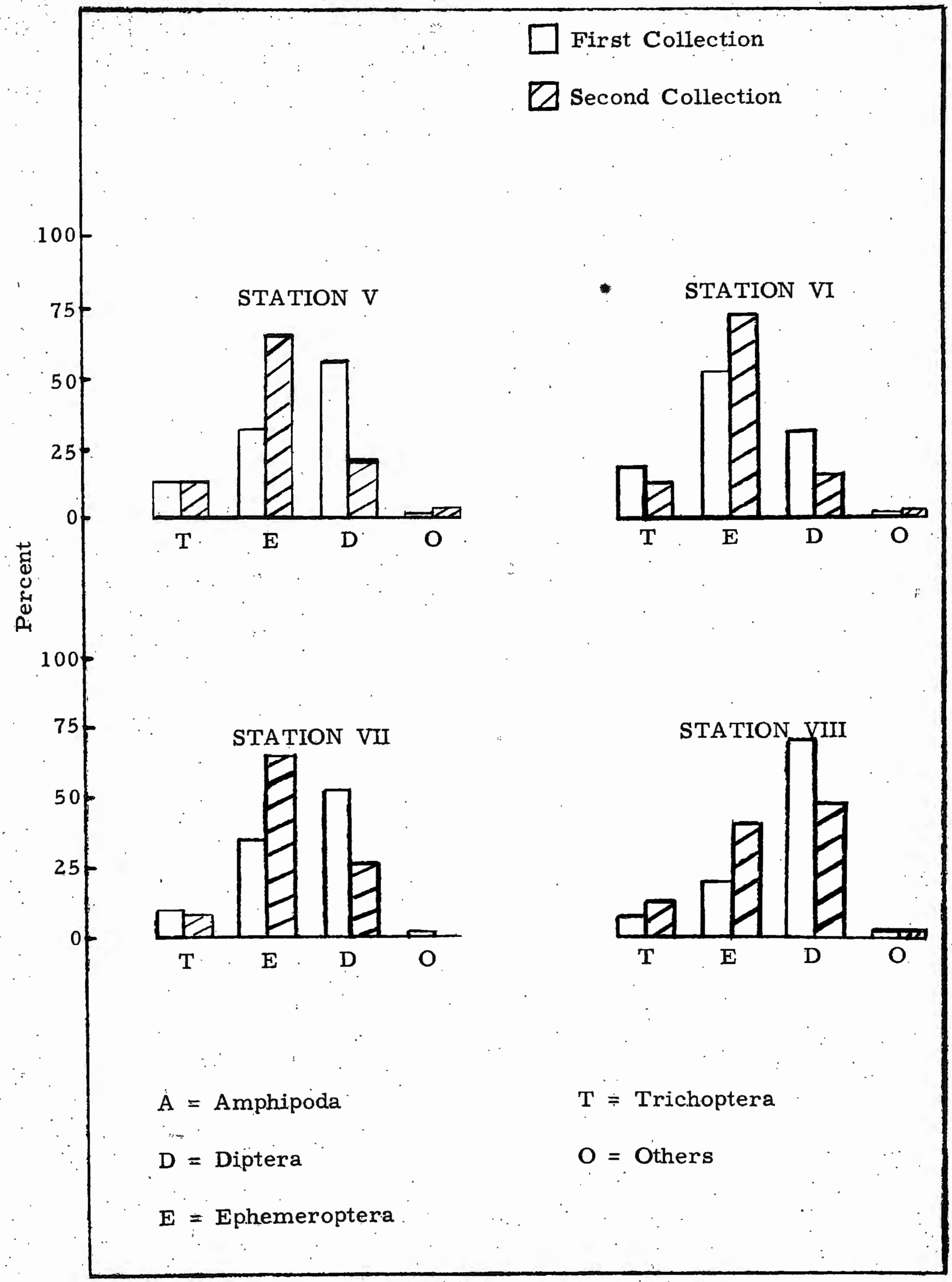

First Collection
Second Collection
STATION A
100
75
50
25
0
T
E
D
O
Percent
STATION I
STATION II
A
STATION III
STATION IV
A = Amphipoda
D = Diptera
E = Ephemeroptera
T = Trichoptera
O = Others

Figure 4 (Continued)



First Collection
Second Collection
Percent
100
75
50
25
0
STATION V
STATION VI
STATION VII
STATION VIII
T
E
D
O
A = Amphipoda
D = Diptera
E = Ephemeroptera
T = Trichoptera
O = Others

TABLE XII

A COMPARISON OF THE AUFWUCHS FAUNA (MEAN NUMBER PER SUBSTRATE) TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER DURING THE SUMMERS OF 1954 AND 1955

