Gould

Statement of Permission to Copy

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature ______________________________

Date ________________________________

T-90

THE RESPONSES OF INSECT COMMUNITIES IN THE EAST GALLATIN RIVER, MONTANA, TO SEWAGE EFFLUENTS

by

THOMAS HARVEY GLORVIGEN

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

Zoology

Approved:

____
Head, Major Department

____
Chairman, Examining Committee

____
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

August, 1972

VITA

Thomas Harvey Glorvigen was born in Fergus Falls, Minnesota on November 24, 1942. He is the son of Mr. and Mrs. H. W. Glorvigen. He attended Fergus Falls public schools and graduated from Fergus Falls High School in June 1960. In September 1960 he entered the University of Arizona. In September 1961 he transferred to the University of Minnesota from which he received a Bachelor of Arts degree in Zoology in June 1964. Following graduation he taught ~~at~~ in high schools ~~level~~ before beginning graduate studies at Montana State University in September 1968.

ACKNOWLEDGMENT

The author wishes to express his appreciation to those who assisted him during the course of the study. Dr. William R. Gould directed the study and assisted in preparation of the manuscript. Dr. Martin Hamilton assisted with the statistical analysis. Sincere appreciation for the identification of the aquatic insects is extended to Drs. William L. Peters (Ephemeroptera), W. E. Ricker (Plecoptera), O. S. Flint (Trichoptera), Reece I. Sailer (Diptera) and Robert Gordon (Coleoptera). The project was financed by F. W. Q. A. Research Fellowship 5T2-WP-228-03 and the Montana Cooperative Fishery Unit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The responses of insect communities in the East Gallatin River, Montana, to two sewage effluents were studied. Numbers of Ephemeroptera, Plecoptera and Trichoptera were low and numbers of Diptera were high 0.72 km below Outfall I. The diversity index of this community was low. The community structure was believed to be primarily due to the abundant growths of "sewage fungus" present. Mayflies appeared to increase in numbers rapidly ~~at Station 2 shortly after~~ 0.72 below Outfall I, after the use of the the ~~use of Outfall~~ outfall I was discontinued. Nine months later the diversity index at this location was similar to those of the other stations. There was no apparent effect of the sewage effluent from Outfall II on the insect community 6.32 km below it.

numbers and diversity of ?

INTRODUCTION

The addition of domestic sewage to a stream can alter its natural characteristics. Areas affected by sewage effluents often have small numbers of a few kinds of clean water insects, large numbers of a few kinds of tolerant forms, depressed dissolved oxygen levels and abundant growths of "sewage fungus" (Gaufin 1958; Hawkes 1963).

Avery (1970) studied the effects of the sewage effluent from the primary treatment plant for the City of Bozeman on the East Gallatin River. A comparison of areas above and below the outfall indicated there were smaller numbers of Trichoptera, Ephemeroptera, Plecoptera and Coleoptera, higher numbers of Diptera, an abundance of "sewage fungus", little reduction of dissolved oxygen levels and fewer species of fish in the area below the outfall.

This study was undertaken to assess the effects of changes in Bozeman's sewage disposal procedures upon the aquatic insects of the East Gallatin River. During collections made from April 7 through November 15, 1970, the city's sewage effluent entered the river from the primary treatment plant at a point 0.80 km below the river's origin. This sampling period and outfall location ~~is~~ are referred to as Sampling Period I and Outfall I, respectively.

On December 2, 1970, Bozeman's sewage effluent began entering the river at a new location. During collections taken from December 5, 1970 through September 17, 1971, the sewage entered the river from ~~its~~ Bozeman's the city's secondary treatment plant at a point 6.85 km downstream from Outfall I. This collecting period and outfall location will be referred to as Sampling Period II and Outfall II, respectively. Sewage from this new facility received only limited and sporadic secondary treatment until August, 1971, when 80% began receiving secondary treatment on a sustained basis.

The objectives of this study were to determine the responses of insect communities in the East Gallatin River to: (1) the sewage effluent from Outfall I, (2) the elimination of the sewage effluent from Outfall I and (3) the introduction of a sewage effluent at Outfall II.

DESCRIPTION OF THE STUDY AREA

The East Gallatin River lies in Gallatin County in southwestern Montana. It is formed by the confluence of Bozeman and Rocky Creeks 0.8 km north of the City of Bozeman and flows north and west about 60 km before joining the West Gallatin River. The East Gallatin River drains an area of about 383 km^2 in which the major land uses are cattle ranching and wheat farming.

