INVERTEBRATE COMMUNITIES OF SMALL STREAMS IN NORTHEASTERN WYOMING

By David A. Peterson

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4287

Cheyenne, Wyoming

1990

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Readers who prefer to use metric (International System) units rather than the inch-pound units used in this report may use the following conversion factors:

Multiply inch-pound unit	By	To obtain metric unit
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
square foot	0.0929	square meter
inch	2.540	centimeter
mile	1.609	kilometer

To convert degrees Celsius (°C) to degrees Fahrenheit (°F), use the following formula:

$$°F = 9/5\ (°C) + 32$$

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ABSTRACT

Invertebrate communities of small streams in an energy-mineral-development area, the Powder River structural basin of northeastern Wyoming, were studied during 1980-81. The largest average density of benthic invertebrates among 11 sites was 1,040 invertebrates per square foot at a site on a perennial stream, the Little Powder River at State Highway 59. The smallest average densities were 3.4 invertebrates per square foot in Salt Creek and 16.6 invertebrates per square foot in the Cheyenne River, two streams where the invertebrates were stressed by degraded water quality or inadequate substrate or both. The drift rates of invertebrates were larger in three perennial streams than the drift rates in intermittent and ephemeral streams.

Analysis of the invertebrate communities using the Jaccard coefficient of community similarity and a cluster diagram showed communities inhabiting perennial streams were similar to each other, because of the taxa adapted to flowing water in riffles and runs. Communities from sites on ephemeral streams were similar to each other, because of the taxa adapted to standing water and vegetation in pools. Communities of intermittent streams did not form a group; either they were relatively similar to those of perennial or ephemeral streams or they were relatively dissimilar to other communities. The communities of the two streams stressed by degraded water quality or inadequate substrate or both, Salt Creek and the Cheyenne River, were relatively dissimilar to communities of the other streams in the study.

INTRODUCTION

The large and continuing expansion of the energy-mineral industry in the Powder River structural basin has created public interest in the condition of streams of the area. The energy-mineral developments of greatest economic importance currently (1985) are coal surface mines and oil wells, but uranium and bentonite also have been mined in the basin. Most streams in the area of active development are small plains streams that do not support a sport fishery, provide a municipal water supply, or provide substantial quantities of water for irrigation; consequently they have received little attention. The resulting lack of data has handicapped regulatory agencies, land-use planners, industry, and other groups concerned with assessing the possible effects of energy-mineral development on the flow and aquatic environment of small streams. Because invertebrate communities are indicators of the quality of the aquatic environment, the U.S. Geological Survey conducted a study of invertebrate communities in the Powder River structural basin during 1980-81 as part of its Coal Hydrology Program.

Knowledge of the composition of benthic invertebrate communities can be useful in water-quality studies, as well as in evaluating ecological effects of energy-mineral development. Past environmental conditions in a stream can be theorized by studying the existing aquatic community, because the community is composed of types of organisms adapted to the long term environmental conditions. The use of aquatic invertebrates as indicators of water quality has been well documented (Larimore, 1974; Wilhm and Dorris, 1966).

Purpose and Scope

The purpose of this report is to describe the benthic invertebrate communities of streams in an energy-mineral-development area, in a manner useful to regulatory agencies, industry, and other groups. During this study, an attempt was made to determine which, if any, aquatic invertebrates are unique to alluvial valley floors, and whether they form a recognizable community that could be used in identification of alluvial valley floors. The occurrence of invertebrate communities restricted to a flowing-water habitat and their potential for recolonization after disturbance were assessed.

Eleven stream sites were sampled 7 times during 11 months in 1980-81; 4 other sites were sampled on a miscellaneous basis. Invertebrates were sampled in stream riffles, runs, and pools, and under drifting conditions, to determine the community composition. Physical and chemical measurements were made to characterize the habitats and to identify critical factors in community development.

Aquatic Biota

The invertebrates found in streams generally are immature insects, such as mayfly nymphs (Ephemeroptera), dragonfly and damselfly nymphs (Odonata), caddisfly larvae (Trichoptera), and midge, blackfly, deerfly, and other true fly larvae (Diptera). The adults of these insects are terrestrial. Other insects, such as beetles (Coleoptera) and true bugs (Hemiptera) can be aquatic during both immature and adult stages. Aquatic invertebrates that are not insects include snails, leeches, aquatic earthworms, and crustaceans. Aquatic invertebrates are illustrated and described in more detail by Pennak (1978) and Merritt and Cummins (1978).

Invertebrates often are referred to in this report as either benthic or drift. Benthic invertebrates are found within or on the substrate, which is the stream bottom including submerged objects such as vegetation and logs. Drift invertebrates are those drifting with the stream current. Waters (1972) defined three drift patterns: behavioral drift, which occurs during the night or some consistent period of the day; catastrophic drift, which occurs as a result of a physical disturbance of the invertebrates; and constant drift, which occurs at all times and involves a few occasional individuals of all taxa present. Taxon (plural, taxa) is a general term used to describe a distinct taxonomic entity that is not necessarily identified to a consistent taxonomic level (such as genus level).

Aquatic vegetation is important to invertebrate communities, because the vegetation provides food or shelter or both. Aquatic vegetation includes macrophytes, periphyton, and phytoplankton. Macrophytes are relatively large plants, with roots, stems, and leaves, and may be submerged or emergent. Periphyton is algae attached to the substrate. Although algae are single-celled, some algae grow in filaments and form clumps of periphyton. The third type of aquatic vegetation is phytoplankton, which is algae suspended in the water.

Description of the Study Area

The Powder River structural basin is located in northeastern Wyoming and southeastern Montana. The sample-collection sites are located in or near the Wyoming part of the basin (fig. 1). A semiarid climate prevails throughout the study area, which receives an average-annual precipitation of 12 to 16 inches. The predominant vegetation is sagebrush and grass.

Streams in the study area can be grouped into three streamflow types: (1) Perennial streams that flow all year; (2) intermittent streams that often cease flowing during the seasonal low-flow period; and (3) ephemeral streams that flow only in response to precipitation. Each of the three stream types supports an aquatic community adapted to the duration of flow and other environmental factors.

Invertebrate habitat in streams includes riffles, runs, and pools. Within the context of an aquatic continuum, with riffles at one end of the scale and pools at the other end, runs are an intermediate gradation having some characteristics of both pools and riffles. Runs have slower water velocities and are deeper than riffles, but have faster velocities and are shallower than pools. For comparison, riffles may be considered equivalent to lotic-erosional habitats, and runs equivalent to lotic-depositional habitats, as described by Merritt and Cummins (1978, p. 30).

The flow pattern of a stream is displayed graphically in a flow-duration curve. A curve from a perennial stream either has a relatively flat slope throughout the range of flow or has a steep slope at large streamflows and a flat slope at small streamflows. The flatness at small streamflows is due to ground-water inflow to the stream, sustaining flow between precipitation runoff. In contrast, the flow-duration curve of an ephemeral stream is steeply sloped throughout the range of flow, with no flow indicated for a large percentage of the time. The steep slope indicates a "flashy" type of flow, rapidly increasing and decreasing in direct response to precipitation. The flow-duration curve of an intermittent stream has a small flat area at small streamflows, intermediate to the curves of perennial and ephemeral streams. At least 5 years of daily streamflow record usually is needed to plot a flow-duration curve representative of long-term average flow conditions. Examples of flow-duration curves for each of the three streamflow types are included in subsequent sections of this report. Searcy (1959) gives more detailed description of plotting and interpretation of flow-duration curves.

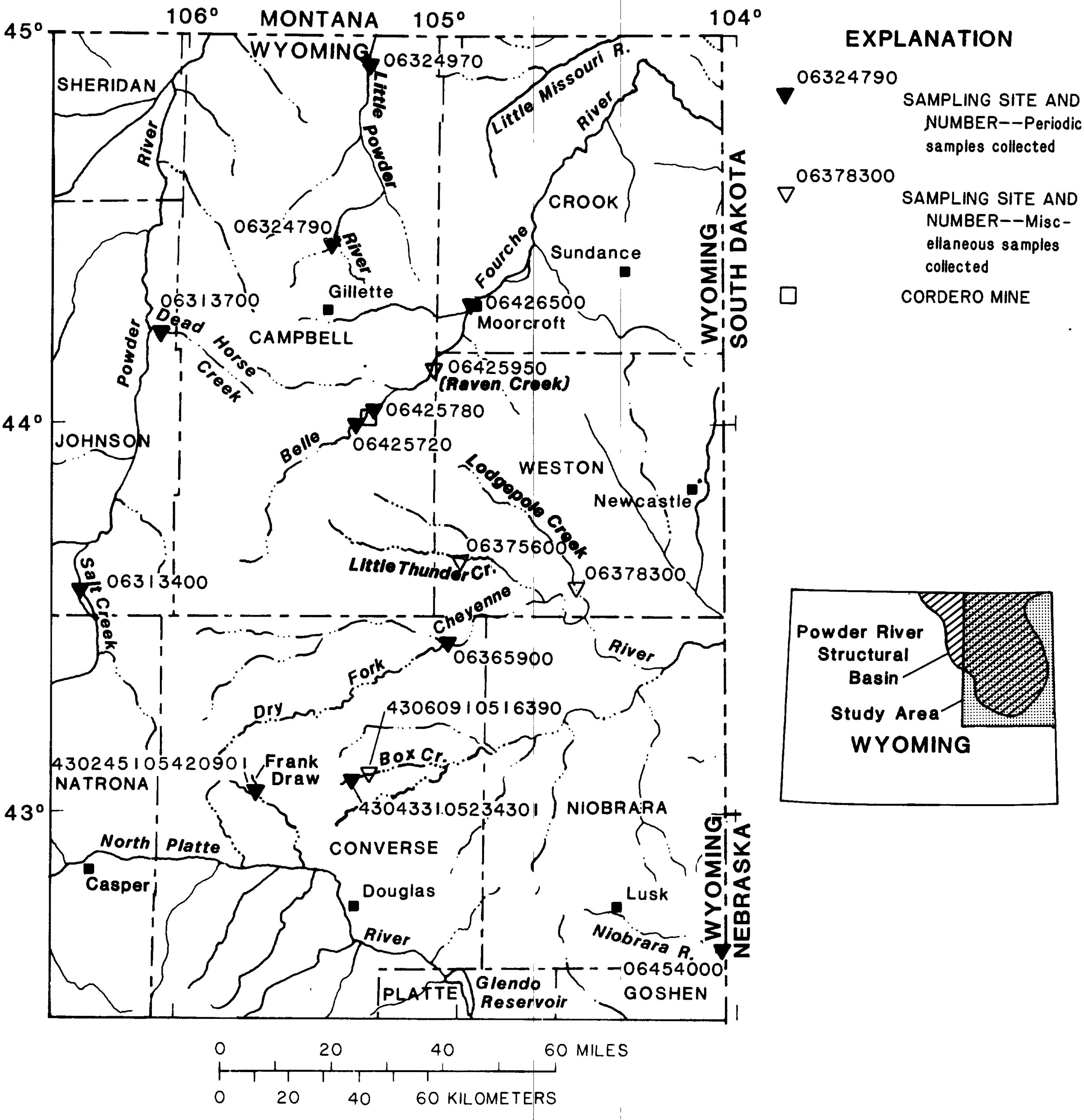


Figure 1.--Location of sampling sites.

The location of the sample-collection sites and their identification numbers are shown in figure 1. Eight-digit station-identification numbers customarily are assigned to locations where samples or measurements are made on a repetitive basis. The first two digits indicate the river basin in which the station is located; for example, 06 refers to the Missouri River basin. The remaining six digits are based on position in the river basin and increase in the downstream direction. Fifteen-digit station numbers are assigned to locations where samples or measurements are made on a miscellaneous basis. The 15-digit numbers consist of the latitude and longitude of the location and a 2-digit sequence number.

