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Environmental Effects of Western Coal Combustion

Part II
The Aquatic Macroinvertebrates of Rosebud Creek, Montana

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ENVIRONMENTAL EFFECTS OF WESTERN COAL COMBUSTION
Part II - The Aquatic Macroinvertebrates of Rosebud Creek, Montana

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FOREWORD

The following report describes the impact of a mine mouth coal-fired power plant on the macroinvertebrates of Rosebud Creek, Montana. The study was limited to a short period of operation after start-up and before all units were operating. Factors such as turbidity and temperature among others appeared to cause more change than impact from the power plant. Other surveys over time are needed to be sure of the true impacts.

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ABSTRACT

The aquatic macroinvertebrates of Rosebud Creek, Montana, were sampled between February 1976 and March 1977 to provide data on their abundance, distribution, and diversity. The sampling program was initiated during the first year of operation of the coal-fired power plants located at Colstrip, Montana. The purpose of the study was to determine if any immediate impacts of the power plant operation on the macroinvertebrate communities of Rosebud Creek could be detected and to provide data for comparisons with future studies.

Rosebud Creek supported a diverse bottom fauna with high population numbers composed of species adapted to the turbid, silty conditions which are common in the prairie streams of eastern Montana. Intact riparian vegetation appeared to be important in maintaining stream bank stability and provided an essential food source.

It was concluded that faunal variation among sampling stations during the study period was attributable to physical factors including turbidity, water temperature, current velocity, and substrate, and not to potential impacts from coal mining and combustion.

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SECTION I

INTRODUCTION

Expansion of coal mines and construction of coal combustion facilities for the generating of electricity is underway in eastern Montana. Two 350-megawatt electricity generators adjacent to the strip mines at Colstrip became operational in 1975 and 1976; two 750-megawatt power plants are now being planned for this same location. These facilities, and others being considered for eastern Montana, have the potential to impact the limited water resources of this region. Consequently, the need to document the water quality of the lotic and lentic environments of eastern Montana is important. Information obtained can be useful for site planning and construction design or for modification of existing and proposed power generators both in eastern Montana and elsewhere in the northern Great Plains.

The benthic macroinvertebrates, an important component of the aquatic biota, are primary and secondary consumers in the aquatic ecosystem and are a food source for fishes and other aquatic animals. Knowledge of their species composition, distribution, and relative abundance provides a tool for measuring water quality. The present study was undertaken to examine the benthic macroinvertebrate community in Rosebud Creek, an eastern Montana prairie stream which flows within 13 km of Colstrip, and in so doing, flows into and out of possible environmental impact areas near the Colstrip coal mine and power plant. Groundwater from the eastern portion of the strip mine fields at Colstrip flows eastward toward Rosebud Creek (Montana State Department of Natural Resources, 1974). The prevailing wind direction is southeasterly which may result in the deposition of smokestack emissions in the Rosebud Creek drainage including the north and south forks of Cow Creek, a small intermittent stream which flows into Rosebud Creek (Skogerboe et al., 1978). It is not known to what extent the water quality of Rosebud Creek may be affected by inorganic salts and organic compounds and complexes resulting from the coal mining and combustion operation at Colstrip.

There is little published information on the physical and biological characteristics of north-central United States prairie streams. Traditionally, streams of the midcontinent (Kansas, Nebraska, South Dakota) have been considered typical of the prairie. Jewell (1927) described the aquatic biology of the prairie and presented a description of a typical prairie stream. McCoy and Hales (1974) surveyed the physical, chemical, and biological characteristics of eight eastern South Dakota streams. Limnology of major lakes and drainages was summarized for the midcontinent states by Carlander et al. (1963) and for Minnesota and the Dakotas by Eddy (1963). Limnology of these regions may be similar in many respects to that of eastern Montana due to similar topographies and climates.

In the more immediate vicinity of Rosebud Creek, Clancy (1978) has surveyed the benthic fauna of Sarpy Creek, a small ephemeral stream which flows northward into the Yellowstone River, northwest of Colstrip. East of the Rosebud drainage, Gore (1975) studied the composition and abundance of the benthic invertebrates in the Tongue River, and Rehwinkel et al. (1976) studied the invertebrates of the Powder River. Both of these rivers also flow northward into the Yellowstone. Information has also been provided on the composition and abundance of benthic macroinvertebrates of the Yellowstone River by Newell (1976).

The primary objective of the present study was to obtain information on the species composition, distribution, and abundance of the benthic macroinvertebrates of Rosebud Creek during the early operational stages of the Colstrip power plants. A variety of macroinvertebrate sampling techniques was used to determine which might be most efficient to sample Rosebud Creek. The study was conducted between July 1976 and March 1977. Data obtained will provide a basis for comparisons with results of future studies of Rosebud Creek after the present and possible additional power plants at Colstrip have been operational for some time, and will also add to the current limited body of knowledge about benthic macroinvertebrate communities in eastern Montana prairie streams and rivers.

SECTION II

CONCLUSIONS

1. Present longitudinal variations in abundance, distribution, and composition of the benthic invertebrate fauna in Rosebud Creek are attributed to the intrinsic physical-chemical characteristics of the stream: i.e., temperature, turbidity, substrate, and current velocity. There was no evidence that these variations were attributable to influences from coal mining and combustion.

2. Rosebud Creek supports an abundant benthic invertebrate fauna which is adapted to the conditions (i.e., high turbidity, slow current velocity, warm summer water temperature, and silted substratum) of a transition prairie stream; however, increased severity of these conditions corresponds with decreased numbers and diversity of less tolerant species at downstream stations.

3. Intact riparian vegetation, particularly grasses, stabilizes the banks of Rosebud Creek and prevents serious erosion, sedimentation, and the consequential unproductive shifting substrate common in many prairie streams.

4. Introduced substrate samplers were efficient in collecting taxa from long, slow stretches common in Rosebud Creek and provided a reliable method for comparing invertebrate populations among sampling stations. A modified Hess sampler was inadequate for this type of stream due to insufficient riffle habitat for sampling. The Ekman dredge, effective only for sampling areas of fine substrate, provided less information than did introduced artificial substrates.

SECTION III

RECOMMENDATIONS

1. Because of the projected increase in coal mining and combustion operations in and near the Rosebud Creek drainage, and the resultant potential for disturbance of the aquatic fauna, monitoring of the aquatic macroinvertebrate fauna in Rosebud Creek should continue. Future studies should be conducted on a year-round basis and should include comprehensive monitoring of water chemistry.

2. Future coal mining, agriculture, and other activities in the vicinity of Rosebud Creek and tributary streams should ensure maintenance of a buffer zone of riparian vegetation and grasses to minimize erosion.

3. It is recommended for future surveys that the uppermost (control) sampling station of this study be located downstream where ecological conditions are more comparable to the other stations, and that the lowermost sampling station be moved farther upstream for the same reason. Physical and biological characteristics of the lowest station in the present study showed influence of the Yellowstone River.

SECTION IV

DESCRIPTION OF STUDY AREA

Rosebud Creek originates on the east slope of the Wolf Mountains in Bighorn County, Montana, in the Crow Indian Reservation. It then flows northeast through the Northern Cheyenne Indian Reservation and privately owned lands for approximately 370 stream kilometers before joining the Yellowstone River near Rosebud, Montana (Figure 1). The total area drained is approximately 3,372 km^2 (U.S. Geological Survey, 1976). An alluvial plain about 0.8 km wide supports a sparsely populated, agriculturally oriented economy. Alfalfa, wild hay, and cereal grains are cultivated, and the stream provides water for irrigation and livestock.

The headwaters of Rosebud Creek are erosional in nature; there is a steep gradient (4.8 m/km) with a riffle-pool system that is similar to many mountain streams. After leaving the mountains near the town of Busby and flowing onto the plains, the gradient decreases (2.5 m/km) and the stream becomes depositional in nature. Long, slow reaches with sand or gravel bottoms predominate, and silted areas are common. Suspended and dissolved solids also increase progressively downstream.

The shallow valley of Rosebud Creek is cut in sedimentary layers of the Tertiary period. Relief is composed mainly of strata from the Paleocene epoch, specifically sandstones, shales, and coal of the Fort Union formation which erode at moderate rates. Coal outcrops have burned in the middle and upper Rosebud drainage and have metamorphosed adjacent layers producing beds of highly fractured clinker, red to lavender in color, often incorrectly called scoria (Renick, 1929). This material is highly resistant to weathering and forms much of the substratum of Rosebud Creek.

Alluvial soils of the floodplain and adjacent low terraces generally consist of Havre and Glendive loams, Harlem silty clay loams, and aeric fluvaquents. These form deep, calcareous soils of good water-holding capacity subject to moderate erosion. Areas of moderately saline soil are present along the floodplain (L. Daniels, U.S. Soil Conservation Service, Forsyth, Montana, personal communication).

Mean monthly flows for Rosebud Creek from October 1974 to September 1976 are shown in Figure 2. Normal peak flows occur during the spring resulting from snowmelt runoff. Rapid fluctuations in discharge can occur during spring and summer because of rainfall. The historical mean annual flow is 35.8 cfs (1.01 m^3 per sec); mean flow for March, the month of maximum flow, is 84.3 cfs (2.39 m^3 per sec); and the mean flow for September, the month of minimum flow, is 6.4 cfs (0.18 m^3 per sec). Records show approximately

Figure 1. Benthic invertebrate sampling stations, Rosebud Creek, Montana.

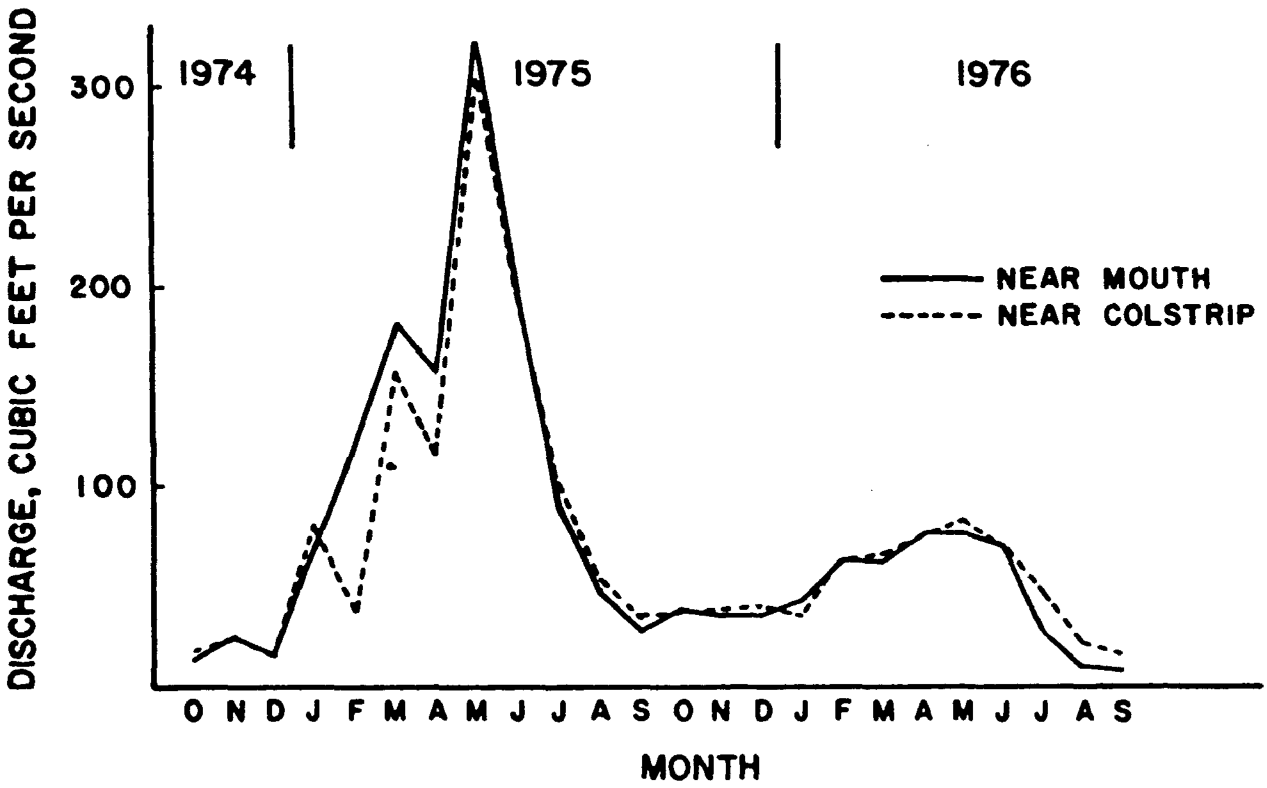

Figure 2. Monthly mean discharges for Rosebud Creek at the mouth and near Colstrip for USGS water years 1975 and 1976 (U.S. Geological Survey, 1976, 1977)

3000 cfs (84.9 m^3 per sec) in March and periods of "no flow" in dry years (U.S. Geological Survey, 1976, 1977).

Water temperature records in July and August range from 21°C to a maximum on record of 26.7°C; minimum temperatures are at freezing for many days during winter months (Aagaard, 1969) and the stream is usually frozen over from December to mid-February.

Riparian vegetation includes mixed grass, boxelder (*Acer negundo* L.), green ash (*Fraxinus pennsylvanica* Marsh), chokecherry (*Prunus* sp.), rose (*Rosa* spp.), willow (*Salix* spp.), and buffaloberry (*Shepherdia* sp.). Common grasses are reed canarygrass (*Phalaris arundinacea* L.), prairie cordgrass (*Spartina pectinata* Link.), smooth brome (*Bromus inermis* Leys.), and American bulrush (*Scirpus americanus* Pers.), all rhizomatous in character and especially important in streambank stability. Streamside vegetation is generally intact which provides good wildlife habitat and aids in soil stabilization.

Rosebud Creek is characterized by heavily vegetated banks, extensive organic deposits in the substrate and a moderately diverse benthic fauna with high population numbers. These features are atypical of traditional prairie streams, which have been described as being nearly devoid of benthic life and having substrates practically free of organic deposits (Carlander et al., 1963). However, Rosebud Creek does have relatively high turbidity, areas of shifting substrate, and rapid fluctuations in discharge; these characteristics are descriptive of traditional prairie streams. Because its headwaters originate in and flow through mountainous terrain and the lower reaches flow through a prairie environment, Rosebud Creek can be termed a transition prairie stream.

SECTION V

DESCRIPTION OF SAMPLING STATIONS

Seven benthic invertebrate sampling stations were established in February 1976 and numbered consecutively upstream (Table 1, Figure 1). Selection was made on the basis of concurrent chemical sampling locations (Skogerboe et al., 1978), physical similarity, access, and potential for evaluating impacts from coal development. An attempt was made to include three habitat types (riffles, hard-bottom slow stretches, and pools) at each station.

Station 1 was downstream from the theoretical plume emission fallout area from the Colstrip stack. Stations 2 through 5 were within the primary theoretical plume fallout area. In addition, Stations 3 and 4 bracketed Cow Creek to evaluate potential effluents from that source. As a control, Station 6 was established upstream from the theoretical plume fallout area. Rosebud Creek at Station 7 was similar in nature to a mountain stream and provided information concerning longitudinal changes in the invertebrate community of the Rosebud Creek system.

In addition to other physical parameters a subjective evaluation of the predominant substrate type at each station was made utilizing the classification of Cummins (1962) (Table 2). Station 1 is unique in having a substrate of washed rubble and boulder from Yellowstone alluvium and a riffle-pool habitat caused by an increase in gradient as Rosebud Creek enters the Yellowstone Valley. Typical substrate at Station 2 consists of flocculent clay or silt with gravel common only in meanders at the valley edge. Stations 3, 4, and 5 have long meandering stretches with slow current velocity and a substratum of gravel, sand, and silt. Station 6, in addition to long, slow stretches, has sections of clean, rubble-bottom riffles alternating with sand-bottom pools. The substrate at Station 7 consists mainly of gravel and rubble in riffles and sand in pools.

Shallow riffles for bottom sampling were not common at Stations 2 through 5; however, riffle sampling sites were established at Stations 1, 3, 5, 6, and 7; physical parameters are given in Table 3. The riffle at Station 3, due to depth, was sampled only during periods of low flow.

As shown in Table 4, Rosebud Creek waters are alkaline with a very basic pH and a high concentration of electrolytes. The water is a carbonate-sulfate-magnesium type and unusual due to the higher concentration of magnesium than calcium. Dissolved oxygen is near saturation throughout the year.

TABLE 1. DESCRIPTIONS AND LOCATIONS OF SAMPLING STATIONS, ROSEBUD CREEK, MONTANA

Station	Elevation (m)	Kilometers from Yellowstone River	Legal description	Description
1	756	0.7	NE1/4 Sec 21 R42E T6N	U.S.G.S gauging station near I-90
2	814	15.4	SW1/4 Sec 30 R43E T4N	Polich ranch
3	869	29.7	NE1/4 Sec 5 R43E T1N	Kluver ranch, 480 m downstream of Cow Creek
4	869	30.0	SE1/4 Sec 5 R43E T1N	Kluver ranch, 680 m upstream of Cow Creek
5	896	36.8	NW1/4 Sec 34 R42E T1N	W. McRae ranch
6	960	51.4	SW1/4 Sec 8 R41E T2S	Bailey ranch, border of Northern Cheyenne Reservation
7	1195	85.8	NW1/4 Sec 29 R39E T6S	Near Kirby at Highway 314 culvert

TABLE 2. PHYSICAL CHARACTERISTICS OF SAMPLING LOCATIONS IN 1976

	Station						
	1	2	3	4	5	6	7
Mean width (m)	7.5	5.0	4.2	3.6	5.5	6.1	2.5
Mean depth (m)	0.4	0.7	0.6	0.7	0.8	0.6	0.4
Valley gradient (m/km to next site)	2.46	2.38	2.39	2.39	2.74	4.80	
Stream gradient (m/km to next site)	1.32	1.09	0.99	0.99	1.01	1.60	
Mean turbidity (nephelometric units)	11.4	9.5	4.9	4.7	4.5	4.9	5.5
Temperature (°C)							
Mean August maximum	23.4		22.0		19.5		20.0
Mean August minimum	19.3		20.4		17.4		15.9
Mean October maximum	4.1		3.7				5.2
Mean October minimum	2.1		2.8				3.5
Substrate[a/]	40,60,0,0,0	0,40,10,10,40	10,60,10,20,0	0,70,0,20,10	10,50,20,20,0	30,30,30,10,0	10,40,30,20,0
Vegetation[b/]	0,1,99	73,5,22	18,5,77	6,4,90	18,20,62	13,41,46	28,33,39

[a/] Composition (%) in the following sequence: rubble, gravel, sand, silt, clay.

