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BENTHIC INVERTEBRATE DISTRIBUTION, ABUNDANCE, AND DIVERSITY IN ROSEBUD CREEK, MONTANA

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

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in

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Approved:

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VITA

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He and Cynthia Ann Hall of San Diego, California, were married in 1968 and now have two children, Chris, 7 years, and Aaron, 1 year.

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ABSTRACT

Rosebud Creek, Montana, was sampled monthly during 1976 and 1977 to provide baseline data on macroinvertebrate abundance, distribution, and diversity in relation to potential effects from nearby coal development. Introduced substrate in baskets, an Ekman dredge, and a modified Hess sampler were used to sample runs, pools, and riffles, respectively. Faunal variation among sampling stations was due to physical factors including turbidity, water temperature, current velocity, and substrate, and not to impacts from coal mining and combustion. Rosebud Creek supported a diverse bottom fauna with high population numbers and adapted to turbid, silty conditions common in a transition prairie stream; i.e., originating in the mountains then flowing onto the plains.

Intact riparian vegetation was presumed important in stream bank stability and in providing an energy source to compensate for limitations imposed on primary production by high turbidity.

INTRODUCTION

Development of large scale coal mining and combustion for electrical generation is underway in eastern Montana. Two 350 megawatt coal-fired generators became operative at Colstrip, Montana, in 1976; two 750 megawatt power plants are in the final planning stages. The Colstrip power complex has potential for massive utilization of, and intense impact on, water resources of southeastern Montana. Consequently, the need to document the status of existing and changes in water quality is important in this region where water resources are limited. Information obtained may be useful for the planning of future power generators elsewhere in the northern Great Plains.

Rosebud Creek flows approximately 13 km east of Colstrip and is of interest since it may be a prime recipient of effluents from coal development. Groundwater flows eastward from the mining and power plant area through aquifers that include the coal seam being mined (Montana State Department of Natural Resources 1974) and may carry leachates from mining or combustion spoils. In addition, the prevailing wind direction is southeasterly (Thurston et al. 1976) which may result in the deposition of smokestack emissions in the Rosebud Creek drainage. Finally, Cow Creek, a small, intermittent stream originating in strip-mined areas, may carry effluents by seepage or runoff into Rosebud Creek (Thurston et al. 1976). These factors may result in an influx of complex inorganic salts and trace metals which could alter the composition of the aquatic macroinvertebrate community of Rosebud Creek.

A study of the toxic effects of coal and oil shale development to the aquatic biota was started in 1975 (Thurston et al. 1976). As a sub-project of this study, a one-year survey of the aquatic macroinvertebrate fauna of Rosebud Creek was begun in 1976 with the objective of providing baseline data on existing macroinvertebrate abundance and distribution. This data will also provide information for current taxonomic studies and give a description of the fauna of a southeastern Montana prairie stream.

Very little is known concerning the benthic invertebrate fauna of prairie streams in southeastern Montana. Recently, interest in these streams has grown due to proposed use of water resources for coal development. Preliminary results from an invertebrate study on the Powder River indicate low population numbers (Rehwinkel et al. 1976). Work by Newell (1976) on the Yellowstone River and by Gore (1975) on the Tongue River provide information on the composition and abundance of benthic invertebrates. The benthic fauna of Sarpy Creek, a small ephemeral stream, has also been surveyed (Clancy 1977).

Literature on the physical and biological characteristics of prairie streams is limited. Traditionally, streams of the mid-continent (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 mid-continent 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.

Basic techniques for stream surveys have been presented by Cairns and Dickson (1971) and Cummins (1962). These researchers recommended that similar habitats with respect to substrate, current velocity, depth, width, and bank cover be sampled at each station. Hence, sample variability is reduced by standardizing these variables and fewer samples give reliable results (Dickson et al. 1971). In addition, Cummins (1962) suggested that faunal surveys should include year-round sampling of all habitat types.

The use of introduced artificial substrates in stream surveys reduces sample variability by providing a uniform sample size and similar substrate for colonization by aquatic invertebrates. They reduce the subjectivity involved in selecting similar habitats and in the amount of sampling effort involved at each station (Crossman and Cairns 1974). Several types of samplers have been developed ranging from the "brush box" sampler of Scott (1958) and the hardboard multiplates (Hester and Dendy 1962) to the limestone and spherical porcelain filled barbecue baskets of Mason et al. (1967). Moon (1940) imbedded gravel-filled trays into the substrate for later removal and enumeration of colonized organisms. Stanford and Reed (1974) buried samplers in the natural substrate and concluded that this technique probably gives optimum quantitative results. This conclusion is supported by Coleman and Hynes (1970) who found that 80% of the organisms collected were deeper than 7.5 cm in the substrate. Mason et al. (1973) suspended samplers in the water column of the Ohio River and found that depth of placement and length of exposure time influenced species diversity, composition, and total numbers. Thus, consistent sampler installation with regard to physical variables is necessary to make benthic sample comparisons between stations in stream surveys.

Several workers have compared the efficiencies of artificial substrate samplers with conventional sampling methods. Anderson and Mason (1968) found that suspended samplers collected greater numbers and variety than a Peterson dredge but were not efficient in collection of burrowing invertebrates including oligochaetes, burrowing mayflies, and molluscs. Mason et al. (1973) found that limestone-filled baskets collected a greater variety and number of aquatic invertebrates than the hardboard multiplates of Hester and Dendy (1962). Crossman and Cairns (1974), in placing artificial substrates on the stream bottom, collected a more diverse fauna than conventional Surber or kick screen samplers. Floating samplers tended to be selectively colonized by beetles, mayflies, and caddisflies.

Changes in benthic community structure due to stress, and the presence or absence of indicator organisms are used to aid in the classification of stream health. Certain organisms, e.g., rattail maggots (*Eristalis* spp.), sludgeworms (*Tubifex tubifex*), and bloodworms (*Chironomus tentans*), are tolerant of organic enrichment and may reach high population numbers (Bartsch 1948). Conversely, many intolerant organisms, including certain stoneflies, mayflies, and caddisflies, may be conspicuously absent. The addition of toxic wastes, i.e., certain metals, acids, and salts, usually affects all species and causes an overall decrease in the number of benthic organisms (Surber 1953). When using indicator organisms to classify streams, the relative abundance of all species collected should be considered because tolerant forms often inhabit unpolluted waters in low numbers (Gaufin and Tarzwell 1952). Indicator organisms should be recognized at the species level since a single genus may tolerate a variety of conditions (Patrick 1949).