Station	First Collection				Second Collection			
	Bricks		Shingles		Bricks		Shingles	
	1954	1955	1954	1955	1954	1955	1954	1955
I	23.0	21.8	55.0	14.4	3.7	97.6	57.2	9.5
A*	. .	99.0	. .	81.9	. .	22.0	. .	25.3
II	128.0	31.0	25.0	21.3	43.0	25.6	8.7	20.8
III	14.8	13.6	9.7	13.4	21.3	22.4	6.3	5.5
IV	10.2	22.4	13.2	13.6	15.5	9.0	4.2	9.7
V	26.2	68.0	12.8	13.1	19.0	12.8	2.5	14.9
VI	86.5	68.2	26.8	30.1	17.2	68.8	1.0	22.8
VII	238.7	99.8	15.8	18.9	24.3	53.2	60.2	47.5
VIII	233.4	106.8	161.5	44.8	38.8	72.8	25.7	35.1

*No Control Station A in 1954.

III is associated with the large quantity of silt which deposited on the bricks and shingles. Thus an explanation for the greater number per substrate at stations VI, VII, and VIII is that the bricks and shingles at these stations were less subject to silt deposition.

Bottom fauna. The bottom organisms cover a large taxonomic range, but only a few families of Insecta are of a quantitative importance (Table XIII). A qualitative comparison for 1954 and 1955 shows an increase in the taxonomic composition of the bottom fauna in 1955. In 1954 Baetidae, Elmidae, Brachycentridae, Tendipedidae, and the Oligochaetes made up 79 percent of all bottom organisms. Oligochaetes by themselves made up 48 percent of the total number (Grzenda, 1955). In 1955 the Oligochaetes comprised only 28 percent of the total population. Ephemeridae, Baetidae, Brachycentridae, Rhyacophilidae, Elmidae, Tendipedidae, and Oligochaetes made up approximately 90 percent of the total number of organisms. The main difference between the two years is the greater number of Ephemeridae, Rhyacophilidae, and Brachycentridae in 1955.

The percent composition of the bottom fauna with regard to orders for 1955 may be seen in Table XIV. A comparison of the bottom fauna data with those obtained by Grzenda in 1954 shows a decrease in the Oligochaetes and dipterans and a substantial increase

TABLE XIII

TAXONOMIC COMPOSITION AND ENUMERATION OF THE BOTTOM FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER

Taxonomic Groups	Collection Date								
	June	July					August		
	24	1	8	13	20	27	12	19	25
Diptera									
Rhagionidae	5	3	2	3	2	0	6	2	1
Tendipedidae . . .	4	6	17	24	15	16	14	3	3
Simuliidae	0	9	8	1	0	3	1	4	0
Empididae	3	2	8	7	1	2	0	1	0
Tipulidae	0	1	3	0	1	1	1	1	0
Tabanidae	2	0	6	3	2	8	2	0	0
Heleidae	0	1	0	0	0	1	1	1	0
Culicidae	0	0	0	1	0	0	0	0	0
Subtotals	14	22	44	39	21	31	24	12	4
Trichoptera									
Rhyacophilidae . .	57	6	9	17	12	2	2	4	2
Brachycenttridae .	48	53	53	66	69	34	162	121	121
Hydropsychidae .	0	1	2	2	2	4	1	77	1
Psycomyiidae . . .	0	1	1	0	0	2	0	5	0
Leptoceridae . . .	0	0	7	0	1	0	0	0	0
Molannidae	0	2	3	0	1	2	3	1	0
Limnephilidae . .	2	5	0	2	5	5	2	0	0
Phryganiidae . . .	0	0	0	2	0	1	2	0	0
Hydroptilidae . . .	3	0	0	0	0	0	0	0	0
Philoptamidae . .	0	1	0	0	0	0	0	0	0
Subtotals	110	69	75	89	90	50	172	208	124

TABLE XIII (Continued)

Taxonomic Groups	Collection Date								
	June	July					August		
	24	1	8	13	20	27	12	19	25
Ephemeroptera									
Ephemeridae . . .	7	7	57	18	28	32	37	28	26
Baetidae	80	69	27	33	20	19	19	6	6
Heptageniidae . . .	12	4	1	5	5	2	0	0	0
Subtotals	99	80	85	56	53	53	56	34	32
Plecoptera									
Nemouridae	0	0	0	1	0	0	1	2	1
Perlidae	0	1	0	0	0	0	0	0	0
Pteronarcidae . .	5	0	0	6	3	2	2	2	9
Perlodidae	2	0	1	1	1	0	2	2	4
Subtotals	7	1	1	8	4	2	5	6	14
Coleoptera									
Elmidae	11	22	7	19	12	9	3	1	9
Dytiscidae	0	0	0	1	0	0	0	0	0
Subtotals	11	22	7	20	12	9	3	1	9
Odonata									
Cordulegasteridae	2	4	0	5	6	4	5	3	4
Gomphidae	0	0	0	1	0	1	1	0	0
Subtotals	6	6	1	0	1	2	2	1	2

TABLE XIII (Continued)