[b/] Composition (%) in the following sequence: trees, shrubs, grass.

TABLE 3. PHYSICAL CHARACTERISTICS OF RIFFLE SITES IN 1976

	Station				
	1	3	5	6	7
Mean current velocity (m/sec)	0.52	0.35	0.39	0.51	0.46
Mean depth (m)	0.18	0.31	0.16	0.17	0.09
Substrate	rubble, boulder	rubble	gravel	rubble	rubble

TABLE 4. WATER QUALITY DATA,[a] MEANS AND RANGES (IN PARENTHESES), MARCH 1976 TO MARCH 1977

	Station						
	1	2	3	4	5	6	7
pH	8.45 (8.12-8.80)	8.49 (8.17-8.81)	8.49 (8.09-8.70)	8.51 (8.08-8.76)	8.52 (8.17-8.91)	8.47 (8.12-8.85)	8.47 (8.15-8.81)
Specific conductivity (μmhos)	1364.0 (558-1798)	1282.0 (539-1531)	1281.0 (856-1496)	1274.0 (967-1437)	1241.0 (954-1435)	1164.0 (978-1325)	911.0 (846-979)
Alkalinity (mg/l $CaCO_3$)	409.0 (313-492)	396.0 (298-498)	398.0 (294-480)	404.0 (341-488)	402.0 (323-486)	412.0 (348-490)	383.0 (325-425)
Suspended solids (mg/l)	534.0 (7.9-4308.0)	267.0 (10.1-1494.0)	99.0 (9.8-459.0)	100.0 (10.8-463.0)	154.0 (7.7-629.0)	129.0 (5.4-573.0)	26.0 (6.3-68.0)
Dissolved solids (mg/l)	965.0 (431-1367)	878.0 (697-1335)	845.0 (610-980)	816.0 (591-1000)	814.0 (586-1080)	744.0 (598-960)	572.0 (500-780)
Dissolved oxygen (mg/l)	9.8 (7.4-12.1)	9.8 (6.9-12.3)	9.6 (6.7-11.6)	9.8 (7.0-12.3)	9.6 (7.1-12.4)	9.7 (7.3-12.9)	11.2 (9.2-12.2)
Ca^{2+} (mg/l)	84.3 (45-150)	82.8 (37-140)	88.4 (56-140)	90.4 (56-140)	89.3 (56-140)	87.4 (55-130)	100.3 (75-110)
NO_3^- (mg/l)	0.18 (0.14-0.21)	0.13 (0.12-0.13)	0.09 (0.08-0.09)	0.08 (0.06-0.10)	0.05 (0.05-0.05)	0.05 (0.05-0.05)	--
PO_{3-4} (mg/l)	0.53 (0.02-5.00)	0.25 (0.02-1.70)	0.14 (0.02-0.40)	0.12 (0.02-0.30)	0.13 (0.02-0.30)	0.16 (0.02-0.75)	0.09 (0.04-0.15)
$SO_4^=$ (mg/l)	404.0 (160-605)	358.0 (160-515)	336.0 (250-405)	325.0 (180-375)	336.0 (204-540)	270.0 (155-400)	151.0 (110-260)
Cl^- (mg/l)	8.2 (2.1-28.0)	5.8 (2.7-10.0)	5.2 (2.8-8.0)	5.1 (3.0-8.0)	5.0 (3.0-8.5)	5.0 (3.0-11.0)	3.4 (1.5-7.0)
As (μg/l)	2.7 (1.1-9.5)	2.64 (1.0-8.4)	1.77 (1.0-3.6)	1.64 (0.9-3.2)	1.92 (0.4-4.4)	1.95 (0.6-5.2)	1.3 (0.9-2.4)
Cu (mg/l)	0.007 (0.005-0.010)	0.015 (0.003-0.074)	0.012 (0.003-0.046)	0.010 (0.003-0.059)	0.008 (0.003-0.027)	0.008 (0.003-0.043)	0.005 (0.003-0.006)
Dissolved Fe (mg/l)	0.04 (0.01-0.11)	0.04 (0.01-0.13)	0.06 (0.01-0.16)	0.06 (0.01-0.18)	0.05 (0.01-0.13)	0.03 (0.01-0.10)	0.04 (0.02-0.05)

TABLE 4 (continued). WATER QUALITY DATA,[a] MEANS AND RANGES (IN PARENTHESES), MARCH 1976 TO MARCH 1977

	Station						
	1	2	3	4	5	6	7
Undissolved Fe (mg/l)	6.88 (0.25-44.0)	2.97 (0.24-17.0)	1.34 (0.16-4.3)	1.26 (0.20-3.7)	1.88 (0.18-7.6)	1.94 (0.20-7.6)	0.52 (0.23-1.1)
Hg (µg/l)	1.68 (0.07-10.3)	1.75 (0.12-9.4)	3.08 (0.05-16.0)	2.40 (0.05-18.3)	1.65 (0.10-15.0)	1.07 (0.05-9.0)	0.36 (0.05-0.29)
K (mg/l)	13.3 (7.4-23.0)	13.2 (8.5-23.0)	13.0 (7.8-22.0)	12.9 (7.7-22.0)	12.7 (7.6-21.0)	11.9 (7.3-19.0)	7.0 (5.0-9.2)
Mg (mg/l)	115.0 (30-190)	110.0 (30-190)	117.0 (69-170)	116.0 (79-170)	112.0 (86-180)	108.0 (78-160)	67.0 (61-74)
Mn (mg/l)	0.014 (0.001-0.05)	0.036 (0.001-0.32)	0.014 (0.001-0.05)	0.012 (0.001-0.05)	0.016 (0.001-0.05)	0.020 (0.001-0.056)	0.028 (0.003-0.05)
Na (mg/l)	166.0 (60-740)	80.0 (45-100)	72.0 (45-90)	71.0 (43-87)	66.0 (58-85)	53.0 (44-66)	22.0 (17-25)
Ni (mg/l)	0.004 (0.003-0.005)	0.005 (0.003-0.011)	0.007 (0.005-0.030)	0.008 (0.003-0.040)	0.005 (0.002-0.010)	0.006 (0.002-0.020)	0.005 (0.005-0.005)
Se (µg/l)	0.48 (0.3-0.8)	0.49 (0.3-0.7)	0.43 (0.3-0.6)	0.49 (0.3-0.6)	0.43 (0.03-0.7)	0.51 (0.4-0.7)	0.44 (0.3-0.5)
Zn (mg/l)	0.012 (0.001-0.032)	0.012 (0.001-0.050)	0.045 (0.001-0.380)	0.011 (0.001-0.048)	0.014 (0.001-0.090)	0.007 (0.001-0.017)	0.011 (0.001-0.034)

[a] Collected and determined by the Fisheries Bioassay Laboratory, Montana State University, Bozeman, Montana, and the Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado.

SECTION VI

MATERIALS AND METHODS

Sampling was initiated in March 1976 using a modified Hess sampler (Waters and Knapp, 1961) to sample riffles. An Ekman dredge fastened to a steel handle and with a manual closing release was used to sample pools. Substrate in baskets was introduced in hard-bottom slow stretches, a common habitat of Rosebud Creek, for colonization by macroinvertebrates.

Baskets, constructed from 1.27 cm hardware cloth, had dimensions of 15 × 15 × 30 cm and were filled with 40 pieces of hand-sorted clinker measuring 5 to 8 cm along the longest axis. At each station two samplers were anchored on the bottom at similar depth and current velocity. The samplers were allowed to be colonized for 6 weeks, and samples were then collected monthly. The sampling procedure involved placing a nylon dip net (1 mm mesh) immediately downstream to catch organisms dislodged as the sampler was lifted. Debris on the anchoring stake or basket handle was discarded, but debris clinging to the sampler was collected. Substrate was removed and scrubbed with a brush. For each sample, current velocity was determined using a Gurley (Model 625-F) current meter 15 cm in front of the basket; depth was also measured. A subjective evaluation was made concerning the amount of sediment and debris in the sampler. Baskets were sampled monthly from May to November 1976, and in March 1977. Because of continuous ice cover the samplers were removed from December 1976 to February 1977.

Two 0.023 m^2 Ekman dredge samples were taken at each station during March, June, August, and October 1976. Two 0.093 m^2 Hess samples were taken at Stations 1, 5, 6, and 7 in March, June, August, and November 1976, and in February and March 1977. Samples were collected at Station 3 in August and November 1976 and March 1977, using a modified Hess sampler. Qualitative samples were collected at various locations at each station using a dip net. All samples were preserved initially in 10% formalin.

Samples were later screened through a No. 30 U.S.A. Standard sieve (11.0 meshes/cm, 0.589 mm opening) and organisms were hand-sorted and stored in 70% ethanol. Invertebrates were identified to genus or species where feasible and possible, using keys by Brown (1972), Edmunds et al. (1976), Gaufin et al. (1972), Jensen (1966), Johannsen (1934, 1935), Needham and Westfall (1955), Pennak (1953), Roemhild (1975, 1976), Ross (1944), and Usinger (1971). Specimens were sent to recognized taxonomic experts for confirmation of identifications. To aid in identifications, emerging adult insects were collected and some naiads were reared to adults in an artificial stream at Montana State University. Wet weight of the collections was determined with a Mettler Type B5 analytical balance following the procedure of Slack et al. (1973).

Species diversity was calculated using the Simpson Index (Simpson, 1949), the Margalef Index (Margalef, 1957), and the Shannon Index (Patten, 1962) as modified by Hamilton (1975). Calculations were performed using the Montana State University Sigma 7 computer.

In August 1976, stream width and thalweg depth at each station were recorded at 10 locations 50 m apart. In addition, a subjective evaluation was made concerning substrate and riparian vegetation compositon at each location. At the riffle sites, water depth and current velocity 5 cm from the substrate were measured at 30 cm intervals along transects spaced 2 m apart.

Water samples were collected for turbidity analyses in October and November 1976 and February 1977. Determinations were made using a nephelometer (HF Instruments, Model DRT 200), following the procedure given by the American Public Health Association (1976).

Continuous recording thermographs (Ryan Model D-15) were utilized at Stations 1, 3, 5, and 7 during 10-25 August and 16-31 October 1976.

SECTION VII

RESULTS

The total number of samples collected at each station by each sampling method is given in Table 5. Mean current velocities immediately upstream from the introduced substrate samplers are given in Table 6. Aquatic macroinvertebrate abundance in terms of average total numbers of individuals, wet weight, and number of taxa is shown in Table 7 and Figures 3, 4, and 5. Analysis of variance of these parameters based on the method of unweighted means (Snedecor and Cochran, 1967) showed that station means were significantly different ($\alpha = 0.01$) for total numbers of individuals, wet weight, and number of taxa. Means were grouped according to the Newman-Keuls sequential comparison test (Snedecor and Cochran, 1967) (Figure 6). Results from modified Hess samples for Station 3 were not analyzed statistically due to the small number of samples.

Pool habitats in Rosebud Creek supported a smaller standing crop than riffles. Average wet weight per m^2 was 10.8 g in riffles and 2.9 g in pools. The mean number of individuals per m^2 was 6007 in riffles and 4993 in pools; these nearly corresponding numbers were due to the abundance of low-mass individuals (e.g., Chironomidae and Oligochaeta) in pools.

MACROINVERTEBRATE NUMBERS

Invertebrate numbers were generally greater at Stations 5, 6, and 7 relative to Stations 2, 3, and 4. Station 1 normally had higher numbers than Stations 2, 3, and 4.

Introduced Substrate Samplers

Analysis of introduced substrate samples gave results (Table 7) consistent with the trends mentioned above. Average number of macroinvertebrates per sample was greatest at Stations 5 and 6 and lowest at Station 2. Numerical abundance was similar at Stations 1 and 7. Likewise, Stations 3 and 4 were similar and supported low numbers of individuals.

Average total numbers per taxon and relative average percent of the total sample is presented in Table 8 and Figure 7. Trichoptera, comprised mainly of Hydropsychidae, were the most common invertebrates at most stations, constituting from 22% of the total sample at Station 3 to 55% at Station 5. *Cheumatopsyche* spp. were abundant at all stations; *Cheumatopsyche lasia* (Ross) may be a dominant species, as adults (Table 9) were commonly collected at all stations. A *Hydropsyche* spp. complex of at least four species was abundant at most stations. Lower numbers of Trichoptera were present at

TABLE 5. TOTAL NUMBER OF SAMPLES FROM EACH STATION BY THREE SAMPLING METHODS, MARCH 1976 TO MARCH 1977

	Station						
	1	2	3	4	5	6	7
Introduced substrates	13	15	15	15	15	15	15
Ekman dredge	8	8	8	8	8	8	8
Modified Hess	12	0	6	0	12	12	12

TABLE 6. MEAN CURRENT VELOCITIES 7.5 CM FROM THE SUBSTRATE AND 15 CM UPSTREAM OF INTRODUCED SUBSTRATE SAMPLERS, MAY 1976 TO MARCH 1977

	Station						
	1	2	3	4	5	6	7
Current velocity (m/sec)	0.36	0.42	0.46	0.38	0.50	0.38	0.41

TABLE 7. AVERAGE TOTAL NUMBERS, WET WEIGHTS, AND NUMBERS OF TAXA OF BENTHIC MACROINVERTEBRATES, MARCH 1976 TO MARCH 1977

	Station	Introduced substrates[a/]	Ekman dredge[b/]	Modified Hess[b/]
Average total numbers	1	1090	4402	6852
	2	830	2077	
	3	994	4774	5278
	4	953	4876	
	5	1633	7664	2081
	6	1317	3073	8690
	7	1029	8076	7134
Average wet weight (g)	1	1.92	2.20	12.49
	2	3.25	1.98	
	3	1.72	0.95	6.24
	4	1.84	3.23	
	5	2.75	2.07	2.15
	6	2.29	1.03	9.15
	7	3.17	8.74	24.11
Average total taxa	1	20.9	6.5	15.4
	2	16.3	7.1	
	3	19.0	5.6	13.5
	4	18.9	8.8	
	5	22.5	10.5	10.7
	6	24.0	5.8	18.6
	7	22.9	5.4	19.1

[a/]Average total numbers and wet weights per sample.

[b/]Average total numbers and wet weights per m^2.

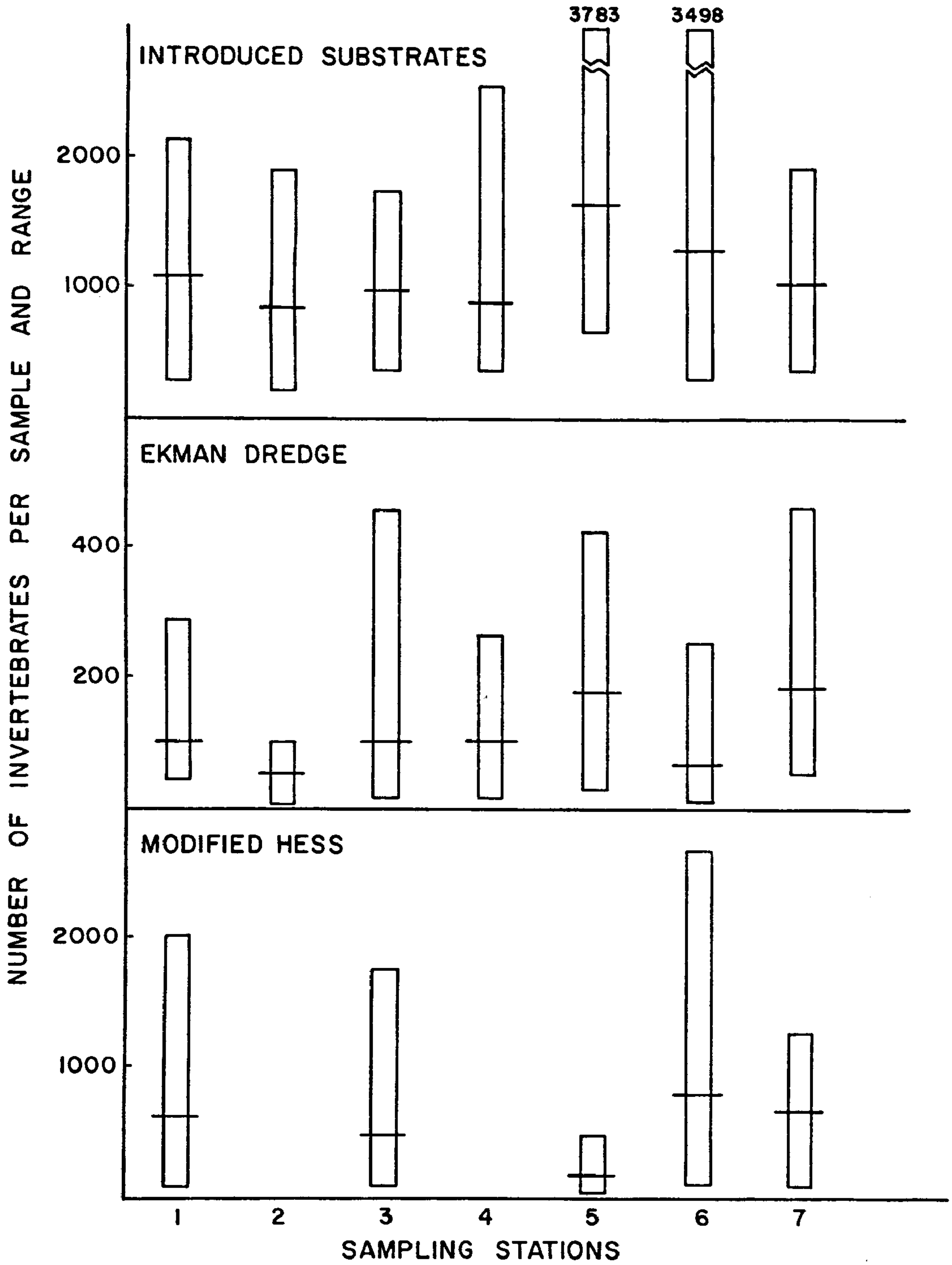

Figure 3. Mean numbers (horizontal line) and ranges (vertical bar) of aquatic macroinvertebrates per sample, March 1976 to March 1977.