METHODS OF INVESTIGATION

The study focused on 11 sample-collection sites, which were visited 7 times during about 1 year. Samples also were collected on a miscellaneous basis at four other sites. The sites were selected on the basis of streamflow type, water quality, and substrate, in order to sample a variety of environments.

The choice of sampling devices varied with the conditions at the site. Devices included a Surber sampler, drift net, Ekman grab sampler, and dip net. The techniques used for invertebrate sampling and analysis have been described by Greeson and others (1977).

A Surber sampler and drift net were used when sufficient flow was present. The Surber sampler delineated 1 square foot of substrate, which was agitated and the rocks were scrubbed, so that the stream current carried the invertebrates into a catch net with a mesh-opening size of 1,050 micrometers. The 1,050-micrometer mesh was chosen instead of the more common 210-micrometer mesh because samples collected with the large mesh net contained a sufficient number of invertebrates to characterize the communities, and time and personnel costs for sorting of samples were less than with the smaller mesh size. One to four Surber samples were collected from the riffles (or runs) and composited for analysis. Duplicate samples also were collected on a few occasions and analyzed as separate samples.

Samples of the invertebrates drifting with the stream current were collected with a drift net during the daytime, generally for 1 hour. Samples also were collected at three sites during diel (24-hour) drift studies. The drift net had a mouth opening of 1.0 by 1.4 feet and a net mesh opening of 363 micrometers. The drift net, placed in riffles, was positioned to receive as much of the streamflow as possible, if streamflow was insufficient to totally immerse the net.

An Ekman grab sampler was used to sample 0.25-square-foot areas of pool substrates, when pools comprised all or a significant part of the aquatic habitat in the sample reach. Replicate samples were collected on many occasions, to better characterize the invertebrate community of the pools. The grab samples were rinsed through a sieve with a mesh opening of 210 micrometers. Qualitative samples were collected with a dip net on a few occasions.

Shannon-Weaver diversity indices of the invertebrate samples were calculated using a method described by Lloyd and others (1968). The equation used is:

$$H' = \frac{c}{N} (N \log_{10} N - n_i \log n_i), \qquad (1)$$

where H' is diversity;

c is 3.32, a factor for converting base-10 logarithms to base-2 logarithms;

N is total number of individuals;

n is number of individuals within the i th taxon; and

i is number of taxa.

The Shannon-Weaver indices were calculated using the greatest level of taxonomic identification, usually genus level. Generally, an index greater than 3 indicates a healthy community, an index of 1 to 3 indicates possible stress on the community, and an index less than 1 indicates severe stress on the community (Wilhm and Dorris, 1968). The Shannon-Weaver diversity index and other indices in common use are valid for infinitely large communities, but are susceptible to error with small collections. Because some of the collections in this study contained few individuals, the number of taxa identified in the samples also is discussed as a measure of diversity.

Physical and chemical measurements included dissolved oxygen, specific conductance, pH, and temperature, which were determined at the sampling site, usually for each sample date and site, using methods described by Skougstad and others (1979). In addition, samples for turbidity analysis usually were collected for each sample date and site. Samples for dissolved-solids and principal-ion concentrations were collected at selected sites during June, 1980. Results of the sampling-site determinations and the turbidity and chemical analyses were published by the U.S. Geological Survey (1981, 1982).

Bed-material samples were collected at 11 sites during June 1980, using methods described by Guy and Norman (1970). The samples were analyzed for particle-size distribution and the results are on file at the U.S. Geological Survey office in Cheyenne, Wyoming.

INVERTEBRATE COMMUNITIES IN PERENNIAL STREAMS

Invertebrate communities were sampled in four perennial streams: the Niobrara River, Frank Draw tributary number 2, the Little Powder River, and Salt Creek. These streams are representative of perennial streams in the study area. Flow duration curves for sites on the Niobrara River and Salt Creek are shown in figure 2.

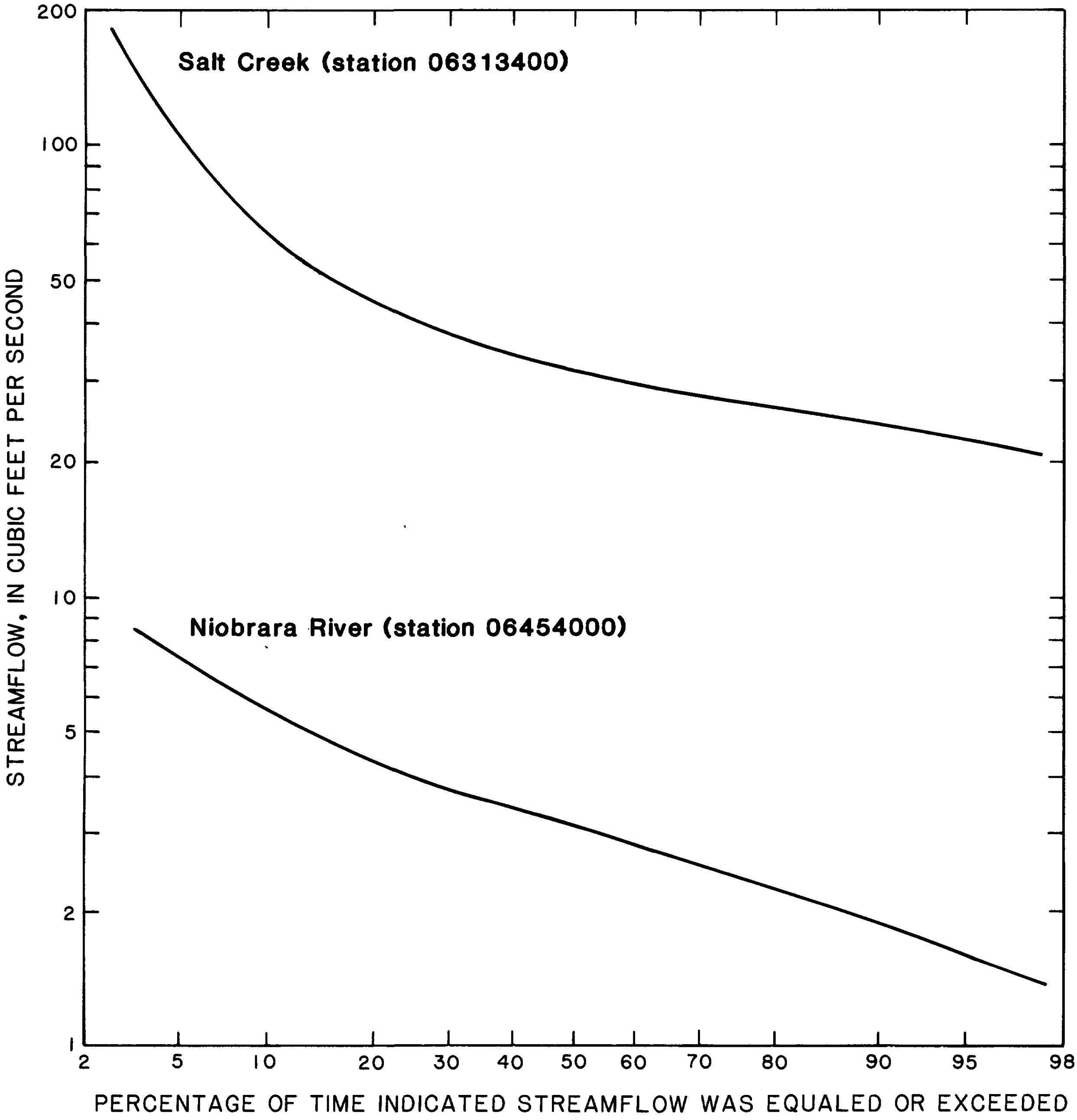


Figure 2.--Flow-duration curves for two perennial streams.

Niobrara River

The sample-collection site was located at gaging station 06454000, Niobrara River at Wyoming-Nebraska State line. Daily mean streamflow on the sample dates averaged 3.4 cubic feet per second. Aquatic habitat consisted of riffles and runs, without pools. The substrate of the riffles contained more than 80 percent gravel and cobbles. The substrate of the runs contained about 50 percent gravel and cobbles, and was covered with a layer of silt and organic matter. The runs also supported thick mats of macrophytes and periphyton during the summer months. Die-off and breakup of the mats during September affected the dissolved-oxygen concentrations and the drift samples.

Water-quality measurements included onsite determinations of dissolved oxygen, specific conductance, water temperature, and pH and sample collection for laboratory analysis of turbidity, usually on each sampling visit. Dissolved-oxygen concentrations were 10.0 milligrams per liter or greater on the sample dates, with the exception of September 1980. A minimum value of 4.4 milligrams per liter was recorded at 0215 hours on September 30, due to plant respiration and decomposition of the dead mats described above. The turbidity levels of 1 to 2 nephelometric turbidity units and specific conductance values of about 400 microsiemens per centimeter at 25 °Celsius reflect the generally small quantities of suspended and dissolved materials in the water, relative to other streams in this study. The median pH was 7.4.

Riffles in the Niobrara River supported relatively large numbers of benthic invertebrates. The maximum density was 2,770 invertebrates per square foot, during December 1980 (fig. 3). The average density was 772 invertebrates per square foot; the median density was 572 invertebrates per square foot. The median of the Shannon-Weaver diversity indices (fig. 3) was 2.57, indicating a relatively diverse and healthy community.

Trichoptera (caddisflies) predominated in many of the riffle samples (fig. 3). Numerically dominant caddisflies were: Helicopsyche borealis which normally is associated with running water (Wiggins, 1977, p.90), Cheumatopsyche which spins nets to filter food from flowing water (Wiggins, 1977, p. 100), and Onocosmoecus which can be found in either lentic (standing) or lotic (flowing) water (Wiggins, 1977, p. 268). The mayfly Baetis (Ephemeroptera) also was common in the samples. Baetis usually is found in shallow flowing water (Edmunds and others, 1976, p. 158-161).

Runs in the Niobrara River supported an average of 773 invertebrates per square foot, based on eight samples. The dominant invertebrates in samples from the runs were the midges (Diptera:Chironomidae) Limnochironomus and Cryptochironomus, and aquatic worms of the class Oligochaeta. An average of 16.2 taxa contributed to the median Shannon-Weaver diversity index of 1.88.

The aquatic vegetation supported many invertebrates, including some not usually found in the riffle or run samples. Examples were the midge Cricotopus, the scud or sideswimmer Hyallela azteca (Crustacea), and the mayfly Caenis, which were found in qualitative samples of the vegetation collected during August and September.