Taxonomic Groups	Collection Date								
	June	July					August		
	24	1	8	13	20	27	12	19	25
Oligochaeta	149	125	131	119	89	59	106	34	20
Amphipoda	0	0	0	0	0	0	1	7	2
Gastropoda	0	1	0	1	2	0	1	0	1
Pelecypoda	1	1	0	0	0	2	0	0	0
Hirudinae	0	1	10	0	0	1	0	2	0
Totals	399	332	354	338	278	214	377	308	212
No./sq. ft.	33.3	27.7	29.5	28.2	23.2	17.8	31.2	26.3	17.7

TABLE XIV

COMPOSITION BY PERCENT OF THE NUMBER OF BOTTOM FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER FOR THE SUMMER OF 1955

Collection Date	Taxonomic Group						
	Ephemeroptera	Trichoptera	Plecoptera	Coleoptera	Diptera	Oligocheata	Others
				June			
24	24.8	27.6	1.8	2.8	3.5	37.3	2.3
				July			
1	24.1	20.8	0.3	6.6	6.6	37.7	3.9
8	24.0	21.2	0.3	2.0	12.4	37.0	3.1
13	16.6	26.3	2.4	5.9	11.5	35.2	2.1
20	19.1	32.4	1.4	4.3	7.6	32.0	3.2
27	24.8	23.4	0.9	4.2	14.5	27.6	4.7
				August			
12	14.9	45.6	1.3	0.9	6.4	28.1	2.7
19	11.0	67.5	1.9	0.3	3.9	11.0	4.3
25	15.1	58.5	6.6	4.2	1.9	9.4	4.2

in Trichoptera in 1955. The increase in Trichoptera is due mainly to the greater abundance of Rhyacophilidae and Brachycentridae in 1955.

The mean number per square foot per collection date approximates a bimodal curve for both the 1954 and 1955 collections (Figure 5). Analysis of variance tests were used to see if these differences were statistically significant. A preliminary examination of the data showed a linear relationship between the mean and the mean square for both 1954 and 1955. Because such a condition is contrary to the basic assumption behind an analysis of variance test (Bartlett, 1947), a logarithmic transformation was used to overcome this relationship. In 1954 analysis of variance showed a significant difference among collections at the 5 percent level. The difference appeared to be caused from the variation among the Oligochaetes which comprised 48 percent of the total number of organisms (Grzenda, 1955). Therefore, Grzenda performed another analysis of variance test, omitting the Oligochaetes, the result showing no statistically significant difference among collections. In 1955 the analysis of variance test, including Oligochaetes (Table XV), also showed no statistically significant difference among collections. Such phenomenon is contrary to what one would expect from a bimodal curve. It may be that the variability is so great within collections

Figure 5. A comparison of the numerical abundance of bottom fauna collected during the summers of 1954 and 1955.