The river has an average elevation of about 1,390 m above mean sea level and a gradient of 4.4 m/km. In the study area, the river varies from 3 to 12 m in width and in depth from a few centimeters in the riffles to 2.0 m in the pools (Avery, 1970). Records from 1939 to 1961 show low flows were commonly about 0.5 m^3/sec and occurred during the winter seasons (U.S.G.S. 1964). High flows were about 55 m^3/sec and took place during the spring seasons. The average flow from 1939 to 1961 was 2.40 m^3/sec. During this study, the average discharge of sewage into the river was about 0.14 m^3/sec.

METHODS

Collecting Stations

Five stations were sampled on the East Gallatin River (Fig. 1). These stations were located in the same riffles sampled by Avery (1970). Station 1 was situated 0.22 km above Outfall I. Station 2 was located 0.72 km below Outfall I. Station 3 was located 6.52 km below Outfall I and 0.33 km above Outfall II. Station 4 was located 13.17 and 6.32 km below Outfalls I and II, respectively. Station 5 was 20.94 and 14.09 km below Outfalls I and II, respectively. All stations had similar substrates (Avery, 1970), with at least 70% of the substrate particles being between 19.1 and 50.8 mm in size.

Insect Sampling and Analysis

Insect samples were collected monthly during April 1970, from July 1970 through March 1971, and from July 1971 through September 1971. Collections were made with a Surber sampler having 25 meshes/2.54 cm. Three 0.09 m^2 samples were collected on a transect in each riffle on each sampling date. The samples were spaced about 2 meters apart on each transect and atypical areas were avoided. The initial transect was positioned at the lower end of a riffle and each succeeding one was located about 2 meters upstream from the preceding one. A minimum of four months elapsed before an area in a previous