Samples of drifting invertebrates were collected on each sample date and during a diel period in September 1980. Drift rates averaged 561 invertebrates per hour and were largest during December and March. The median drift

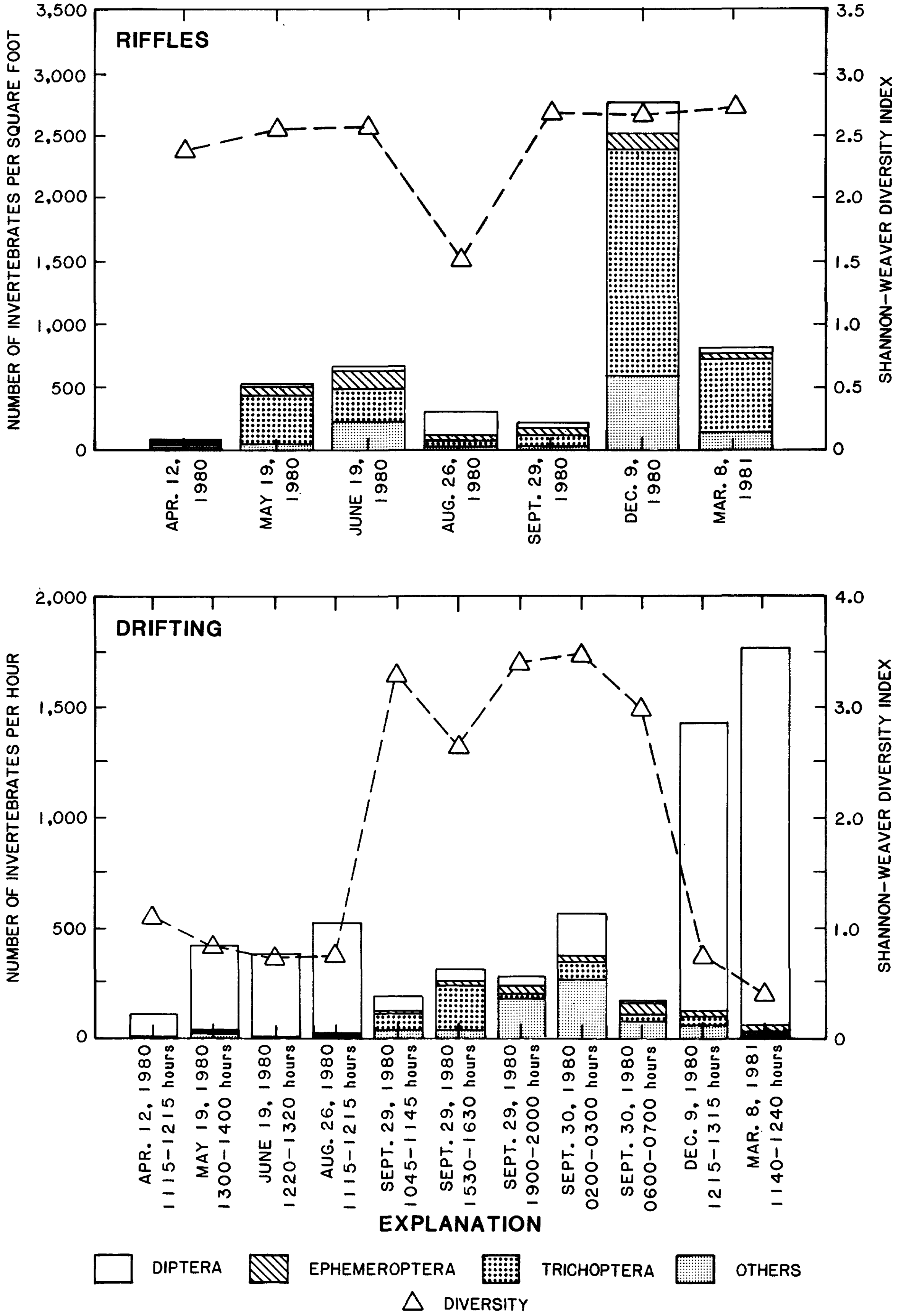


Figure 3.--Composition, density, and diversity of benthic invertebrates from riffles and of drifting invertebrates in the Niobrara River (station 06454000).

rate was 386 invertebrates per hour. The midges Cricotopus and Limnochironomus generally dominated the drift samples (Diptera, in fig. 3). The diel samples collected during September generally were dominated by caddisflies during the daytime and flatworms (Planariidae) during the nighttime. The sample collected between 0600 and 0700 hours was dominated by Baetis. Mats of vegetation drifting downstream affected the composition of the diel samples, due to the invertebrates attached to the mats. Sixteen taxa that were not found in riffle or run samples during September were found in the diel drift samples; of these 16 taxa, 10 were not collected from the Niobrara River on any other sample date. Most of the rare taxa were beetles (Coleoptera). An average of 21.2 taxa were collected in the diel-drift samples.

Frank Draw Tributary Number 2

The sample-collection site was located on a small, formerly ephemeral draw that receives discharge from mine dewatering. Water pumped from Kerr-McGee's Bill Smith Uranium Mine enters Frank Draw tributary number 2, after passing through a barium-chloride precipitation plant and settling ponds. The site was about 0.25 mile downstream of the outflow from the settling ponds. Miscellaneous measurements of streamflow made on the sample dates are listed by the U.S. Geological Survey (1981, 1982) at a site identified by number 430245105420901. The average of the 7 streamflow measurements was 2.8 cubic feet per second. Habitat at the site primarily was runs, with few riffles or pools. The bed material was a hard, relatively homogenous mixture of clay and sand.

Water-quality measurements consisted of onsite determinations and sample collection for laboratory analysis. During each visit, measurements of dissolved oxygen, specific conductance, pH, and water temperature, were made onsite; turbidity samples were collected for analysis at the laboratory. Dissolved-oxygen concentrations were greater than 8 milligrams per liter on the sample dates. Specific conductance was less than 1,000 microsiemens per centimeter at 25 °Celsius, and pH ranged from 8.1 to 8.9 on the sample dates. The maximum measured water temperature was 20.0 °Celsius. The maximum turbidity was 4 nephelometric turbidity units. Samples for analysis of dissolved solids, principal ions, trace metals, and dissolved organic carbon were collected during June 1980. The analysis indicated calcium and sulfate were the predominant ions. The concentration of total barium was 300 micrograms per liter, which was considerably less than the limit of 1,000 micrograms per liter for domestic water supply recommended by the U.S. Environmental Protection Agency (1976, p. 36-37).

Benthic-invertebrate densities in the runs at Frank Draw tributary number 2 averaged 329 invertebrates per square foot. Densities generally were less than 230 invertebrates per square foot, with the exception of the sample collected during March 1981 (fig. 4). The relatively large density during March may be related to emergence later during the spring. The run samples contained an average of 9.1 taxa. The median of the Shannon-Weaver diversity indices, which are shown in figure 4, is 1.61.

The predominant benthic invertebrate on five of the seven sample dates was the caddisfly Hydropsyche (Trichoptera, fig. 4). Other common invertebrates, also adapted to flowing water, were the blackfly Simulium, and the mayflies Tricorythodes and Baetis. Pennak (1978, p. 686-687) notes blackfly larvae

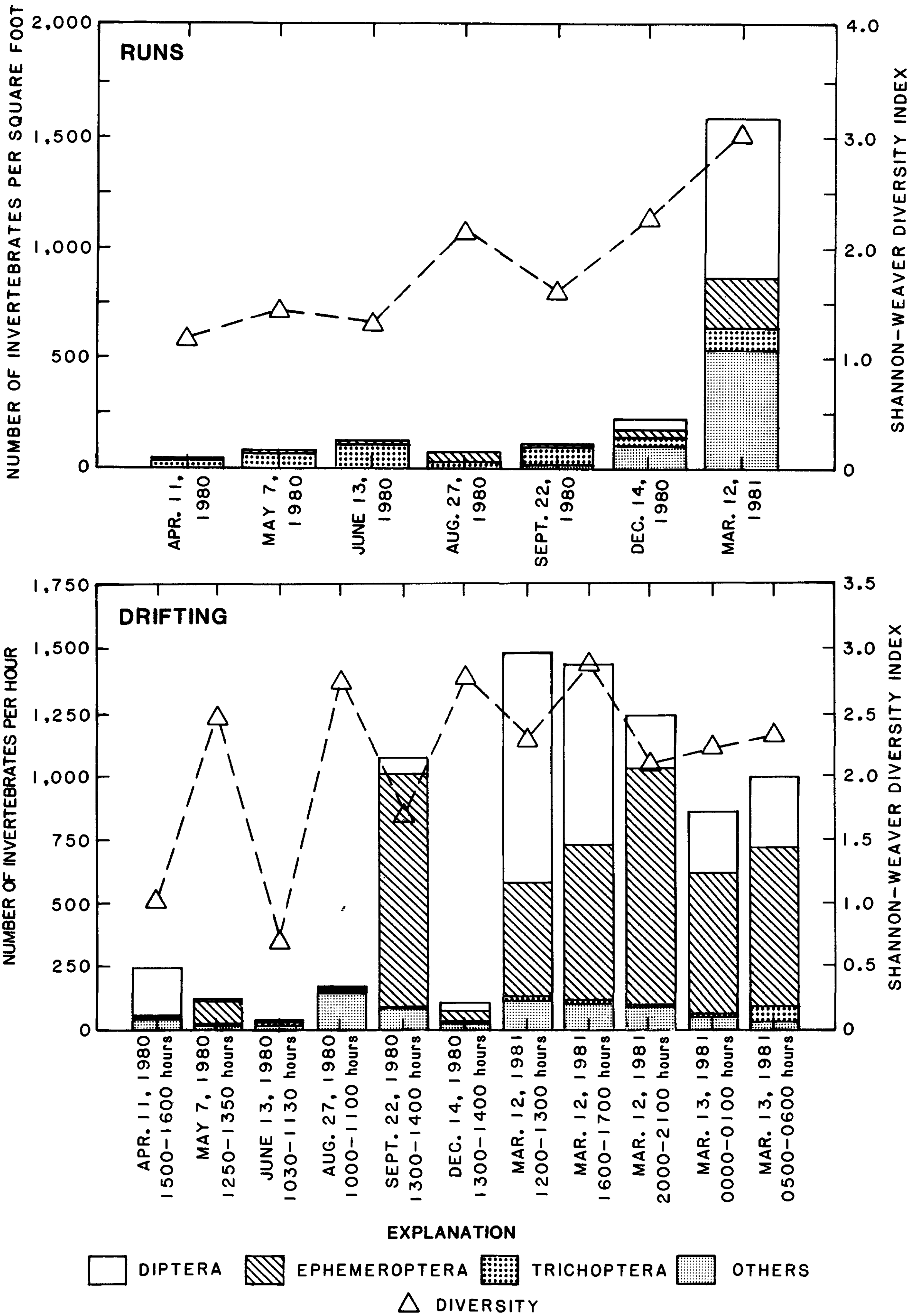


Figure 4.--Composition, density, and diversity of benthic invertebrates from runs and of drifting invertebrates in Frank Draw tributary number 2 (site 430245105420901).

(Diptera:Simuliidae) use mouth fans to filter plankton and organic debris from swift currents. The run sample collected during March was numerically dominated by Chironomids. The pond snail Physa was a numerical subdominant during March and a dominant during December. The mayfly Caenis, and small numbers of various caddisfly and beetle larvae were occasionally present.

Aquatic vegetation reached its maximum growth during late summer. At that time, beds of Chara and attached periphyton covered 25 to 50 percent of the streambed. Baetis, Tricorythodes, and Simulium were common in the vegetation; these invertebrates also were common in the run samples. Invertebrates common only in the vegetation included Hyallela azteca, the predatory midge Ablabesmyia, and the damselfy Enallagma. Qualitative samples of the vegetation contained 8 taxa during June and 13 taxa during September 1980.

The maximum numbers of drifting invertebrates occurred during September 1980, and March 1981 (fig. 4). The relatively large drift rates during March coincided with a relatively large benthic density. A 1-hour-long sample of the drift was collected on each sample date except March, when ten, 1-hour-long samples were collected during 23 hours. The average rate of all the drift samples was 816 invertebrates per hour; the samples contained an average of 16.3 taxa.