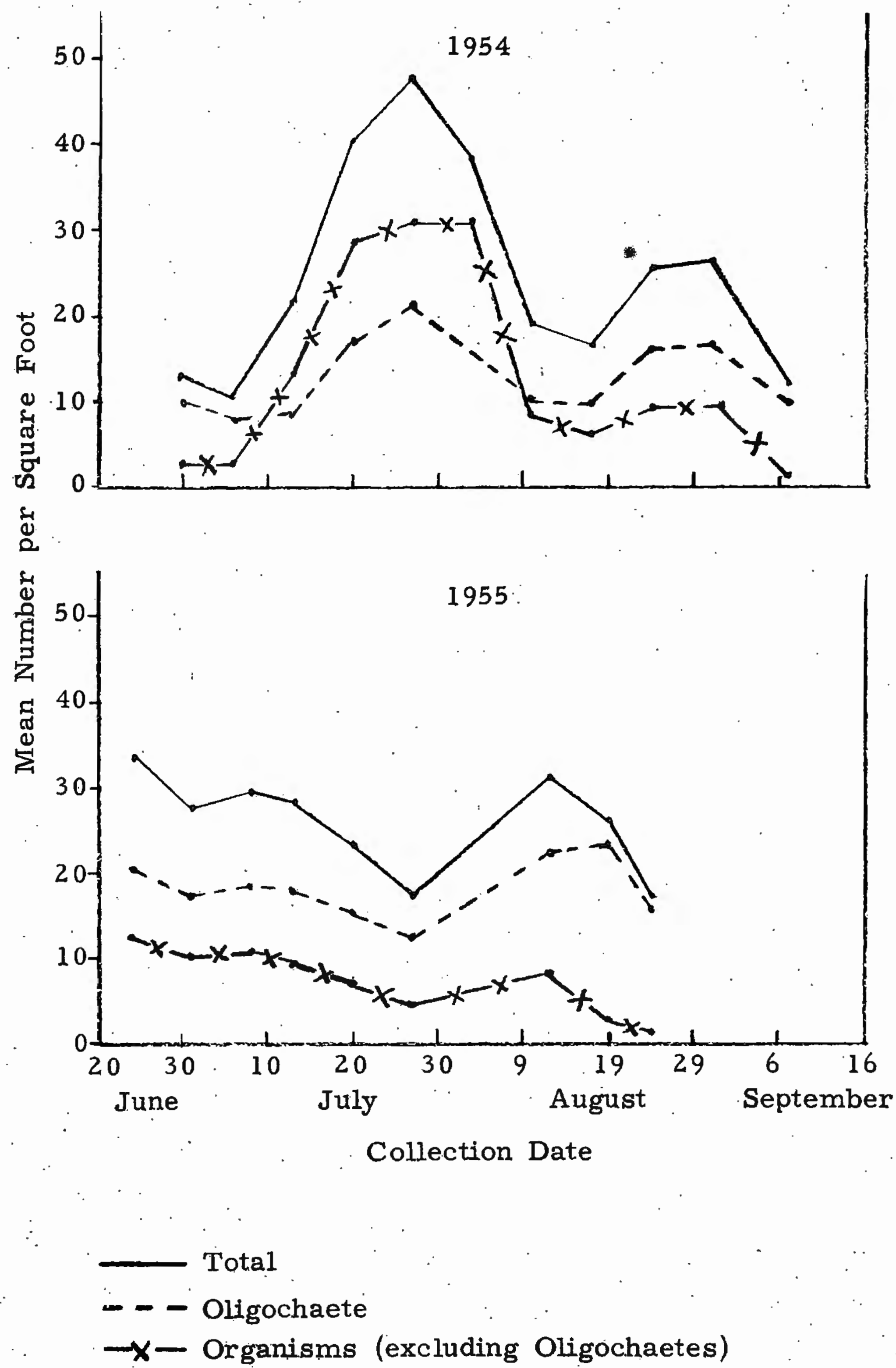

1954
1955
Mean Number per Square Foot
50
40
30
20
10
0
20 30 10 20 30 9 19 29 6 16
June
July
August
September
Collection Date
Total
Oligochaete
Organisms (excluding Oligochaetes)

TABLE XV

ANALYSIS OF VARIANCE OF NUMBERS OF BOTTOM FAUNA SAMPLES FROM THE WEST BRANCH OF THE STURGEON RIVER FOR THE SUMMER OF 1955

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	"F"
Total	107	12.5945	0.1177	
Among collections	8	1.0037	0.1254	1.0717
Within collections	99	11.5908	0.1177	

that an analysis of variance test will not detect variation among collections.

A comparison of the mean number per square foot for the two years, as shown by Figure 5, provides a graphic illustration showing that in 1955 there was a decrease in the number of Oligochaetes and an increase in the remaining organisms when the Oligochaetes are excluded.

Although the volume of bottom fauna for both years was so small that no detailed study was accomplished, the data do show an increase (approximately 14 percent) in the volume of organisms in 1955. The total volume and mean volume per square foot of bottom fauna taken at each collection in 1955 are shown in Table XVI.

Surber (1951), working on a trout stream that he considered to be of "average richness," found that the average wet weights of square foot samples collected during the months of June, July, and August were 1.65, 1.18, and 1.96 respectively. Using a conversion of one cubic centimeter equaling one gram (Ball, 1948) comparable values obtained from the west branch for June, July, and August were 0.28, 0.22, and 0.28 in 1954 (Grzenda, 1955), and 0.33, 0.33, and 0.41 in 1955, respectively. A comparison of these values with those obtained by Surber shows production to be quite low in the west branch of the Sturgeon River.

TABLE XVI

CONDENSATION OF THE NUMBER AND VOLUME OF BOTTOM FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER FOR THE SUMMER OF 1955

Collection Date	Total Number	Total Volume (c.c.)	* Number per Square Foot	Volume per Square Foot (c.c.)
June 24	399	4.0	33.3	.33
July 1	332	2.0	27.7	.17
July 8	354	3.5	29.5	.29
July 13	338	5.5	28.2	.44
July 20	278	4.0	23.2	.33
July 27	214	5.5	17.8	.44
August 12	377	4.5	31.2	.36
August 19	308	6.0	26.3	.50
August 25	212	5.0	17.7	.41

Fish samples. The results for both 1954 and 1955 (Table XVII) show that there is a longitudinal distribution of trout in the west branch of the Sturgeon River. Longitudinal succession, as described by Odum (1953), is more pronounced in the first few miles of stream; also the number of individuals decreases downstream but the size of the fish increases so that the biomass density remains about the same. In general, this situation was found to be true in the west branch. At Station II, approximately one mile downstream, large numbers of small brook trout were sampled. The trout population at this station was entirely brook trout. Samples at Station V, approximately seven miles downstream, consisted of brooks, rainbows, and a few brown trout. Approximately eleven miles downstream from Hoffman Lake (Station VIII) the trout population was mainly rainbows, browns (many legal-size), and a few brook trout.