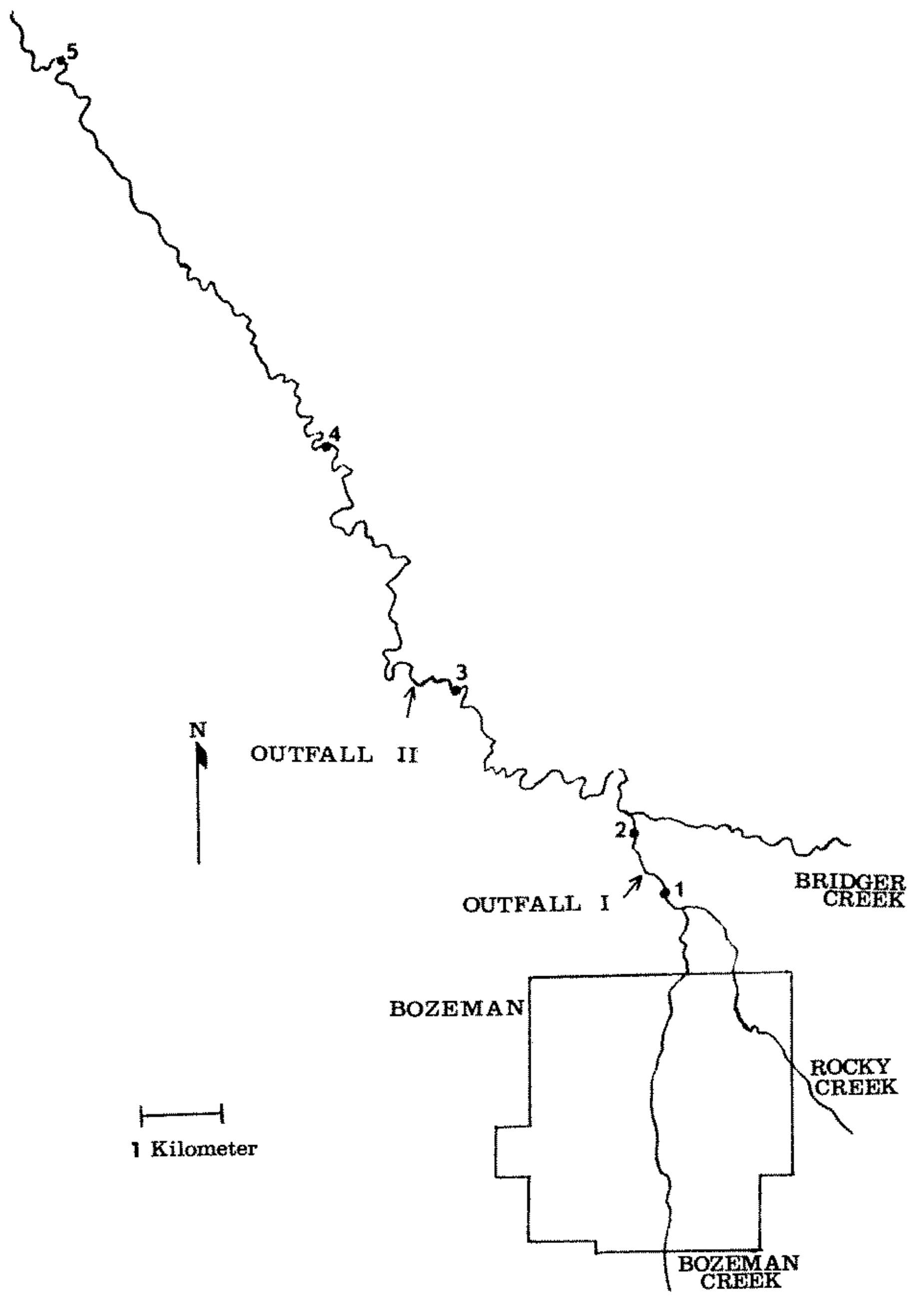

Figure 1. Map of study area showing the locations of sampling stations and sewage outfalls for the City of Bozeman.

transect was resampled. All samples were taken in water depths of 0.16 to 0.20 m.

Insect samples were preserved in the field with 10% formalin. Separation of insects from vegetation and bottom materials was performed in the laboratory with the aid of the sugar floatation technique (Anderson, 1959). Insects from each sample were then identified to order, counted and stored in 40% isopropyl alcohol.

The Freidman test (Kraft & van Eeden, 1968) was used to compare the median numbers of insects, by order, among the five stations during Sampling Periods I and II, separately. After differences among medians were indicated, a nonparametric multiple comparison procedure (Miller, 1966) was applied to determine which pairs of stations were most responsible for the significant difference.

Insects collected in August and September of 1970 and 1971 were identified to genus. Diversity indexes were obtained from these collections using the equation of Margalef (1951), $d=m-1/\ln N$, where m is the number of species, N is the total number of individuals, and d is the index of diversity.

Chemical-Physical Analysis

Ten monthly samples were taken from April, 1970 through July, 1971. Six samples were taken during Sampling Period I and four during Sampling Period II.

Temperatures were measured at all stations on each sampling date with a Taylor pocket thermometer. Dissolved oxygen determinations were made in the field by titration. A 1000 ml water sample was collected from each station on each sampling date and taken to the Hydrobiology Laboratory at Montana State University where determinations of pH, specific conductance, alkalinity, ammonia, nitrite, nitrate, and inorganic phosphate were made within 12 hours of collection. Hydrogen ion concentrations were determined with a Beckman Expanded Scale pH meter (Model 76). Specific conductance was measured with a YSI Conductivity Bridge (Model 31) and an Industrial Instruments (Model CEL 4) dipping cell. Total alkalinity, ammonia, and orthophosphate determinations were made following the procedures described in the American Public Health Association (1965). Nitrite and nitrate determinations were made following Hach Chemical Company Methods (1967). A Klett spectrometer was used in determining nitrogen and orthophosphate levels.

RESULTS

Aquatic Insects

The numbers of insects collected at each station on each sampling date are presented in Table 1. The lowest number of insects taken on any collecting date was 625 collected on January 8, 1971 and the highest was 6349 taken on September 17, 1971. The total number of insects collected at Station 5 was nearly 3000 higher than at any other station.

The total numbers and ordinal compositions of insects taken at each station during Sampling Period I are shown in Table 2. Total numbers decreased from Stations 1 to 2 and progressively increased at stations downstream from Station 2. The proportions of Ephemeroptera and Diptera at Station 2 were notably the lowest and highest, respectively, of all the stations and the proportions of Plecoptera and Trichoptera were also somewhat lower. Most of the stoneflies, caddisflies, and mayflies collected at Station 2 during Sampling Period I were found with profuse growths of "sewage fungus", of which the filamentous bacterium *Sphaerotilus* is a component, covering much of their bodies. Avery (1970) also found this condition at Station 2. Many insects collected at Station 3 during the winter months of Sampling Period I also bore strands of "sewage fungus".