Composition of the drift samples varied greatly. Diptera pupae, presumably near hatching, were numerically predominant in the sample collected during April 1980. The mayfly Tricorythodes (Ephemeroptera, fig. 4) dominated the May and June drift samples. The August drift sample was dominated by the pond snail Physa. The mayfly Baetis, in both nymph and adult stages, comprised more than one-half of the September drift sample. Baetis also dominated the December sample. The blackfly Simulium was common, but not dominant, in the September and December samples. Hydrophilidae (water scavenger beetles) were present on all sample dates. The mayflies Epeorus and Ameletus were found infrequently. Epeorus nymphs attach themselves to firmly anchored material in shallow, cool or cold, rapidly flowing water (Edmunds and others, 1976, p. 190) and the nymphs of Ameletus usually are found in small, rapidly flowing streams (Edmunds and others, 1976, p. 131).

The diel-drift study consisted of ten, 1-hour drift samples collected during 23 hours on March 12-13, 1980. Composition, density, and diversity of five representative samples are shown in figure 4. The mayfly Baetis dominated all of the diel-drift samples except the sample collected between 1200 and 1300 hours, which was dominated by Chironomid larvae. The number of Baetis per sample was at a maximum in the sample collected between 2000 and 2100 hours, when 787 Baetis per hour comprised more than one-half of the invertebrates in the sample. This peak near sunset results from behavioral, or voluntary drifting of Baetis. Behavioral drifting of Baetis during the night, especially shortly after sunset, has been described by Waters (1962, 1972). The mayfly Tricorythodes, adult beetles, especially Tropisternus and Agabus, the blackfly Simulium and the damselfly Amphiagrion were common in all or most of the diel-drift samples.

The March drift samples contained 24 taxa that were not found in the March benthic sample. Of the 24 taxa found in the March drift samples, but not the March benthic sample, 11 taxa were not found at Frank Draw tributary number 2 in any other samples. Several of the 11 taxa may have avoided capture during earlier sampling, through their swimming ability.

Little Powder River at State Highway 59

The sample-collection site was located near the headwaters of the Little Powder River, at station 06324790. An open-pit coal mine and a ranching operation are located less than 2 miles upstream from the sample reach. The Little Powder River was rated as a limited fishery resource by the U.S. Fish and Wildlife Service (1978). The average of 7 streamflow measurements at the site was 1.1 cubic feet per second. The aquatic habitat at this site was diverse, and samples were collected from riffles, runs, and pools. The riffle substrate was composed mainly of gravel; the pool substrate was composed mainly of clay and silt.

Results of onsite determinations and turbidity analyses were: (1) Dissolved-oxygen concentrations ranged from 7.2 to 13.1 milligrams per liter; (2) specific conductance values averaged 1,610 microsiemens per centimeter at 25 °Celsius; (3) pH values ranged from 7.8 to 8.4; (4) maximum water temperature measured was 21.0 °Celsius during August 1980; and (5) turbidity values commonly were 3 nephelometric turbidity units or less, indicative of the clear water at this site.

The maximum benthic invertebrate density in the riffle samples was 1,970 invertebrates per square foot during September 1980 (fig. 5); the average density was 653 invertebrates per square foot. The riffle samples contained an average of 13 taxa. The maximum Shannon-Weaver diversity index was 2.81 in the June sample (fig. 5), and the minimum diversity was 0.41 in the August sample, due to the abundance of the caddisfly *Cheumatopsyche* in the riffle community.

The riffles were dominated by invertebrates adapted to flowing water. The riffle samples collected during August, September, and December 1980, and March 1981, contained 60 percent or more *Cheumatopsyche* (Trichoptera, fig. 5). The maximum density of *Cheumatopsyche* was 1,480 larvae per square foot during September. *Simulium* was the most common invertebrate during April, whereas the riffle beetle *Dubiraphia* was the most common invertebrate during May and June. Pennak (1978) notes that riffle beetles, both larvae and adults, generally are found in running waters. The mayflies *Caenis* and *Choroterpes*, the midge *Cricotopus*, the creeping water bug *Ambrysus*, the snail *Physa*, and fingernail clams (family Sphaeriidae) usually were present in the riffle samples, but not in large numbers. *Choroterpes* generally is found under rocks, sticks, or algal mats in areas of slow water movement (Edmunds and others, 1976, p. 215).

The runs supported smaller numbers of benthic invertebrates than the riffles. Samples collected from the runs on 4 dates contained an average of 176 invertebrates per square foot. Invertebrates common in the runs and the riffles included *Dubiraphia*, *Cheumatopsyche*, and *Ambrysus*. Invertebrates found only in the runs included the riffle beetle *Optioservus*, and Diptera larvae such as the biting midge *Palpomyia*, the moth fly *Pericoma*, the cranefly *Tipula*, and the Muscid fly *Limnophora*. Oligochaeta were more common in the runs than the riffles.

The pools generally supported larger invertebrate densities than did the riffles or runs. Samples were collected from the pools with an Ekman grab sampler on five of the seven sample dates. Qualitative samples of the vegetation in the pools were collected on three dates and contained nearly the same

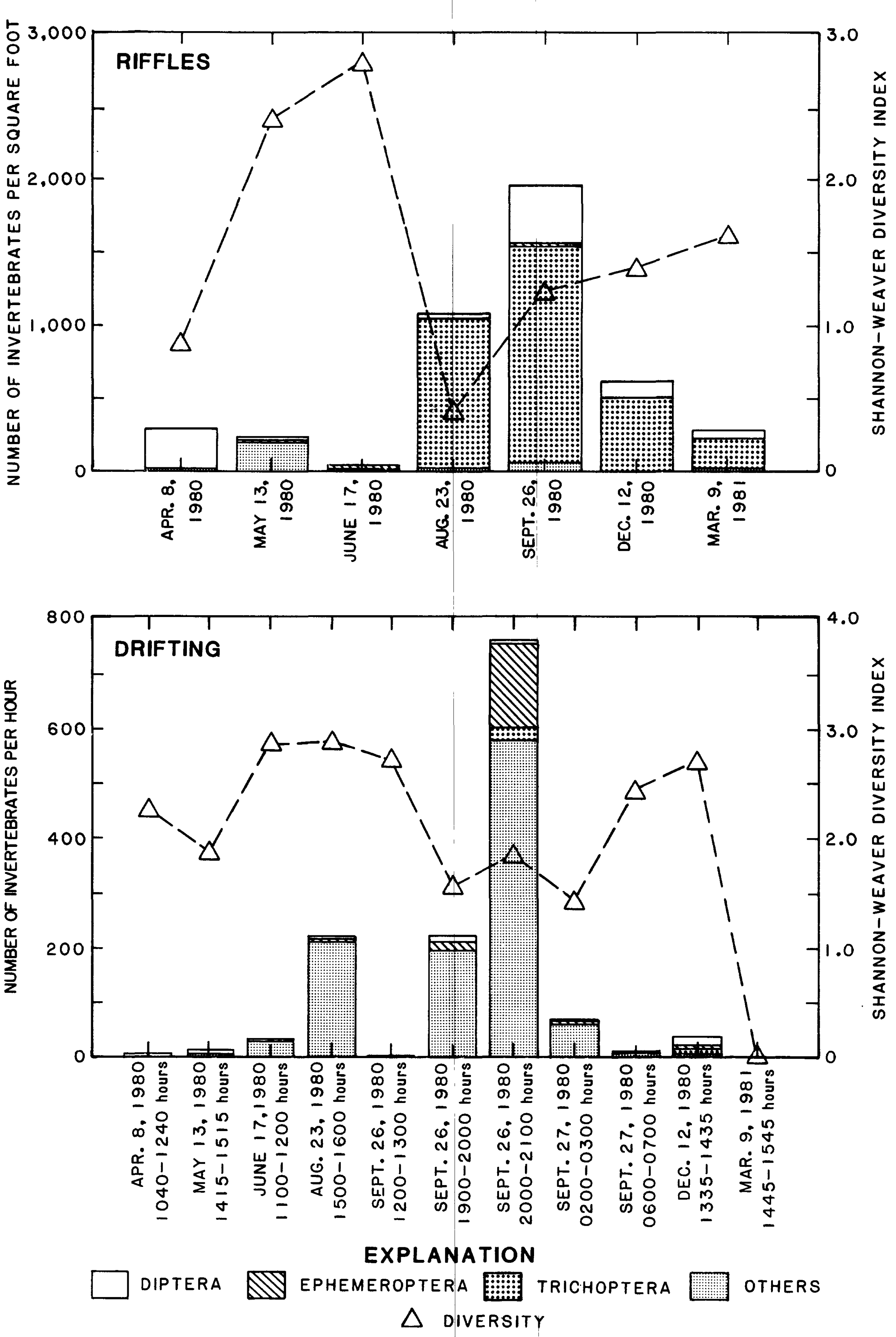


Figure 5.--Composition, density, and diversity of benthic invertebrates from riffles and of drifting invertebrates in the Little Powder River at State Highway 59 (station 06324790).

invertebrates as the grab samples. The average density in the pools was 2,260 invertebrates per square foot. The pool samples contained an average of 13.2 taxa. The median Shannon-Weaver diversity index for the pool samples was 2.09. The number and types of taxa and the diversity indicate a moderately healthy community adapted to the abundant vegetation and standing water in the pools.

The dominant invertebrate in the pool samples was the scud Hyallela azteca. The midge Tanytarsus and the beetle larvae Dubiraphia were subdominants. Hyallela azteca is an omnivorous scanvenger, feeding on plant material and dead organisms (Pennak, 1978, p. 452). The scuds were most common in or beneath vegetation. Coffman (1978, p. 376) lists Tanytarsus as a climber-clinger type dweller on vascular hydrophytes, which is where they were found in the pools. The mayfly Caenis, the caddisfly Polycentropus, the damselfly Ishnura, and the snail Gyralus were common in the pool samples, but not numerically dominant. Mites (Order Acarina) and the predaceous diving beetle larvae Deronectes were sometimes abundant.

The number of drifting invertebrates peaked during August and September 1980 (fig. 5). One sample of the drift was collected on each sample date, except September when ten, 1-hour diel-drift samples were collected during 23 hours. The diel-drift samples collected during September showed a pronounced variation in numbers with time. Representative samples are shown in figure 5. The maximum rate recorded was 763 organisms per hour, between 2000 and 2100 hours. Between 1900 and 2000 hours (the hour after sunset) and between 2100 and 2200 hours, the second- and third-largest rates of the diel-drift samples were collected.

Numerically dominant invertebrates in the drift generally were mites (Acarina) with the exception of September. Hyallela azteca dominated all but three of the diel-drift samples collected during September, including the peak concentrations. Mites (Acarina) dominated the two diel-drift samples collected between 1600 and 1800 hours. The mayflies Baetis and Caenis were much more common in the two samples collected between 2000 and 2100 hours and between 2100 and 2200 hours than in samples from other time periods.

Seven taxa were found in the diel-drift samples collected during September that were not found in the September benthic samples. Of those seven taxa, three taxa, the caddisfly Oxyethira, the mayfly Callibaetis, and the predaceous diving beetle Oreodytes, were not found in any other samples from the Little Powder River at State Highway 59.

Salt Creek

The sample-collection site, at station 06313400, is located on Salt Creek downstream from a major oilfield. Inflow of water from oilfield activity affects the water quality of the creek. The flow-duration curve (fig. 2) shows streamflow is generally 20 cubic feet per second or more. The habitat in Salt Creek consisted primarily of runs. The bed material in the runs primarily was a soft, unstable mixture of sand and smaller-size particles. One riffle, composed of gravel and cobbles, was present at the site, but was covered with the sand mixture on most sample dates. The suspended-sediment concentration in eleven samples collected during the study period ranged from 61 to 5,030 milligrams per liter.