A comparison of the mean length per year-class for 1954 and 1955 indicates great variability within the year classes (Table XVIII). A trend can be seen towards a general increase in the mean length per year-class for the brook trout. Other than this, the variability is too great to draw any definite conclusions. Growth studies of brook trout in the north branch of the Au Sable, the Pigeon River, and Hunt Creek show that by the middle of June the mean length per Year-class I were 6.9, 5.7, and 5.1 inches, respectively, in each

TABLE XVII

COMPOSITION AND ENUMERATION OF TROUT SAMPLES FROM THE WEST BRANCH OF THE STURGEON RIVER USING A DIRECT CURRENT SHOCKER

Station	No. of Fish	Brook Trout		Brown Trout		Rainbow Trout	
		No.	Pct.	No.	Pct.	No.	Pct.
		Collected July 6, 1955					
II	332	332	100.0				
V	153	71	46.4	21	13.7	61	39.9
VIII	117	9	7.7	70	59.9	38	32.5
		Collected August 30, 1955					
II	303	303	100.0				
V	225	93	41.3	11	4.9	121	53.8
VIII	189	4	2.1	80	42.3	105	55.6

TABLE XVIII

A COMPARISON OF THE MEAN LENGTH IN INCHES OF TROUT SAMPLES FROM THE WEST BRANCH OF THE STURGEON RIVER, JULY 6, 1954, AND 1955

Species	1954			1955		
	Mean Length	Standard Error of Mean	Sample Size	Mean Length	Standard Error of Mean	Sample Size
			Year Class I			
Brook	4.7	0.07	88	5.0	0.06	134
Brown	5.4	0.11	23	5.1	0.14	29
Rainbow	4.5	0.09	46	4.6	0.07	63
			Year Class II			
Brook	6.5	0.15	48	7.6	0.20	19
Brown	8.4	0.51	7	8.2	0.24	11
Rainbow	7.2	0.16	30	6.4	0.08	9
			Year Class III			
Brook	9.3	0.27	9	10.4	. .	1
Brown	10.4	0.26	9	11.4	0.27	12
Rainbow	. .	. .	. .	8.2	. .	2

of these streams (Cooper, 1953). The mean lengths of brook trout of Year-class I collected from the west branch in 1954 and 1955 were 4.7 and 5.0 inches respectively. Considering the Pigeon River as having average productivity and Hunt Creek to be very unproductive, the data indicate even lower productivity in the west branch of the Sturgeon River. The poor growth may be the result of the paucity of bottom fauna. The significance of the relationship between trout growth and the abundance of bottom fauna is also suggested by Allen (1951). The slight increase in the mean length per year-class found among the brook trout may be the result of the 14 percent increase in the volume of bottom fauna previously mentioned in this dissertation.

A regression analysis (covariance analysis) following Ostle (1954) was used to test whether changes in the length-weight relationship ($W = cL^n$) occurred from year to year. Comparisons based on the length-weight relationship are complicated in that the relationship is based on two different kinds of measurement of growth: First, the exponent n (the slope in the logarithmic form of $W = cL^n$) measures the proportional increase in weight with an increase in length, and secondly, the position of the line measures the relative weight at a given length.

Briefly, the test is a method for determining if a real difference, either in slope or in position (elevation or mean value), existed between the relationship for the two years (1954 and 1955) for each species of trout. A regression analysis tests, first, whether the two regression lines differ to a statistically important degree; second, if they do, whether the difference is in the slopes of the regression lines regardless of positions; and third, if there is no appreciable difference in slope, whether the difference is in position, the answers depending on the outcome of the "F" value.

The results of the regression analysis for the three species of trout sampled in the west branch during the summers of 1954 and 1955 are shown in Tables XIX, XX, and XXI. Only among the rainbow trout was there a highly significant difference in the n value (Table XXI). The difference in slope (n) of the regression lines for both years can not be explained except the slope (n value for 1955) indicates that the older rainbows may be in better condition in 1955 ($n = 3.21$) than in 1954 ($n = 2.90$).

Surber (1951) found that rainbow trout eat quantities of filamentous algae, which brook trout do not eat, and that rainbow trout seem to have a greater preference for aquatic forms of food than brook trout. Therefore, assuming there was an increase in bottom fauna and aufwuchs production, it is reasonable to

TABLE XIX

REGRESSION (COVARIANCE) ANALYSIS OF ln LENGTH–ln WEIGHT[a] RELATIONSHIP IN BROOK TROUT TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, 1954 AND 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	233	111.3863	
Due to general regression	1	105.1240	105.1240
Deviations from general regression	232	6.2623	.0269
a. Can one regression line be used for all observations?			
Gain from two separate regressions over general regression	2	.0424	.0212
Deviations from separate regressions	231	6.2199	.0269
("F" = 1.2688; answer is yes.)			