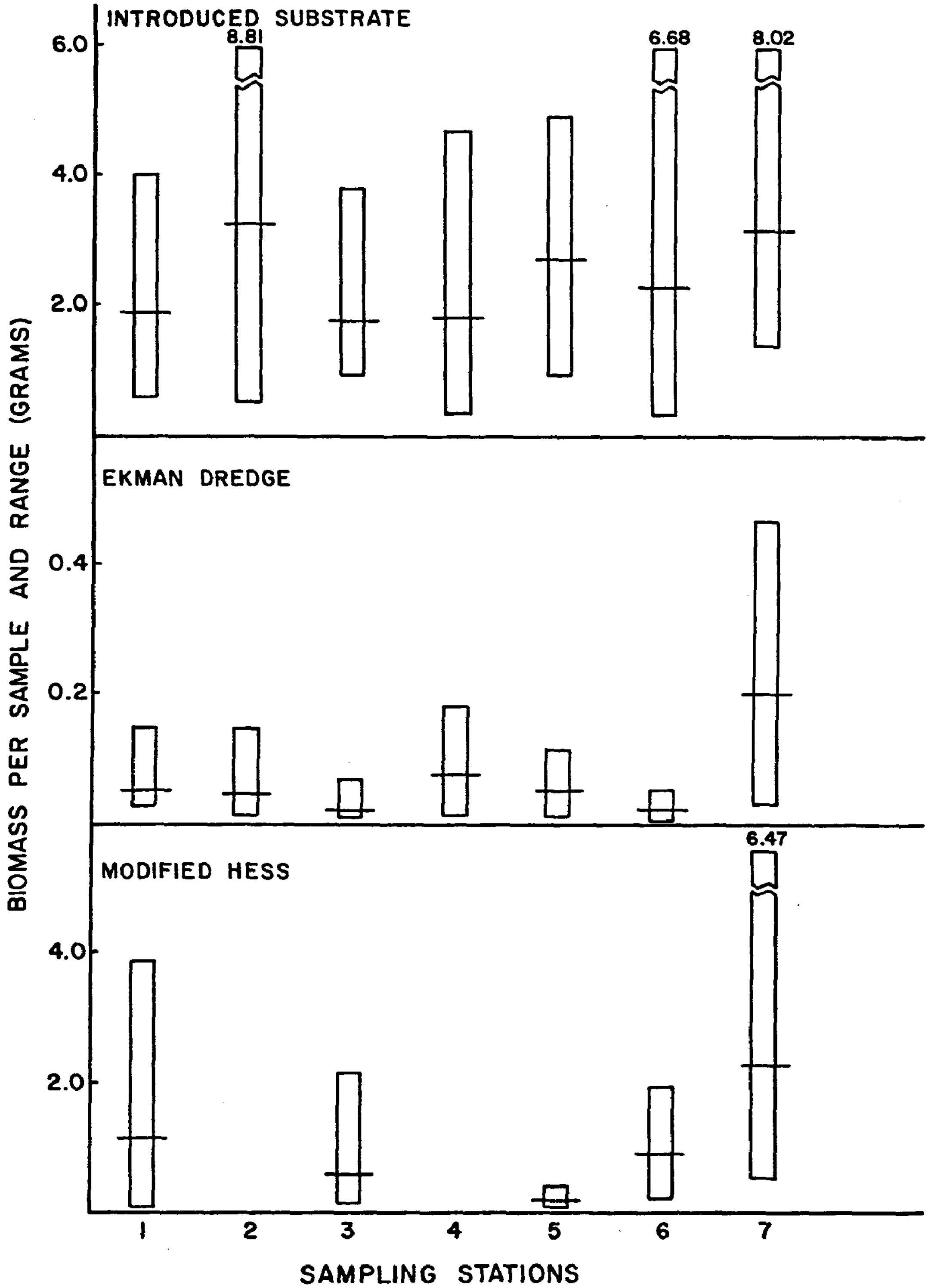

Figure 4. Mean wet weights (horizontal line) and ranges (vertical bar) of aquatic macroinvertebrates per sample, March 1976 to March 1977.

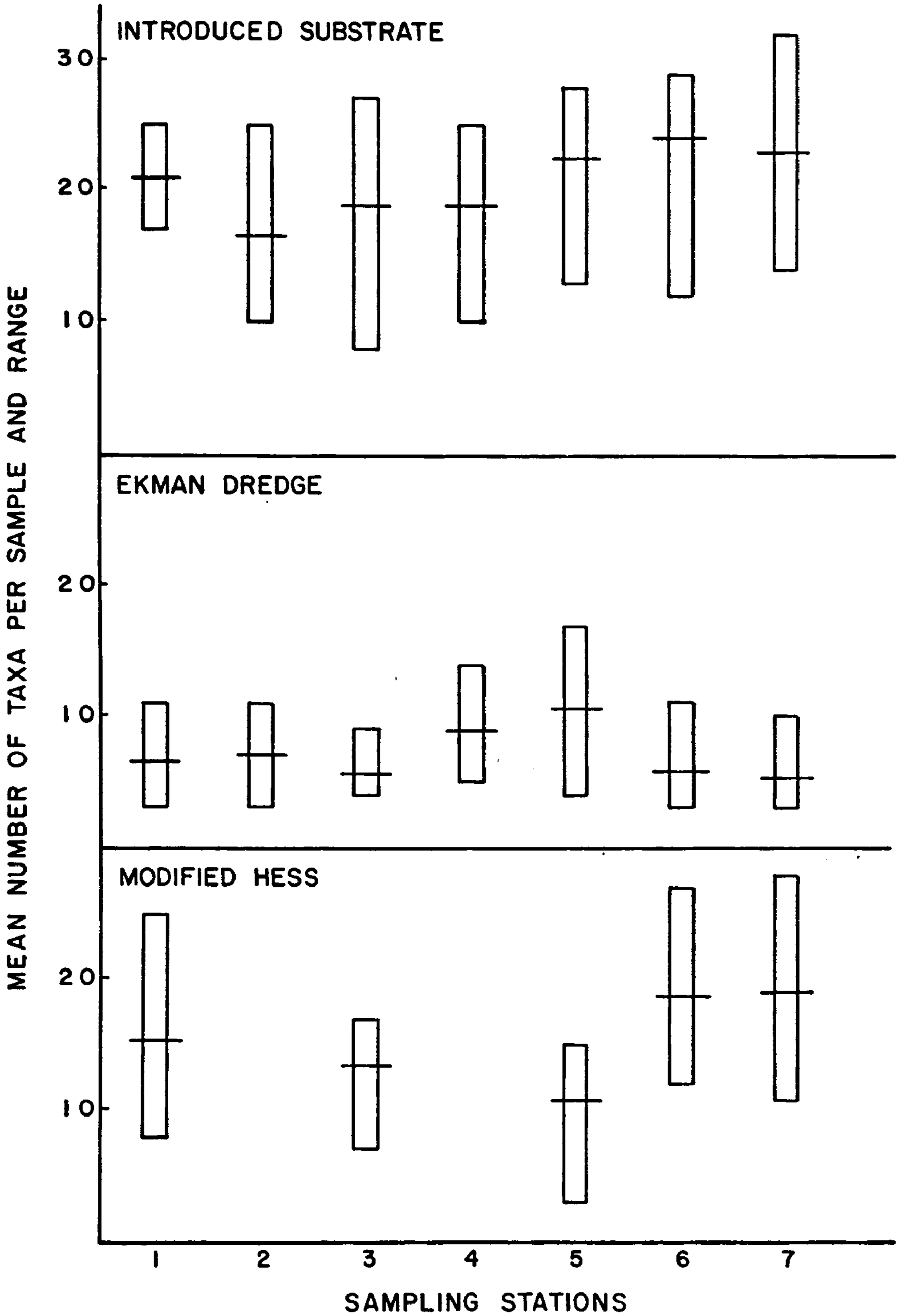

Figure 5. Mean numbers (horizontal line) and ranges (vertical bar) of aquatic macroinvertebrate taxa per sample, March 1976 to March 1977.

INTRODUCED SUBSTRATE:

	1	2	3	4	5	6
7	W	T	TW	TW	M	W
6	T	TW	T	T	M	
5	MW	MT	MTW	MTW		
4		W				
3		W				
2	TW					

EKMAN DREDGE:

	1	2	3	4	5	6
7	MW	MW	MW	MW	TW	MW
6					MT	
5	T	MT	T			
4			T			
3						
2						

MODIFIED HESS:

	1	5	6
7		TW	
6		MT	
5	MT		

Figure 6. Significantly different means[a,b] for total macroinvertebrates, taxa, and wet weights per sample.

[a] M, T, and W indicate a significant difference (0.05) for mean total macroinvertebrates, taxa, and wet weight, respectively. Where symbols are absent, no real difference existed.

[b] Compare stations in the left vertical column with those in the horizontal row.

TABLE 8. MACROINVERTEBRATE[a] MEAN TOTAL NUMBERS PER TAXON AND MEAN PERCENTAGES[b] OF THE SAMPLE (INTRODUCED SUBSTRATE), MAY 1976 TO MARCH 1977

Station	Ephem.	Odon./ Zygop.	Plecop.	Trich.	Coleop.	Dipt.	Oligo.	Mollusc.	Hemip.
1	85 (7.8)	3 (0.3)	--	587 (53.9)	67 (5.1)	332 (30.4)	13 (1.2)	2 (0.2)	<1 (<0.1)
2	65 (7.8)	<1 (<0.1)	<1 (<0.1)	364 (43.9)	22 (2.7)	350 (42.1)	2 (0.3)	17 (2.1)	8 (1.0)
3	192 (19.3)	<1 (<0.1)	1 (0.1)	214 (21.6)	35 (3.5)	540 (54.3)	5 (0.5)	1 (0.1)	4 (0.4)
4	162 (17.0)	1 (0.1)	1 (0.1)	394 (41.4)	52 (5.4)	329 (34.5)	6 (0.6)	3 (0.4)	4 (0.4)
5	203 (12.5)	2 (0.1)	<1 (<0.1)	902 (55.3)	77 (4.7)	431 (26.4)	3 (0.2)	1 (<0.1)	6 (0.4)
6	185 (14.1)	8 (0.6)	1 (0.1)	521 (39.6)	80 (6.0)	496 (37.7)	19 (1.4)	1 (<0.1)	4 (0.3)
7	83 (8.1)	2 (0.1)	14 (1.3)	506 (49.2)	15 (1.5)	378 (36.7)	27 (2.6)	3 (0.3)	1 (0.1)

[a] Ephem = Ephemeroptera, Odon = Odonata, Zygop = Zygoptera, Plecop = Plecoptera, Coleop = Coleoptera, Dipt = Diptera, Oligo = Oligochaeta, Mollusc = Mollusca, Hemip = Hemiptera.

[b] In parentheses.

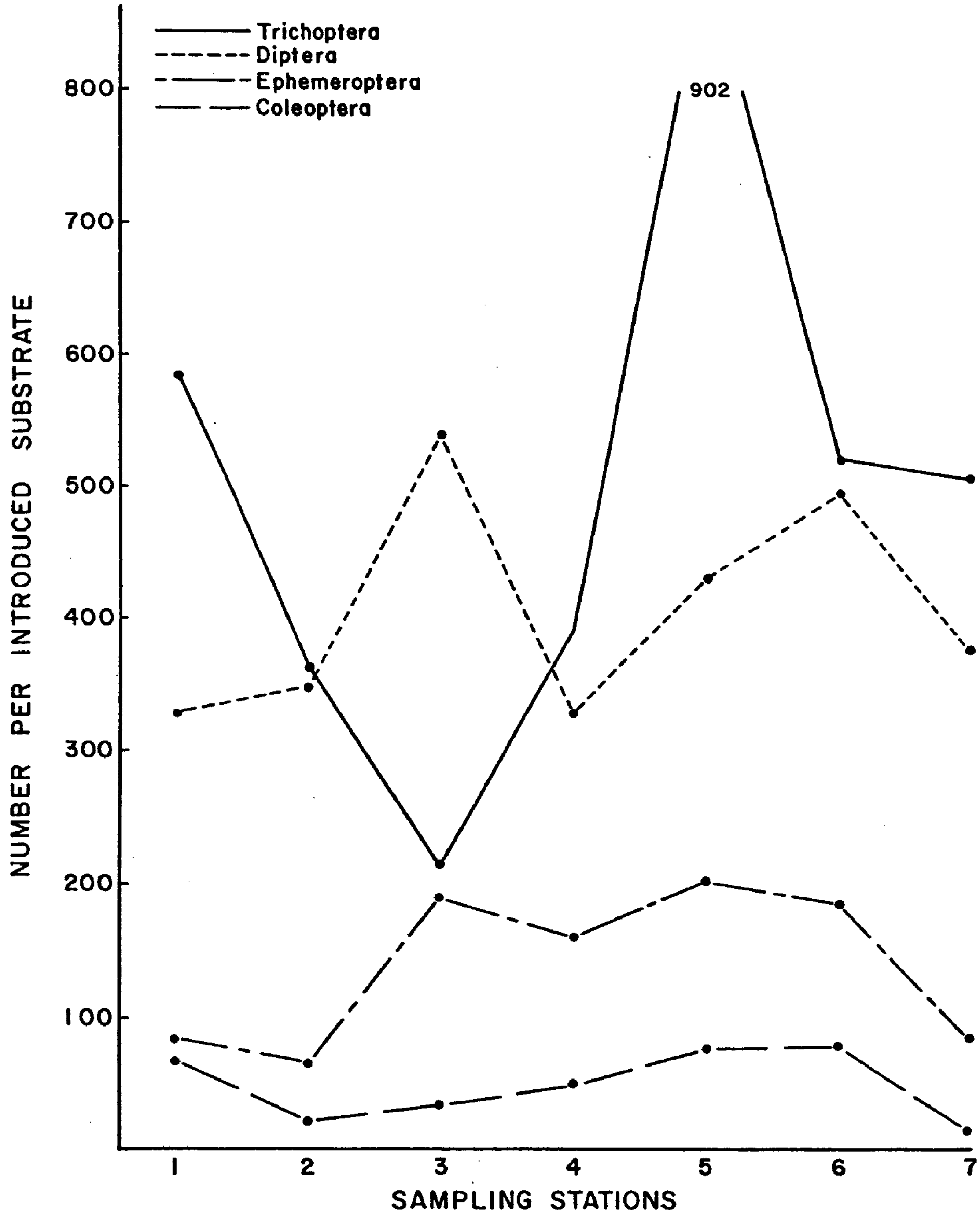

Figure 7. Average numbers of aquatic macroinvertebrates per introduced substrate sample, May 1976 to March 1977.

TABLE 9. ADULT AQUATIC INSECTS COLLECTED ALONG ROSEBUD CREEK DURING 1976

Ephemeroptera
- Baetidae
  - *Baetis* (near *propinquus*)
- Leptophlebiidae
  - *Choroterpes albiannulata* McDunn.

Odonata
- Gomphidae
  - *Gomphus externus* Hagen
- Libellulidae
  - *Sympetrum occidentale* Walker

Zygoptera
- Coenagrionidae
  - *Argia fumipennis-violacea* (Hagen)
  - *Ischnura perparva* (Selys)
- Calopterygidae
  - *Hetaerina americana* (Fabricius)

Hemiptera
- Gerridae
  - *Gerris remiges* Say
- Veliidae
  - *Rhagovelia distincta* Champion

Trichoptera
- Hydropsychidae
  - *Hydropsyche bronta* Ross
  - *Hydropsyche separata* Banks
  - *Arctopsyche* sp.
  - *Cheumatopsyche lasia* Ross
  - *Cheumatopsyche analis* (Banks)
  - *Cheumatopsyche campyla* Ross
- Psychomyiidae
  - *Polycentropus cinereus* Hagen
- Leptoceridae
  - *Oecetis avara* (Banks)
  - *Leptocella albida*
  - *Leptocella* (near *candida*)
- Brachycentridae
  - *Brachycentrus occidentalis* Banks

Plecoptera
- Nemouridae
  - *Brachyptera fosketti* Ricker
- Perlodidae
  - *Isoperla patricia* Frison

Diptera
- Tabanidae
  - *Chrysops proclivis* Osten Sacken
- Tipulidae
  - *Tipula vicina* Dietz

most stations. Lower numbers of Trichoptera were present at Stations 2, 3, and 4. Diptera, particularly Chironomidae, were the next most abundant taxon. Highest numbers were collected at Stations 3 and 6; fewer individuals were present at Stations 1, 2, and 4. Ephemeroptera were most common at Stations 3 and 4 where *Choroterpes albiannulata* was the major species. Coleoptera appeared to increase in numbers from Station 2 through 6, then declined at Station 7. Plecoptera were uncommon in basket samples and were numerous only at Station 7, the most upstream location. Molluscs were most abundant at Stations 2, 6, and 7, and Hemiptera were most common in the mid-Rosebud (Stations 2 through 6). Oligochaeta appeared to increase in abundance progressively upstream.