Water-quality measurements included onsite determinations and samples for turbidity. The minimum dissolved-oxygen concentration measured was 6.7 milligrams per liter. Specific conductance usually was about 6,000 microsiemens per centimeter at 25 °Celsius, but was greater than 8,000 microsiemens per centimeter during April and May 1980. The median pH was 8.3. The maximum water temperature measured was 25.0 °Celsius. Turbidity values reached a maximum of 600 nephelometric turbidity units. Peterson (1988, p. 10) reported an average dissolved-solids concentration of 4,074 milligrams per liter and an average chloride concentration of 1,133 milligrams per liter.

The average density of benthic invertebrates was 3.4 invertebrates per square foot, based on 8 samples. Invertebrates were absent from the March 1981, run sample. The maximum density was 10 invertebrates per square foot, in a sample collected from a riffle during September 1980, when the surfaces of the gravel and cobbles were relatively free of sand and silt. The samples contained an average of 1.8 taxa. The median of their Shannon-Weaver diversity indices was 0.88. These numbers reflect the sparse invertebrate population and indicate a community stressed by degraded water quality, or inadequate substrate or both. The water quality was degraded because of the large concentrations of chemical constituents. The substrate was inadequate to support large numbers of invertebrates because the soft, unstable sand mixture did not provide stable microhabitat for the benthic-invertebrate community.

The most common invertebrates were Chironomid larvae (Diptera), especially Cricotopus, and bottom-feeding worms of the class Oligochaeta. Coffman (1978, p. 373) lists Cricotopus as a burrower and feeder on detritus and algae. The burrowing habits of the dominant invertebrates help them survive in the unstable substrate. Badly damaged mayfly nymphs were collected on two sample dates, but their poor condition and the absence of live specimens indicate they may have drifted in from a tributary. The invertebrates adapted to flowing water that dominated the communities of other perennial streams in the study area generally were not found in Salt Creek. During a reconnaissance in 1977, 327 Simulium per square foot were collected from Salt Creek. Simulium, which is a Dipteran adapted to flowing water, was found in the other perennial streams in this study.

Drift samples contained fewer than 20 invertebrates per hour, with 2 exceptions. The drift samples collected during September 1980 contained 124 invertebrates per hour, and the December 1980 sample contained 70 invertebrates per hour. An average of 2.3 taxa were collected from the 7 drift samples. The median of their Shannon-Weaver diversity indices is 0.99. These values are quite small and are due to the sparse invertebrate population of the streambed. The large quantity of suspended material in the water affected the sampling procedures. The drift net generally was removed from the water after a 30-minute interval, instead of the 60-minute interval generally used at other sites, to avoid backwash caused by the clogged mesh of the net.

The most common invertebrates in the drift were the ones most common in the benthic samples, Cricotopus and Oligochaeta. The Chironomids Limnochironomus and Diamesa, and water boatmen (Hemiptera:Corixidae) were found in samples of the drift, but not in the benthic samples.

INVERTEBRATE COMMUNITIES IN INTERMITTENT STREAMS

Invertebrate communities were sampled in three intermittent streams: Box Creek, the Little Powder River, and the Cheyenne River. The intermittent reach of the Little Powder River described in this section is approximately 30 miles north (downstream) of the perennial reach described in the previous section (fig. 1).

Box Creek at County Highway 32

The sample-collection site was located in the southern part of the Powder River Basin, at site number 430433105234301. Average streamflow was 0.17 cubic feet per second, based on measurements on the 7 sample dates. Aquatic habitat consisted of pools connected by shallow riffles (fig. 6). Emergent macrophytes were common along the banks of the stream. Submerged macrophytes and algae usually lined the edges of the channel and sometimes filled it, but were relatively sparse in the pools. More than 80 percent of the bed material was sand-size or smaller in the pools and riffles.

Water-quality determinations in Box Creek included onsite measurements and samples for turbidity. Dissolved-oxygen concentrations ranged from 8.6 to 12.4 milligrams per liter. Specific conductance ranged from 850 to 1,380 microsiemens per centimeter at 25 °Celsius. The median pH was 7.7. The maximum water temperature measured was 21.5 °Celsius during August 1980. Turbidity values were less than 10 nephelometric turbidity units.

The riffles in Box Creek sometimes contained large numbers of invertebrates. The maximum density was 3,930 invertebrates per square foot during December 1980, when plant growth was at a minimum. Plant growth covered much of the riffles during June, August, and September; invertebrate densities were relatively small during those months (fig. 7). An average of 929 invertebrates per square foot and 16.9 taxa were collected in the riffle samples. The minimum number of taxa was nine, during August, due to the scouring action of floods a few days prior to sampling.

The most common invertebrates in the riffles were the caddisfly Cheumatopsyche, the scud Hyallela azteca, the snail Physa, fingernail clams (Sphaeriidae), and the mayfly Caenis. Cheumatopsyche is adapted to flowing water, and was at a maximum density during December 1980, and March 1981, when aquatic vegetation was at a minimum and did not restrict streamflow velocity. Cheumatopsyche was not found during June and August 1980, when the vegetation choked the stream channel and restricted streamflow. Hyallela azteca and Caenis normally are associated with vegetation and were common in Box Creek throughout the study period. Oligochaeta and Chironomids also were common. Vegetation-feeding beetles usually were present in small numbers, as were dragonfly and damselfly nymphs.

Pools in Box Creek supported much smaller invertebrate densities than the riffles. The maximum density occurred during May 1980 (fig. 7). Possible causes for the small densities in the pools (average 98 invertebrates per square foot) are the paucity of submerged vegetation and poor circulation of the water. The pool sediments changed to a black anoxic ooze immediately below the surface, indicating an environment deficient in oxygen.

Figure 6.--Box Creek looking south from the sample-collection site at County Road 32 during summer 1980 (site 430433105234301).

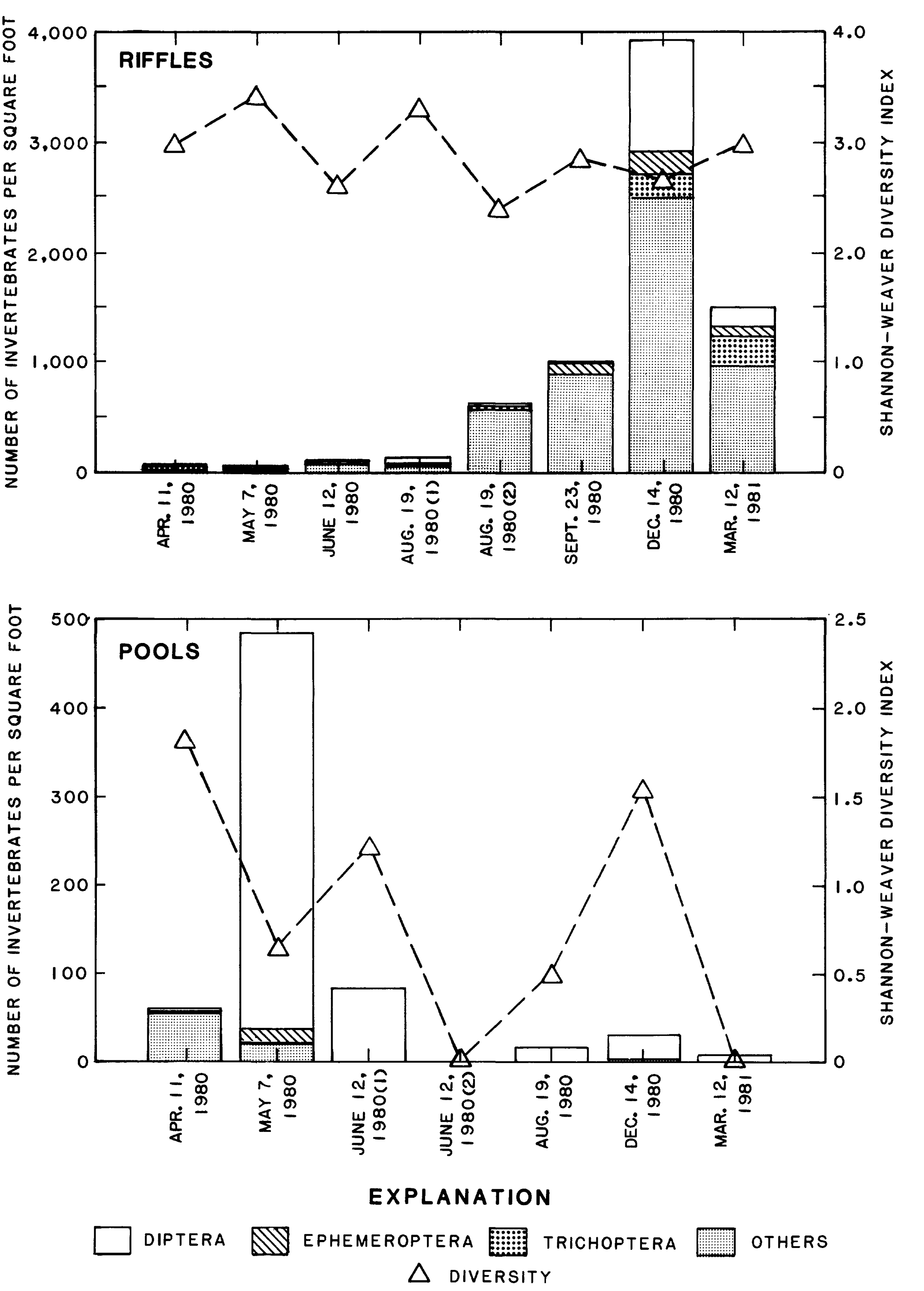


Figure 7.--Composition, density, and diversity of benthic invertebrates from riffles and pools in Box Creek (site 430433105234301). Number in parentheses after date distinguishes duplicate samples.

The pool community was dominated by Chironomids (Diptera, fig. 7), particularly red Stictochironomus. Snails sometimes were common in the pool samples, and Oligochaeta were collected on two sample dates. Organic matter deposited in the pools forms a food base for the community. Besides the small benthic invertebrate density, the average diversity index of 0.82 also was an indicator of stressful conditions for invertebrates.

Little Powder River Near The Wyoming-Montana State Line

The sample-collection site is located at streamflow-gaging station 06324970. The flow-duration curve (fig. 8) indicates the intermittent character of streamflow at the site. The average of the daily mean streamflows on the sample dates was 2.7 cubic feet per second; the minimum daily mean streamflow was 0.01 cubic feet per second on the day of sampling, September 25, 1980. The site contains an alternating sequence of short riffles and pools. Some of the pools result from normal stream hydraulics and others were formed behind beaver dams. The bed material consisted of coarse sand to small gravel, with smaller proportions of clay, silt, and large gravel.

Some of the water-quality measurements showed large variation. For example, specific conductance ranged from 1,020 to 5,500 microsiemens per centimeter at 25 °Celsius. The minimum specific conductance was measured during August 1980, after floods caused by rainstorms. The minimum dissolved-oxygen concentration of 7.4 milligrams per liter also was recorded during August. The median pH was 8.1. Maximum water temperature recorded was 24.0 °Celsius, during June. The turbidity measured 700 nephelometric turbidity units during August; the median turbidity was 15 nephelometric turbidity units. Peterson (1988) reported an average dissolved-solids concentration of 2,150 milligrams per liter at this site.

Samples were collected from riffles on six of the seven sample dates. The flow was insufficient to collect riffle or drift samples during September 1980. Invertebrate densities in the riffles were largest during December and smallest during August and May (fig. 9). The average density was 107 invertebrates per square foot. The flooding preceding the sampling during August probably scoured the substrate, causing the small density. Daily mean streamflow on the day before sampling was 43 cubic feet per second; maximum daily streamflow in the preceding week was 180 cubic feet per second. The median of the Shannon-Weaver diversity indices, which are shown in figure 9, was 1.60. The value indicates possible stress on the riffle community, such as the occasional drying of the streambed in the riffles.