[a]"ln" = natural logarithm.

TABLE XX

REGRESSION (COVARIANCE) ANALYSIS OF ln LENGTH–ln WEIGHT[a] RELATIONSHIP IN BROWN TROUT TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, 1954 AND 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	96	109.1647	
Due to general regression	1	107.8941	107.8941
Deviation from general regression	95	1.2706	.0120
a. Can one regression line be used for all observations?			
Gain from two separate regressions over general regression	2	.0116	.0058
Deviations from separate regressions	93	1.2590	.0135
(''F'' = 2.32758; answer is yes.)			

[a]''ln'' = natural logarithm.

TABLE XXI

REGRESSION (COVARIANCE) ANALYSIS OF ln LENGTH–ln WEIGHT[a] RELATIONSHIP IN RAINBOW TROUT TAKEN FROM THE WEST BRANCH OF THE STURGEON RIVER, 1954 AND 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	98	51.2815	
Due to general regression	1	50.4645	50.4645
Deviation from general regression	97	.8170	.0084
a. Can one regression line be used for all observations?			
Gain from two separate regressions over general regression	2	.1169	.0584
Deviations from separate regressions	96	.7001	.0072
(''F'' = 8.1111*; answer is no.)			
b. Can a common slope be used for the separate regression line?			
Deviation about lines with common slope but fitted through mean of each set of data	97	.8170	.0084
Further gains from fitting separate regressions	1	.0827	.0827
Deviations about separate regressions	96	.7001	.0027
(''F'' = 11.4860*; answer is no.)			

[a]''ln'' = natural logarithm.

*Significant at the 95 percent level.

believe that the rainbows are most likely to benefit and would be the first to show an improvement in condition.

SUMMARY

1. The west branch of the Sturgeon River is located in the northern Lower Peninsula of Michigan. The watershed is in the interlobate area of the Port Huron Morainic System, an area of extremely rough land unsuitable for farming due to the associated sandy soils and unfavorable slopes.

2. The physicochemical and biological characteristics of the stream indicate low productivity. The stream bottom is composed of large stretches of unproductive sand.

3. During the summer of 1955, two applications of inorganic commercial fertilizer were made to Hoffman Lake, the source of the west branch of the Sturgeon River. Following fertilization there was an increase in total and soluble phosphorus, ammonia nitrogen, and possibly, sulfates at Station I only. The alkalinity determinations indicate that the stream contains large quantities of calcium and magnesium carbonates, thus making the west branch an efficient buffer system. There were no changes in alkalinity, hydrogen-ion concentration, and conductivity at the stations which could be attributed to fertilization.

4. Both in 1954 and 1955 there was an obvious increase in aufwuchs flora at Station I following fertilization. Contrary to the 1954 results, in 1955 the thirty-day collections showed a decrease in flora production at the downstream stations. This is not in agreement with the results of the weekly collections where a statistically significant increase was detected following fertilization. Such factors as limited carrying capacity of the shingles, erosion, predation, et cetera, may cause the shingles left in the stream for thirty-day periods to lose their efficiency in the accumulation of aufwuchs flora. This is the first year that weekly collections were obtained. From the results it is recommended that in future work the necessity of taking weekly samples be given considerable thought.

5. A comparison of the mean number per substrate of the aufwuchs fauna for both 1954 and 1955 show great variation in the abundance of organisms at the collecting stations. The variation is believed to be the result of difference in bottom type at the various stations.

6. The bottom organisms cover a large taxonomic range but only a few families are quantitatively important. There was approximately a 14 percent increase in the volume of organisms from 1954 to 1955. The average wet weight per square foot values show

production to be low in the west branch of the Sturgeon River as compared with other similar streams.

7. There is evidence of longitudinal distribution of trout in the west branch. Starting with brook trout at the headwaters, there is a gradual displacement by rainbow and brown trout downstream. A comparison of brook trout growth in the west branch with those of other northern Michigan trout streams also indicates very low productivity in the west branch of the Sturgeon River. Results of the regression analysis for the species of trout show that only among the rainbow trout was there a highly significant difference in slope of the regression lines, indicating that the older rainbows may be in better condition in 1955. The improvement in condition may be the result of difference in food preference exhibited by the rainbows.