During Sampling Period II, total numbers of insects increased progressively from Stations 1 through 5 and the ordinal compositions

Table 1. Numbers (per 0.27 m^2) of aquatic insects collected from stations on the East Gallatin River during Sampling Period I (above dashed line) and Sampling Period II (below dashed line).

Orders	Ephemeroptera					Plecoptera					Trichoptera					Diptera					Coleoptera				
Stations	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1970 April 7	142	68	86	514	544	3	3	0	6	56	3	2	6	5	14	18	35	123	147	30	3	1	1	1	1
July 9	58	112	223	559	688	0	0	0	1	1	4	8	6	1	2	24	110	45	21	8	2	3	0	0	1
August 14	210	17	213	289	532	4	0	3	2	17	2	0	1	15	86	83	293	284	81	52	1	0	1	2	0
Sept. 10	401	15	348	699	502	15	0	2	72	144	21	0	18	256	255	192	206	76	273	285	10	0	3	3	5
Oct. 7	109	8	31	248	451	13	0	15	71	276	7	1	3	49	225	112	111	34	158	198	0	0	2	0	0
Nov. 15	89	6	24	1373	651	3	1	14	171	273	4	0	2	127	260	178	217	17	206	331	0	0	4	2	0
Dec. 5	21	49	49	57	231	4	2	16	42	83	0	2	0	7	6	12	53	13	22	29	1	0	0	0	0
1971 Jan. 8	25	85	23	43	138	5	3	4	10	39	3	4	1	6	20	6	168	5	23	9	4	1	0	0	0
Feb. 12	296	199	111	346	921	57	9	10	10	40	9	2	1	7	37	43	12	28	114	56	1	0	0	1	0
March 13	220	138	179	382	504	44	16	12	59	60	2	3	0	42	49	60	9	168	94	66	0	0	0	2	0
July 4	39	41	140	219	846	2	1	2	2	24	6	1	0	0	1	13	7	0	7	7	2	7	2	7	1
August 12	176	308	505	339	549	15	12	29	9	66	12	12	26	26	145	46	58	12	62	398	2	4	0	0	0
Sept. 17	380	250	692	701	552	27	55	87	64	311	149	291	170	339	975	239	145	129	535	215	8	2	12	17	6

Table 2. Ordinal numbers and percentages (in parentheses) of insects collected during Sampling Period I.

Station	1	2	3	4	5
Ephemeroptera	1009(59.0)	226(18.5)	925(58.3)	3682(68.8)	3368(57.2)
Plecoptera	38(2.2)	4(0.5)	34(2.1)	323(6.0)	767(13.0)
Trichoptera	41(2.4)	11(0.9)	36(2.3)	453(8.4)	842(14.3)
Diptera	607(35.5)	972(79.6)	579(36.5)	886(16.5)	904(15.3)
Coleoptera	16(0.9)	4(0.5)	11(0.8)	8(0.2)	7(0.1)
Total	1711(100.0)	1217(100.0)	1585(100.0)	5352(100.0)	5888(100.0)

at all stations were similar (Table 3). Insects collected during Sampling Period II did not have noticeable growths of "sewage fungus" on them.

A comparison of the ordinal compositions of individual stations during Sampling Periods I and II shows a sizable increase in mayflies at Station 2 in Sampling Period II. The percentage compositions of Plecoptera and Trichoptera also increased at Stations 1, 2, and 3 during Sampling Period II with the largest increases occurring at Station 2. Conversely, the composition of Diptera at Station 2 decreased strikingly. The percentage composition of Coleoptera was similar at all stations before and after the movement of outfalls. Little compositional change occurred at Stations 4 and 5 throughout the study.

The Freidman test showed significant differences in the median numbers of mayflies and stoneflies, respectively, occurring at the stations in Sampling Period I (Table 4). The station pairs most likely responsible for the significant differences are shown in Table 5. The first member of each station pair has the higher median number of insects.

Analysis of samples taken during Sampling Period II showed significant differences in median numbers of mayflies, stoneflies, and caddisflies among stations (Table 6). The station pairs having the greatest differences are shown in Table 7.

Table 3. Ordinal numbers and percentages (in parentheses) of insects collected during Sampling Period II.

