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EFFECTS OF DOMESTIC SEWAGE ON AQUATIC INSECTS AND SALMONIDS OF THE EAST GALLATIN RIVER, MONTANA

by

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

of

MASTER OF SCIENCE

in

Fish and Wildlife Management

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MONTANA STATE UNIVERSITY
Bozeman, Montana

June, 1969

VITA

The author, Eddie Lee Avery, was born in Wichita, Kansas on October 13, 1944, to Colquette Odell and Evelyn Marie Avery. He graduated from Wichita High School North in June, 1962. He entered Kansas State University in September, 1962, and received a Bachelor of Science degree in Fish and Wildlife Management in January, 1967. From February to May, 1967, he was temporarily employed as a Wildlife Biologist with the Department of the Army, Ft. Riley, Kansas. He began graduate studies at Montana State University in June of 1967 as a Graduate Research Assistant with the Montana Cooperative Fisheries Unit. He is married to the former Evelyn Kaye Schultz and they have two children, Julie Brette, 4, and Bryan Odell, $1\frac{1}{2}$.

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, aided in field work, and assisted in preparation of the manuscript. Mr. E. Richard Vincent of the Montana Fish and Game Department offered valuable suggestions pertaining to the shocking technique and, along with graduate student members of the Montana Cooperative Fisheries Unit, assisted in the field work. Dr. Marvin M. Lentner assisted with statistical analysis. I am indebted to my wife, Kaye, for assistance in the field and for encouragement while preparing the manuscript. The investigation was financed by the Montana Cooperative Fisheries Unit and the Montana Fish and Game Department under Federal Aid to Fish Restoration Project F-9-R.

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ABSTRACT

Aquatic insect communities and salmonid populations were sampled above and below a municipal sewage outfall on the East Gallatin River. Numbers of Trichoptera, Ephemeroptera, Coleoptera, and Plecoptera 0.45 mile (0.72 km) below the sewage outfall were lower than those found above. This reduction was associated with the occurrence of "sewage fungus" (*Sphaerotilus* sp.) on the bottom. An increase in the number of Diptera was associated with intra-ordinal changes in genera. Volumes of insects in each of these five orders declined. A partial recovery in the insect community was indicated at 3.85 miles (6.19 km) below the sewage outfall by an increase in numbers and volumes of all insects. At 12.65 miles (20.35 km) below the outfall, the number of aquatic insects was more than 13 times that found above. This was attributed to a return to carrying capacity and/or to the "fertilizing" effect of the sewage. Rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), and mountain whitefish (*Prosopium williamsoni*) were found above the sewage outfall but only rainbow trout were present after complete mixing of the sewage had occurred. Rainbow trout was the most numerous salmonid in the river. Above the outfall, the standing crop of rainbow trout was the same in summer and winter. Below the outfall, a marked drop in the standing crop occurred during winter. This was associated with an increase of free ammonia ($N\text{-}NH_3$) in the river.

INTRODUCTION

Surveys by the Montana Fish and Game Department in 1966 indicated a low standing crop of salmonids with few yearlings in a section of the East Gallatin River below the sewage outfall from the city of Bozeman, Montana. Domestic sewage has been shown to have detrimental effects on the biota of the receiving waters (Katz & Gaufin, 1953; Gaufin, 1958; and Hawkes, 1963). The present study was undertaken to determine if the sewage from Bozeman adversely affected the aquatic insect and salmonid populations of this river. Field work was conducted from September, 1967, through November, 1968.

DESCRIPTION OF THE STUDY AREA

The East Gallatin River is formed by the union of Rocky and Bozeman Creeks 0.5 mile (0.80 km) north of Bozeman, Montana (Fig. 1). It flows northwesterly approximately 37 miles (59.53 km) before merging with the West Gallatin River below Manhattan, Montana. The drainage area comprises 148 square miles (238.13 sq km) and the major land use is livestock grazing, haying, and wheat farming.

Discharge measurements of the East Gallatin River approximately 500 ft (152.5 m) below the confluence of Rocky and Bozeman Creeks averaged 84.7 cfs for the 22 year period from 1939 to 1961 (U.S.G.S., 1961). Maximum discharge was 1,230 cfs on 4 June 1953, and minimum was 12 cfs on 9 December 1944, and 24-26 March 1955.

The East Gallatin River was 10 to 40 ft (3.1 to 12.2 m) wide during low water stages and varied in depth from a few inches in the riffles to more than 8 ft (2.4 m) in a few pools during the study period. The river has an average elevation of about 4,560 ft (1,389.8 m) above mean sea level and a gradient of 23 ft (7.3 m) per mile. The flow is maintained by ground water and surface runoff and augmented by the effluent from the Bozeman Sewage Treatment Plant. The sewage effluent contributed an average of 3.3 million gallons (5.11 cfs) per day of primary treated sewage during the study period. This comprised from 4.7 to 14.2% of the total stream flow.