Ekman Dredge Samples

Mean numbers of aquatic macroinvertebrates collected with an Ekman dredge from pools are given in Table 7. Macroinvertebrate populations per m^2 were most dense at Stations 5 and 7 while Stations 2 and 6 supported the lowest numbers. Stations 1, 3, and 4 supported similar total population numbers.

Average total numbers per taxon is presented in Table 10. Diptera were the most common macroinvertebrates collected, and ranged from 51 to 84% of the total sample at each station; numbers were highest at Stations 5 and 7 and lowest at Station 2. Oligochaetes, the next most common group in Ekman samples, were found in high numbers at Stations 1 and 7; Stations 2 and 3 supported the lowest populations. Molluscs were collected in significant numbers only at Stations 2, 3, and 4. Coleoptera, particularly *Dubiraphia minima*, comprised a large portion of the benthic population in pools and were common at Stations 1 through 5. Trichoptera were found in highest numbers at Station 5. Other taxa were uncommon and Plecoptera were absent from Ekman dredge samples.

Modified Hess Samples

Macroinvertebrates were most abundant at Station 6 and least abundant at Station 5 (Table 7). Stations 1 and 7 were similar in population densities. Average total numbers per taxon and relative percent of the total sample are presented in Table 10. Diptera were numerically the most abundant taxon collected by this method and highest numbers were present at Station 6. Trichoptera, the next most numerous taxon, were most common at Station 7 and least at Stations 3 and 5. Taxa were often collected in low numbers at Station 5.

MACROINVERTEBRATE WET WEIGHTS

Wet weight usually reflected numbers of individuals; however, certain species of large body size contributed disproportionately to the sample weight. For example, at Station 2 numerous Mollusca, *Ambrysus mormon*, and Hydropsychidae resulted in high average wet weight per introduced substrate sample even though total numbers of macroinvertebrates were low. Although general trends for distribution of wet weight among stations were not evident, Station 7 consistently supported high biomass.

TABLE 10. MEAN TOTAL NUMBERS OF AQUATIC MACROINVERTEBRATES[a/] PER M^2 AND AVERAGE PERCENTAGES OF THE SAMPLE,[b/] MARCH 1976 TO MARCH 1977

Station	Ephem.	Odon./ Zygop.	Plecop.	Trich.	Coleop.	Dipt.	Oligo.	Mollus.	Hemip.
					Ekman dredge				
1	5 (<0.1)	11 (0.2)	0	70 (1.6)	963 (21.9)	2179 (49.5)	1124 (25.6)	11 (0.2)	38 (0.9)
2	22 (1.0)	16 (0.8)	0	86 (4.1)	425 (20.5)	1130 (54.4)	344 (16.6)	54 (2.6)	0
3	59 (1.2)	5 (0.1)	0	32 (0.7)	651 (13.6)	3190 (66.8)	780 (16.3)	48 (1.0)	5 (0.1)
4	183 (3.7)	32 (0.7)	0	129 (2.6)	850 (17.4)	2905 (59.6)	699 (14.3)	48 (0.9)	5 (0.1)
5	204 (2.7)	11 (0.1)	0	603 (7.9)	672 (8.8)	5902 (77.0)	248 (3.2)	0	0
6	38 (1.2)	32 (1.1)	0	151 (4.9)	124 (4.0)	2577 (83.9)	145 (4.7)	0	0
7	31 (0.4)	6 (0.1)	0	117 (1.4)	283 (3.5)	5896 (73.0)	1722 (21.3)	12 (0.2)	0
					Modified Hess				
1	615 (9.0)	2 (<0.1)	2 (<0.1)	2909 (42.5)	760 (11.1)	2185 (31.9)	349 (5.1)	5 (0.1)	2 (<0.1)
3	2505 (47.5)	2 (<0.1)	4 (0.1)	362 (6.9)	77 (1.5)	2249 (42.6)	40 (0.7)	18 (0.3)	5 (0.1)

TABLE 10 (continued). MEAN TOTAL NUMBERS OF AQUATIC MACROINVERTEBRATES[a] PER M^2 AND AVERAGE PERCENTAGES OF THE SAMPLE,[b] MARCH 1976 TO MARCH 1977

Station	Ephem.	Odon./ Zygop.	Plecop.	Trich.	Coleop.	Dipt.	Oligo.	Mollus.	Hemip.
5	294 (14.1)	0	0	351 (16.9)	126 (6.0)	1163 (55.9)	128 (6.2)	0	7 (0.3)
6	1246 (14.3)	98 (0.1)	14 (0.2)	2309 (26.6)	627 (7.2)	4321 (49.7)	118 (1.4)	1 (<0.1)	9 (0.1)
7	582 (8.2)	109 (0.1)	32 (0.5)	4617 (64.7)	275 (3.9)	1313 (18.4)	278 (3.9)	19 (0.3)	0

[a] Ephem = Ephemeroptera, Odon = Odonata, Zygop = Zygoptera, Plecop = Plecoptera, Trich = Trichoptera, Coleop = Coleoptera, Dipt = Diptera, Oligo = Oligochaeta, Mollus = Mollusca, Hemip = Hemiptera.

[b] In parentheses.

Introduced Substrate Samples

Mean wet weight (Table 7) was greatest at Station 2 and lowest at Station 3. Average wet weight per sample was also high at Stations 5 and 7.

Average wet weight and percent of the total sample for certain taxa are presented in Table 11 and Figure 8. Trichoptera was the most common taxon in most samples; however, in contrast to numbers, weight was low at Station 6 and high at Station 2, indicating differences in average larval size, state of development, or species composition. Wet weight per sample for Odonata and Zygoptera appeared to increase progressively upstream to Station 6. Ephemeroptera biomass was low at Station 2 and high at Stations 3 through 6 due mainly to large numbers of *Choroterpes albiannulata* and *Baetis* spp. Wet weights for Diptera were relatively high at all stations, especially 3 and 6. Coleoptera biomass was higher at Stations 5 and 6 and Plecoptera comprised a considerable portion of the wet weight only at Stations 6 and 7.

Ekman Dredge Samples

Macroinvertebrate wet weight per m^2 was greatest at Station 7 where high numbers of Chironomidae were collected (Table 7). All other stations were not significantly different. Average wet weight and relative percent of the total sample for certain taxa is given in Table 12. Diptera and Oligochaeta constituted a large portion of the total wet weight; Diptera biomass was high at Stations 5 and 7 and Oligochaeta at Stations 1 and 7.

Modified Hess Samples

Macroinvertebrate wet weight per m^2 for modified Hess samples was highest at Station 7 followed by Station 1 (Table 7); the lowest average wet weight was found at Station 5. Average wet weight and percent of the total sample for certain taxa is presented in Table 12. The largest portion of most samples was comprised of Trichoptera with the exception of Stations 3 and 5 where total numbers were also low. Wet weights for many taxa were low at Station 5.

MACROINVERTEBRATE DISTRIBUTION

A checklist of total taxa collected from Rosebud Creek and their respective distributions with regard to sampling stations is given in Table 13. The number of occurrences and average number per occurrence for individual taxa is listed for each sampling method in Tables 14, 15, and 16. Average numerical abundance per introduced substrate sampler for common macroinvertebrates is shown in Figure 9. Average numbers and occurrences often tended to be lowest at Station 2, then increased progressively upstream, often declining at Station 7. Numbers were usually greater at Station 1 relative to Station 2. Organisms with this pattern of distribution included *Leptophlebia gravastella, Tricorythodes minutus, Baetis* sp. B, *Hydroptila* spp., *Stenelmis oregonensis, Helichus striatus*, and *Heptagenia elegantula*. Other macroinvertebrates (e.g., *Choroterpes albiannulata, Brachyptera* sp., *Ambrysus mormon, Simulium* spp., and *Sphaerium* spp.) appeared to be most abundant in the mid-Rosebud and did not increase in numbers progressively

TABLE 11. MEAN WET WEIGHTS[a/] FOR MACROINVERTEBRATE TAXA[b/] AND AVERAGE PERCENTAGES[c/] OF THE SAMPLE (INTRODUCED SUBSTRATE), MAY 1976 TO MARCH 1977

Station	Ephem.	Odon./ Zygop.	Plecop.	Trich.	Coleop.	Dipt.	Oligo.	Mollus.	Hemip.
1	0.15	0.04	0.00	1.26	0.05	0.40	<0.01	0.03	<0.01
	(7.6)	(1.8)	--	(65.4)	(2.4)	(21.1)	(0.2)	(1.5)	(<0.1)
2	0.07	0.05	<0.01	1.95	0.03	0.54	<0.01	0.28	0.32
	(2.1)	(1.7)	(0.1)	(60.0)	(0.8)	(16.8)	(<0.1)	(8.7)	(9.7)
3	0.23	0.06	<0.01	0.50	0.03	0.74	<0.01	0.03	0.12
	(13.6)	(3.6)	(<0.1)	(29.3)	(1.5)	(43.3)	(<0.1)	(2.0)	(6.7)
4	0.27	0.11	<0.01	0.65	0.04	0.46	<0.01	0.25	0.06
	(14.6)	(5.9)	(0.1)	(35.3)	(2.2)	(24.7)	(0.1)	(13.5)	(3.3)
5	0.26	0.22	<0.01	1.51	0.14	0.43	<0.01	0.01	0.18
	(9.5)	(8.0)	(0.1)	(54.9)	(4.9)	(15.5)	(<0.1)	(0.3)	(6.5)
6	0.37	0.35	0.01	0.58	0.14	0.67	<0.01	0.03	0.12
	(16.0)	(15.4)	(0.5)	(25.3)	(5.9)	(29.4)	(0.1)	(1.3)	(5.4)
7	0.11	0.23	0.08	2.26	0.04	0.37	0.01	0.05	0.01
	(3.6)	(7.4)	(2.4)	(71.2)	(1.3)	(11.5)	(0.2)	(1.7)	(0.4)

[a/] In grams per sample.

[b/] Ephem = Ephemeroptera, Odon = Odonata, Zygop = Zygoptera, Plecop = Plecoptera, Trich = Trichoptera, Coleop = Coleoptera, Dipt = Diptera, Oligo = Oligochaeta, Mollus = Mollusca, Hemip = Hemiptera.

[c/] In parentheses.

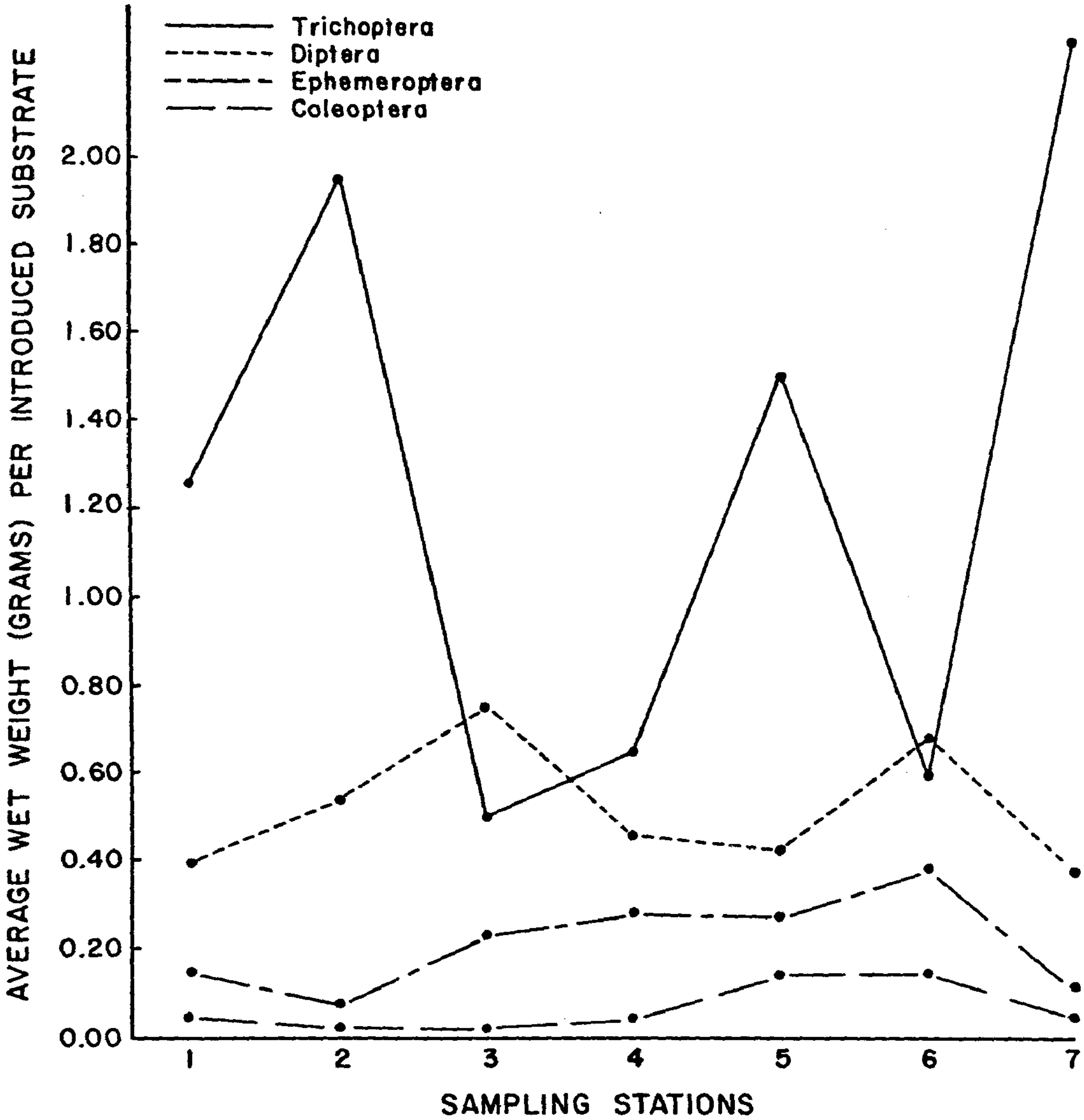

Figure 8. Average macroinvertebrate wet weights (grams) per introduced substrate sample, May 1976 to March 1977.

TABLE 12. MEAN WET WEIGHTS[a/] PER M² AND AVERAGE PERCENTAGES OF THE SAMPLE[b/] FOR AQUATIC MACROINVERTEBRATES,[c/] MARCH 1976 TO MARCH 1977

Station	Ephem.	Odon./ Zygop.	Plecop.	Trich.	Coleop.	Dipt.	Oligo.	Mollus.	Hemip.
				Ekman dredge					
1	0.0	0.06 (2.9)	0.0	0.18 (8.4)	0.28 (12.8)	0.53 (24.3)	1.10 (50.1)	0.01 (<0.1)	0.03 (1.2)
2	0.02 (0.8)	0.55 (28.1)	0.0	0.17 (8.7)	0.12 (6.3)	0.45 (22.6)	0.28 (14.2)	0.38 (19.1)	0.0
3	0.03 (2.8)	0.02 (2.2)	0.0	0.0	0.13 (13.4)	0.33 (34.1)	0.35 (36.3)	0.09 (9.5)	0.01 (1.1)
4	0.28 (8.7)	0.52 (16.1)	0.0	0.69 (21.6)	0.22 (6.9)	0.23 (7.2)	0.35 (10.9)	0.87 (27.0)	0.01 (0.3)
5	0.05 (2.6)	0.19 (9.1)	0.0	0.43 (20.6)	0.18 (8.9)	1.12 (54.2)	0.09 (4.4)	0.0	0.0
6	0.05 (4.8)	0.51 (49.7)	0.0	0.16 (15.9)	0.05 (5.3)	0.18 (18.0)	0.06 (6.3)	0.0	0.0
7	0.01 (0.1)	0.01 (<0.1)	0.0	0.74 (8.4)	0.05 (0.6)	5.94 (67.9)	1.56 (17.9)	0.34 (3.9)	0.0
				Modified Hess					
1	0.88 (7.0)	0.24 (1.9)	0.03 (0.2)	9.03 (72.3)	0.33 (2.6)	1.13 (9.0)	0.33 (2.7)	0.22 (1.7)	0.07 (0.6)
3	1.64 (26.1)	0.07 (1.1)	0.06 (1.0)	0.65 (10.3)	0.03 (0.4)	2.03 (32.4)	0.01 (0.2)	1.64 (26.1)	0.13 (2.1)

TABLE 12 (continued). MEAN WET WEIGHTS[a/] PER M^2 AND AVERAGE PERCENTAGES OF THE SAMPLE[b/] FOR AQUATIC MACROINVERTEBRATES,[c/] MARCH 1976 TO MARCH 1977

Station	Ephem.	Odon./ Zygop.	Plecop.	Trich.	Coleop.	Dipt.	Oligo.	Mollus.	Hemip.
5	0.34 (16.1)	0.0	0.0	0.60 (27.9)	0.04 (1.8)	1.05 (49.2)	0.05 (2.4)	0.0	0.04 (1.7)
6	0.99 (10.8)	0.92 (10.1)	0.07 (0.8)	3.89 (42.7)	0.23 (2.5)	2.77 (30.4)	0.04 (0.4)	0.0	0.16 (0.7)
7	0.56 (2.3)	1.40 (5.8)	0.07 (0.3)	16.85 (69.8)	0.16 (0.7)	4.47 (18.5)	0.14 (0.6)	0.28 (1.2)	0.0

a/ In grams.

b/ In parentheses.

c/ Ephem = Ephemeroptera, Odon = Odonata, Zygop = Zygoptera, Plecop = Plecoptera, Trich = Trichoptera, Coleop = Coleoptera, Dipt = Diptera, Oligo = Oligochaeta, Mollus = Mollusca, Hemip = Hemiptera.