Station	1	2	3	4	5
Ephemeroptera	1157(60.0)	1070(54.9)	1699(70.0)	2087(58.0)	3741(58.6)
Plecoptera	154(8.0)	98(5.0)	160(6.6)	196(5.4)	623(9.8)
Trichoptera	181(9.4)	315(16.2)	198(8.2)	427(11.9)	1233(19.3)
Diptera	419(21.7)	452(23.2)	355(14.6)	857(23.8)	780(12.2)
Coleoptera	18(0.9)	14(0.7)	14(0.6)	27(0.9)	7(0.1)
Total	1929(100.0)	1949(100.0)	2426(100.0)	3594(100.0)	6384(100.0)

Table 4. Results of Freidman test showing ordinal differences in the median numbers of insects among stations during Sampling Period I.

Order	Ephemeroptera	Plecoptera	Trichoptera	Diptera	Coleoptera
Calculated Freidman Values	20.53*	17.23*	9.47	4.00	7.67

*Significance at 5% level (X^2_4 = 9.49)

Table 5. Station pairs exhibiting significant differences in median numbers of insects at the 5% level in Sampling Period I.

Order	Ephemeroptera	Plecoptera
Station Pairs	4-1, 4-2 5-1, 5-2 1-2, 4-3 3-2, 5-3	5-1, 4-3 1-2, 5-3 4-2, 5-4 5-2

Table 6. Results of Freidman test indicating ordinal differences in the median numbers of insects among stations during Sampling Period II.

Order	Ephemeroptera	Plecoptera	Trichoptera	Diptera	Coleoptera
Calculated Freidman Values	17.06*	16.77*	14.77*	7.66	4.69

*Significance at 5% level (X^2_4 = 9.49)

Table 7. Station pairs exhibiting significant differences in median numbers of insects at the 5% level in Sampling Period II.

Order	Ephemeroptera	Plecoptera	Trichoptera
Station Pairs	4-1 5-1 5-2	5-1, 5-4 5-2 5-3	4-1, 5-3 5-1, 5-4 5-2

Twenty-four taxa were identified from samples collected in August and September of 1970 and 1971 (Tables 8 and 9). During the combined August and September collections of Sampling Period I, Stations 1, 2, 3, 4 and 5 contained 15, 5, 10, 14 and 21 taxa respectively. The low number of taxa at Station 2 was primarily due to the absence of stonefly and caddisfly taxa and a smaller number of mayfly taxa (Table 8).

In August and September of Sampling Period II, Stations 1, 2, 3, 4 and 5 had 18, 17, 17, 20 and 21 taxa, respectively (Table 9). All stations had a greater number of taxa in Sampling Period II than in Sampling Period I, with Station 2 showing the greatest increase. The appearance of stonefly, mayfly, caddisfly and fly taxa accounted for the increase of forms at Station 2.

Diversity indexes are presented in Figure 2. During Sampling Period I, the diversity decreased sharply from Station 1 to 2 and increased progressively downstream from Station 2. Diversity indexes were generally higher at the stations during Period II with Station 2 showing the greatest increase. During Sampling Period II, differences

Table 8. Numbers and taxa of insects in combined August and September samples (0.54 m^2) of Sampling Period I.

Taxa	1	2	3	4	5
EPHEMEROPTERA					
Baetis parvus	448	30	461	645	517
Ephemerella (spinifera and *enermis)*	40	2	38	12	29
Tricorythodes minutus	110	-	49	300	469
Rithrogena undulata	-	-	-	-	1
Heptagenia simpliciodes	13	-	13	42	18
PLECOPTERA					
Pteronarcella sp.	28	-	5	59	102
Arcynopteryx parallela	1	-	-	1	4
Iso genus elongatus	-	-	-	2	2
Isoperla sp.	-	-	-	12	47
Alloperla sp.	-	-	-	-	2
TRICHOPTERA					
Brachycentrus sp.	9	-	-	-	9
Hydropsyche sp.	14	-	19	260	329
Arctopsyche grandis	-	-	-	-	2
Glossosoma sp.	-	-	-	-	1
DIPTERA					
Atherix variegata	76	4	12	15	134
Simulium arcticum	3	-	-	-	3
Hexatoma sp.	29	-	-	-	31
Diamesinae	160	484	344	327	131
Tipula sp.	7	9	4	12	37
COLEOPTERA					
Optioservus quadrimaculatus	8	-	4	4	3
Zaitzevia parvula	3	-	-	1	2

Table 9. Numbers and taxa of insects in combined August and September samples (0.54 m^2) of Sampling Period II.