Diversity indices based on information theory have enjoyed popularity in the past few decades as a tool to summarize data concerning the aquatic biota. Patten (1962) used a formula derived from information theory (Shannon 1948) to measure species diversity ($\bar{H}$) of marine phytoplankton. He concluded that Shannon's formula permitted summarization of large amounts of data concerning numbers and kinds of organisms and reflected the distribution of individuals among the species. Two components are inherent to Shannon's formula: species richness and evenness of distribution of individuals among the species (Lloyd and Ghelardi 1964); both of these components can influence $\bar{H}$. Despite the development of other indices (Simpson 1949, Margalef 1957), the Shannon Index has been the most widely used in aquatic work.

The use of diversity indices to summarize faunal changes resulting from pollution or other stress has been recommended. Wilhm and Dorris (1966) correlated low benthic invertebrate diversity with enrichment from a sewage effluent. Wilhm (1970) surveyed several streams subject to various industrial or urban impacts and concluded that $\bar{H}$ was a reasonable measure to describe benthic communities; values of less than 1 indicated communities under pollutional stress and values of 3 to 4 were found in streams of high water quality. Cairns and Dickson (1971) summarized that stress to a stream lowers invertebrate diversity; conversely, clean streams supported diverse, more stable faunas. Ransom and Prophet (1974) used the Shannon Index to describe benthic invertebrate diversity and generalized on water quality from these observations.

It has been proposed that highly diverse communities are more stable than less diverse ones (Elton 1958, Odum 1971). This concept may be related to a function ($S = \Sigma p_i \log p_i$) proposed to measure community stability in terms of energy passing through trophic levels (MacArthur 1955); hence stability was related to the number of links in the food web. This function resembles the Shannon equation for diversity with the exception that units of energy are replaced by numbers and species.

The concept of community diversity and diversity-stability has been criticized. Sager and Hasler (1969) stated that the indices are insensitive to rare species which may be biologically important. Hurlbert (1971) called species diversity a non-concept without biological relevance whose use should be at least restricted to measuring species richness and evenness. These two components have been criticized, however. Low numbers of individuals evenly distributed among a few taxa can result in high diversity and the term evenness may be misleading since most communities are dominated by a few successful species at each trophic level (Hocutt 1975). Goodman (1975) reviewed the stability-diversity theory and concluded that there was no scientific proof yet to support this concept.

The inherent physical nature of a stream influences the faunal composition and should be at least qualitatively evaluated in stream surveys. Substrate may be the most important factor affecting invertebrate distribution and standing crop (Pennak 1971). Larger substrate sizes and bedrock have been shown to support a greater standing crop and different species composition than finer substrates (Pennak and

Van Gerpen 1947, Barber and Kevern 1973). However, certain insects may preferentially select habitats on the basis of small substrate particles (Cummins and Lauff 1969). Substrate composition is often related to the sorting action of current (Macan 1961); however, current velocity itself may influence invertebrate distributions. Dodds and Hisaw (1925a) noted that certain caddisflies were selective to current velocity in their choice of habitat. The distribution of the blackfly larva, *Simulium ornatum* Mg., is related to current speed (Phillipson 1956) and the distribution of net spinning caddisflies is influenced by current velocity (Edington 1968).

Temperature influences the range of aquatic insects by limiting the success of sensitive stages or by influencing emergence (Macan 1960). Dodds and Hisaw (1925b) related the altitudinal zonation of aquatic insects to gradations in water temperature.

Other physical factors including stream width and vegetation affect invertebrate distributions. Narrow streams generally support a less diverse fauna (Pennak 1971), and riparian vegetation influences water temperature and primary production by shading, is an energy source, and provides oviposition sites for certain aquatic organisms.

DESCRIPTION OF STUDY AREA

Rosebud Creek originates on the east slope of the Wolf Mountains in Bighorn County, Montana, then flows northeast for approximately 370 stream kilometers before joining the Yellowstone River near Rosebud, Montana. The total area drained is near 3,372 km^2 (U.S. Geological Survey 1975). A sparsely populated alluvial plain about 0.8 km wide supports the agriculturally oriented domiciles. Alfalfa, wild hay, and grains are cultivated and livestock are pastured on the flood plain and the stream provides water for irrigation and livestock. Near the headwaters Rosebud Creek flows through the Northern Cheyenne Indian Reservation and past the town of Busby, Montana.

Riparian vegetation consists of mixed grasses, boxelder (*Acer negundo* L.), green ash (*Fraxinus pennsylvanica* Marsh), chokecherry (*Prunus* sp.), rose (*Rosa* spp.), willow (*Salix* spp.), and buffaloberry (*Shepherdia* sp.). Grasses include 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 providing good wildlife habitat and aiding in soil stabilization.

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

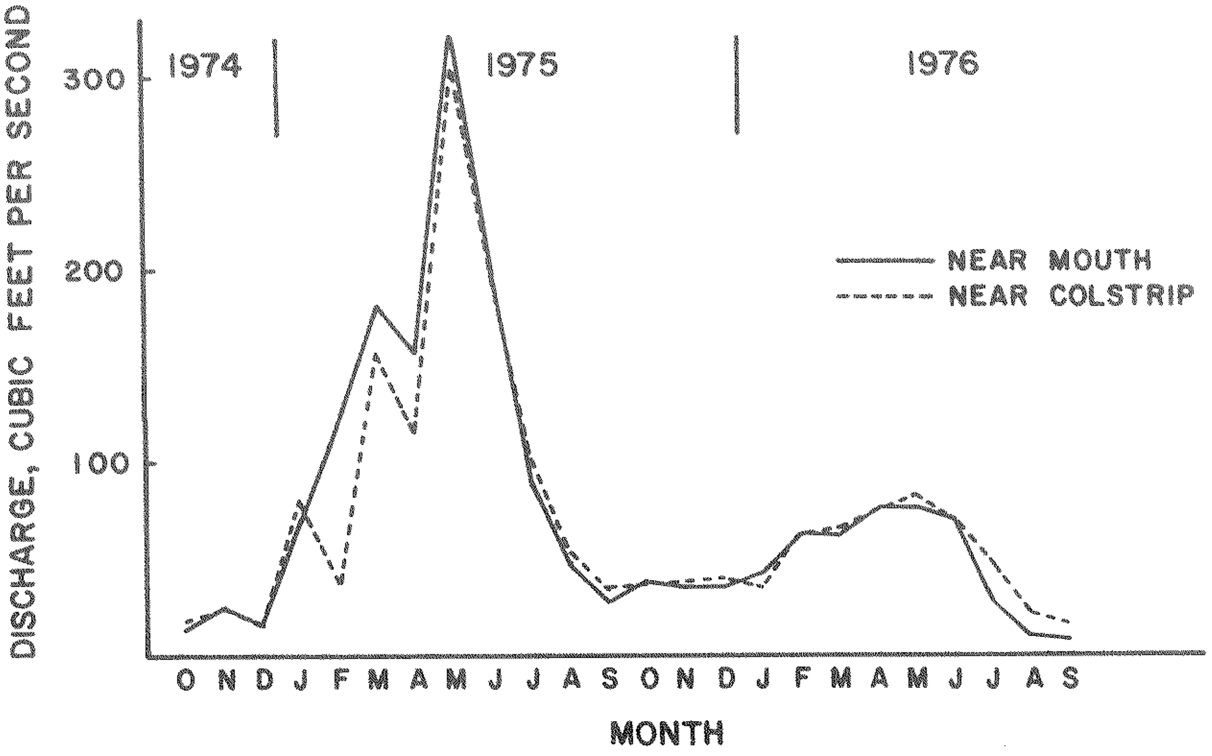
Union formation which erode at moderate rates. Coal outcrops have burned in the middle and upper Rosebud drainage and have metamorphically altered adjacent layers producing red to lavender beds of highly fractured clinker often incorrectly called scoria (Renick 1929). This material is highly resistant 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, personal communication).