TABLE 13. CHECKLIST AND DISTRIBUTION OF AQUATIC MACROINVERTEBRATES, MARCH 1976 TO MARCH 1977

	1	2	3	4	5	6	7
Ephemeroptera							
Ephemeridae							
Ephoron album (Say)			X		X		
Heptageniidae							
Heptagenia elegantula (Eaton)	X	X	X	X	X	X	X
Heptagenia sp. A	X						
Stenonema terminatum (Walsh)	X				X		
Rhithrogena sp.			X			X	
Baetidae							
Baetis sp. A	X	X	X	X	X	X	X
Baetis sp. B	X	X	X	X	X	X	X
Centroptilum sp.	X	X	X	X	X	X	
Pseudocloeon sp.	X	X	X	X	X	X	X
Callibaetis sp.	X						
Isonychia sicca (Walsh)	X						
Leptophlebiidae							
Choroterpes albiannulata McDunn.	X	X	X	X	X	X	X
Leptophlebia gravastella (Eaton)	X	X	X	X	X	X	X
Traverella albertana (McDunnough)	X						
Ephemerellidae							
Ephemerella inermis Eaton			X		X	X	
Caenidae							
Caenis sp.	X						X
Tricorythidae							
Tricorythodes minutus Traver	X	X	X	X	X	X	X
Odonata							
Gomphidae							
Gomphus sp. A	X	X	X	X	X	X	X
Gomphus sp. B						X	
Ophiogomphus sp. (near *severus*)	X		X	X	X	X	X
Libellulidae							
Sympetrum sp.	X						
Zygoptera							
Calopterygidae							
Hetaerina americana (Fabricius)	X		X	X	X	X	
Coenagrionidae							
Amphagrion abbreviatum (Selys)	X					X	X
Argia fumipennis-violacea (Hagen)	X	X		X	X	X	
Enallagma sp.	X	X	X	X		X	X

TABLE 13 (continued). CHECKLIST AND DISTRIBUTION OF AQUATIC MACROINVERTEBRATES, MARCH 1976 TO MARCH 1977

	1	2	3	4	5	6	7
Plecoptera							
Nemouridae							
Brachyptera sp. (prob. *fosketti*)	X	X	X	X	X	X	
Nemoura sp.							X
Capnia sp.							X
Perlodidae							
Isoperla patricia Frison			X		X	X	X
Hemiptera							
Corixidae							
Palmacorixa gilleti Abbott	X			X	X	X	
Trichocorixa sp.	X		X	X	X	X	
Naucoridae							
Ambrysus mormon Montandon	X	X	X	X	X	X	X
Megaloptera							
Sialidae							
Sialis sp.						X	X
Trichoptera							
Psychomyiidae							
Polycentropus cinereus ?	X					X	X
Hydropsychidae							
Hydropsyche bronta Ross	X	X	X	X	X	X	X
Hydropsyche sp. A	X	X	X	X	X	X	X
Hydropsyche sp. B	X	X	X	X	X	X	X
Hydropsyche sp. C	X						
Cheumatopsyche spp.	X	X	X	X	X	X	X
Hydroptilidae							
Hydroptila sp. A	X	X	X	X	X	X	X
Hydroptila sp. B	X			X	X	X	X
Mayatrichia sp.	X	X	X	X	X	X	
Ithytrichia sp.	X	X	X	X	X	X	
Phryganeidae							
Ptilostomis sp.	X			X	X		X
Limnephilidae							
Limnephilus sp.	X	X	X		X	X	X
Onocosmoecus sp.	X			X	X	X	X
Anabolia sp.						X	X
Leptoceridae							
Oecetis avara (Banks)	X	X	X	X	X	X	X
Triaenodes sp. (near *tarda*)	X					X	
Nectopsyche sp. (*Leptocella*)	X	X	X	X	X	X	X
Brachycentridae							
Brachycentrus sp.	X	X	X	X	X	X	X

TABLE 13 (continued). CHECKLIST AND DISTRIBUTION OF AQUATIC MACROINVERTEBRATES, MARCH 1976 TO MARCH 1977

	1	2	3	4	5	6	7
Lepidoptera							
Pyralidae							
Cataclysta sp.	X						
Coleoptera							
Dytiscidae							
Liodessus affinis (Say)				X	X		X
Hydrophilidae							
Helophorus sp.	X	X					
Dryopidae							
Helichus striatus LeConte	X	X	X	X	X	X	X
Helichus suturalis LeConte						X	
Elmidae							
Stenelmis oregonensis	X	X	X	X	X	X	X
Dubiraphia minima	X	X	X	X	X	X	X
Microcylloepus pusillus (LeConte)	X	X	X	X	X	X	X
Optioservus divergens (LeConte)					X	X	X
Diptera							
Tipulidae							
Tipula spp.					X	X	X
Holorusia sp.					X		X
Ormosia spp.	X			X			X
Dicranota spp.	X	X	X	X	X	X	X
Limnophila (Eloeophila) sp.							X
Hexatoma (Eriocera) sp.		X			X		
Psychodidae							
Pericoma sp. A							X
Pericoma sp. B							X
Psychoda sp.			X				
Culicidae							
Chaoborus sp.			X				
Simuliidae							
Simulium spp.	X	X	X	X	X	X	X
Chironomidae	X	X	X	X	X	X	X
Heleidae							
Palpomyia spp.					X		X
Dasyhelea spp.					X		X
Stratiomyidae					X		X
Tabanidae							
Chrysops spp.			X		X		X
Tabanus sp.							X
Dolichopodidae							
Hydrophorus sp.					X		

TABLE 13 (continued). CHECKLIST AND DISTRIBUTION OF AQUATIC MACROINVERTEBRATES, MARCH 1976 TO MARCH 1977

	1	2	3	4	5	6	7
Diptera (continued)							
Empididae							
sp. A	X	X	X	X	X	X	X
sp. B		X	X	X	X	X	X
Turbellaria			X	X	X	X	
Nematomorpha	X			X			
Oligochaeta	X	X	X	X	X	X	X
Hirudinea							
Glossiphoniidae		X		X			
Amphipoda							
Talitridae							
Hyalella azteca (Saussure)	X		X	X	X	X	X
Acari	X		X		X	X	X
Basommatophora							
Physidae							
Physa spp.	X	X	X	X	X	X	X
Lymnaeidae							
Lymnaea sp.		X			X	X	
Ancylidae							
Ferrissia sp.							X
Planorbidae							
Gyraulus sp.							
Heterodonta							
Sphaeriidae							
Sphaerium sp.	X	X	X	X	X	X	X
Pisidium sp.		X	X	X			X
Eulamellibranchia							
Unionidae	X	X	X	X	X		
Total taxa	60	42	50	50	60	59	60

TABLE 14. NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN INTRODUCED SUBSTRATE SAMPLES, MAY 1976 TO MARCH 1977

	Sampling stations						
	1	2	3	4	5	6	7
Ephemeroptera							
Heptageniidae							
Heptagenia elegantula (Eaton)	11(3)	7(2)	13(5)	13(7)	15(15)	12(13)	13(6)
Heptagenia sp. A	3(3)	--	--	--	--	--	--
Stenonema terminatum (Walsh)	2(1)	--	--	--	--	--	--
Rhithrogena sp.	--	--	1(1)	--	--	1(3)	--
Baetidae							
Baetis sp. A	6(24)	5(19)	8(32)	6(36)	8(29)	7(24)	1(1)
Baetis sp. B	7(11)	9(6)	10(4)	8(3)	11(18)	10(50)	15(31)
Centroptilum sp.	1(4)	--	3(1)	3(2)	2(4)	2(6)	--
Pseudocloeon sp.	1(1)	3(2)	3(17)	4(7)	5(23)	6(12)	1(5)
Callibaetis sp.	1(1)	--	--	--	--	--	--
Isonychia sicca (Walsh)	1(1)	--	--	--	--	--	--
Leptophlebiidae							
Choroterpes albiannulata McDunn.	13(46)	15(54)	15(138)	15(114)	15(118)	15(84)	6(3)
Leptophlebia gravastella (Eaton)	3(12)	1(1)	6(3)	5(4)	3(13)	9(9)	7(9)
Ephemerellidae							
Ephemerella inermis Eaton	--	--	1(1)	--	1(1)	1(2)	--
Caenidae							
Caenis sp.	2(1)	--	--	--	--	--	10(5)
Tricorythidae							
Tricorythodes minutus Traver	12(17)	6(2)	13(28)	12(27)	11(43)	12(45)	15(38)
Odonata							
Gomphidae							
Gomphus sp. A	1(1)	3(1)	1(1)	7(1)	7(2)	6(3)	1(1)
Gomphus sp. B	--	--	--	--	--	1(1)	--
Ophiogomphus sp. (near *severus*)	1(1)	--	3(1)	2(1)	4(2)	10(2)	9(1)
Libellulidae							
Sympetrum sp.	1(1)	--	--	--	--	--	--

TABLE 14 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN INTRODUCED SUBSTRATE SAMPLES, MAY 1976 TO MARCH 1977

	Sampling stations						
	1	2	3	4	5	6	7
Zygoptera							
Calopterygidae							
Hetaerina americana (Fabricius)	5(3)	--	1(2)	1(1)	2(1)	7(7)	--
Coenagrionidae							
Amphagrion abbreviatum (Selys)	1(3)	--	--	--	--	4(1)	1(1)
Argia fumipennis-violacea (Hagen)	6(2)	2(2)	--	1(1)	1(1)	3(1)	--
Enallagma sp.	4(3)	1(1)	1(1)	2(2)	--	4(5)	5(2)
Plecoptera							
Nemouridae							
Brachyptera sp. (prob. *fosketti*)	--	3(2)	3(2)	4(2)	1(1)	4(3)	--
Perlodidae							
Isoperla patricia Frison	--	--	2(1)	--	1(1)	4(2)	10(21)
Hemiptera							
Corixidae							
Palmacorixa gilleti Abbott	--	--	--	1(1)	2(4)	--	--
Trichocorixa sp.	2(1)	--	--	--	1(1)	1(1)	--
Naucoridae							
Ambrysus mormon Montandon	--	10(12)	9(7)	6(10)	9(9)	7(9)	7(1)
Megaloptera							
Sialidae							
Sialis sp.	--	--	--	--	--	1(1)	5(1)

TABLE 14 (continued). NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN INTRODUCED SUBSTRATE SAMPLES, MAY 1976 TO MARCH 1977

	Sampling stations						
	1	2	3	4	5	6	7
Trichoptera							
Psychomyiidae							
Polycentropus cinereus ?	--	--	--	--	--	1(1)	3(1)
Hydropsychidae							
Hydropsyche bronta Ross	13(136)	11(5)	9(10)	11(4)	15(14)	7(7)	13(5)
Hydropsyche sp. A	9(20)	10(9)	10(3)	13(18)	13(26)	9(3)	1(1)
Hydropsyche sp. B	11(155)	14(123)	12(52)	13(43)	15(125)	15(37)	15(197)
Hydropsyche sp. C	7(11)	--	--	--	--	--	--
Cheumatopsyche spp.	13(234)	15(196)	15(62)	15(177)	15(609)	15(390)	15(193)
Hydroptilidae							
Hydroptila sp. A	4(24)	3(7)	7(3)	4(6)	5(5)	10(17)	14(58)
Hydroptila sp. B	4(5)	--	--	1(1)	1(1)	5(18)	--
Mayatrichia sp.	1(1)	1(1)	3(2)	1(1)	--	2(1)	--
Ithytrichia sp.	7(13)	3(4)	6(3)	6(4)	5(4)	3(5)	--
Phryganeidae							
Ptilostomis sp.	1(3)	--	--	2(1)	1(1)	--	2(1)
Limnephilidae							
Limnephilus sp.	1(1)	2(2)	1(4)	--	2(6)	3(3)	3(2)
Onocosmoecus sp.	1(1)	--	--	1(1)	3(5)	2(2)	6(6)
Anabolia sp.	--	--	--	--	--	2(2)	2(1)
Leptoceridae							
Oecetis avara (Banks)	9(14)	8(4)	10(5)	8(5)	9(6)	13(7)	9(1)
Triaenodes sp. (near *tarda*)	1(2)	--	--	--	--	1(4)	--
Nectopsyche sp. (*Leptocella*)	8(8)	1(1)	2(2)	2(2)	7(1)	9(12)	2(2)
Brachycentridae							
Brachycentrus sp.	11(28)	12(24)	6(211)	6(237)	6(130)	6(29)	14(22)

TABLE 14 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN INTRODUCED SUBSTRATE SAMPLES, MAY 1976 TO MARCH 1977

	Sampling stations						
	1	2	3	4	5	6	7
Coleoptera							
Dytiscidae							
Liodessus affinis (Say)	--	--	--	--	1(1)	--	2(1)
Hydrophilidae							
Helophorus sp.	1(1)	1(1)	--	--	--	--	--
Dryopidae							
Helichus striatus LeConte	2(2)	5(4)	4(3)	4(3)	7(15)	7(14)	7(6)
Helichus suturalis LeConte	--	--	--	--	--	1(1)	--
Elmidae							
Stenelmis oregonensis	8(29)	9(10)	11(10)	10(17)	14(31)	13(50)	7(1)
Dubiraphia minima	11(11)	8(3)	10(6)	12(22)	13(11)	13(17)	11(8)
Microcylloepus pusillus (LeConte)	13(39)	12(17)	13(27)	13(25)	15(32)	11(21)	10(4)
Optioservus divergens (LeConte)	--	--	--	--	1(1)	--	10(5)
Diptera							
Tipulidae							
Tipula (Yamatotipula) spp.	--	--	--	--	1(1)	3(1)	5(1)
Holorusia sp.	--	--	--	--	--	--	2(1)
Ormosia spp.	--	--	--	--	--	--	--
Dicranota spp.	1(1)	2(4)	4(2)	3(5)	8(11)	3(2)	8(3)
Limnophila (Eloeophila) sp.	--	--	--	--	--	--	1(1)
Hexatoma (Eriocera) sp.	--	1(1)	--	--	1(1)	--	--
Psychodidae							
Pericoma sp. A	--	--	--	--	--	--	1(1)
Pericoma sp. B	--	--	--	--	--	--	1(1)
Simuliidae							
Simulium spp.	10(217)	14(304)	15(390)	14(238)	15(246)	14(281)	9(9)
Chironomidae	13(165)	15(63)	15(147)	15(104)	15(173)	15(228)	15(363)

TABLE 14 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN INTRODUCED SUBSTRATE SAMPLES, MAY 1976 TO MARCH 1977

	Sampling stations						
	1	2	3	4	5	6	7
Diptera (continued)							
Heleidae							
Palpomyia spp.	1(2)	2(3)	3(2)	3(1)	6(2)	11(5)	5(4)
Dasyhelea spp.	--	--	--	--	1(1)	--	1(44)
Stratiomyidae	--	--	--	--	1(1)	--	1(1)
Tabanidae							
Chrysops spp.	--	--	1(1)	--	--	--	--
Dolichopodidae							
Hydrophorus sp.	--	--	--	--	1(1)	--	--
Empididae							
sp. A	1(1)	6(2)	8(5)	5(3)	7(7)	6(3)	8(4)
sp. B	--	1(6)	2(1)	1(1)	2(8)	3(2)	4(1)
Turbellaria	--	--	2(4)	5(4)	6(19)	3(6)	--
Nematomorpha	1(1)	--	--	1(1)	--	--	--
Oligochaeta	10(17)	8(5)	11(6)	12(8)	11(4)	14(20)	13(31)
Hirudinea							
Glossiphoniidae	--	1(1)	--	--	--	--	--
Malacostraca							
Amphipoda							
Talitridae							
Hyalella azteca (Saussure)	5(2)	--	3(4)	2(3)	3(1)	3(4)	3(1)
Acari	--	--	1(1)	--	1(2)	2(1)	2(1)

TABLE 14 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN INTRODUCED SUBSTRATE SAMPLES, MAY 1976 TO MARCH 1977

	Sampling stations						
	1	2	3	4	5	6	7
Basommatophora							
Physidae							
Physa spp.	8(4)	12(21)	4(3)	4(1)	6(1)	4(2)	8(3)
Lymnaeidae							
Lymnaea sp.	--	1(1)	--	--	1(1)	1(1)	--
Ancylidae							
Ferrissia sp.	--	--	--	--	--	--	5(3)
Heterodonta							
Sphaeriidae							
Sphaerium sp.	1(1)	2(1)	3(2)	7(7)	1(1)	2(2)	1(3)

a/ Dash indicates absence from samples.

b/ In parentheses.