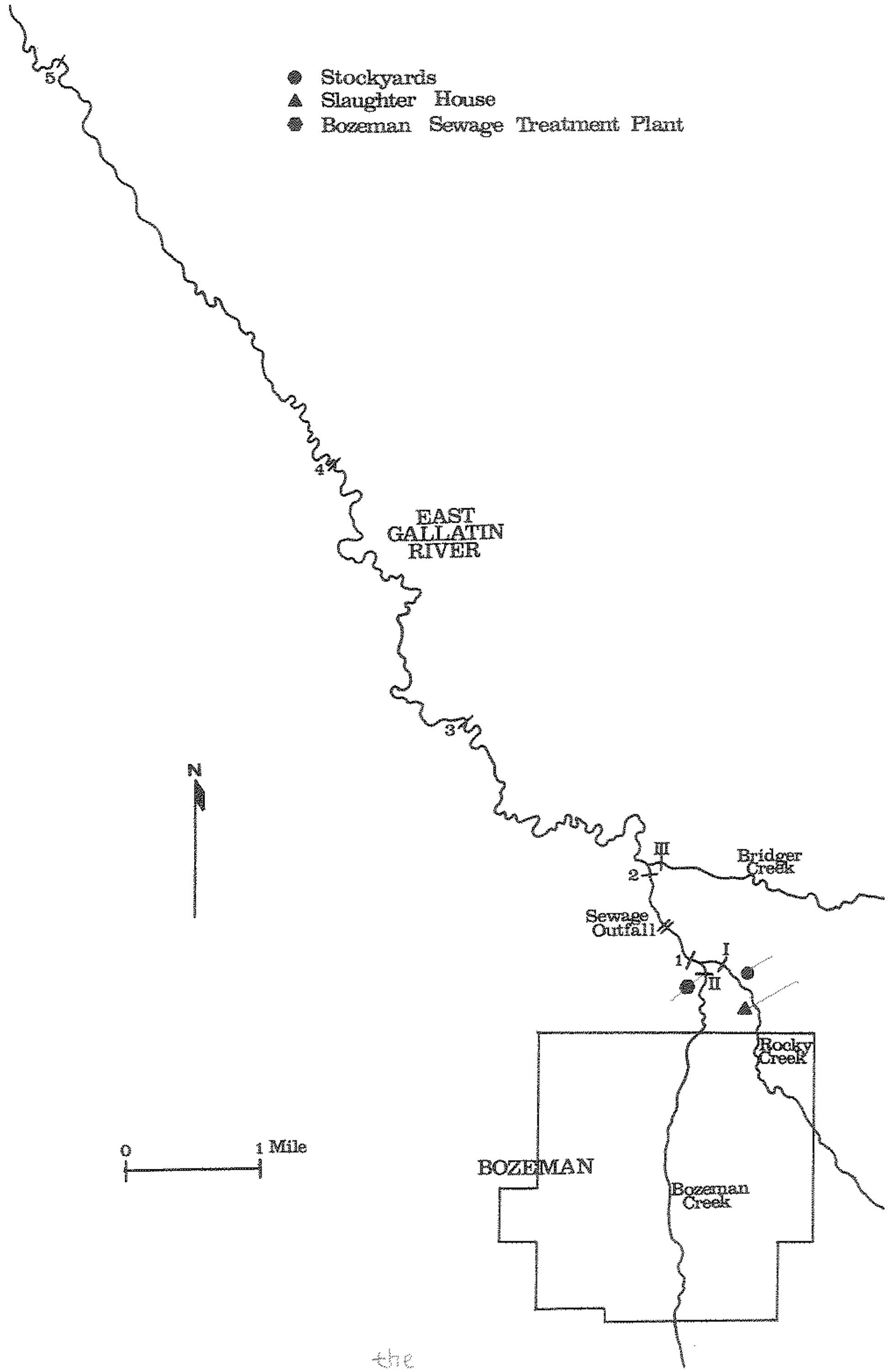

Figure 1. Map of a portion of the East Gallatin River system showing location of study area and insect sampling stations.

METHODS

Insect Sampling

Five insect sampling stations were established on the East Gallatin River (Fig. 1). Station 1 served as the "control" and was 0.14 mile (0.22 km) below the confluence of Rocky and Bozeman Creeks and 0.35 mile (0.56 km) above the sewage outfall. Station 2 was 0.45 mile (0.72 km) below the sewage outfall and above the confluence of Bridger Creek. Station 3 was 3.85 miles (6.19 km) below the sewage outfall and below the confluence of Bridger Creek. Stations 4 and 5 were 7.85 and 12.65 miles (12.63 and 20.35 km) below the sewage outfall, respectively.

Three insect sampling stations were located on tributary streams (Fig. 1). Station I was on Rocky Creek 0.15 mile (0.24 km) above its confluence with Bozeman Creek. Station II was on Bozeman Creek 0.07 mile (0.11 km) above its confluence with Rocky Creek. Station III was on Bridger Creek 0.02 mile (0.03 km) above its confluence with the East Gallatin River.

Sampling stations were established in riffles selected on the basis of similar substrates. Two 1 sq ft (0.3 m^2) samples of the stream bottom were collected in each riffle with a Surber sampler. These were taken in water between 0.2 and 1.0 ft (6.10 and 30.50 cm) in depth. Material was collected to a depth of about 3 inches (7.62 cm), dried, and put through a series of Tyler soil screens separating it into six size categories. The volumes of each size category in the two samples from each station were determined by water displacement and the percent of total volume calculated (Table I).