Taxa	1	2	3	4	5
EPHEMEROPTERA					
Baetis parvus	375	344	1123	1211	725
Ephemerella (spinifera and *enermis)*	162	142	103	45	33
Tricorythodes minutus	6	4	35	63	90
Rithrogena undulata	13	10	123	80	249
Heptagenia simpliciodes	-	-	-	-	2
Paraleptophlebia bicornuta	-	-	-	3	5
PLECOPTERA					
Pteronarcella sp.	33	52	84	59	335
Arcynopteryx parallela	3	7	11	2	30
Isogenus elongatus	-	-	-	2	3
Isoperla sp.	4	6	20	9	17
Alloperla sp.	-	-	-	-	1
Acroneuria pacifica	2	2	3	1	1
TRICHOPTERA					
Brachycentrus sp.	8	11	23	7	2
Hydropsyche sp.	148	286	170	353	1105
Arctopsyche grandis	3	5	3	4	4
Rhyacophila bifila	2	-	-	-	-
Glossosoma sp.	-	-	-	1	9
DIPTERA					
Atherix variegata	137	95	25	81	16
Simulium arcticum	11	3	9	224	463
Hexatoma sp.	15	11	1	12	8
Diamesinae	120	93	104	258	126
Tipula sp.	2	1	2	22	-
COLEOPTERA					
Optioservus quadrimaculatus	10	6	12	17	6

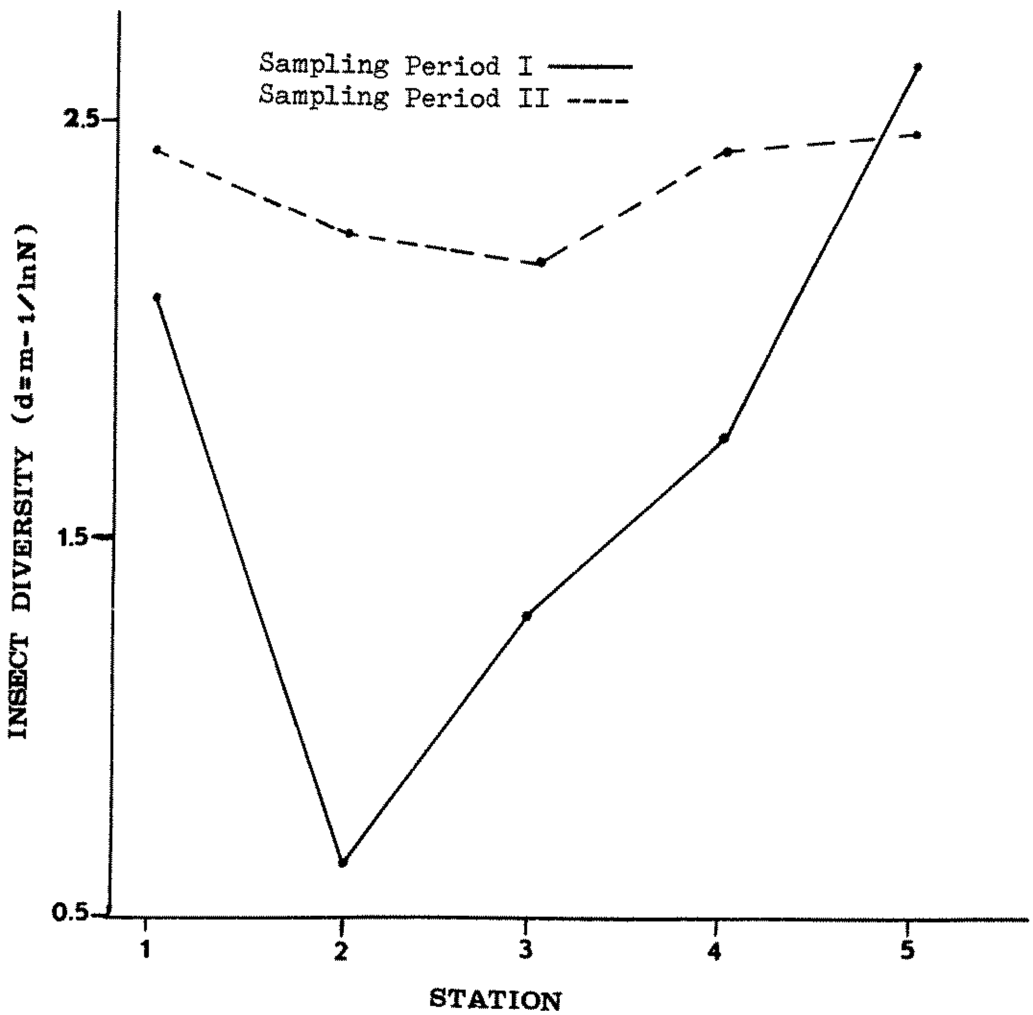

Figure 2. Indexes of insect diversity in combined August and September samples during Sampling Periods I and II.

in diversity among the stations were less than in Period I.