The numerically dominant invertebrate in the riffles during May and December 1980, and March 1981, was the blackfly Simulium (Diptera, fig. 9). Chironomids, Oligochaeta, Caenis, and Cheumatopsyche were dominants or subdominants on the remaining sample dates. Simulium and Cheumatopsyche are filter feeders, whereas a majority of the collected Chironomids, Oligochaeta and Caenis are adapted for feeding on organic material that is deposited or is growing on the substrate. The mayfly Choroterpes and the alderfly Sialis were found in some of the samples collected from riffles. Edmunds and others (1976, p. 215) note that Choroterpes are found on the underside of firmly attached objects in areas of slow-moving water. This is an accurate description of their location in the Little Powder River near the Wyoming-Montana State line.

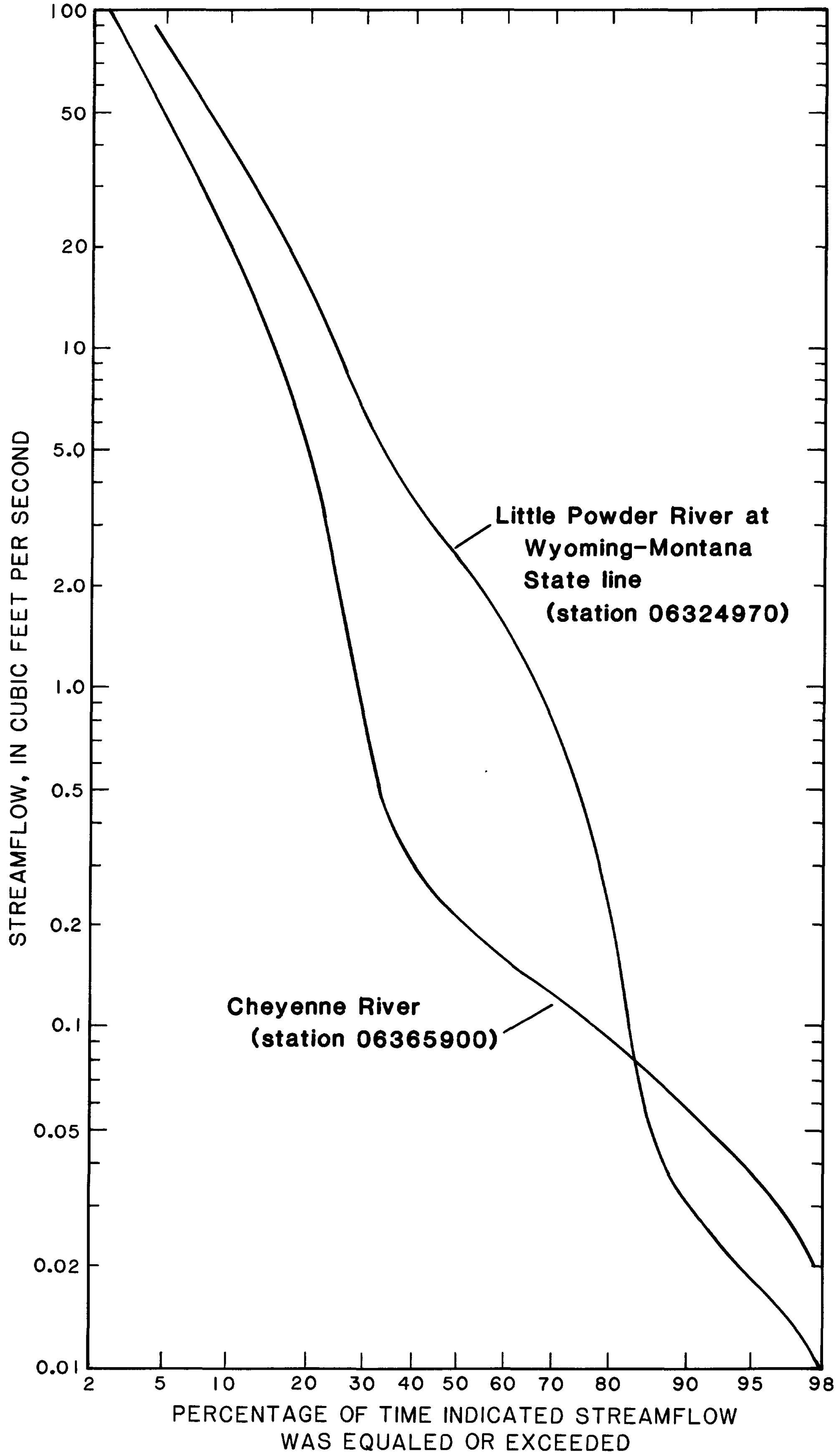


Figure 8.--Flow-duration curves for two intermittent streams.

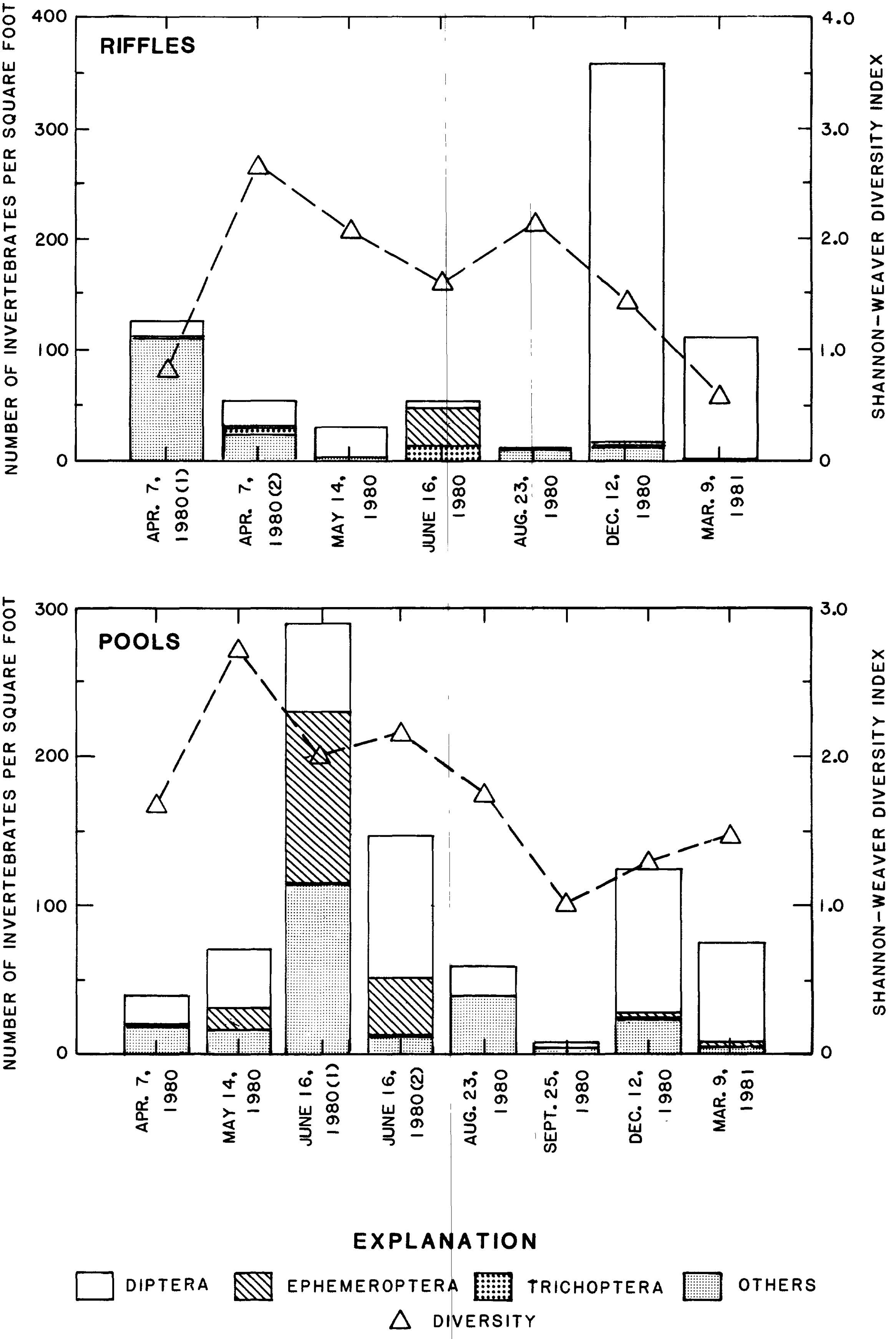


Figure 9.--Composition, density, and diversity of benthic invertebrates from riffles and pools in the Little Powder River near the Wyoming-Montana State line (station 06324970). Number in parentheses after date distinguishes duplicate samples.

The pools contained an average of 102 invertebrates per square foot, which is nearly the same as the density found in the riffles. Density, composition, and diversity of the pool samples are shown in figure 9. The sample with minimum density was collected during September 1980.

Pool communities were dominated by Dubiraphia, Caenis, Chironomids, and Oligochaeta. Organic material forms a food source for the dominants. Snails, scuds, and dragonfly and damselfly nymphs comprised a large part of the pool communities at other sites in this study. However, these taxa generally were absent from pools at this site, possibly due to the paucity of aquatic vegetation.

Samples of the drift in the Little Powder River generally contained a small number of invertebrates. The average rate of 6 samples was 58 invertebrates per hour. The maximum rate was 262 invertebrates per hour during May, when the sample contained 168 blackfly larvae (Diptera:Simuliidae). The maximum number of taxa collected per drift sample, eight, occurred during August, due to catastrophic drift caused by flooding. The average was 3.2 taxa per drift sample.

Cheyenne River

The sample-collection site was located at streamflow-gaging station 06365900. The flow-duration curve (fig. 8) indicates intermittent streamflow. Daily mean streamflow on the sample dates ranged from 0.15 to 7.4 cubic feet per second and averaged 2.1 cubic feet per second. Habitat consisted of shallow, interbraided channels, with slow water velocities. Although the stream consisted primarily of runs, temporary pools and riffles sometimes were present, dependent on the shifts in the channel. The bed material was an unstable mixture of sand and small gravel.

Water-quality measurements included onsite determinations and samples collected for turbidity analysis. Dissolved-oxygen concentrations ranged from 6.3 to 12.8 milligrams per liter. Specific conductance generally was about 3,000 microsiemens per centimeter at 25 °Celsius, with the exception of 510 microsiemens per centimeter at 25 °Celsius during August. The pH ranged from 7.6 to 8.4. Maximum water temperature recorded was 31.0 °Celsius. Turbidity was variable, ranging from 2 to 1,000 nephelometric turbidity units. The maximum turbidity occurred during August 1980, as a result of rainstorms preceding sampling. The water contained an average dissolved-solids concentration of 2,100 milligrams per liter, based on 64 water-quality samples (Peterson, 1988).

Invertebrate densities in samples from runs in the Cheyenne River averaged 16.6 invertebrates per square foot and ranged from zero during August 1980 to 59 invertebrates per square foot during March 1981 (fig. 10). A large flood (daily mean discharge of 198 cubic feet per second) occurred 4 days before the August sample trip, presumably either burying the invertebrates through shifting of the unstable substrate or washing them downstream by scouring of the substrate. The sample diversities (fig. 10) are small, indicating stress on the invertebrate community.