TABLE I. Average values of each size class of substrate from the study riffles.

Class	Size (mm)	Percent of Total Volume at Each Station							
		1	2	3	4	5	I	II	III
Cobble									
Large	>50.8	24.9	25.1	23.4	27.1	25.0	51.8	46.1	41.0
Medium	38.1-50.7	22.1	21.6	26.3	16.6	21.8	15.1	14.0	14.0
Small	19.1-38.0	30.3	31.2	26.8	27.0	25.2	17.8	19.3	21.4
Pebble	4.8-19.0	17.7	16.4	16.1	20.7	21.7	12.3	15.0	16.1
Gravel	2.0-4.7	2.8	3.3	4.7	4.6	3.5	1.7	3.3	4.3
Sand	<1.9	2.2	2.5	2.7	4.0	2.9	1.3	2.3	3.2

Insect samples were collected monthly from each station on the East Gallatin River from September through November in 1967, and in February, March, and July through November in 1968. Those from Rocky, Bozeman, and Bridger Creeks were collected in September of 1967, and February and July of 1968.

Aquatic insect samples were collected with a Surber sampler having 25 mesh per inch (2.54 cm). Three 1 sq ft (0.3 m^2) samples, spaced 4 ft (1.2 m) apart along a transect, were collected in each riffle on each sampling date. Areas with large amounts of aquatic vegetation and/or large cobble were avoided. Initial samples were taken at the lower end of each riffle and succeeding samples on transects established about 4 ft (1.2 m) upstream from the preceding ones. All samples were taken in water depths of 0.2 to 1.8 ft (6.10 to 54.90 cm) with 155 of the 174 samples taken at 1.0 ft (0.3 m) or less.

Samples were preserved with 10% formalin in the field and taken to the laboratory where they were separated from vegetation and bottom materials. Insects were sorted to order, counted, measured volumetrically to the nearest 0.01 cc, and preserved in 70% ethyl alcohol. Separating the insects from vegetation and bottom materials was accomplished by picking each sample twice and subjecting the remaining material to the sugar floatation technique (Anderson, 1959). Trichoptera cases were not included in volumetric measurements.

Nonparametric statistical analysis was applied to the number of aquatic insects sampled from the East Gallatin River. The Friedman test (Kraft & van Eeden, 1968) was used to determine if differences in the mean number of insects in each order existed at the five stations. A nonparametric multiple comparison procedure (Miller, 1966) was applied to determine which pairs of stations were most likely different.

Physical-Chemical Sampling

Physical and chemical data were collected at each insect sampling station on the East Gallatin River on each sampling date. Water temperatures were taken with a Taylor pocket thermometer and flows were calculated from measurements made with a Gurley current meter at 2 ft (0.6 m) intervals on a transect across the river. Water temperatures and flow measurements also were taken of Bridger Creek and the sewage outfall on each date insect samples were collected. Discharge measurements of the sewage were obtained from the Bozeman Sewage Treatment Plant.

Two 300 ml water samples were collected at each station on the East Gallatin River on each insect sampling date. One sample was "fixed" immediately for dissolved oxygen determination. Specific conductance, pH, turbidity, alkalinity, and chloride concentration were determined from the other sample in the laboratory within 24 hours after collection. Specific conductance was measured with a YSI Conductivity Bridge (Model 31) and Industrial Instruments (Model CEL 4) dipping cell, then corrected for temperature and cell resistance. Hydrogen-ion concentrations were determined with a Beckman Expanded Scale pH meter (Model 76) and turbidities (in Jackson units) determined with a B & L Spectronic 20. All other determinations were made according to Hach Chemical Company methods (1967).

Fish Sampling

Two sections on the East Gallatin River, one above and one below the sewage outfall, were established to determine the species composition and standing crop of salmonids. Section A was about 1,845 ft (562.7 m) in length and included the East Gallatin River from the confluence of Rocky and Bozeman Creeks to the sewage outfall. Section B was about 2,904 ft (885.7 m) in length and included the East Gallatin River from the sewage outfall to about 400 ft (122.0 m) above the confluence of Bridger Creek.

Salmonids in both sections were sampled in August, 1967 and 1968, and March, 1968 and 1969, with a 1,000 watt continuous current DC shocker. A mark and recapture technique with a single marking and a single recapture run was employed for each sample. On the marking run, captured fish were anesthetized with MS-222 (Tricane Methanesulfonate), fin clipped, measured to the nearest 0.1 inch (0.25 cm), weighed to the nearest 0.02 lb (9.08 gm), and released near the capture site. Three to four days later, on the recapture run, the same procedures were followed except no additional fish were fin clipped. The salmonids found, in order of decreasing abundance, were rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), mountain whitefish (*Prosopium williamsoni*), and brook trout (*Salvelinus fontinalis*).