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APPENDIX

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station I)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	0	0	0	2
Tendipedidae	1	15	2	14
Rhagionidae	0	0	0	1
Subtotals	1	15	2	17
Trichoptera				
Brachycentridae . . .	0	1	0	0
Hydropsychidae . . .	15	117	1	51
Psychomyiidae	0	8	0	4
Subtotals	15	126	1	55
Ephemeroptera				
Baetidae	27	45	36	27
Heptageniidae	0	2	3	4
Subtotals	27	47	39	31
Plecoptera				
Perlidae	0	0	0	1
Subtotals	0	0	0	1
Coleoptera				
Elmidae	2	6	0	2
Subtotals	2	6	0	2
Odonata				
Agrionidae	2	0	0	0
Coenagrionidae	0	3	2	4
Gomphidae	0	0	0	1
Subtotals	2	3	2	5
Amphipoda	19	4	444	32
Hirudinae	21	0	0	0
Gastropoda	0	1	0	0
Subtotals	40	5	444	32
Totals	87	202	488	143
Mean no./substrate . .	21.8	14.4	97.6	9.5

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station A)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	217	453	1	3
Tendipedidae	34	68	5	30
Subtotals	251	521	6	33
Trichoptera				
Hydropsychidae	0	2	0	2
Rhyacophilidae	7	0	0	1
Psychomyiidae	0	0	0	3
Subtotals	7	2	0	6
Ephemeroptera				
Baetidae	38	697	80	257
Heptageniidae	0	0	0	1
Subtotals	38	697	80	258
Plecoptera				
Pteronarcidae	0	5	0	1
Perlodidae	1	0	2	0
Perlidae	0	0	0	4
Nemouridae	0	4	0	1
Subtotals	1	9	2	6
Amphipoda	0	0	0	1
Totals	297	1229	88	304
Mean no./substrate . . .	99.0	81.9	22.0	25.3

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station II)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	59	3	6	0
Tendipedidae	15	154	3	61
Rhagionidae	0	0	0	2
Empididae	0	2	0	1
Heleidae	0	0	0	3
Subtotals	75	159	9	67
Trichoptera				
Brachycentridae	4	29	19	88
Hydropsychidae	8	7	4	12
Psychomyiidae	0	1	3	7
Limnephilidae	0	5	0	0
Subtotals	12	42	26	107
Ephemeroptera				
Ephemeridae	0	7	0	0
Baetidae	36	107	92	94
Heptageniidae	0	1	0	0
Subtotals	36	115	92	94
Plecoptera				
Perlidae	0	1	0	0
Perlodidae	0	0	1	0
Nemouridae	0	2	0	1
Subtotals	0	3	0	1
Hirudinae	1	0	0	0
Gastropoda	0	0	0	1
Oligochaeta	0	0	0	1
Totals	124	319	128	271
Mean no./substrate	31.0	21.3	25.6	20.8

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station III)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	4	0	14	0
Tendipedidae	4	93	11	14
Rhagionidae	0	3	0	0
Empididae	0	1	0	0
Heleidae	0	2	0	0
Subtotals	8	99	25	14
Trichoptera				
Brachycentridae	0	0	0	1
Hydropsychidae	20	10	44	12
Rhyacophilidae	0	4	0	0
Limnephilidae	0	2	0	2
Subtotals	20	16	44	15
Ephemeroptera				
Ephemeridae	0	3	0	0
Baetidae	37	72	38	17
Heptageniidae	1	2	5	31
Subtotals	38	77	43	48
Plecoptera				
Perlodidae	1	0	0	0
Subtotals	1	0	0	0
Coleoptera				
Elmidae	1	4	0	0
Subtotals	1	4	0	0
Amphipoda	0	5	0	5
Totals	68	201	112	82
Mean no./substrate	13.6	13.4	22.4	5.5

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station IV)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	2	3	0	0
Tendipedidae	4	74	1	28
Rhagionidae	0	5	0	1
Subtotals	6	82	0	29
Trichoptera				
Brachycentridae	0	1	2	1
Hydropsychidae	50	20	2	49
Rhyacophilidae	1	3	0	2
Limnephilidae	0	0	0	1
Psychomyiidae	0	1	1	0
Subtotals	51	25	5	53
Ephemeroptera				
Baetidae	48	85	38	36
Heptageniidae	0	1	1	2
Subtotals	48	86	39	38
Plecoptera				
Perlidae	0	2	0	0
Perlodidae	0	0	0	1
Pteronarcidae	0	0	0	3
Subtotals	0	2	0	4
Coleoptera				
Elmidae	7	3	0	1
Subtotals	7	3	0	1
Megaloptera				
Corydalidae	0	4	0	0
Subtotals	0	4	0	0
Amphipoda	0	1	0	0
Hirudinae	0	0	0	1
Hydracarina	0	1	0	1
Totals	112	204	45	126
Mean no./substrate	22.4	13.6	9.0	9.7

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER

(Station IVA)