Mean monthly flows for Rosebud Creek during water years 1975 and 1976 are shown in Figure 1. Rapid fluctuations in discharge can occur during spring and summer rainfall. The mean annual flow is 35.8 cfs; mean flow for March, the month of maximum flow, is 84.3 cfs, and the mean flow for September, the month of minimum flow, is 6.4 cfs. There are records of approximately 3000 cfs in March and periods of no flow occur in dry years (U.S Geological Survey 1975).

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

Figure 1. Monthly mean discharge for Rosebud Creek at the mouth and near Colstrip for water years 1975 and 1976[a] (U.S. Geological Survey 1975).



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[a] 1976 data are provisional and subject to change

The headwaters of Rosebud Creek are erosional in nature due to the steep gradient (4.8 m/km) and a riffle-pool system exists that is similar to a mountain stream. On leaving the mountains near Busby, Montana, and flowing onto the plains; however, 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. Turbidity and suspended sediments also increase downstream.

The last 80 km of Rosebud Creek could be called a transition prairie stream. A typical prairie stream has been described as having high turbidity and being depositional in nature. Rapid fluctuations in discharge result in removal of humus or organic material from the substrate which is generally unstable and composed of shifting clay, sand, or gravel. In addition, streamside vegetation is sparse (Jewell 1927). Carlander et al. (1963) described a true prairie stream as being nearly devoid of benthic life and having substrates practically free of organic deposits. Certain of these criteria, notably, high turbidity, areas of shifting substrate, and rapid fluctuations in discharge, are true of Rosebud Creek. However, the banks are heavily vegetated, there are extensive organic deposits in the substrate, and a moderately diverse benthic fauna with high population numbers exists. Consequently, Rosebud Creek would not be called a typical prairie stream according to either of the classifications given above.

DESCRIPTION OF SAMPLING STATIONS

Seven benthic invertebrate sampling stations were established in February 1976 and numbered consecutively upstream (Table 1 and Figure 2). Selection was made on the basis of concurrent chemical studies (Thurston et al. 1976), physical similarity, access, and potential for evaluating impacts from coal development. An attempt was made to include three habitat types (riffles, runs, and pools) at each station.

Station 1 is downstream from direct effluents from coal development. Stations 2 through 5 are within the projected plume fallout area from generator stack emissions. In addition, stations 3 and 4 bracket Cow Creek to evaluate potential effluents from that source. As a control, station 6 was established upstream from the plume fallout area. Rosebud Creek, at station 7, is similar in nature to a mountain stream; this aided in describing the composition and distribution of benthic invertebrates.

In addition to other physical parameters (Table 2), a subjective evaluation of the predominant substrate type at each station was made utilizing the classification of Cummins (1962). 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

Table 1. Sampling stations, locations and descriptions, Rosebud Creek, Montana.

Station	Elevation (meters)	Kilometers from Yellowston R.	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 N. Cheyenne Reservation
7	1195	85.8	NW1/4 Sec 29 R39E T6S	Near Kirby at Highway 314 culvert