Physical-Chemical Characteristics

The physical-chemical characteristics at the stations during Sampling Periods I and II are presented in Tables 10 and 11. Water temperature in the East Gallatin River ranged from a low of 0°C in January, to a high of 20°C in August of 1970. The sewage discharge did not cause any appreciable temperature change in the river between stations. Differences in water temperatures from Station 1 to Station 5 never exceeded 5°C on any single sampling date. During Sampling Period I, Station 2 had the lowest pH values and highest mean values of ammonia, nitrate and orthophosphate (Table 10). Nitrite levels progressively increased downstream from Station 2. The average values of dissolved oxygen, alkalinity, and conductivity were similar at all stations.

During Sampling Period II, mean values of ammonia, nitrite, and nitrate were highest at Stations 4 and 5 (Table 11). Dissolved oxygen, pH, alkalinity and conductance values were similar at all stations. Nitrite and orthophosphate values generally increased progressively downstream from Station 1.

Table 10. Average values and ranges (in parentheses) of chemical and physical characteristics at sampling stations during Sampling Period I.

Characteristic	Station 1	2	3	4	5
Dissolved Oxygen (ppm)	10.4 (8-12)	9.7 (6-11)	10.0 (7-11)	10.2 (8-11)	10.2 (8-11)
pH	(8.30-8.80)	(8.12-8.30)	(8.15-8.30)	(8.30-8.58)	(8.32-8.70)
Alkalinity (mg/1)	3.41 (3.30-3.90)	3.62 (3.39-3.70)	3.67 (3.43-3.82)	3.59 (3.44-3.78)	3.64 (3.43-3.80)
Conductance (Umhos)	395 (350-420)	420 (380-440)	410 (340-420)	400 (380-410)	405 (380-420)
Ammonia-nitrogen (mg/1)	.141 (.065-.193)	.530 (.354-.830)	.279 (.121-.505)	.172 (.115-.231)	.158 (.115-.211)
Nitrite-nitrogen (mg/1)	.005 (.003-.009)	.014 (.009-.046)	.020 (.009-.046)	.043 (.021-.090)	.051 (.028-.072)
Nitrate-nitrogen (mg/1)	.247 (.168-.374)	.552 (.362-.750)	.384 (.274-.615)	.346 (.244-.547)	.390 (.425-.638)
Inorganic phosphate (mg/1)	.148 (.079-.213)	.735 (.366-1.135)	.39 (.204-.717)	.56 (.382-.755)	.65 (.391-.936)
Temperature (°C)	7 (1-18)	7 (1-18)	8 (0-19)	8 (0-19)	8 (0-20)

Table 11. Average values and ranges (in parentheses) of chemical and physical characteristics at sampling stations during Sampling Period II.

Characteristic	Station 1	2	3	4	5
Dissolved Oxygen (ppm)	10 (8-12)	10 (8-12)	10 (8-11)	10 (8-12)	10 (8-12)
pH	(8.27-8.78)	(8.22-8.75)	(8.20-8.81)	(8.11-8.60)	(8.15-8.70)
Alkalinity (me/l)	3.50 (3.20-3.90)	3.57 (3.35-3.92)	3.54 (3.27-3.95)	3.74 (3.50-3.93)	3.75 (3.60-3.92)
Conductance (Umhos)	390 (370-410)	400 (380-420)	395 (370-420)	420 (390-440)	410 (380-430)
Ammonia-nitrogen (mg/l)	.125 (0.73-.156)	.142 (.107-.276)	.147 (.129-.212)	.210 (.172-.314)	.184 (.153-.241)
Nitrite-nitrogen (mg/l)	.007 (.004-.010)	.011 (.005-.016)	.028 (.006-.053)	.050 (.026-.087)	.049 (.021-.074)
Nitrate-nitrogen (mg/l)	.26 (.20-.36)	.36 (.29-.43)	.33 (.19-.45)	.58 (.26-.84)	.48 (.38-.66)
Inorganic phosphate (mg/l)	.16 (.09-.24)	.47 (.19-1.21)	.42 (.24-.71)	.63 (.41-.87)	.72 (.47-.89)
Temperature (°C)	5 (1-13)	5 (1-13)	5 (1-14)	6 (1-14)	6 (1-15)

DISCUSSION

Lotic habitats in the midwestern United States receiving heavy organic loads are characterized by relatively low numbers and diversity of mayflies, stoneflies and caddisflies, high numbers of a few kinds of flies, profuse growths of "sewage fungus", large numbers of *Tubifex* and periods of low dissolved oxygen levels (Gaufin and Tarzwell, 1956). During Avery's (1970) study and Sampling Period I of this study, Station 2, and to a lesser extent Station 3, had these characteristics, with the exception of low dissolved oxygen levels.