Population estimates were determined using the Bailey modification of the Peterson single census method (Ricker, 1958). Due to differential catchability related to size (Cooper and Lagler, 1956), rainbow trout were grouped into size intervals of 4.0-7.9, 8.0-11.9, and 12+ inches (10.16-20.07, 20.32-30.23 and 30.48+ cm) for population estimates. Confidence intervals at the 95% level were computed using formula 6 of the Michigan Institute for Fisheries Research (1960). Numbers of salmonids other than rainbow trout were too few to provide reliable population estimates.

Lengths and average widths of sections A and B were taken from aerial photographs with a scale of 1 inch (2.54 cm) equal to 250 ft (76.2 m) to determine the number of surface acres in each section. Lengths were determined with a map measurer and average widths computed from 30 measurements taken every 0.5 inch (1.27 cm). The numbers and pounds per acre of rainbow trout in each section were determined.

RESULTS

Community Composition

Numbers and volumes of aquatic insects/3 ft^2 (~~0.9~~ m^2) 0.3m^2 collected at stations on the East Gallatin River are presented in Table II. Trichoptera, Ephemeroptera, and Diptera together comprised 96% of the total number and 91% of the total volume of all aquatic insects collected. Trichoptera, Ephemeroptera, and Diptera accounted for 24, 33, and 39% of the total number and 35, 14, and 42% of the total volume, respectively. Plecoptera and Coleoptera together comprised only 4% of the total number and 9% of the total volume of all aquatic insects. Coleoptera accounted for less than 0.5% of the totals in both categories.

Numbers and volumes of aquatic insects/3 ft^2 (~~0.9~~ m^2) 0.3m^2 collected from Rocky, Bozeman, and Bridger Creeks are presented in Table III. Trichoptera, Ephemeroptera, and Diptera together comprised 92% of the total number and 85% of the total volume of all aquatic insects collected. Trichoptera, Ephemeroptera, and Diptera comprised 26, 33, and 33% of the total number and 21, 20, and 44% of the total volume, respectively. Plecoptera and Coleoptera together comprised 8% of the total number and 15% of the total volume of all aquatic insects. Coleoptera accounted for 3 and 2%, respectively, of the total number and volume.

Eighteen families and 27 genera of aquatic insects were identified from samples taken from the East Gallatin River in March and September, 1968 (Table IV). Numerically, the dominant taxa within each order were: *Cheumatopsyche* (Trichoptera); *Baetis* and *Ephemerella* (Ephemeroptera);

TABLE II. Numbers (~~per 0.9~~ 0.3 m^2) and volumes (cc/m^2) of aquatic insects collected from stations on the East Gallatin River (volumes in parentheses).

Orders	Tricoptera					Ephemeroptera					Diptera					Plecoptera					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
1967																									
Sept. 8	1 t	2 t	44 (0.55)	407 (3.20)	1748 (11.25)	195 (0.98)	8 t	348 (1.09)	934 (2.20)	1545 (3.00)	57 (0.87)	831 (0.80)	692 (1.18)	875 (4.60)	1901 (3.75)	0 0	0 0	2 t	15 (0.30)	47 (0.90)	18 (0.07)	5 (0.02)	9 (0.03)	8 (0.02)	0 0
Oct. 7	3 t	2 t	40 (0.74)	525 (8.31)	2130 (19.20)	29 (0.27)	0 0	51 (0.37)	230 (0.85)	463 (0.76)	42 (5.13)	197 (1.95)	406 (1.34)	520 (14.20)	296 (10.30)	0 0	0 0	1 t	4 (0.17)	53 (0.92)	10 (0.05)	1 t	7 (0.05)	1 t	0 0
Nov. 4	7 (0.01)	1 t	51 (0.95)	613 (12.84)	2143 (23.12)	39 (0.67)	0 0	59 (0.64)	355 (0.90)	707 (1.11)	35 (9.64)	155 (1.95)	327 (2.23)	458 (9.87)	316 (9.73)	0 0	0 0	3 (0.25)	8 (0.21)	82 (2.15)	26 (0.08)	2 t	15 (0.05)	3 t	0 0
1960																									
Feb. 10	—	0 0	17 (0.22)	150 (3.20)	949 (12.75)	—	7 (0.18)	671 (1.99)	671 (2.00)	1157 (2.62)	—	669 (3.72)	244 (15.23)	123 (9.15)	319 (1.12)	—	0 0	17 (1.22)	11 (0.60)	154 (1.85)	—	1 t	7 (0.03)	4 t	0 0
March 16	13 (0.25)	1 (0.03)	0 0	151 (2.30)	292 (5.10)	134 (1.80)	16 (0.20)	71 (0.32)	687 (2.48)	868 (3.00)	227 (6.80)	69 (2.72)	217 (1.35)	509 (5.80)	125 (14.35)	5 (0.23)	0 0	0 0	6 (0.24)	202 (1.65)	16 (0.15)	1 t	3 t	2 t	0 0
July 9	14 (0.17)	5 (0.01)	25 (0.20)	2 (0.10)	49 (1.23)	18 (0.17)	34 (0.47)	264 (2.45)	235 (1.08)	238 (1.15)	36 (0.15)	114 (0.32)	122 (0.25)	79 (0.15)	30 (0.13)	4 (0.15)	0 0	3 (0.10)	0 0	25 (0.40)	1 t	1 t	0 0	0 0	0 0
Aug. 8	35 (0.28)	2 t	4 t	15 (0.07)	215 (0.65)	198 (0.62)	49 (0.26)	530 (2.07)	568 (1.73)	1824 (3.28)	232 (1.24)	670 (0.55)	572 (0.57)	371 (0.40)	1622 (2.58)	9 (0.35)	1 (0.06)	7 (0.10)	0 0	184 (0.63)	4 (0.04)	2 t	4 t	0 0	0 0
Sept. 7	91 (0.95)	2 (0.04)	5 (0.06)	99 (0.69)	812 (5.49)	224 (0.85)	48 (0.27)	334 (1.17)	742 (1.81)	933 (2.10)	379 (0.95)	706 (0.63)	314 (0.34)	197 (0.55)	382 (1.18)	18 (0.61)	0 0	0 0	11 (0.19)	186 (1.82)	14 (0.05)	2 t	5 (0.02)	1 t	2 (0.01)
Oct. 7	101 (2.06)	0 0	7 (0.18)	286 (3.43)	1030 (12.96)	70 (1.14)	3 (0.05)	116 (1.44)	102 (0.82)	333 (1.71)	243 (1.40)	419 (1.13)	500 (3.03)	538 (1.83)	1265 (3.61)	22 (1.03)	0 0	12 (1.47)	18 (0.71)	336 (7.50)	20 (0.05)	3 (0.03)	2 t	1 t	2 t
Nov. 11	77 (2.03)	3 (0.10)	4 (0.16)	104 (1.42)	823 (12.05)	58 (1.53)	3 (0.08)	91 (2.23)	519 (1.01)	747 (3.55)	110 (1.60)	247 (0.56)	211 (5.13)	854 (7.09)	886 (6.29)	11 (0.60)	1 (0.08)	2 (0.28)	8 (0.43)	304 (10.65)	21 (0.17)	1 t	25 (0.22)	6 (0.07)	0 0