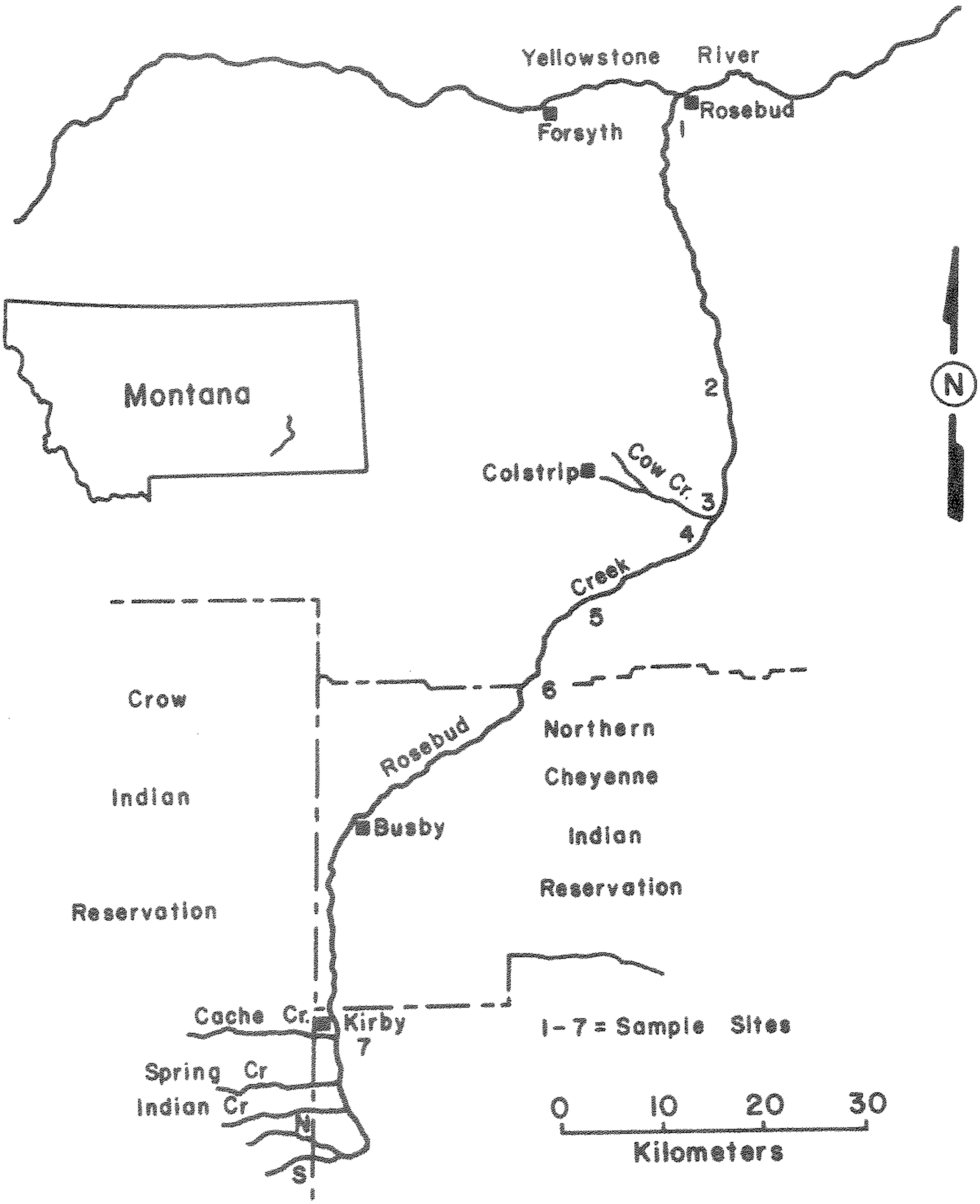


Figure 2. Rosebud Creek benthic invertebrate sampling stations.

Table 2. Physical measurements of Rosebud Creek sampling locations in 1976.

Station	1	2	3	4	5	6	7
Mean width (meters)	7.5	5.0	4.2	3.6	5.5	6.1	2.5
Mean depth (meters)	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 Aug. max.	23.4		22.0		19.5		20.0
Mean Aug. min.	19.3		20.4		17.4		15.9
Mean Oct. max.	4.1		3.7				5.2
Mean Oct. min.	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 (percent) in the following sequence: rubble, gravel, sand, silt, clay

[b] Composition (percent) in the following sequence: trees, shrubs, grass

Table 11 (continued)

	1	2	3	4	5	6	7
Trichoptera (continued)							
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
Lepidoptera							
Pyralidae							
Cataclysta sp.	X						
Coleoptera							
Dytiscidae							
Liodessus affinis (Say)				X	X		X
Hydrophilidae							
Helophorus spp.	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		

Table 11 (continued)

	1	2	3	4	5	6	7
Diptera (continued)							
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		
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

Table 11 (continued)

	1	2	3	4	5	6	7
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 12. Number of occurrences[a] and average number per occurrence[b] for aquatic macroinvertebrates collected in introduced substrate samplers, Rosebud Creek, Montana, 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)	--	--	--	--	--	--
Rithrogena 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)

Table 12 (continued)

	Sampling Stations						
	1	2	3	4	5	6	7
Odonata (continued)							
Libellulidae							
Sympetrum sp.	1(1)	--	--	--	--	--	--
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 12 (continued)

	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 12 (continued)

	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 12 (continued)

	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 12 (continued)

	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 spp.	1(1)	2(1)	3(2)	7(7)	1(1)	2(2)	1(3)

[a] dash indicates absence from samples

[b] in parentheses

Table 13. Number of occurrences[a] and average number per occurrence[b] for aquatic macroinvertebrates collected in Ekman dredge samples, Rosebud Creek, Montana, 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 spp.	2(3)	--	1(1)	1(1)	--	--	--

Table 13 (continued)

	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 (*Leptocella*) sp.	--	--	--	--	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 13 (continued)

	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)	--	--	--
Basommatophora							
Physidae							
Physa spp.	1(1)	--	--	2(2)	--	--	--

Table 13 (continued)

	Sampling Stations						
	1	2	3	4	5	6	7
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 14. Number of occurrences[a] and average number per occurrence[b] for aquatic macroinvertebrates collected in modified Hess samples, Rosebud Creek, Montana, March 1976 to March 1977.

	Sampling Stations				
	1	3	5	6	7
Ephemeroptera					
Ephemeridae					
Ephoron album (Say)	--	2(2)	1(1)	--	--
Heptageniidae					
Heptagenia eleganula (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 14 (continued)

	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 14 (continued)

	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 14 (continued)

	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 14 (continued)

	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 number of selected taxa per introduced substrate sample, Rosebud Creek, Montana, May 1976 to March 1977.