TABLE 15. NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN EKMAN DREDGE SAMPLES, MARCH 1976 TO OCTOBER 1976

	Sampling stations						
	1	2	3	4	5	6	7
Ephemeroptera							
Heptageniidae							
Heptagenia elegantula (Eaton)	--	1(1)	--	1(2)	--	--	--
Baetidae							
Baetis sp. B	--	1(1)	--	1(1)	--	--	--
Centroptilum sp.	--	1(1)	--	--	--	--	--
Leptophlebiidae							
Choroterpes albiannulata McDunn.	--	--	2(6)	3(2)	2(2)	1(3)	1(1)
Caenidae							
Caenis sp.	--	--	--	--	--	--	2(2)
Tricorythidae							
Tricorythodes minutus Traver	1(1)	1(1)	--	3(8)	6(6)	2(2)	--
Odonata							
Gomphidae							
Gomphus sp. A	1(1)	2(1)	1(1)	3(1)	1(2)	4(1)	--
Ophiogomphus sp. (near *severus*)	1(1)	--	--	--	--	1(1)	--
Zygoptera							
Coenagrionidae							
Argia fumipennis-violacea (Hagen)	--	1(1)	--	--	--	--	--
Enallagma sp.	--	--	--	--	--	--	1(1)
Hemiptera							
Corixidae							
Palmacorixa gilleti Abbott	1(1)	--	--	--	--	--	--
Trichocorixa sp.	2(3)	--	1(1)	1(1)	--	--	--

TABLE 15 (continued). NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN EKMAN DREDGE SAMPLES, MARCH 1976 TO OCTOBER 1976

	Sampling stations						
	1	2	3	4	5	6	7
Megaloptera							
Sialidae							
Sialis sp.	--	--	--	--	--	--	1(1)
Trichoptera							
Psychomyiidae							
Polycentropus cinereus ?	1(1)	--	--	--	--	--	--
Hydropsychidae							
Hydropsyche bronta Ross	1(1)	--	--	--	1(1)	--	--
Hydropsyche sp. A	--	--	--	1(1)	2(1)	--	--
Hydropsyche sp. B	2(1)	3(1)	--	3(2)	5(2)	1(1)	2(5)
Cheumatopsyche spp.	2(3)	5(2)	--	4(2)	7(10)	2(12)	2(2)
Hydroptilidae							
Hydroptila sp. A	1(2)	--	--	--	--	1(1)	--
Limnephilidae							
Limnephilus sp.	--	--	--	--	1(4)	1(1)	2(1)
Leptoceridae							
Oecetis avara (Banks)	1(1)	1(1)	--	--	2(1)	--	--
Nectopsyche sp. (*Leptocella*)	--	--	--	--	3(4)	--	--
Brachycentridae							
Brachycentrus sp.	--	--	2(3)	3(3)	4(2)	1(1)	1(3)
Coleoptera							
Elmidae							
Stenelmis oregonensis	1(1)	2(2)	1(1)	3(3)	5(3)	3(1)	--
Dubiraphia minima	8(21)	6(12)	8(15)	7(21)	8(13)	7(2)	7(7)
Microcylleopus pusillus (LeConte)	4(2)	3(1)	2(2)	3(1)	3(2)	1(3)	--

TABLE 15 (continued). NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN EKMAN DREDGE SAMPLES, MARCH 1976 TO OCTOBER 1976

	Sampling stations						
	1	2	3	4	5	6	7
Diptera							
Tipulidae							
Ormosia spp.	--	--	--	1(1)	--	--	--
Dicranota spp.	--	3(3)	--	1(3)	4(3)	1(2)	--
Psychodidae							
Psychoda sp.	--	--	1(1)	--	--	--	--
Simuliidae							
Simulium spp.	2(4)	3(2)	1(7)	1(3)	4(2)	1(1)	1(11)
Chironomidae	8(48)	8(24)	8(61)	8(42)	8(132)	8(48)	7(134)
Heleidae							
Palpomyia spp.	5(3)	4(2)	5(19)	4(40)	6(4)	3(31)	2(4)
Tabanidae							
Chrysops spp.	--	--	1(1)	--	1(1)	--	--
Empididae							
sp. B	--	--	--	1(1)	--	--	--
Turbellaria	--	--	--	--	2(2)	1(1)	--
Oligochaeta	8(26)	7(9)	8(18)	8(16)	8(6)	7(4)	7(40)
Hirudinea							
Glossiphoniidae	--	--	--	1(1)	--	--	--
Malacostraca							
Amphipoda							
Talitridae							
Hyalella azteca (Saussure)	--	--	--	2(2)	--	--	--

TABLE 15 (continued). NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN EKMAN DREDGE SAMPLES, MARCH 1976 TO OCTOBER 1976

	Sampling stations						
	1	2	3	4	5	6	7
Basommatophora							
Physidae							
Physa spp.	1(1)	--	--	2(2)	--	--	--
Heterodonta							
Sphaeriidae							
Sphaerium sp.	--	2(2)	1(2)	2(1)	--	--	1(1)
Pisidium sp.	--	3(2)	3(2)	2(2)	--	--	1(1)
Eulamellibranchia							
Unionidae	1(1)	--	--	--	--	--	--

a/ Dash indicates absence from samples.

b/ In parentheses.

TABLE 16. NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN MODIFIED HESS SAMPLES, MARCH 1976 TO MARCH 1977

	Sampling stations				
	1	3	5	6	7
Ephemeroptera					
Ephemeridae					
Ephoron album (Say)	--	2(2)	1(1)	--	--
Heptageniidae					
Heptagenia elegantula (Eaton)	1(4)	1(1)	--	3(1)	3(3)
Baetidae					
Baetis sp. A	2(42)	2(5)	2(3)	2(11)	--
Baetis sp. B	9(8)	2(1)	5(7)	12(39)	12(35)
Pseudocloeon sp.	3(8)	2(2)	3(1)	4(13)	1(1)
Leptophlebiidae					
Choroterpes albiannulata McDunn.	11(42)	5(270)	11(25)	12(45)	--
Leptophlebia gravastella (Eaton)	1(2)	1(1)	--	2(4)	--
Traverella albertana (McDunnough)	1(1)	--	--	--	--
Caenidae					
Caenis sp.	--	--	--	--	1(3)
Tricorythidae					
Tricorythodes minutus Traver	7(6)	3(9)	4(3)	11(28)	10(21)
Odonata					
Gomphidae					
Ophiogomphus sp. (near *severus*)	2(1)	1(1)	--	7(1)	5(2)
Zygoptera					
Calopterygidae					
Hetaerina americana (Fabricius)	--	--	--	1(1)	--
Coenagrionidae					
Enallagma sp.	--	--	--	--	1(2)

TABLE 16 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN MODIFIED HESS SAMPLES, MARCH 1976 TO MARCH 1977

	Sampling stations				
	1	3	5	6	7
Plecoptera					
Nemouridae					
Nemoura sp.	--	--	--	--	1(1)
Brachyptera sp. (prob. *fosketti*)	1(2)	2(1)	--	3(3)	--
Capnia sp.	--	--	--	--	1(1)
Perlodidae					
Isoperla patricia Frison	--	--	--	5(1)	8(4)
Hemiptera					
Corixidae					
Palmacorixa gilleti Abbott	--	--	--	1(1)	--
Naucoridae					
Ambrysus mormon Montandon	2(1)	2(2)	2(4)	3(3)	--
Megaloptera					
Sialidae					
Sialis sp.	--	--	--	--	1(3)
Trichoptera					
Hydropsychidae					
Hydropsyche bronta Ross	12(71)	4(3)	4(4)	6(5)	10(3)
Hydropsyche sp. A	3(10)	2(2)	2(1)	3(2)	--
Hydropsyche sp. B	11(105)	3(8)	7(4)	12(36)	12(162)
Hydropsyche sp. C	2(6)	--	--	--	--
Cheumatopsyche spp.	12(84)	6(25)	10(34)	12(149)	12(231)
Hydroptilidae					
Hydroptila sp. A	6(4)	3(2)	1(1)	9(24)	11(32)
Hydroptila sp. B	2(8)	--	1(1)	3(1)	1(11)
Mayatrichia sp.	2(1)	--	1(1)	1(15)	--

TABLE 16 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN MODIFIED HESS SAMPLES, MARCH 1976 TO MARCH 1977

	Sampling stations				
	1	3	5	6	7
Trichoptera (continued)					
Limnephilidae					
Limnephilus sp.	--	--	--	1(1)	--
Onocosmoecus sp.	--	--	--	--	1(2)
Leptoceridae					
Oecetis avara (Banks)	5(2)	2(1)	2(4)	4(6)	1(2)
Nectopsyche sp. (*Leptocella*)	--	1(1)	--	1(1)	--
Brachycentridae					
Brachycentrus sp.	4(30)	--	4(7)	3(8)	7(4)
Lepidoptera					
Pyralidae					
Cataclysta sp.	5(4)	--	--	--	--
Coleoptera					
Dryopidae					
Helichus striatus LeConte	1(2)	--	--	--	1(1)
Elmidae					
Stenelmis oregonensis	8(15)	5(5)	9(9)	12(33)	8(2)
Dubiraphia minima	8(3)	2(3)	3(4)	10(4)	10(4)
Microcylloepus pusillus (LeConte)	11(64)	3(5)	4(13)	8(31)	12(8)
Optioservus divergens (LeConte)	--	--	--	4(3)	12(14)
Diptera					
Tipulidae					
Tipula (Yamatotipula) spp.	--	--	--	1(1)	4(4)
Holorusia sp.	--	--	1(2)	--	--
Ormosia spp.	1(1)	--	--	--	3(3)
Dicranota spp.	5(4)	4(4)	7(7)	7(6)	11(4)
Limnophila (Eloeophila) sp.	--	--	--	--	2(2)

TABLE 16 (continued). NUMBER OF OCCURRENCES[a] AND AVERAGE NUMBERS PER OCCURRENCE[b] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN MODIFIED HESS SAMPLES, MARCH 1976 TO MARCH 1977

	Sampling stations				
	1	3	5	6	7
Diptera (continued)					
Culicidae					
Chaoborus sp.	--	1(1)	--	--	--
Simuliidae					
Simulium spp.	12(51)	4(225)	11(63)	12(132)	8(6)
Chironomidae	12(150)	5(66)	12(44)	12(253)	12(108)
Heleidae					
Palpomyia spp.	4(2)	1(1)	7(2)	8(13)	6(4)
Tabanidae					
Chrysops spp.	--	1(1)	--	--	5(1)
Tabanus sp.	--	--	--	--	1(1)
Empididae					
sp. A	3(1)	3(2)	2(4)	5(9)	7(2)
sp. B	--	--	1(4)	2(2)	3(2)
Turbellaria	--	2(4)	3(4)	6(6)	--
Nematomorpha	1(1)	--	--	--	--
Oligochaeta	11(35)	4(6)	9(16)	10(13)	12(26)
Amphipoda					
Talitridae					
Hyalella azteca (Saussure)	--	--	--	1(1)	2(1)
Acari	1(1)	--	--	2(2)	2(1)
Basommatophora					
Physidae					
Physa spp.	--	--	--	--	2(1)

TABLE 16 (continued). NUMBER OF OCCURRENCES[a/] AND AVERAGE NUMBERS PER OCCURRENCE[b/] FOR AQUATIC MACROINVERTEBRATES COLLECTED IN MODIFIED HESS SAMPLES, MARCH 1976 TO MARCH 1977

	Sampling stations				
	1	3	5	6	7
Basommatophora (continued)					
Ancylidae					
Ferrissia sp.	--	--	--	--	1(2)
Heterodonta					
Sphaeriidae					
Sphaerium sp.	3(2)	1(10)	--	1(1)	4(3)
Pisidium sp.	--	--	--	--	1(5)

a/ Dash indicates absence from samples.

b/ In parentheses.

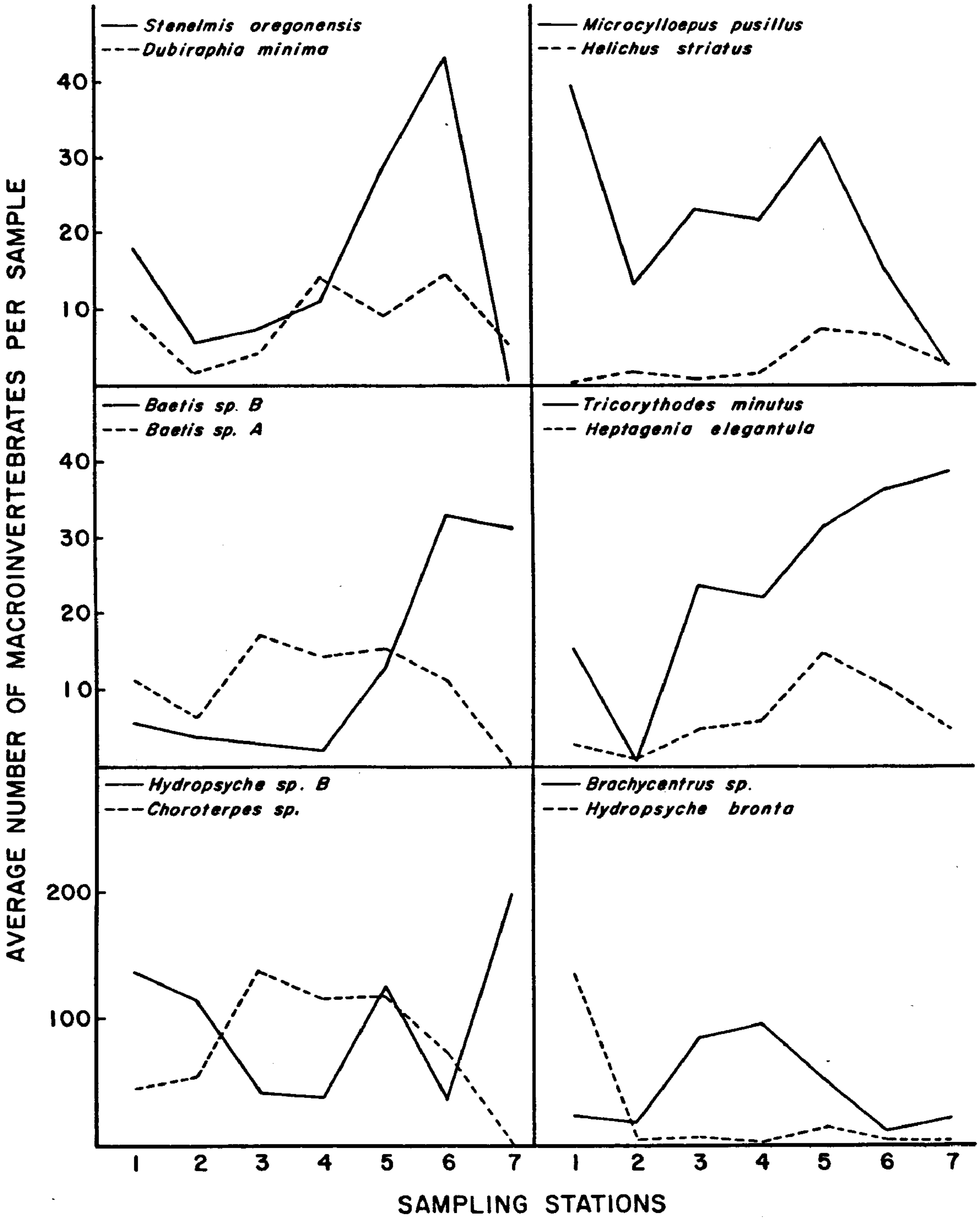

Figure 9. Average numbers of selected taxa per introduced substrate sample, May 1976 to March 1977.

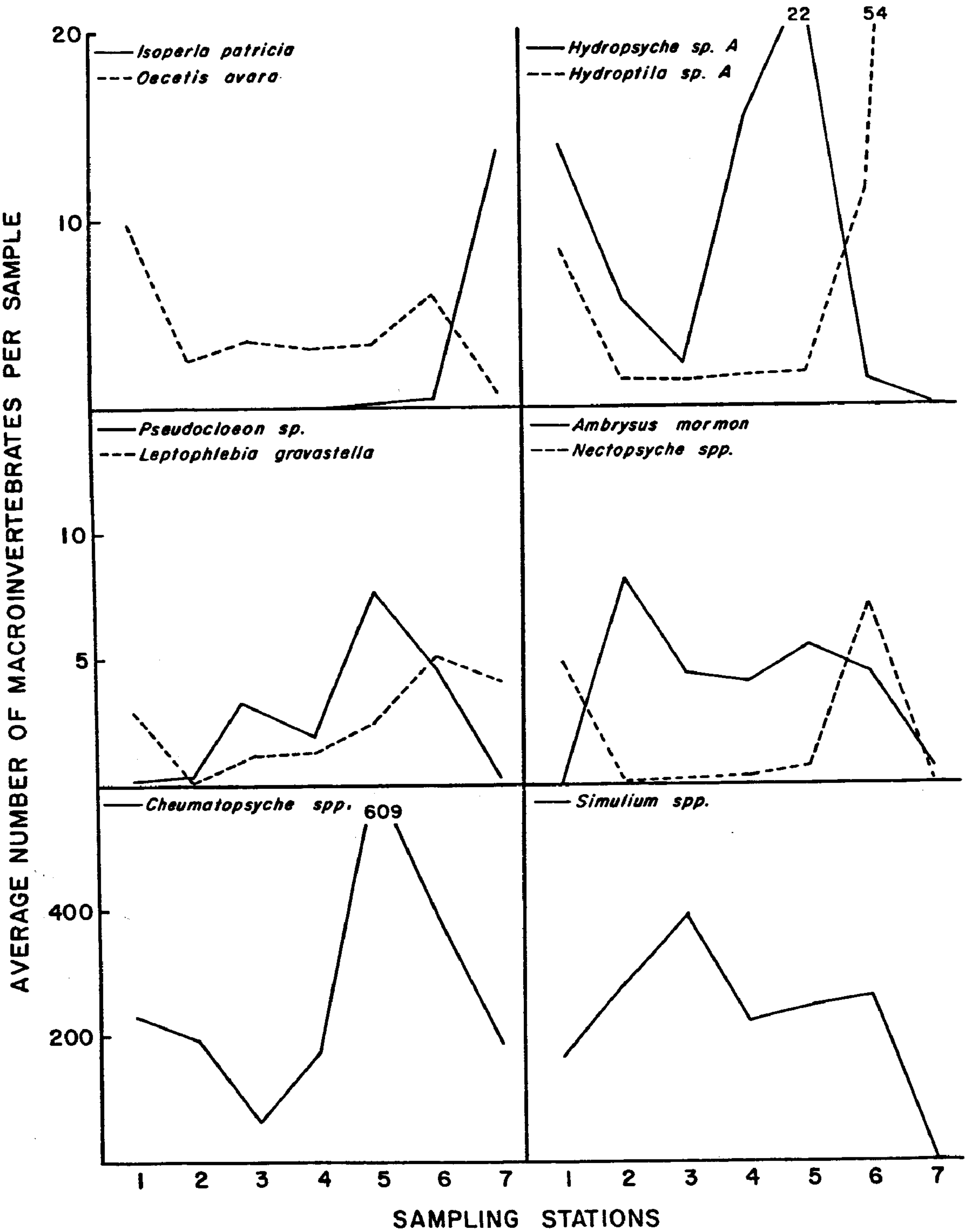

Figure 9 (continued). Average numbers of selected taxa per introduced substrate sample, May 1976 to March 1977.

upstream. *Hydropsyche* sp. A, *Cheumatopsyche* spp., and *Pseudocloeon* sp. were most abundant in introduced substrate samples at Station 5.