t = trace
— = no data

TABLE III. Numbers (~~per 0.9 m^2~~ 0.3 m^2) and volumes (cc/m^2) of aquatic insects collected from stations on Rocky, Bozeman, and Bridger Creeks (volumes in parentheses).

Orders	Trichoptera			Ephemeroptera			Diptera			Plecoptera			Coleoptera		
Stations	Rocky	Bozeman	Bridger	Rocky	Bozeman	Bridger	Rocky	Bozeman	Bridger	Rocky	Bozeman	Bridger	Rocky	Bozeman	Bridger
1967															
Sept. 6	15 (0.34)	0 0	1578 (3.97)	323 (0.71)	48 (0.40)	884 (1.85)	981 (1.95)	19 (0.23)	951 (1.55)	21 (0.30)	0 0	84 (1.06)	24 (0.10)	37 (0.11)	156 (0.25)
1968															
Feb. 2	97 (0.49)	0 0	515 (3.05)	1332 (2.85)	18 (0.30)	90 (0.28)	527 (12.05)	0 0	222 (0.45)	116 (1.07)	0 0	183 (1.30)	33 (0.13)	5 t	29 (0.28)
July 9	5 (0.05)	58 (0.09)	40 (0.37)	105 (0.57)	33 (0.50)	51 (0.60)	148 (0.68)	33 (0.10)	62 (0.29)	8 (0.07)	0 0	11 (1.22)	3 t	4 t	2 t

t = trace

TABLE IV. List of aquatic insects identified from the East Gallatin River, Montana.

- Trichoptera
  - Brachycentridae
    - *Brachycentrus* sp.
  - Hydropsychidae
    - *Arctopsyche* sp.
    - *Cheumatopsyche* sp.
    - *Hydropsyche* sp.
  - Helicopsychidae
    - *Helicopsyche* sp.
  - Lepidostomatidae
    - *Lepidostoma* sp.
  - Rhyacophilidae
    - *Glossosoma* sp.
    - *Rhyacophila* sp.
- Ephemeroptera
  - Baetidae
    - *Baetis* sp.
    - *Ephemerella* spp.
    - *Paraleptophlibia* sp.
    - *Tricorythodes* sp.
  - Heptageniidae
    - *Heptagenia* sp.
    - *Rhithrogena* sp.
- Coleoptera
  - Elmidae
    - *Optioservus* sp.
- Plecoptera
  - Chloroperlidae
    - *Chloroperla* sp.
  - Perlodidae
    - *Isogenus* sp.
    - *Isoperla* sp.
    - *Arcynopteryx* sp.
  - Pteronarcidae
    - *Pteronarcella* sp.
- Diptera
  - Ceratopogonidae
    - *Atrichopogon* sp.
  - Empididae
  - Rhagionidae
    - *Atherix* sp.
  - Simulidae
    - *Simulium* sp.
  - Tabanidae
    - *Tabanus* sp.
  - Tendipedidae
  - Diamesinae
  - Tipulidae
    - *Antocha* sp.
    - *Hexatoma* sp.
    - *Tipula* sp.