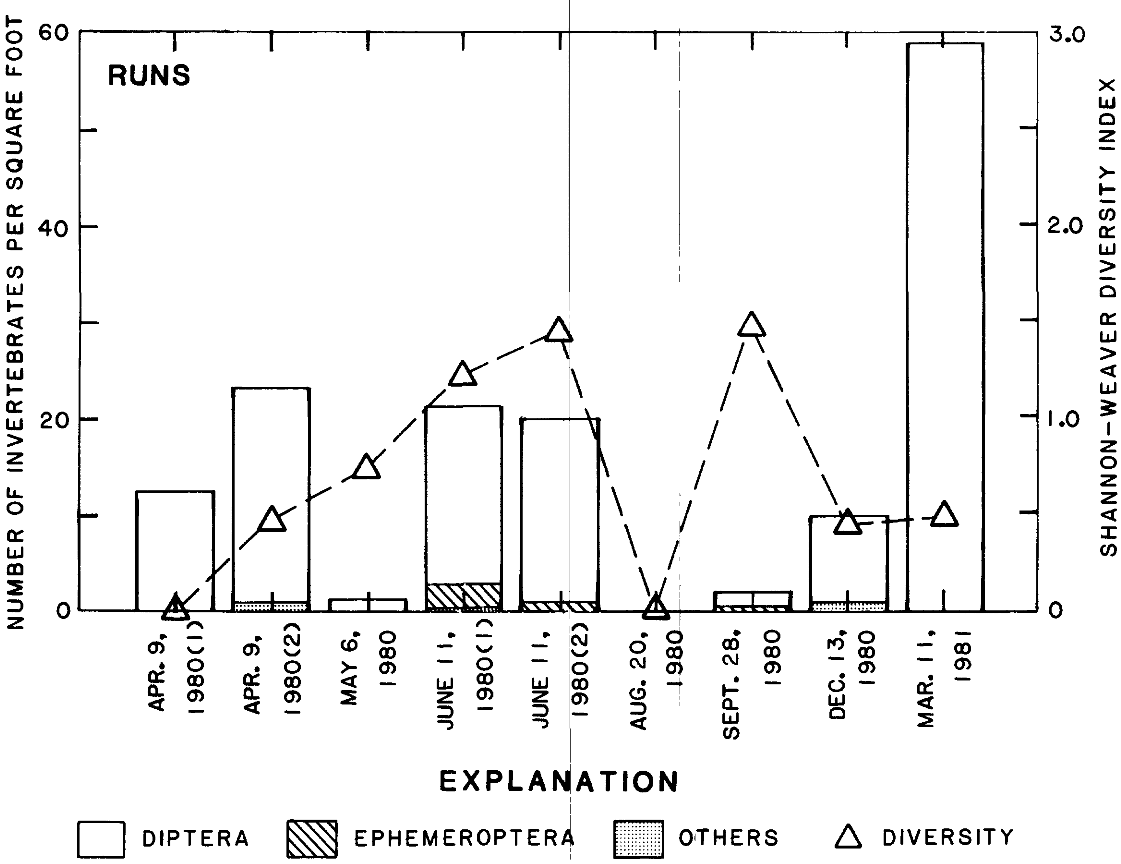


Figure 10.--Composition, density, and diversity of benthic invertebrates from runs in the Cheyenne River (station 06365900).

The benthic invertebrate community was dominated by Diptera, particularly red Stictochironomus (Diptera:Chironomidae). Merritt and Cummins (1978, p. 376) list Stictochironomus as a shredder-herbivore. Cottonwood leaves are abundant in the substrate of the Cheyenne River and may be a food source for Stictochironomus. Other Chironomids and the mayfly Baetis (fig. 11) usually were found in the run samples.

The rate of invertebrate drift was very small, based on seven samples. The maximum rate of seven invertebrates per hour was collected during March; no aquatic invertebrates were collected in the April and September drift samples. Chironomids, Simulium, Baetis, and the caddisfly Limnephilus were found in the drift samples.

Qualitative samples were collected from temporary pools and riffles that provided habitat for several invertebrate taxa not found in the run samples. A pool sampled during March 1981, contained predatory invertebrates such as backswimmers and water boatmen (Hemiptera), predaceous diving beetles (Coleoptera:Dytiscidae), dragonfly nymphs, and the caddisfly Limnephilus. During June, a temporary riffle was created by clinker spread across the channel for a roadbed. Simulium were found in the riffle, attached to the clinker. Mats of filamentous algae hooked on the clinker contained the mayflies Baetis and Heptagenia and the Chironomids Diamesa and Tanytarsus. The variety and types of invertebrates found in the temporary habitats indicate that unstable substrate and lack of habitat may be limiting aquatic communities in the Cheyenne River.

INVERTEBRATE COMMUNITIES IN EPHEMERAL STREAMS

Invertebrate communities were sampled on a repetitive basis in two ephemeral streams: the Belle Fourche River at three locations and Dead Horse Creek. In addition, miscellaneous samples were collected in four ephemeral streams: Raven Creek, Box Creek, Little Thunder Creek, and Lodgepole Creek.

Belle Fourche River Upstream From Cordero Mine

The sample-collection site was located at streamflow-gaging station 06425720 and was the farthest upstream of three sample sites on the Belle Fourche River. The site was located about 4 miles upstream from the Cordero Mine, a surface coal mine. The flow-duration curve indicates an ephemeral stream (fig. 12). Habitat consisted of unconnected pools, 3 feet or more deep, during nearly all of the study period. A small flow between the pools was observed during April. Emergent macrophytes grew along the margins of the pools, and submerged macrophytes and algae were common in the shallower areas of the pools. The substrate contained more than 70 percent sand or smaller-size particles.

Water-quality measurements included onsite determinations of dissolved oxygen, specific conductance, water temperature, and pH and samples for turbidity, usually on each sampling date; samples were collected for analysis of dissolved solids and principal ions during June 1980. Dissolved-oxygen concentrations were at a minimum of 7.8 milligrams per liter in the September and December 1980 samples. Specific conductance varied greatly, from 800 to more than 8,000 microsiemens per centimeter at 25 °Celsius; the median was

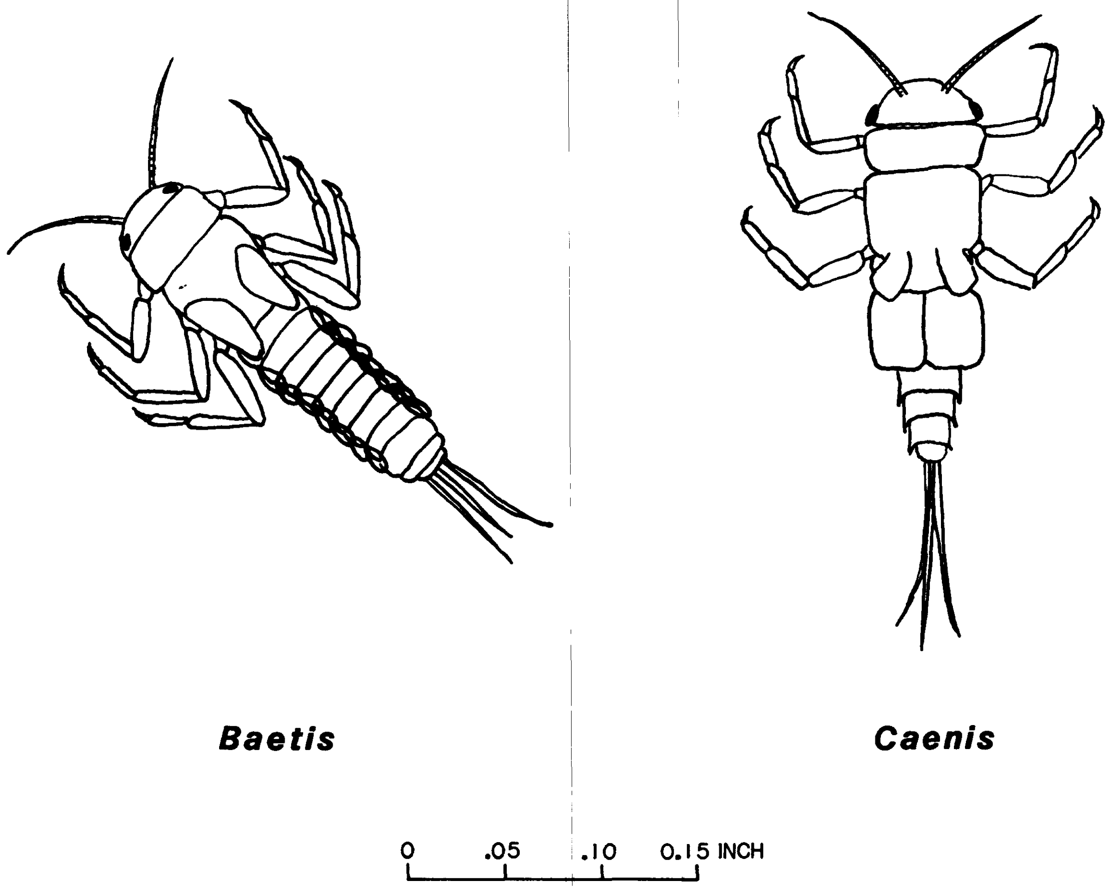


Figure 11.--The mayfly nymphs (Ephemeroptera) ***Baetis*** and ***Caenis*** were found in the Cheyenne River and many other streams in this study.

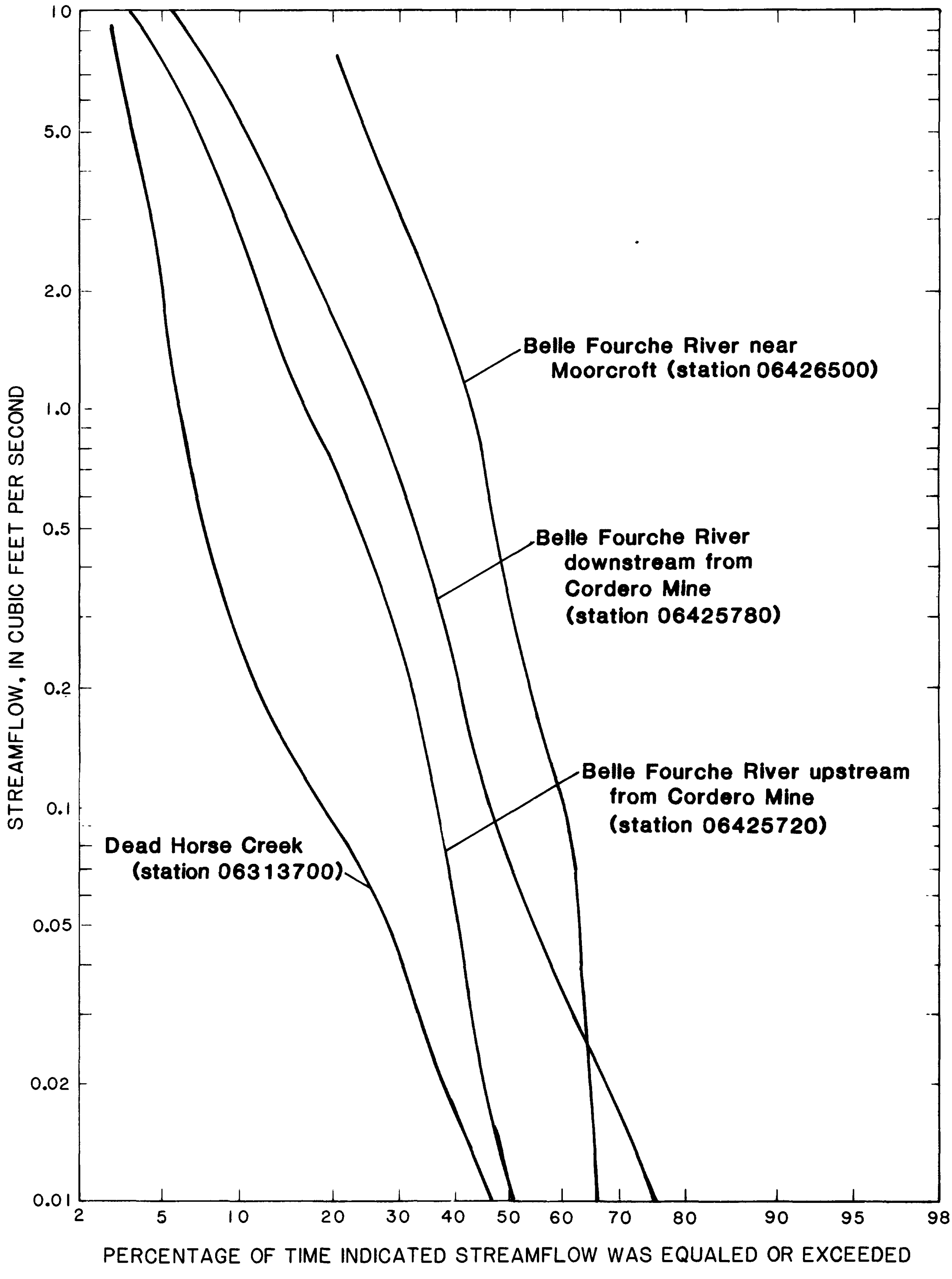


Figure 12.--Flow-duration curves for four ephemeral stream sites.