Restricted distribution patterns were evident for certain taxa (Table 13). *Optioservus divergens* was common only at Station 7 and absent from Stations 1 through 4. *Ephoron album* was collected rarely and only at Stations 3 and 5. *Caenis* spp. was common at Station 7, rare at Station 1, and absent from intervening stations. *Traverella albertana* was collected only once at Station 1 although it was found to be abundant in the Yellowstone River in this vicinity (Newell, 1976). *Sialis* sp., collected in silted substrata at Stations 6 and 7, was absent from Stations 1 through 5. Certain Tipulidae (e.g., *Tipula* spp., *Holorusia* sp., and *Limnophila* sp.) were collected only at Stations 5, 6, and 7. *Pericoma* spp. were collected only at Station 7. Plecoptera were rare; however, nymphs of a winter stonefly, *Brachyptera* spp., were present at Stations 1 through 6 and possibly correspond to adult *Brachyptera fosketti* collected in March 1976. *Isoperla patricia* was present in greatest numbers at Station 7 and was absent from Stations 1, 2, and 4. Certain taxa (e.g., *Isonychia sicca*, *Hydropsyche* sp. C, *Cataclysta* sp., and *Sympetrum* sp.) were collected only from the unique habitat present at Station 1.

A temporal pattern of emergence appeared to be present for certain taxa. Population cycles for *Hydropsyche* sp. B and *Dubiraphia minima* reached numerical peaks during different months depending on the station (altitude) (Figures 10 and 11). In contrast, numbers of *Choroterpes albiannulata* appeared to peak bimodally and simultaneously at all stations (Figure 12).

Results from modified Hess samples (Table 16) showed that individual taxa were often numerically least abundant at Station 5, a distinct contrast with data from introduced substrate samples. Total numbers for individual taxa were generally highest at Stations 1, 6, and 7. The mid-Rosebud (Stations 2, 3, 4, and 5) could not be sampled adequately enough to give species distribution for these stations.

DIVERSITY AND REDUNDANCY

A total of 92 taxa were collected in Rosebud Creek. Stations 1, 5, 6, and 7 had similar numbers of species although the composition varied. Fewer taxa were found at Stations 2, 3, and 4 (Figure 13). Average species diversity and redundancy per sample is presented in Table 17.

Introduced Substrate Samples

The average number of taxa per sample (Table 7) is highest at Stations 5, 6, and 7 corresponding with trends for average numbers and biomass.

Ekman Dredge Samples

The average number of taxa in pools was highest at Stations 4 and 5 and lowest at Stations 6 and 7, a condition contrasting with results from introduced substrate and modified Hess samples. Station 3 was also low for average number of taxa per sample.

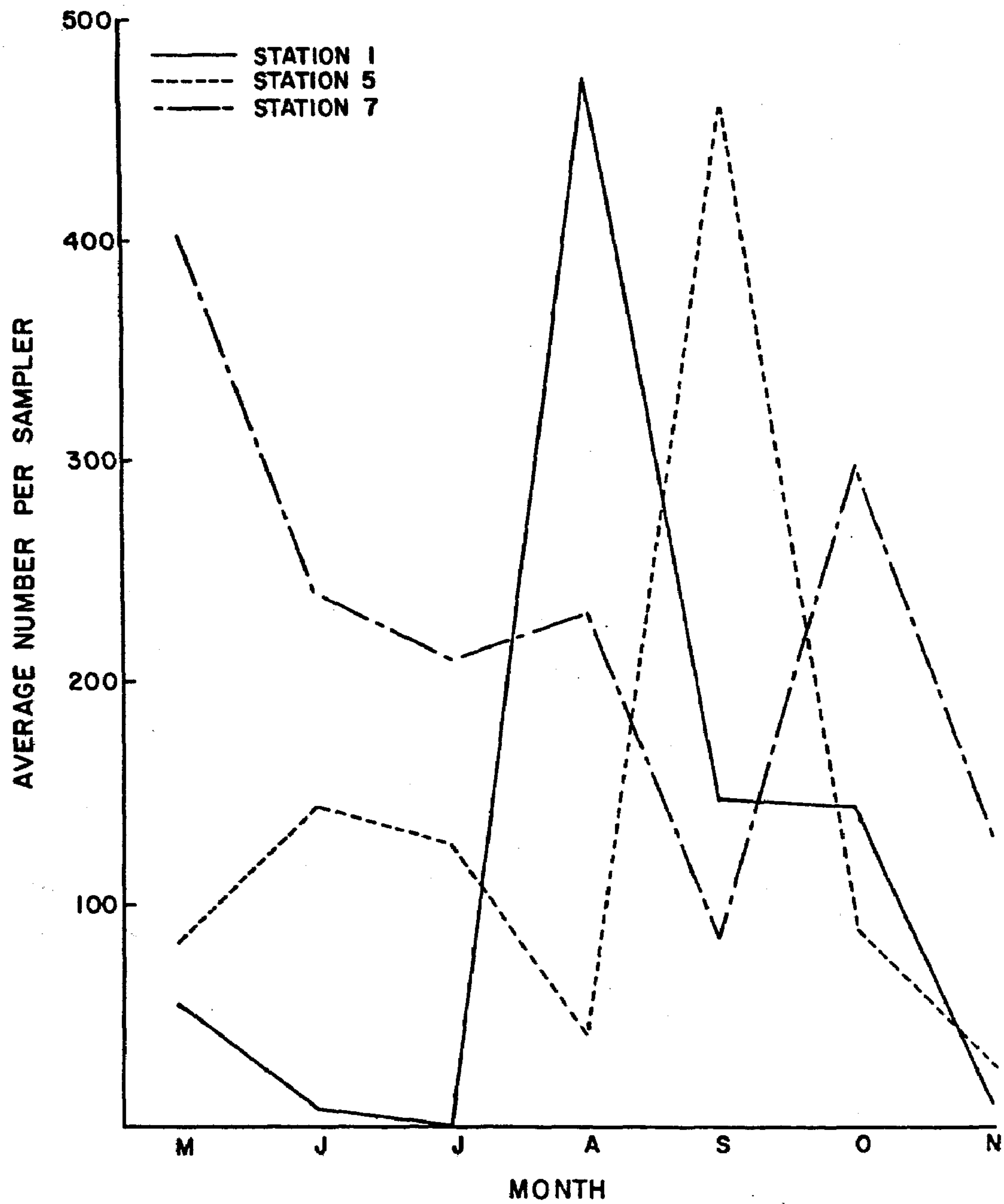

Figure 10. Seasonal variations in mean total numbers of *Hydropsyche* sp. B per introduced substrate sample at Stations 1, 5, and 7, May 1976 to November 1976.

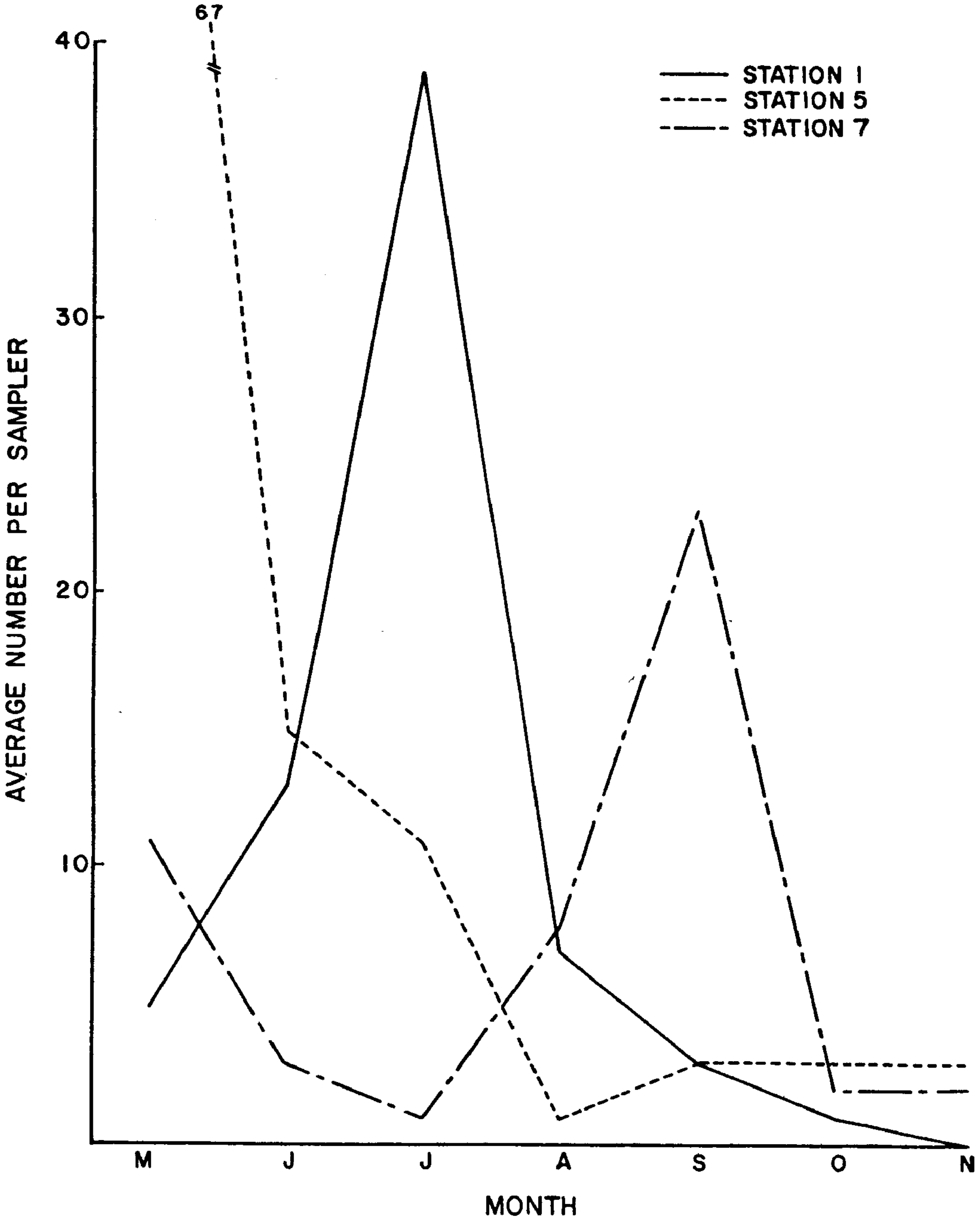

Figure 11. Seasonal variations in mean total numbers of *Dubiraphia minima* per introduced substrate sample at Stations 1, 5, and 7, May 1976 to November 1976.

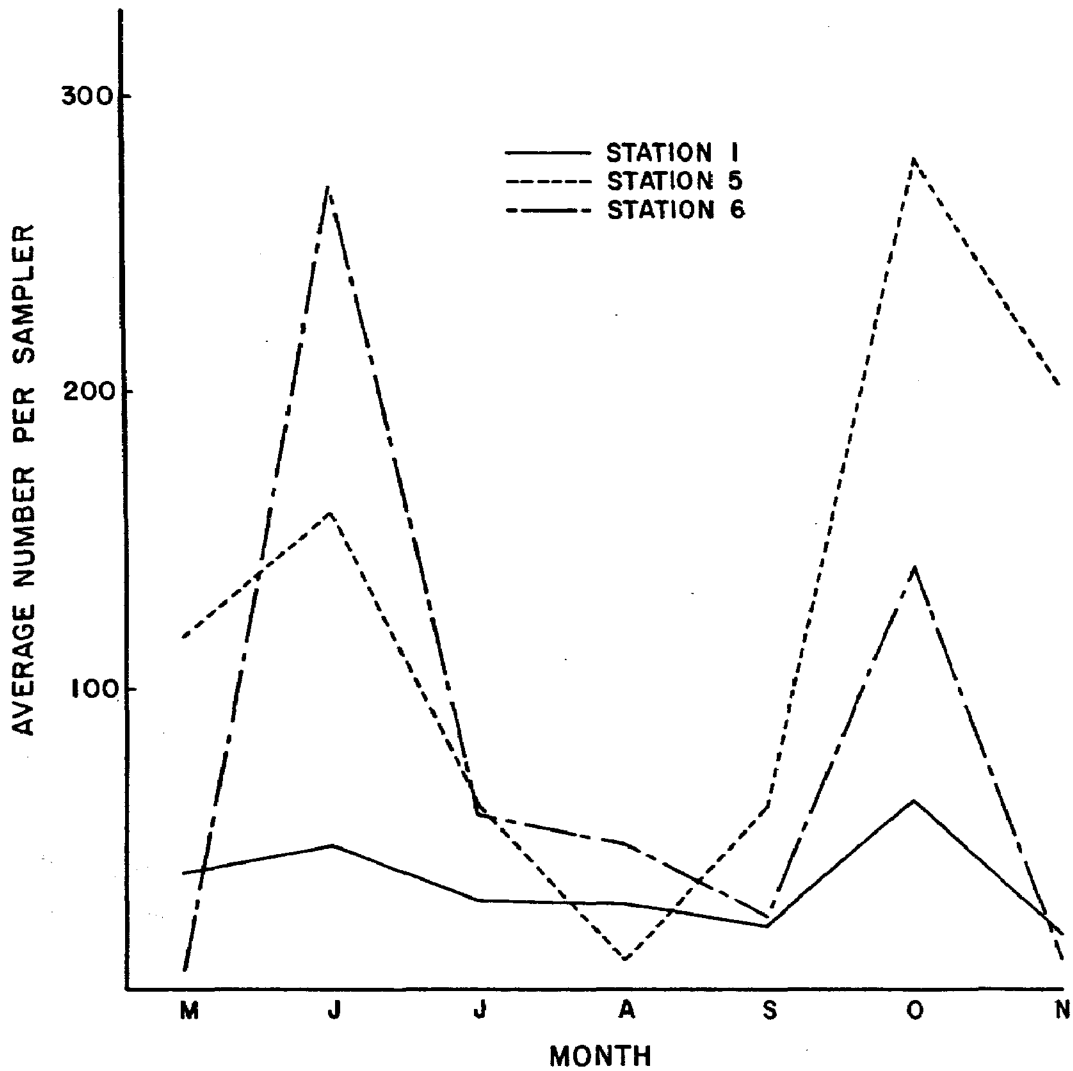

Figure 12. Seasonal variations in mean total numbers of *Choroterpes albiannulata* per introduced substrate sample at Stations 1, 5, and 6, May 1976 to November 1976.

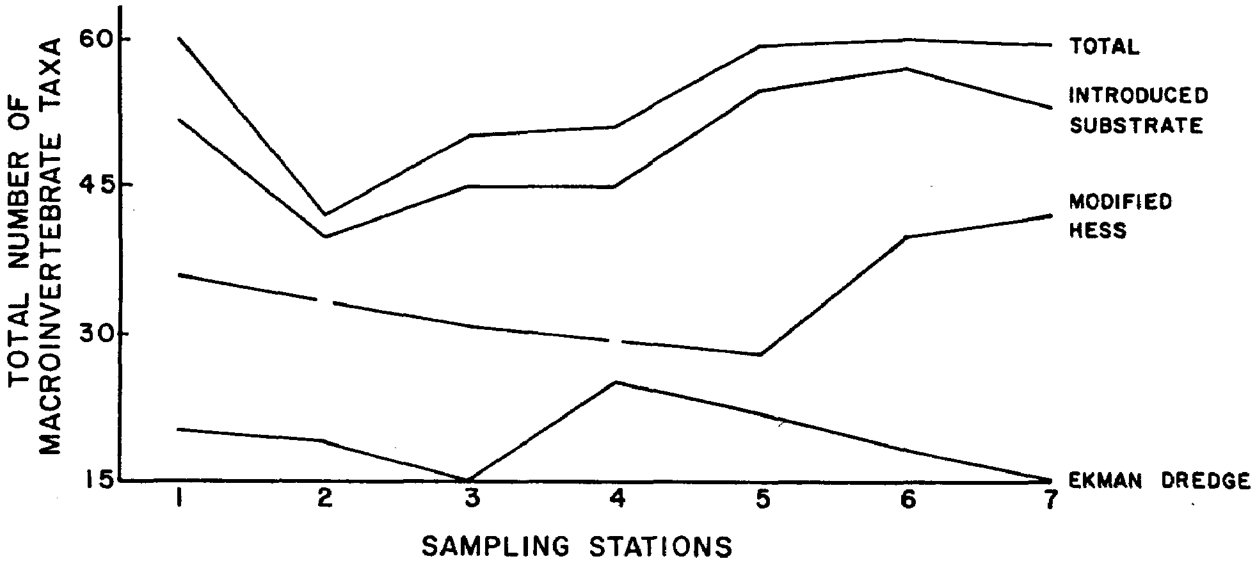

Figure 13. Total taxa per station and taxa collected by each of three sampling methods, March 1976 to March 1977.