Isoperla (Plecoptera); *Optioservus* (Coleoptera); and Diamesinae (Diptera). Volumetrically, the same taxa appeared to be dominant with the exceptions that *Pteronarcella* (Plecoptera) and *Tipula* and *Atherix* (Diptera) also were important within their respective orders.

Community Dynamics

Total numbers and volumes of aquatic insects collected during the study from the East Gallatin River are shown graphically in Figure 2.

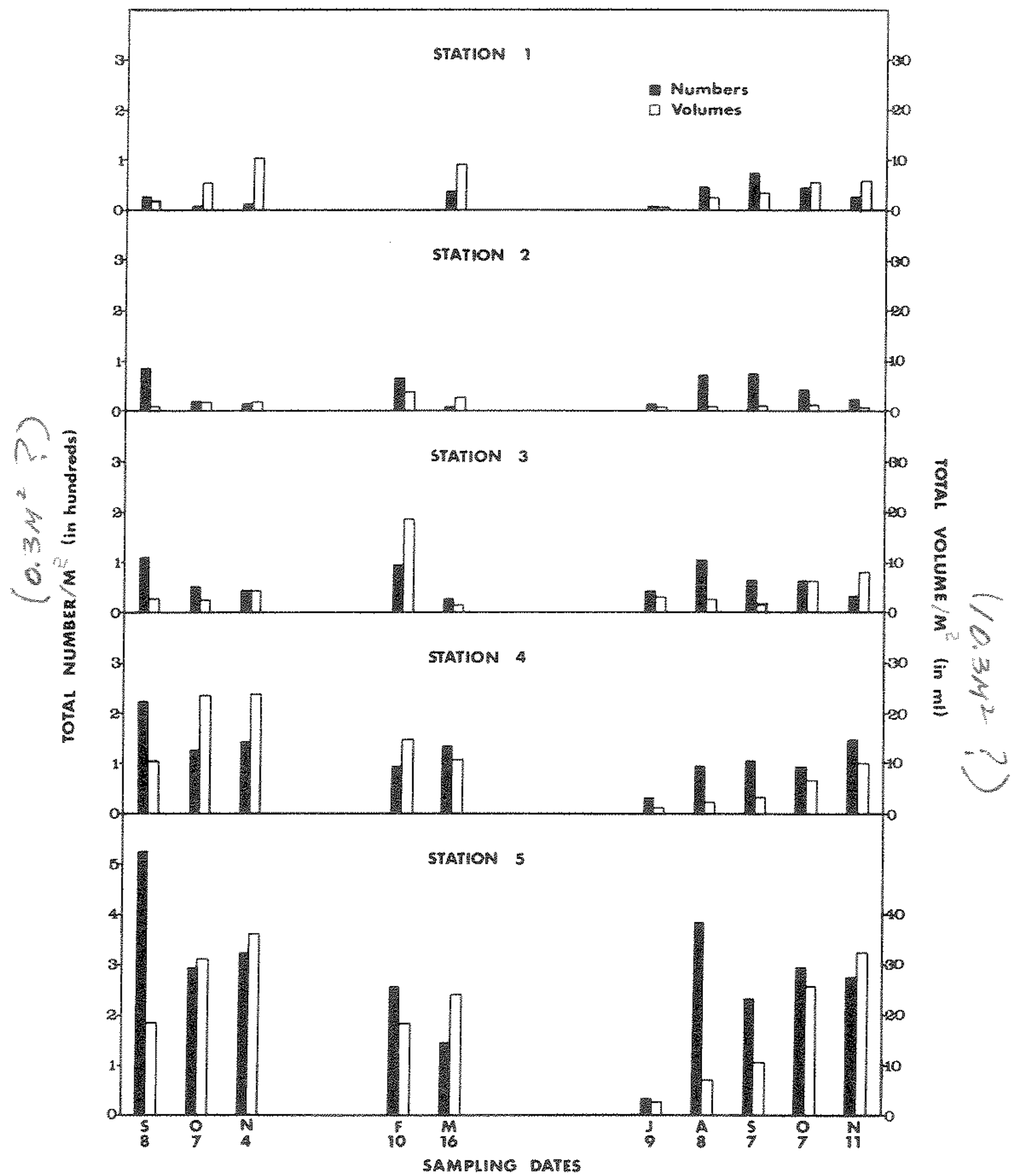

Figure 2. Total numbers and volumes of aquatic insects collected at stations on the East Gallatin River in 1967 and 1968.

Total numbers generally increased from station 1 through station 5 with some deviations occurring at stations 2 and 3. Total volumes generally decreased from station 1 to station 2 and then increased through station 5. Peak numbers occurred in September, 1967, and August, 1968, while peak volumes were in November of both years.

Within each order, the mean number of insects at stations on the East Gallatin River were significantly different at the 5% level (Table V).

TABLE V. Freidman test indicating differences in mean numbers of insects within each order

Order	Trichoptera	Ephemeroptera	Diptera	Plecoptera	Coleoptera
Calculated Freidman Values	27.0*	31.6*	10.4*	24.2*	24.1*

* Significance at 5% level (X_4^2=9.49)

The station pairs most likely responsible for these differences are shown in Table VI. The first member of each significantly different pair is the station exhibiting the higher mean number of insects.