Low dissolved oxygen levels and profuse growths of "sewage fungus" are considered to be important factors causing the community structure seen in polluted habitats in the midwest (Gaufin and Tarzwell, 1955). The minimum dissolved oxygen level recorded at Station 2 during this and other studies (Avery, 1970~~;~~ ~~and~~ Soltero, 1969) was 5 ppm and is, therefore, not considered to be a causative factor in community formation during Sampling Period I at Station 2.

The abundance of "sewage fungus" at Station 2 during Sampling Period I is considered to be the factor most responsible for the relatively low numbers of mayflies, stoneflies, and caddisflies and the low insect diversity found there. "Sewage fungus" covered most of the insects in these orders at this site and probably eliminated many individuals by restricting their respiration and movement.

Baetis parvus appeared to be the only form in the above orders that consistently did not have growths of "sewage fungus" on it. This insect is a known component of the drift community and may have been a transient at this site. "Sewage fungus" also covered much of the substrate at this location and probably limited the available food supply and suitable habitat for certain insects. The high levels of ammonia present may have been toxic to some forms and thereby partially responsible for the reduced numbers and diversity at this location.

Following the disuse of Outfall I, the "sewage fungus" diminished at Station 2 and the insect community changed. Relative numbers of mayflies and flies increased and decreased, respectively, within three days. Numbers of stoneflies and caddisflies increased after eight months and by nine months the diversity index at Station 2 was comparable to those of the other stations.

The insect community at Station 4 apparently was little affected by the sewage effluent from Outfall II. Numbers of flies, stoneflies, caddisflies, and mayflies were substantially lower immediately after the activation of Outfall II. However, numbers of mayflies and flies also decreased substantially at Station I during this period. A comparison of the diversity of insects at Station 4 before and nine months after the introduction of Outfall II indicated no adverse effects by the sewage effluent.

LITERATURE CITED

American Public Health Association. 1965. Standard methods for the examination of water and wastewater. 12th Ed., Amer. Pub. Health Assoc. New York. 769 pp.

Anderson, R. O. 1959. A modified floatation technique for sorting bottom fauna samples. Limnol. and Oceanogr., 4(2): 223-225.

Avery, E. L. 1970. Effects of domestic sewage on aquatic insects and salmonids of the East Gallatin River, Montana. Water Res. 4(2): 165-177.

Gaufin, A. R. 1958. The effects of pollution on a midwestern stream. Ohio J. of Sci. 58(4): 197-208.

__________, and C. M. Tarzwell. 1955. Environmental changes in a polluted stream during winter. Amer. Midl. Natur. 54(1): 77-88.

__________, and C. M. Tarzwell. 1956. Aquatic macro-invertebrate communities as indicators of organic pollution in Lytle Creek. sewage and Ind. Wastes 28(7): 906-924.

Hach Chemical Company. 1967. Water and wastewater analysis procedures. Hach Chemical Co., Ames, Iowa. Cat. No. 10: 104 pp.

Hawkes, H. A. 1963. Effects of domestic and industrial discharge on the ecology of riffles in midland streams. Int. J. of Air and Water Poll. 7(6-7): 565-586.

Kraft, C. H., and C. van Eeden. 1968. A Nonparametric Introduction to Statistics. MacMillan Book Co., New York. 200 pp.

Margalef, R. 1951. Diversidad de especies en las comunidades naturales. P. Inst. Biol., Apl. 9: 5-27.

Miller, R. G. 1966. Simultaneous Statistical Inference. McGraw-Hill Book Co., New York. 272 pp.

Soltero, A. S. 1969. Chemical and physical findings from pollution studies on the East Gallatin River and its tributaries. Water Res. 3: 687-706.

United States Geological Survey. 1964. Compilation of records of surface waters of the United States, October 1950 to September 1960. Part 6-A. Missouri River Basin above Sioux City, Iowa. Geological Survey Water-Supply Paper 1729. 507 pp.