TABLE 17. MEAN MACROINVERTEBRATE DIVERSITIES AND REDUNDANCY PER SAMPLE, MARCH 1976 TO MARCH 1977

Station	Shannon's Index	Margalef Index	Simpson Index	Redundancy
		Introduced substrates		
1	2.89	2.95	0.21	0.36
2	2.20	2.37	0.36	0.48
3	2.30	2.70	0.32	0.47
4	2.42	2.72	0.31	0.46
5	2.40	2.95	0.33	0.49
6	2.61	3.40	0.30	0.46
7	2.55	3.22	0.25	0.46
		Ekman dredge		
1	1.66	1.28	0.42	0.47
2	1.81	1.64	0.38	0.55
3	1.73	1.11	0.37	0.36
4	2.11	1.85	0.31	0.42
5	1.92	2.05	0.41	0.49
6	1.30	1.25	0.53	0.66
7	1.11	0.87	0.58	0.58
		Modified Hess		
1	2.48	2.36	0.28	0.41
3	1.90	2.26	0.38	0.57
5	1.99	1.91	0.39	0.48
6	2.82	2.79	0.21	0.35
7	2.43	2.84	0.26	0.44

Modified Hess Samples

Average number of taxa per sample was highest at Stations 1, 6, and 7 (Table 7). Lowest numbers of taxa were found at Station 5; Station 3 was also low in comparison to Stations 6 and 7.

SECTION VIII

DISCUSSION

Basic information concerning the composition of the macroinvertebrate community of Rosebud Creek in terms of distribution, diversity, and abundance was gathered during this study. Variation of these parameters among sampling stations was considered with respect to potential chemical effluents from coal mining and combustion and with respect to the physical-chemical nature of the Rosebud Creek system.

WATER CHEMISTRY: METALS

Concentrations of selected metals in Rosebud Creek (Table 4) are generally below criterion levels recommended by the U.S. Environmental Protection Agency (1976). Average copper and zinc concentrations are highest at Stations 3 and 4 but probably do not present a threat to the benthic fauna. Present levels are far less than the TL_{50} values (14 day) presented by Nehring (1976) for *Pteronarcys californica* or *Ephemerella grandis* or the 48-hr TL_m determined for copper on *Ephemerella subvaria* (Warnick and Bell, 1969).

Average total mercury exceeded the criterion concentrations of 0.05 µg/l total mercury recommended for freshwater aquatic life and wildlife by the Environmental Protection Agency (1976). Aquatic insects vary widely in their sensitivities to mercury but present concentrations in Rosebud Creek (Table 4) are less than the 2.0 mg/l and 33.5 mg/l toxic concentrations (96-hr TL_m) of mercury ($HgCl_2$) for *Ephemerella subvaria* and *Acroneuria lycorias* given by Warnick and Bell (1969). In this study it was not possible to attribute low average numbers, standing crop, and taxa (introduced substrates) at Stations 2, 3, and 4 to the reported mercury concentrations. Follow up chemical and biological studies are warranted.

PHYSICAL CONDITIONS

Physical conditions of Rosebud Creek are typical of eastern Montana transition prairie streams. Notable conditions include extreme turbidity, high suspended load, and warm water temperatures all of which increase progressively downstream. These factors, and indirect effects from low stream gradient, influence the abundance and distribution of the benthic macroinvertebrate fauna.

Turbidity

Rosebud Creek is extremely turbid even during low flows, particularly at Stations 1 and 2 (Tables 2 and 4). This condition results in a decrease in euphotic zone depth due to light extinction and a consequential reduction in primary production (Bartsch, 1959). Most temperate streams are heterotrophic, that is, production from photosynthesis is exceeded by community respiration and allochthonous material is an important source of energy (Boling et al., 1975). The turbid state of Rosebud Creek results in allochthonous detritus becoming more significant as an energy source and the benthic community is composed of many organisms utilizing primarily detrital food sources. For example, Hydropsychidae and Simuliidae, both common in Rosebud Creek, are omnivorous collectors filtering fine particles from the water column (Ross, 1944). Leptophlebiidae, the dominant mayfly family encountered, are also omnivores and detritivores (Berner, 1959) and the larvae and adults of Elmidae ingest decaying wood and encrusting algae (Brown, 1972).

Temperature

Extreme summer water temperatures occur in Rosebud Creek and influence the distribution of aquatic macroinvertebrates. Dodds and Hisaw (1925) concluded temperature to be the main climatic cause for altitudinal zonation of aquatic organisms. Altitudinal distribution of Plecoptera is due to the maximum water temperature the nymphs can tolerate (Knight and Gaufin, 1966). Of four taxa of Plecoptera collected from Rosebud Creek, two were collected only at the uppermost location (Station 7) and *Isoperla patricia* was common only at Stations 6 and 7. This distribution is probably due to cooler summer water temperatures near the headwaters. *Brachyptera* sp., a stonefly collected at Stations 1 through 6, undergoes rapid development during fall and winter and emerges during late winter or early spring. Naiads of *Brachyptera* undergo summer diapause to escape warm water temperatures at that time (Harper and Hynes, 1970). In addition, water temperature is a factor in timing the emergence of aquatic insects (Nebeker, 1971). The apparent temporal patterns of emergence in *Hydropsyche* sp. B and *Dubiraphia minima* (Figures 10 and 11) may be due to cooler water temperatures at upstream stations.

Substrate, Current Velocity, and Gradient

A complex interaction among stream gradient, discharge, suspended load, and current velocity exists which influences the quality of the benthic habitat. The longitudinal profile or gradient of most streams is typically concave, decreasing downstream (Mackin, 1948) and is usually accompanied by a downstream reduction in substrate size (Leopold and Maddock, 1953). Headwaters typically have boulder or gravel substrates and steep slopes; downstream the size of bed material is smaller and sand may be common. Near the mouth silt or clay may predominate. This generalized description of stream substrate applies to conditions found in Rosebud Creek. Near the headwaters gravel and cobble substrates are common; sand and gravel bed material are more abundant downstream as the slope decreases. At Station 2, long, deep reaches with flocculent clay or silt bottoms are prevalent. At Station 1 the slope increases as Rosebud Creek approaches the Yellowstone River and there is a corresponding increase in pool-riffle periodicity with rubble and boulder substratum in the riffles. Riffles are uncommon at Stations 2, 3, and 4 due to the low stream gradient.

Substrate conditions (i.e., size and degree of sedimentation) have been termed the most important single factor influencing macroinvertebrate habitat quality (Pennak, 1971). Large substrates such as rubble and cobble support larger invertebrate populations than sand and gravel (Pennak and Van Gerpen, 1947). Riffles composed of stable substrates are the most productive type of bottom in streams (Patrick, 1949). Consequently, a longitudinal decrease in substrate size and frequency of riffles as occurs in Rosebud Creek will result in lower macroinvertebrate production and standing crop downstream.

Two consequences of reduced gradient include diminished overall current velocity (Reid, 1961), and lowered sediment carrying capacity which results in deposition of part of the suspended load (Morisawa, 1968). The ultimate factor influencing sediment transport relates to the supplied load; i.e., input from erosion. If supplied load exceeds carrying capacity then deposition and/or change in stream morphology will occur. In Rosebud Creek the combined effect of the increasing sediment load and decreasing gradient in a downstream direction results in deposition of sediments on the substratum (Stations 2 through 5).

Deposition of inorganic sediment can turn otherwise suitable substrate into poor macroinvertebrate habitat (Cordone and Kelley, 1961). Stable substrates are covered and, more importantly, interstitial spaces in the substrate, where much of the secondary production occurs, are filled. Many aquatic organisms seek refuge from swift current and the abrasive effect of bed load by inhabiting spaces between or under rocks. Further, much of the secondary production in streams occurs deep within the substratum. Coleman and Hynes (1970) found that 83% of the benthic community lived below 5 cm in the substrate. Poole and Stewart (1976) reported that 33.6% of the total number of organisms were deeper than 10 cm in the bed of a Texas river. It is evident that occlusion of interstitial spaces with inorganic sediment will eliminate habitat and decrease diversity and secondary production.

Conversely, deposition of organic sediments at slow current velocities may increase benthic production (Ruttner, 1952). At slow current speeds gravel and sand substrates become more stable; this, in combination with enrichment from organic sediments, creates an environment suitable for many invertebrates. In Rosebud Creek, the common long reaches with slow current velocities of 0.6 m/sec and less, support productive bottom faunas, e.g., Oligochaeta and Chironomidae, dependent on allochthonous detritus.

Sedimentation and a decrease in overall substrate size probably contributed to the lower benthic diversity and population numbers at Stations 2, 3, and 4 due to occlusion of interstitial spaces and decrease in habitat variety. Lower diversities, in comparison to other sampling sites, were found at Stations 2, 3, and 4 with introduced substrate samplers, at Stations 3 and 5 with modified Water's round samplers, and at Station 3 using an Ekman dredge. Also, introduced substrates showed low numbers at Stations 2, 3, and 4 which may be due to low populations of benthic macroinvertebrates for sampler colonization in these sections of Rosebud Creek.

Substrate conditions at the point of sampling influenced results from modified Hess and Ekman dredge samplers. The infrequence of riffles in

Rosebud Creek at many stations limited the choice of sampling location. For example, the existing riffle at Station 5 consisted of unstable gravel which resulted in low standing crop, numbers, and diversity from modified Hess samples taken at this station. Conversely, introduced substrates showed Station 5 to have a high population and diversity relative to other sampling sites.

Low numbers, standing crop, and diversity encountered in Ekman dredge samples at Station 6 can likewise be attributed to the sand substratum common in pools. Sand supports notoriously small populations of benthic invertebrates due to its unstable, grinding nature and lack of available food.

Current Velocity

Many stream-dwelling aquatic organisms are morphologically or behaviorally adapted to select habitats on the basis of current velocity. In streams, rapid flowing portions generally support higher numbers of benthic invertebrates than lentic stretches with the same substrate. Long, slow stretches that are common in Rosebud Creek had reduced numbers and fewer species. Hydropychidae, which depend on rapid current for proper functioning of their nets (Ross, 1944), were encountered in lower numbers at Stations 2, 3, and 4 where current velocity is generally slow. Elmidae, known to inhabit rapidly flowing portions of streams (Brown, 1972), were found in lower numbers at Stations 2, 3, and 4. *Choroterpes albiannulata* and *Ambrysus mormon*, both abundant at Stations 2, 3, and 4, are tolerant of slow flowing situations (Edmunds et al., 1976; Roemhild, 1976). Current velocity may have directly influenced the distribution of these and other taxa (Figure 9) but probably had a more profound effect by influencing substrate composition.

The tendency for various taxa to be low in abundance at Stations 2, 3, and 4 (introduced substrates) was influenced by any one or a combination of the physical conditions imposed by extreme turbidity, sediment deposition, small substrate size, slow current velocity, and high temperature in Rosebud Creek. Certain of these conditions were most extreme at Station 2 (low gradient, silted substratum, and slow current velocity) and imposed unfavorable conditions for many macroinvertebrates. Conversely, upstream sections, because of increased gradient, and decreased turbidity and temperature supported more productive macroinvertebrate populations.

MACROINVERTEBRATE ABUNDANCE AND COMPOSITION

The benthic fauna of Rosebud Creek is similar in composition to that found in Sarpy Creek, approximately 40 km west (Clancy, 1977). The lower Yellowstone River and the Powder River support faunas similar to Rosebud Creek and also decrease in diversity downstream (Newell, 1976; Rehwinkel et al., 1976).

Despite an extreme environment, Rosebud Creek supports a surprisingly abundant and diverse fauna that is adapted to the prevailing conditions. In terms of numbers of benthic invertebrates, it could be described as a rich stream. Very little quantitative data exist on comparable streams in eastern Montana; however, population estimates of 4993 and 6007 invertebrates per m^2 from pools and riffles, respectively, in Rosebud Creek were greater than the average 2809 invertebrates per m^2 for the middle Yellowstone River (Thurston et al., 1975). Data from the West Fork of the Gallatin River, a typical mountain stream similar in size to Rosebud Creek, averaged 1877 invertebrates per m^2 during 1970-1971 (unpublished data).

Among important conditions conducive to high population numbers of benthic macroinvertebrates in Rosebud Creek was the intact riparian vegetation which kept the stream within its banks; this prevented extreme erosion, scouring, and siltation. This vegetation was also an important energy source for Rosebud Creek where primary production was limited by turbidity.

Many of the commonly encountered macroinvertebrates of Rosebud Creek were adapted to live in turbid, silt-laden, or slow-flowing habitats. *Cheumatopsyche* spp. have been reported to be tolerant of a wide range of ecological conditions; *Cheumatopsyche lasia* was commonly found in heavily silted streams. *Tricorythodes minutus*, *Caenis* sp., *Choroterpes albiannulata*, *Leptophlebia gravastella*, and *Isonychia sicca* occur in silted or slow-flowing streams (Edmunds et al., 1976). *Microcylloepus pusillus* is tolerant of siltation and turbidity (Brown, 1972). *Isoperla patricia* inhabits prairie streams that originate in the mountains (Ricker, 1946). *Dubiraphia minima*, collected abundantly from pools and riffles, can be classified as tolerant of siltation and slow current velocity. Many taxa that are numerically abundant in the mid-Rosebud, e.g., *Simulium* spp., *Choroterpes albiannulata*, *Sphaerium* spp., and *Ambrysus mormon*, have wide tolerances to ecological conditions. As a generalization, aquatic invertebrates present in large numbers in the prairie portion of Rosebud Creek could be classed as tolerant of turbid, silty conditions.

SAMPLING CONSIDERATIONS

To describe accurately the aquatic fauna, it is necessary to sample as many habitat types and take as many samples as possible. Benthic organisms select habitat on the basis of various physical and chemical conditions, i.e., substrate, current velocity, depth, dissolved oxygen, temperature, etc. Three habitat types including riffles, pools, and long, gravel-bottom runs were sampled semi-quantitatively during this study. Analysis of results indicated that species composition varied with habitat and sampling device. Modified Hess and Ekman dredge samplers collected 62 and 46% of the total taxa found, respectively. Introduced substrates were most efficient in collection of numbers and taxa; 89% of the total taxa collected including 22 not collected by other methods were found in introduced substrate samples. Certain organisms, e.g., *Ephoron album* and *Cataclysta* sp., were collected in modified Hess samples but were absent from other methods. Chironomidae and Oligochaeta composed the majority of the pool fauna; Trichoptera, Diptera, and Ephemeroptera predominated in riffles and in introduced substrate samples.

The long, hard-bottom slow reaches that are the most common habitat in Rosebud Creek could not be effectively sampled using an Ekman dredge or Hess sampler. However, introduced substrate in baskets was an efficient method for sampling these habitats. Their use permitted standardization of substrate kind and size and enabled selection of sampling sites which had comparable water depth and current velocity. This made quantitative comparisons between stations more valid than with conventional grab type samplers. In addition, introduced substrates were proficient in collecting macroinvertebrate taxa. The samplers offered clean unsedimented substrates exposed to the current which were attractive to many organisms including Hydropsychidae, Simuliidae, and Baetidae, and because they rested flat on the substrate, a degree of sedimentation occurred near the basket bottom and invertebrates that dwell in fine substrates (e.g., Oligochaeta, Odonata, Sphaeriidae, and Chironomidae) also colonized the samplers. The number of species found in introduced substrate samples and the distribution of these species among sampling stations was a relatively accurate population parameter. However, introduced substrates are selectively colonized by various insects including mayflies, caddisflies, and beetles (Crossman and Cairns, 1974). Consequently, results did not represent the existing standing crop, population numbers, or distribution of individuals among the species. Accurate measurement of these parameters would necessitate collection and analysis of cores of the existing substrate at each station.

Year-round sampling is necessary to describe macroinvertebrate distribution and abundance. Benthic organisms vary in population numbers from week to week depending on details of life histories (Pennak and Van Gerpen, 1947). In Rosebud Creek *Brachyptera* spp. are present in winter and spring but not in summer samples. Various taxa, i.e., *Simulium* spp. and *Choroterpes albiannulata*, exhibit tremendous peaks in population numbers and form a substantial portion of the standing crop at that time. Their numbers may be an insignificant portion of the total aquatic population at other phases of the life cycle (egg and adult). Life histories also influence accuracy of macroinvertebrate identification. Early instars are often difficult to identify and collection of later stages is needed for accurate identification in many cases.

Longitudinal variations in the benthic macroinvertebrate fauna were due to influences from the unique physical-chemical nature of Rosebud Creek and to influences from domestic and agricultural practices. Variations in the benthic community during the study could not be attributed to effluents from coal mining or combustion.

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16. ABSTRACT

The aquatic macroinvertebrates of Rosebud Creek, Montana, were sampled between February 1976 and March 1977 to provide data on their abundance, distribution, and diversity. The sampling program was initiated during the first year of operation of the coal-fired power plants located at Colstrip, Montana. The purpose of the study was to determine if any immediate impacts of the power plant operation on the macroinvertebrate communities of Rosebud Creek could be detected and to provide data for comparisons with future studies.

Rosebud Creek supported a diverse bottom fauna with high population numbers composed of species adapted to the turbid, silty conditions which are common in the prairie streams of eastern Montana. Intact riparian vegetation appeared to be important in maintaining stream bank stability and provided an essential food source.

It was concluded that faunal variation among sampling stations during the study period was attributable to physical factors including turbidity, water temperature, current velocity, and substrate, and not to potential impacts from coal mining and combustion.

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