TABLE VI. Station pairs exhibiting significant mean differences in numbers of insects at the 5% level.

Orders	Trichoptera	Ephemeroptera	Diptera	Plecoptera	Coleoptera
	5-1	5-1	5-1	5-1	1-5
Station	5-2	5-2		5-2	1-4
Pairs	5-3	4-2		5-3	1-2
	4-2	3-2		5-4	3-5

Aquatic insect samples from Rocky, Bozeman, and Bridger Creeks were not collected often enough to allow a statistical comparison with stations on the East Gallatin River. However, visual comparison with station 1 indicate high numbers and volumes in both Rocky and Bridger Creeks and noticeably low ones in Bozeman Creek (Table III).

Physical-Chemical Characteristics

Water temperatures in the East Gallatin River ranged from 0.3 C in February, to 19.8 C in August, 1968. Although the sewage effluent averaged 7.0 C warmer and 2.5 C cooler than the receiving water during the winter and summer months, respectively, the discharge was not sufficient to cause any appreciable temperature change in the river between stations 1 and 2. Differences in water temperatures from station 1 to station 5 never exceeded 5.0 C on any sampling date. Bridger Creek averaged 0 to 1.8 C cooler than the East Gallatin River at its point of entrance.

Discharge measurements of the East Gallatin River taken in September, October, and November, 1968, averaged 28% greater than in the same period of 1967 (Table VII). During the same time intervals, Bridger Creek showed a similar discharge. Bridger Creek contributed from 17 to 44% of the total East Gallatin flow below its confluence.

TABLE VII. Average flows at stations on the East Gallatin River and Bridger Creek based on single discharge measurements taken in September, October, and November, of 1967 and 1968, respectively.

Stations	Average Flow (cfs)	
	1967	1968
1	60.02	78.20
2	62.24	85.04
3	90.59	121.06
4	83.22	115.72
5	70.40	112.28
Bridger Ck.	18.36	27.73

TABLE VIII. Average values and ranges of chemical and physical characteristics at sampling stations on the East Gallatin River (ranges in parentheses).

Characteristics	Station 1	2	3	4	5
Dissolved Oxygen (ppm)	10.5 (8.2-12.4)	9.8 (8.1-11.4)	10.2 (8.3-11.7)	10.0 (8.2-11.6)	9.9 (8.1-11.4)
Chloride (ppm)	2.5 (1.6-3.4)	5.2 (3.2-9.6)	4.0 (3.1-5.6)	3.2 (1.4-4.5)	3.9 (2.6-5.7)
pH	8.5 (7.5-8.8)	8.4 (7.2-8.6)	8.2 (7.0-8.4)	8.3 (6.7-8.4)	8.2 (6.5-8.3)
Conductance (Umhos)	353.8 (289.2-410.9)	371.2 (307.2-422.3)	371.7 (308.7-421.3)	376.7 (318.5-420.3)	367.9 (314.2-423.2)
Alkalinity (ppm $CaCO_3$)	174.0 (145.0-190.0)	174.2 (150.4-190.0)	180.3 (151.0-195.0)	166.0 (172.0-200.0)	160.6 (169.0-194.6)
Turbidity (Jackson Units)	40 (32-84)	56 (36-128)	40 (22-81)	34 (22-64)	46 (30-109)

Other physical-chemical characteristics of the East Gallatin River are shown in Table VIII. Chloride concentration doubled between stations 1 and 2 and remained higher than above the sewage outfall. No marked differences were apparent in other characteristics measured above and below the sewage outfall.

Salmonid Populations

Rainbow trout was the most numerous salmonid found in the study area. Estimated numbers and pounds per acre in section A were lower than in section B during summer sampling periods but higher during winter sampling periods (Table IX).

TABLE IX. Estimated populations, numbers/acre, and pounds/acre of rainbow trout in sections A and B (95% confidence intervals in parentheses).

	SECTION A—1845 ft			SECTION B—2904 ft		
Date	Population	No/Acre	Lbs/Acre	Population	No/Acre	Lbs/Acre
8-15-67	373 (289-457)	295	113.9	2491 (2047-2935)	1186	381.2
3-15-68	334 (237-431)	264	138.2	100 (63-137)	48	17.5
8-28-68	354 (263-445)	279	94.2	751 (614-888)	358	129.2
3-4-69	306 (272-340)	241	93.1	31 (22-40)	15	4.6

A total of 148 brown trout, brook trout and mountain whitefish also were collected during the four sampling periods. Of these, 127 (86%) were found in section A and 21 (14%) in section B. In section B, these fish were always found in the area immediately below the outfall where complete mixing had not occurred.

DISCUSSION

Numbers of Trichoptera, Ephemeroptera, and Plecoptera larvae are often drastically reduced with Diptera larvae and other organisms showing dramatic increases immediately below sources of organic pollution (Gaufin & Tarzwell, 1952; and Gaufin, 1958). Similar results were found in this study in both numbers and volumes. At station 2, immediately below the sewage outfall, Trichoptera, Ephemeroptera, Plecoptera, and Coleoptera larvae were reduced to 5, 17, 3, and 14% of their respective numbers and 3, 14, 5, and 5% of their respective volumes found at station 1 above the outfall. Diptera number more than doubled at station 2 while volume decreased to less than half that at station 1. The high number of Diptera resulted from an increase in Diamesinae larvae and the low volume was due to a reduction in the number of large Diptera.