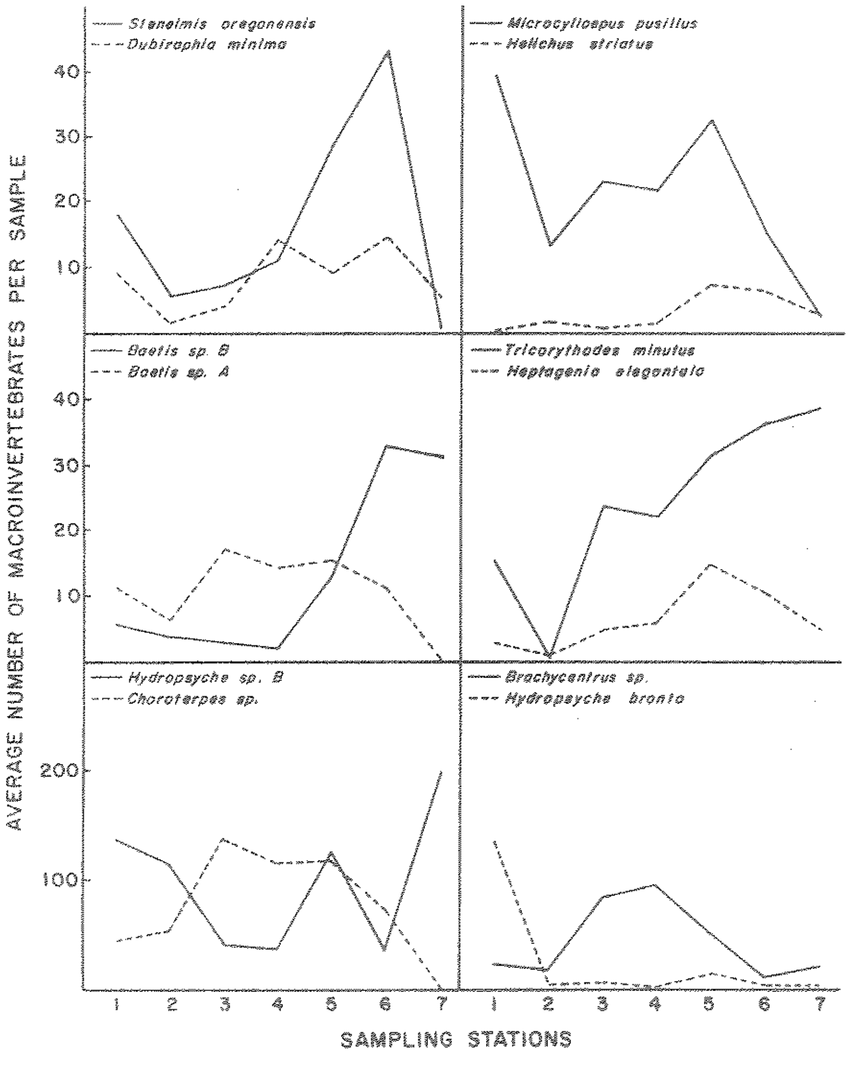
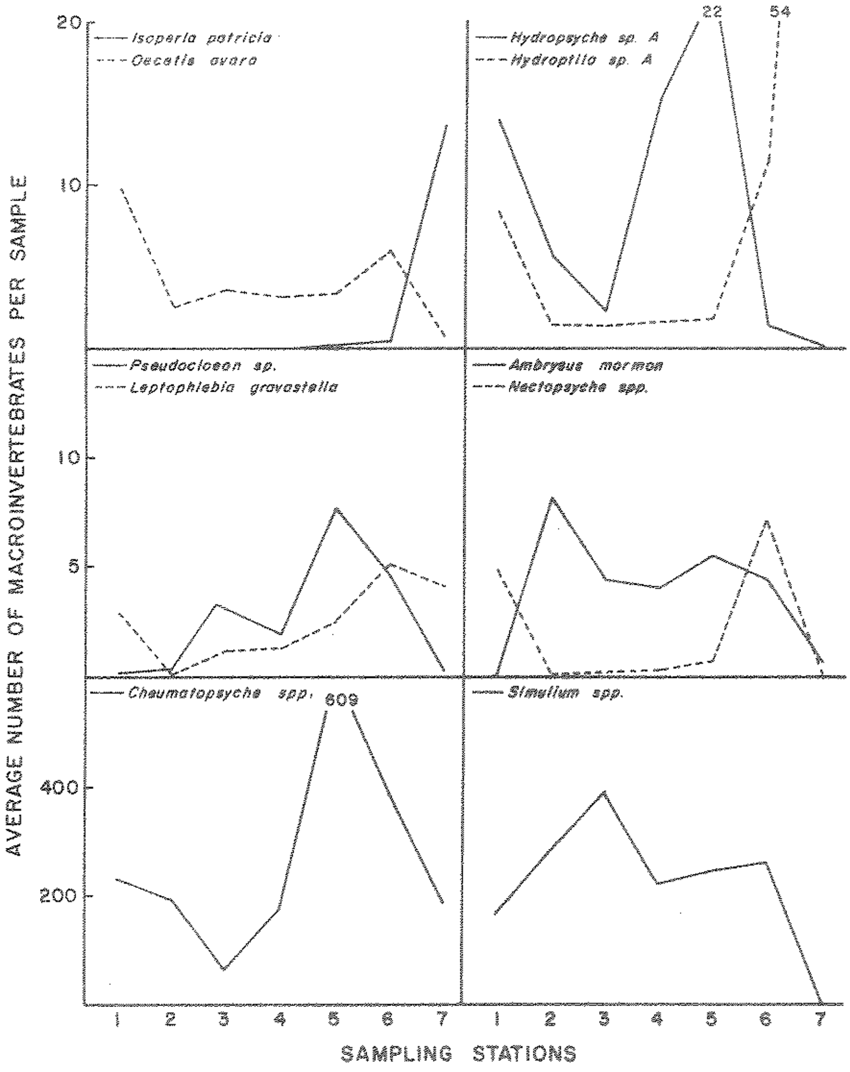


Figure 9. continued:



sp., *Ambrysus mormon*, *Simulium* spp., and *Sphaerium* spp., appeared to be most abundant in the mid-Rosebud and did not increase in numbers progressively upstream. *Hydropsyche* sp. A, *Cheumatopsyche* spp., and *Pseudocloeon* sp., common in Rosebud Creek, were most abundant at station 5.

Restricted distribution patterns were evident in less common taxa (Table 11). *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. was collected in silted substratum at stations 6 and 7 but 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. was collected only at station 7; however, this genus is abundant further upstream in Rosebud Creek. Plecoptera were rare; however, nymphs of a winter stonefly, *Brachyptera* spp., were present at stations 1 through 6 possibly corresponding 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 were collected only from the unique habitat present at station 1; e.g., *Isonychia sicca, Hydropsyche* sp. C, *Cataclysta* sp., and *Sympetrum* sp.

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).

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 15.

Introduced Substrate Samples

The average number of taxa per sampler (Table 5) is highest at stations 5, 6, and 7 in concordance 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 contradictory to