Taxonomic Groups	Collection Date							
	July				August			
	11	16	22	30	9	16	20	27
Diptera								
Simuliidae	0	0	0	0	0	0	0	1
Tendipedidae	4	17	20	14	6	19	0	15
Subtotals	4	17	20	14	6	19	0	16
Trichoptera								
Hydropsychidae . .	0	0	1	0	0	0	0	0
Rhyacophilidae . . .	0	0	0	3	0	1	0	0
Subtotals	0	0	1	3	0	1	0	0
Ephemeroptera								
Baetidae	2	7	35	14	6	10	5	6
Heptageniidae . . .	0	0	0	0	0	0	1	2
Subtotals	2	7	35	14	6	10	6	8
Plecoptera								
Perlidae	0	1	1	0	0	0	4	1
Subtotals	0	1	1	0	0	0	4	1
Coleoptera								
Elmidae	0	0	0	0	0	0	1	0
Subtotals	0	0	0	0	0	0	1	0
Odonata								
Agrionidae	0	0	0	3	1	1	0	0
Subtotals	0	0	0	3	1	1	0	0
Megaloptera								
Corydalidae	0	0	0	0	1	0	1	0
Subtotals	0	0	0	0	1	0	1	0
Amphipoda	0	0	1	1	0	0	0	0
Gastropoda	2	0	0	1	0	0	0	0
Hydracarina	0	1	0	0	0	0	0	0
Totals	8	26	58	36	14	31	8	25
Mean no./substrate . .	0.8	3.3	5.8	3.6	1.6	5.2	1.1	2.8

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station V)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	238	0	5	1
Tendipedidae	0	22	1	44
Rhagionidae	0	4	0	0
Empididae	0	0	1	1
Tipulidae	0	0	0	0
Subtotals	238	26	7	46
Trichoptera				
Brachycentridae . . .	0	9	0	0
Hydropsychidae . . .	38	7	12	7
Rhyacophilidae	0	8	0	14
Psychomyiidae	0	0	0	2
Limnephilidae	0	0	0	1
Subtotals	38	24	12	24
Ephemeroptera				
Baetidae	60	85	41	118
Heptageniidae	1	7	1	17
Subtotals	61	92	42	135
Plecoptera				
Perlidae	0	0	0	1
Pteronarcidae	3	0	0	0
Perlodidae	0	0	1	0
Nemouridae	0	0	0	1
Subtotals	3	0	1	2
Amphipoda	0	0	2	0
Hirudinae	0	2	0	0
Oligochaeta	0	0	0	1
Totals	340	144	64	208
Mean no./substrate . . .	68.0	13.1	12.8	14.9

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station VI)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	67	18	94	0
Tendipedidae	6	139	1	4
Rhagionidae	1	3	0	2
Empididae	0	1	0	0
Subtotals	74	161	95	6
Trichoptera				
Brachycentridae . . .	13	1	6	3
Hydropsychidae . . .	113	11	51	30
Psychomyiidae	0	1	0	2
Leptoceridae	0	0	0	3
Subtotals	126	13	57	38
Ephemeroptera				
Baetidae	139	228	189	285
Heptageniidae	1	18	0	11
Subtotals	140	246	189	296
Plecoptera				
Pteronarcidae	0	0	2	2
Perlodidae	0	0	1	0
Subtotals	0	0	3	2
Coleoptera				
Elmidae	1	1	0	0
Subtotals	1	1	0	0
Totals	341	421	344	342
Mean no./substrate . . .	68.2	30.1	68.8	22.8

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER
(Station VII)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	355	19	144	101
Tendipedidae	4	11	0	6
Rhagionidae	1	4	1	3
Empididae	0	1	0	0
Subtotals	360	35	145	110
Trichoptera				
Brachycentridae . . .	9	0	0	0
Hydropsychidae . . .	49	13	31	49
Psychomyiidae	2	2	2	4
Subtotals	60	15	33	53
Ephemeroptera				
Baetidae	77	161	85	531
Heptageniidae	2	11	2	15
Subtotals	79	172	87	546
Plecoptera				
Perlidae	0	0	0	1
Pteronarcidae	0	0	1	1
Subtotals	0	0	1	2
Megaloptera				
Corydalidae	0	5	0	1
Subtotals	0	5	0	1
Totals	499	227	266	712
Mean no./substrate . . .	99.8	18.9	53.2	47.5

TAXONOMIC COMPOSITION AND ENUMERATION OF AUFWUCHS FAUNA SAMPLED FROM THE WEST BRANCH OF THE STURGEON RIVER (Station VIII)

Taxonomic Groups	First Collection		Second Collection	
	Bricks	Shingles	Bricks	Shingles
Diptera				
Simuliidae	462	262	304	80
Tendipidae	7	21	2	16
Subtotals	469	283	306	96
Trichoptera				
Brachycentridae . . .	10	4	2	7
Rhyacophilidae	0	0	1	8
Hydropsychidae . . .	30	34	11	58
Leptoceridae	0	0	0	1
Psychomyiidae	0	0	0	2
Subtotals	40	38	14	76
Ephemeroptera				
Baetidae	24	205	43	283
Heptageniidae	1	10	0	0
Subtotals	25	215	43	283
Plecoptera				
Perlidae	0	0	1	0
Pteronarcidae	0	2	0	0
Subtotals	0	2	1	0
Gastropoda	0	0	0	1
Totals	534	538	364	456
Mean no./substrate . . .	106.8	44.8	72.8	35.1