Although there were considerable differences in the number of insects in each order collected at station 1 and 2, there were no statistical differences in the mean numbers of insects at these stations except in Coleoptera. This was due to the relatively low number of insects in each order at station 1. Bozeman Creek was known to receive intermittent "slugs" of dry cleaning wastes during the study (Montana Fish & Game Department, personal communication) and these may have been responsible for reduced insect populations in the creek and at station 1 on the East Gallatin River.

Low dissolved oxygen concentrations and dense growths of "sewage fungus" (Sphaerotilus sp.) have been considered to be the two factors most responsible for community changes in aquatic insects below sources of organic pollution (Gaufin & Tarzwell, 1955 and 1956). Low dissolved oxygen was not believed to be responsible for the community changes between stations 1 and 2 in this study. The minimum dissolved oxygen recorded was 8.1 ppm. and 24 hour dissolved oxygens (Soltero, 1968) in late August, 1967, never fell below 5.0 ppm. "Sewage fungus", however, covered the river bottom at station 2 and was found growing on most aquatic insect larvae present (Fig. 3).

The aquatic insect community seemed to show partial recovery at station 3. Numbers and volumes of insects in all orders were greater than those at station 2. Increases in the two more sensitive orders, Trichoptera and Plecoptera, were not proportionately as great as those in the other three.

Numbers and volumes of insects in all orders except Coleoptera were greater at downstream stations 4 and 5. The mean numbers of Trichoptera and Plecoptera at station 5 were statistically greater than their respective means at station 3. These increases may reflect a return toward a natural carrying capacity and/or show the result of enrichment due to bacterial decomposition of the sewage. Brinley (1949) referred to the latter as the "fertilizing" effect of domestic sewage.

The standing crop of rainbow trout and the species diversity of salmonids in the East Gallatin River were different in sections A and B. The standing crop of rainbow trout above the sewage outfall (section A) was essentially constant during both summer and winter. Below the outfall

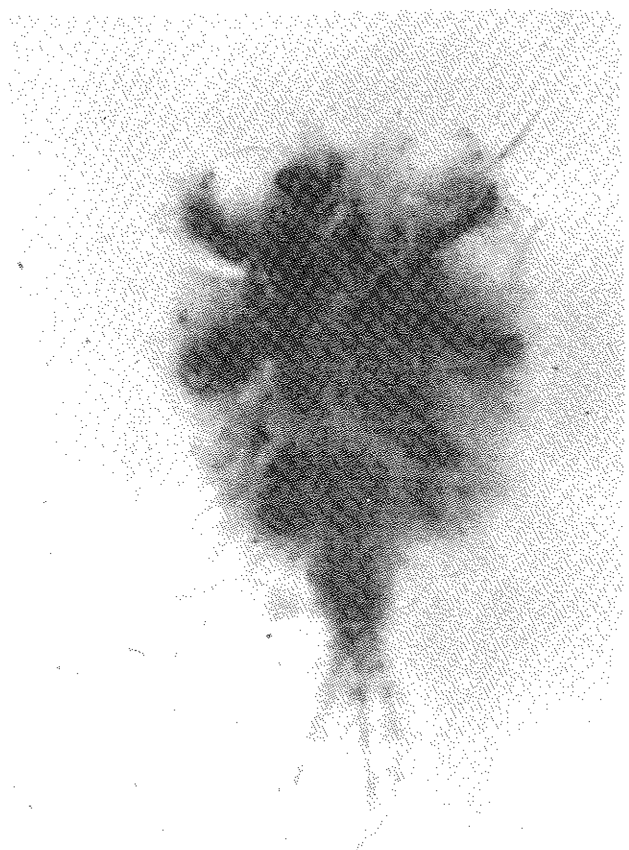

Figure 3. Mayfly (Ephemeroptera) covered with Sphaerotilus sp. at station 2.

(section B), there was a marked drop in the standing crop during the winter. This may have been caused by an increase in free ammonia ($N\text{-}NH_3$) in the sewage and less dilution when the river was at its seasonal low. Free ammonia measured in section B averaged 0.04 ppm from 20 June through 12 September 1967 (Soltero, 1968), and 0.19 ppm from 11 November through 10 March 1968-69 (Bahls, unpublished data). Burrows (1964) found that 0.10 ppm NH_4OH (0.04 ppm free ammonia) produced hyperplasia of gill epithelium and a decrease in stamina and disease resistance in fingerling chinook salmon (Oncorhynchus tshawytscha). Since winter concentrations during this study were well above this level, it may have caused emmigration or death of rainbow trout in section B.

Brown trout, brook trout, and mountain whitefish were found above the sewage outfall but were absent below after complete mixing of the sewage had occurred. Reduction in the species diversity of warm-water fish has been reported below sources of organic pollution (Katz & Gaufin, 1953).

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