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

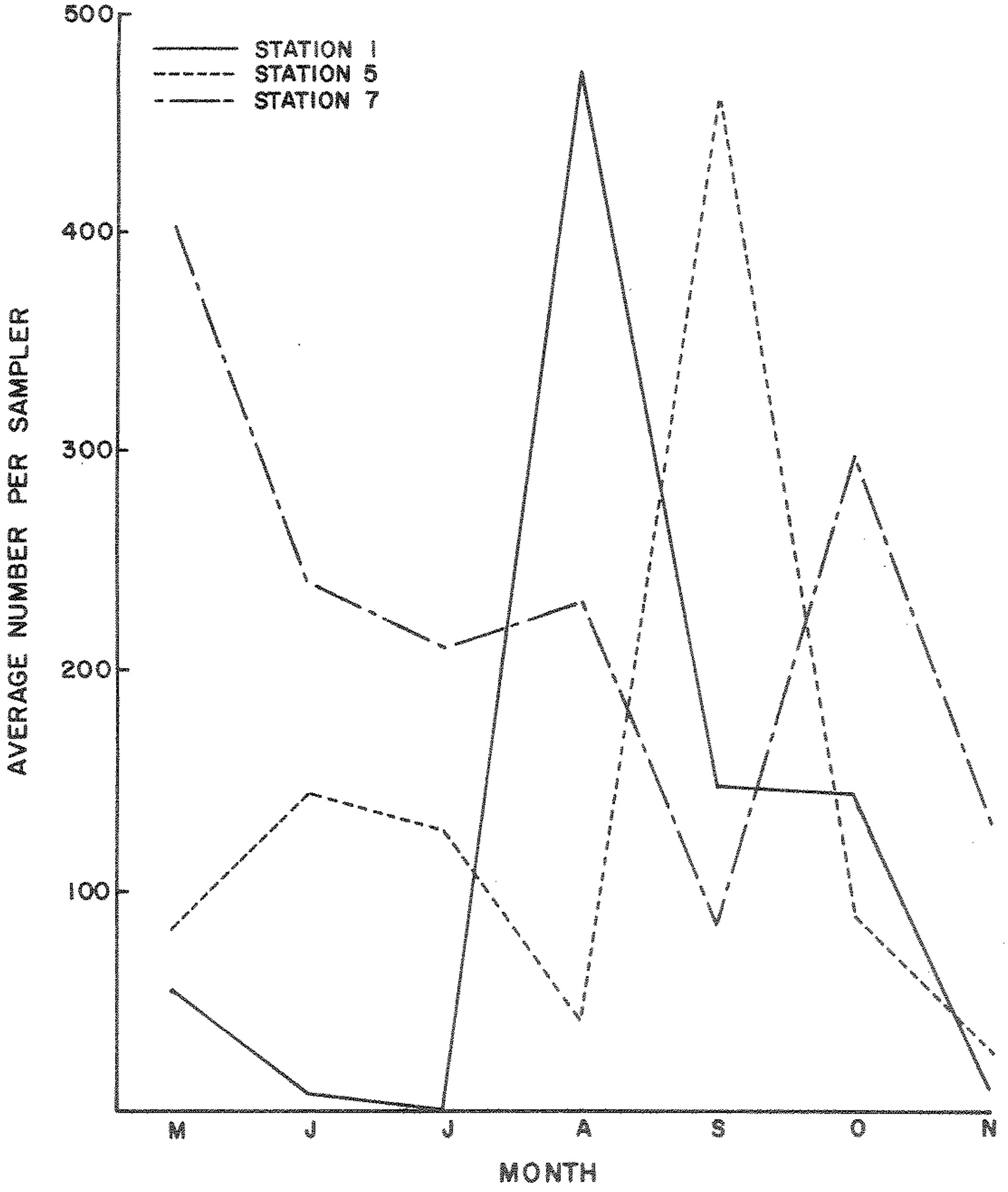


Figure 11. Seasonal variations in mean total numbers of *Dubiraphia minima* per introduced substrate sample at stations 1, 5, and 7, Rosebud Creek, Montana, May 1976 to November 1976.

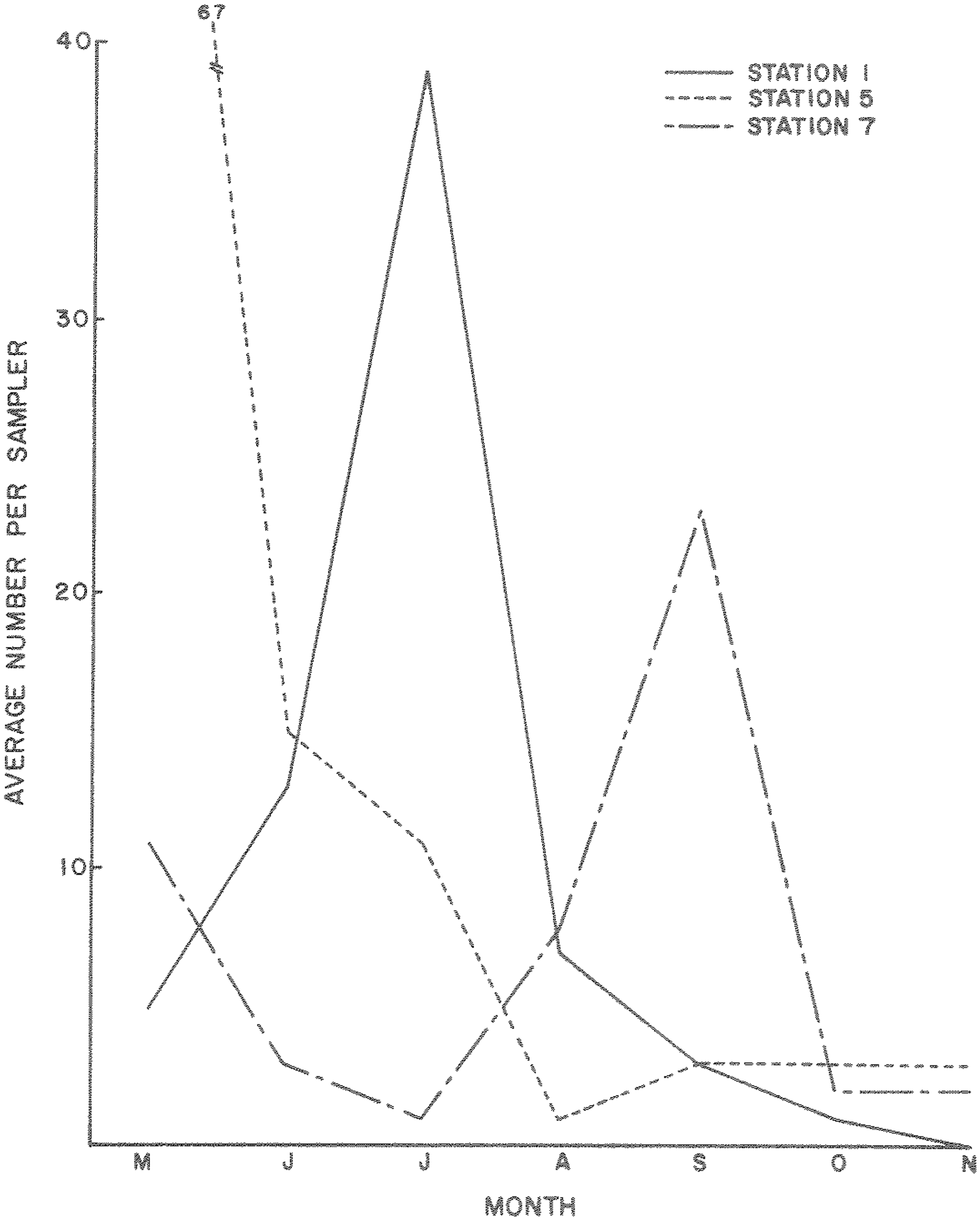


Figure 12. Seasonal variations in mean total numbers of *Choroterpes albiannulata* per introduced substrate sample at stations 1, 5, and 6, Rosebud Creek, Montana, May 1976 to November 1976.

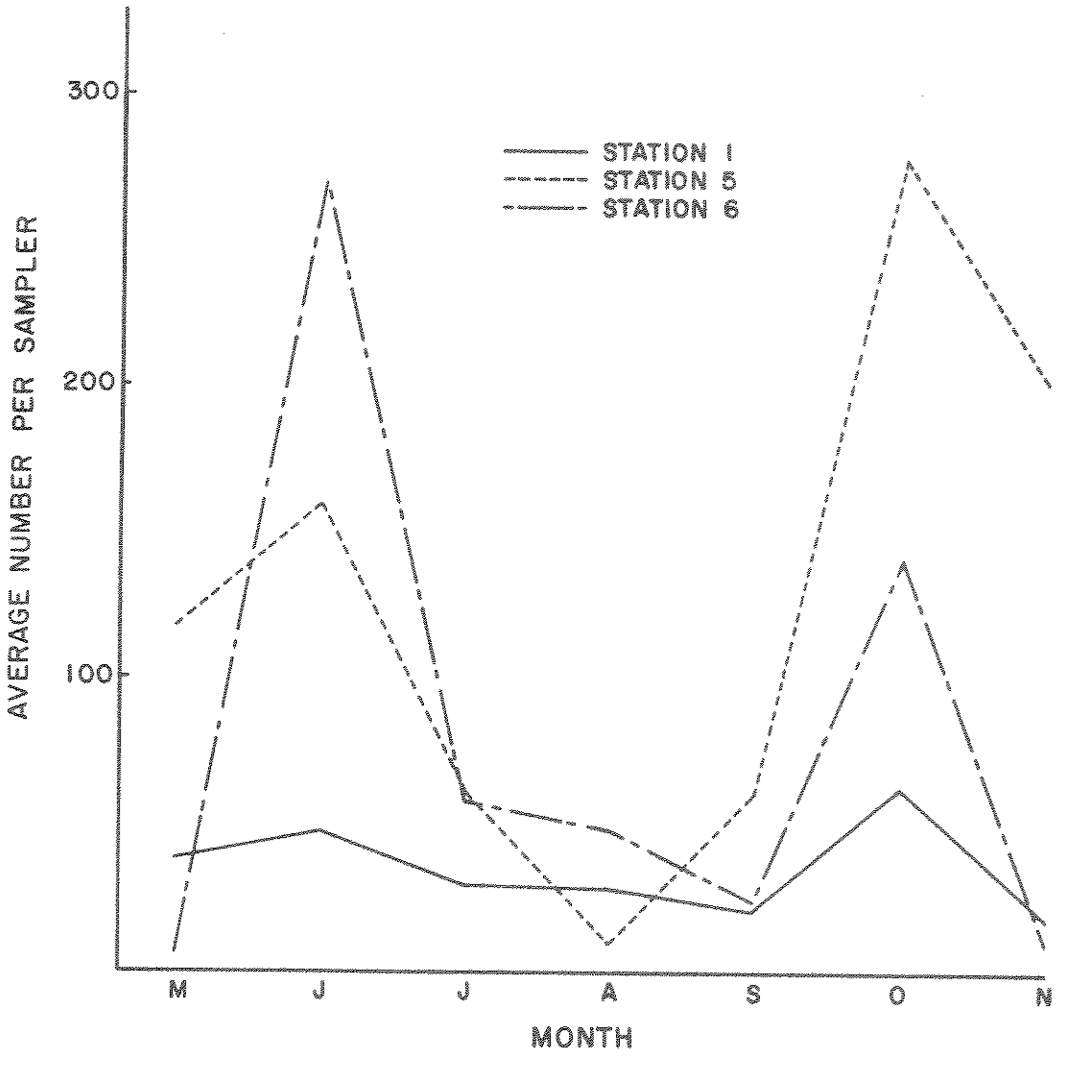


Figure 13. Total number of taxa per station and number of taxa collected by each of three sampling methods from Rosebud Creek, Montana, March 1976 to March 1977.

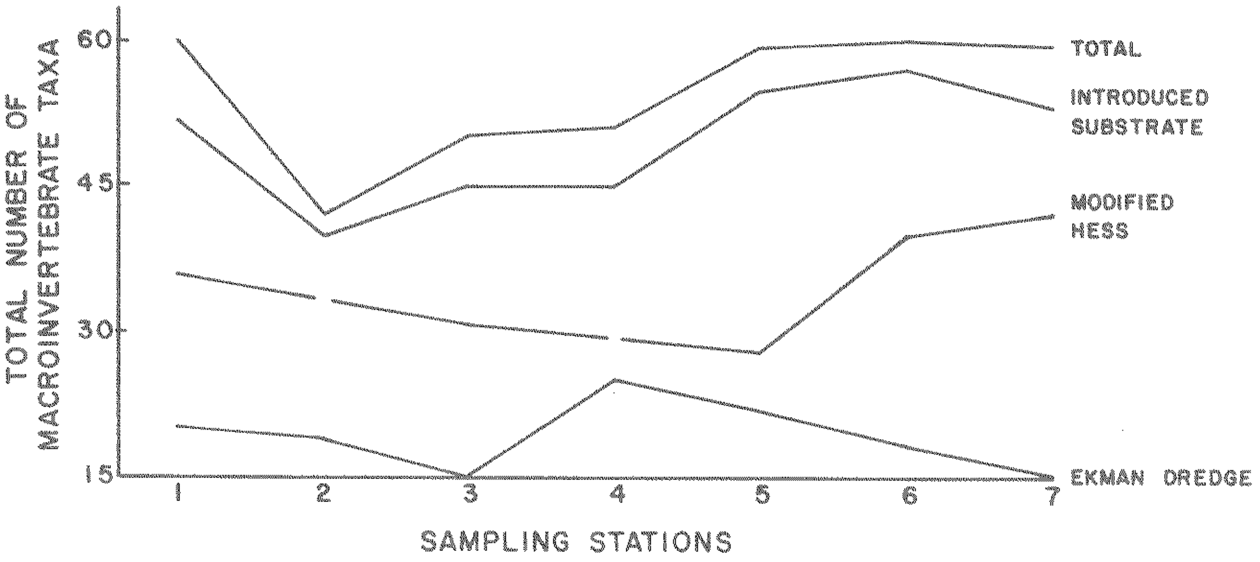


Table 15. Mean macroinvertebrate diversity and redundancy per sample, Rosebud Creek, Montana, March 1976 to March 1977.

	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

results from introduced substrate and modified Hess samples. Station 3 was also low for average number of taxa per sample.

Modified Hess Samples

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

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. Longitudinal variations in the benthic macroinvertebrate fauna are, at this time, attributable to influences from the intrinsic physical-chemical nature of Rosebud Creek and to impacts from domestic and agricultural practices. Variations in the benthis community among sampling stations are not due to effluents from coal mining or combustion.

Water Chemistry

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 was generally low but sporadic influxes occurred which exceeded the criterion concentration of 0.05 μg/l total mercury recommended 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). Although 96 hour tests are not representative of stream conditions, present mercury concentrations will probably have no apparent influence on the macroinvertebrate fauna at this time.

Physical Conditions

Physical conditions of Rosebud Creek are typical of eastern Montana transition prairie streams; i.e., originating in the mountains then flowing onto the plains. 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 (Table 13). Turbidity results, in a traditional sense, from suspended particles or dissolved inorganic or organic substances. Measured by the nephelometric method turbidity is a gross reference to non-filterable colloidal or dissolved substances; however, high turbidity, by any sense, causes a decrease in euphotic zone depth due to light extinction and a consequential reduction in primary production (Bartsch 1959). Production from photosynthesis is exceeded by respiration in most temperate streams; hence, allochthanous material is an important source of energy (Boling et al. 1975). The turbid state of Rosebud Creek may result in allochthanous detritus becoming more significant as an energy source. It is conceivable that the benthic community may be composed of organisms utilizing primarily detrital food sources. Many benthic insects are opportunists using existing food supplies (Cummins et al. 1966). 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 (1925b) 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 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., 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) and may cause the apparent temporal patterns of emergence in *Hydropsyche* sp. B and *Dubiraphia minima* (Figures 10 and 11).

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 well to conditions found in Rosebud Creek. Near the headwaters gravel and cobble substrates are common; sand and gravel bed material is 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.

Two consequences of reduced gradient include diminished overall current velocity (Reid 1961) and lowered 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 competence or capacity then deposition or change in stream morphology will occur. In Rosebud Creek the increasing sediment load downstream coupled with low gradient (stations 2 through 5) results in deposition of sediments on the substratum.

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.

Deposition of inorganic sediment can turn otherwise suitable substrate into poor macroinvertebrate habitat (Cordone and Kelley 1961). Stable substrates are covered and, more important, 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, in Canada, that 83 percent of the benthic community lived below 5 cm in the substrate. Poole and Stewart (1976) reported that 33.6 percent 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). Also, at slow current speeds gravel and sand substrates become more stable and create an enriched environment suitable for many invertebrates. In Rosebud Creek, the predominant long reaches with slow current velocities ranging from approximately 0. to 0.6 m/sec support productive bottom faunas, e.g., Oligochaeta and Chironomidae, dependent on allochthanous detritus.

Sedimentation and a decrease in overall substrate size probably results in 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. Introduced substrates showed low numbers at stations 2, 3, and 4 which, although variables of substrate and current are accounted for, may be due to low populations of benthic macroinvertebrates in these sections of Rosebud Creek.

Substrate conditions at the point of sampling influence results from modified Hess and Ekman dredge samplers. The infrequence of riffles in Rosebud Creek at many stations precludes a choice of sampling location. For example, the existing riffle at station 5 consists of unstable gravel which may be the cause for 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 can likewise be attributed to the influence of sand substratum common in pools at station 6. 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 are usually more productive in terms of benthic invertebrates than lentic stretches with the same substrate. Long, slow stretches in Rosebud Creek may reduce numbers or eliminate various species. For example, Hydropsychidae, encountered in lower numbers at stations 2, 3, and 4, are generally found in rapid portions of streams and depend on current for proper functioning of their nets (Ross 1944). 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 influence the distribution of these and other taxa (Figures 9 and 10) but probably has a more profound effect by influencing substration composition.

The tendency for various taxa to be low in abundance at stations 2, 3, and 4 is influenced by any one or a combination of the physical conditions imposed by extreme turbidity, sediment deposition, substrate size, slow current velocity, and high temperature in Rosebud Creek. Certain of these conditions culminate at station 2 (low gradient, silted substratum, and slow current velocity) and impose unfavorable conditions for many macroinvertebrates. Conversely, upstream sections, because of increased gradient, and decreased turbity and temperature, support 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 Yellowstone River, in this area, 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 exists 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 are greater than the average 2809 invertebrates per m^2 for the middle Yellowstone River (Thurston et al. 1975). In comparison with a typical western Montana mountain trout stream of similar size, Roemhild (1971) collected data showing the West Fork of the Gallatin River and its tributaries to average 1877 invertebrates per m^2.

Among important conditions conducive to high population numbers of benthic macroinvertebrates in Rosebud Creek is the intact riparian vegetation which keeps the stream within its banks preventing extreme erosion, scouring, siltation. In addition, this vegetation provides an important energy source, a prime factor determining microdistribution of aquatic organisms (Egglishaw 1964), and significant in Rosebud Creek where turbidity limits primary production.

Many of the commonly encountered macroinvertebrates of Rosebud Creek are adapted to live in turbid, silt laden, or slow flowing habitats. *Cheumatopsyche* spp. is reported to be tolerant of a wide range of ecological conditions; *Cheumatopsyche lasia* is 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. Taxa that are numerically most abundant in the mid-Rosebud are, interestingly, those thay may have wide tolerances to ecological conditions, e.g., *Simulium* spp., *Choroterpes albiannulata*, *Sphaerium* spp., and *Ambrysus mormon*. As a generalization, aquatic invertebrates present in large numbers in 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 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 bottomed 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 percent of the total taxa found, respectively. Introduced substrates were most efficient in collection of numbers and taxa; 89 percent of the total taxa collected including 22 not collected by other methods was found in introduced substrate samples. Certain organisms, e.g., *Ephoron album* and *Cataclysta* sp., were collected in modified Hess samples but 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 bottomed runs that are the most common habitat in Rosebud Creek were efficiently sampled by introduced substrates.

Variables of sample size, substrate, and current velocity were controlled to some degree making quantitative comparisons between stations more valid than with conventional grab type samplers. In addition, the proficiency for collecting the endemic taxa was remarkable. However, because introduced substrates offer an ideal habitat for selective colonization by certain macroinvertebrates, they did not represent the existing standing crop, population numbers, or distribution of individuals among the species. For example, they may be attractive for colonization by various organisms that prefer clean substrates exposed to the current; e.g., Simuliidae, Hydropsychidae and Baetidae. Yet, because the samplers rest on the substrate, a degree of sedimentation occurs and invertebrates including Chironomidae, Oligochaeta, Odonata, and Sphaeriidae that dwell in fine substrates also colonize the samplers. For these reasons the number of taxa collected and their distributions among sampling stations were representative of the faunal composition and conditions at the sampling sites. To assess population numbers and standing crop, it would be necessary to sample and analyze cores of 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, for example, *Brachyptera* spp.

is present in winter and spring but not 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.

CONCLUSIONS

1. 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, and not to influences from coal mining and combustion.

2. Common macroinvertebrates of Rosebud Creek are adapted to the conditions of a transition prairie stream; i.e., high turbidity, slow current velocity, warm summer water temperature, and silted substratum; however, these conditions caused decreased numbers and diversity at downstream stations (2-4).

3. High turbidity probably interferes with primary production in Rosebud Creek making allochthanous detritus important as a food source for the benthic community.

4. 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.

5. Rosebud Creek supports high numbers of benthic invertebrates in comparison with some other Montana streams.

6. Introduced substrate samplers were efficient in sampling the long, slow runs common in Rosebud Creek.

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APPENDIX

Table 16. Mean current velocity 7.5 cm from the substrate and 15 cm upstream of introduced substrate samplers, Rosebud Creek, Montana, 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 17. Adult aquatic insects from near Rosebud Creek, Montana, during 1976.

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

- 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