4,600 microsiemens per centimeter. The pH values ranged from 7.4 to 8.2. Water temperatures ranged from 0.0 °Celsius during December to 26.0 °Celsius during June. Turbidity values ranged from 4 to 15 nephelometric turbidity units. A water sample collected during June contained a dissolved-solids concentration of 3,610 milligrams per liter.

The density of invertebrates in the pools varied considerably, even among duplicate samples collected on the same date (fig. 13A). Some of the variation in density was due to variation in the number of macrophytes collected with the bottom material, because the macrophytes are a microhabitat for many invertebrates. The average density was 566 invertebrates per square foot. The median of the Shannon-Weaver diversity indices, which are shown in figure 13A, is 1.65.

The most common invertebrates in the pools were the mayfly Caenis and Diptera larvae, especially Limnochironomus and Tanytarsus (Chironomidae). Bottom-feeding worms (Oligochaeta), snails, scuds, and damselfly nymphs were common, but not numerically dominant. Caenis generally is an omnivorous inhabitant of vegetation in quiet water (Edmunds and others, 1976, p. 266-268). Merritt and Cummins (1978, p. 275-376) list Limnochironomus as a collector-gatherer feeder and Tanytarsus as a climber-clinger inhabitant of vascular hydrophytes. The scuds and snails were common inhabitants of aquatic vegetation, as shown by qualitative samples of the vegetation collected during June and September. The Oligochaeta and some chironomid larvae inhabited the sediment, but the nature of the substrate limited the sediment dwellers. The sediment dwellers were found in the top inch of aerated sediment and organic matter, but not in the black, anoxic ooze underneath the top layer.

A riffle sampled during April contained 107 invertebrates per square foot. Oligochaeta dominated the sample, but other invertebrate taxa common in the pools also were found in small numbers. Invertebrates adapted to flowing water were absent, with one exception. The Chironomid Diamesa, which is normally associated with running waters (Coffman, 1978, p. 372) was present at a very small density. The Diamesa may have colonized through drift from a perennial source upstream.

Belle Fourche River Downstream From Cordero Mine

The sample-collection site was located at streamflow-gaging station 06425780, less than 1 mile downstream from the Cordero Mine. The river was rerouted around the mine and received infrequent pumpage from the mine. Pools were the most prevalent habitat, although flow between the pools occurred during the spring. The substrate primarily was sand, with some small gravel.

Water-quality measurements included onsite determinations and samples collected for turbidity analyses. The minimum dissolved-oxygen concentration was 9.2 milligrams per liter. The average specific conductance was 4,820 microsiemens per centimeter at 25 °Celsius. The pH ranged from 7.6 to 8.6. Water temperatures varied from 0.0 °Celsius during December to 22.5 °Celsius during August. The maximum turbidity was 12 nephelometric turbidity units, during March 1981.

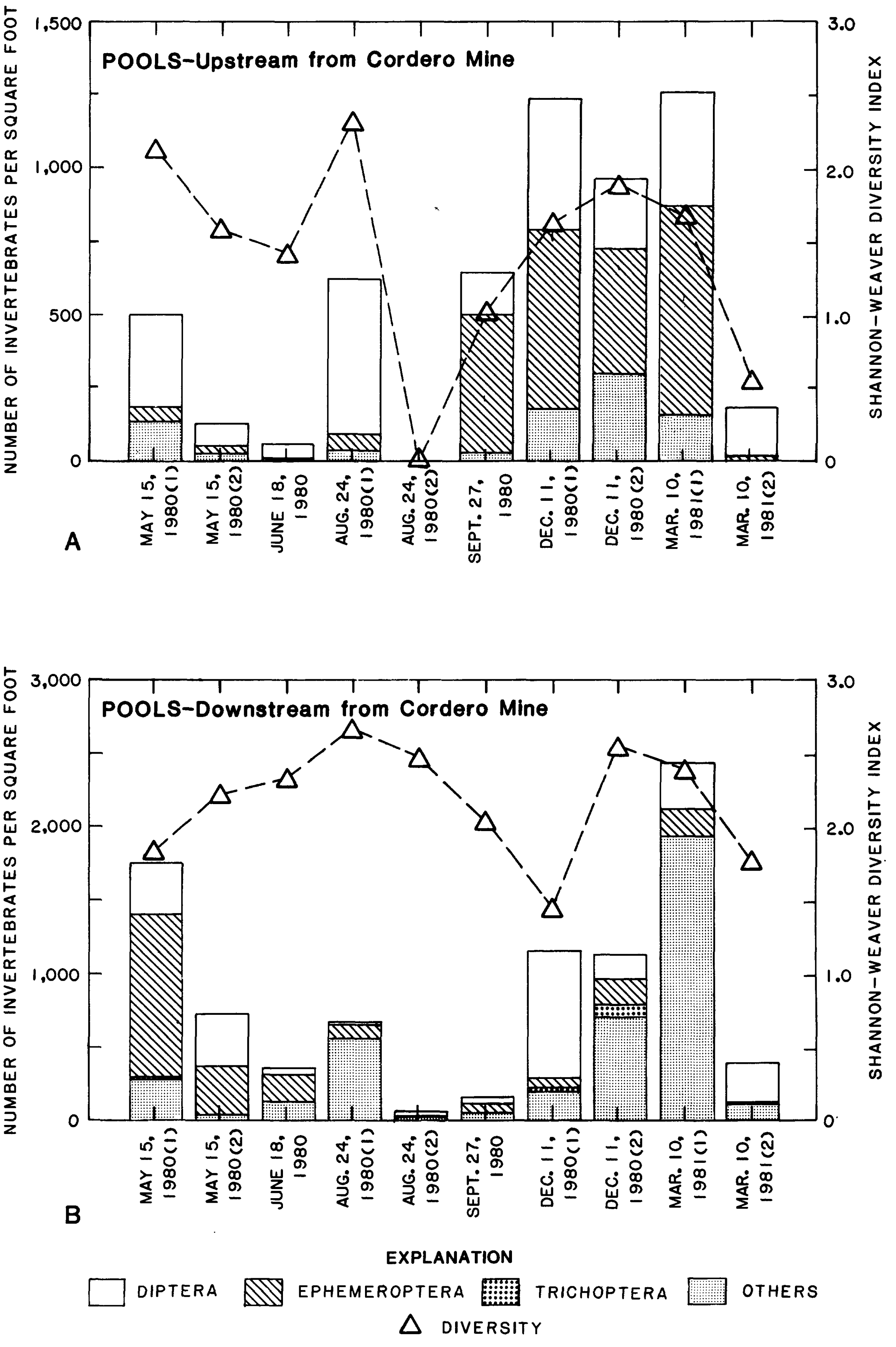


Figure 13.--Composition, density, and diversity of benthic invertebrates from pools in the Belle Fourche River (A) upstream (station 06425720) and (B) downstream (station 06425780) from the Cordero Mine. Number in parentheses after date distinguishes duplicate samples.

The pools were sampled on six dates. The invertebrate density was variable (fig. 13B), partly due to variations in the quantity of macrophytes collected with the sample. The average density was 884 invertebrates per square foot and the median diversity was 2.28 units. The average diversity and density were larger in the Belle Fourche River downstream from the Cordero Mine than upstream from the mine. Between the sites, the river receives intermittent flow from a tributary, is diverted around the mine, and receives infrequent discharge pumped from the mine pit. Any one or a combination of these actions may have affected the invertebrate communities at the site downstream from the mine.

Dominant invertebrates in the pools were Caenis, Chironomid larvae, and the beetle Dubiraphia. The pond snail Physa and the scud Hyallela azteca were common, but not dominant. The relatively large number of invertebrates grouped as "others" during March (fig. 13B) primarily were scuds and beetle larvae. The dense growths of aquatic vegetation provided food and shelter for most of the invertebrates found in the pool samples.

Samples collected from a small riffle contained 59 invertebrates per square foot during April and 128 invertebrates per square foot during June. The riffles were inhabited by invertebrates common in the pools, with one exception. The caddisfly Cheumatopsyche, which is adapted to flowing water, was found in the riffle during June. The presence of this caddisfly may be due to drift from an upstream source.

Belle Fourche River near Moorcroft

This was the farthest downstream sample-collection site on the Belle Fourche River. The site was located at streamflow-gaging station 06426500.

The steep slope of the flow-duration curve (fig. 12) indicates highly variable flow of 0.01 cubic feet per second or more, about 66 percent of the time. Contrary to the expected flow pattern, the river flowed on all sample dates. Municipal sewage and oilfield brines pumped to a tributary may have been responsible for the presence of streamflow during the study period. Habitat consisted of riffles and runs; pools were absent. Neither emergent nor submerged macrophytes grew in the sample reach. Periphytic algae attached to the substrate were abundant in the riffles during the summer. The substrate primarily was small gravel with some sand and silt.

Onsite determinations of water quality and samples for analysis of turbidity were collected on each visit. The minimum dissolved-oxygen concentration was 5.3 milligrams per liter, after a flood during August 1980. The August measurements were made 3 days after the flood. The maximum turbidity occurred during August, as did the minimum specific conductance of 680 microsiemens per centimeter at 25 °Celsius. The average specific conductance was 2,650 microsiemens per centimeter at 25 °Celsius. The water at the site sometimes was murky; turbidities ranged from 8 to 1,100 nephelometric turbidity units. The pH reached a maximum of 8.7. The maximum water temperature was 23.5 °Celsius, recorded during June. Peterson (1988) determined that sodium and sulfate historically were the dominant ions, with an average dissolved-solids concentration of 1,760 milligrams per liter.

The runs were sampled on seven dates; the riffles were sampled on two dates. Invertebrate communities of the runs and riffles at this site were similar and, therefore, the analyses are discussed together. The site was relatively unproductive. Average density was 109 invertebrates per square foot. Minimum densities occurred during June and August 1980 (fig. 14), perhaps due to flooding 1 day before the June sampling and 3 days before the August sampling.

Dominant invertebrates included Chironomids, Simulium and Oligochaeta. The predominance of Diptera in many of the samples (fig. 14) was due to numbers of Chironomids and Simulium. Cheumatopsyche and Dubiraphia were present on all sample dates, but not numerically dominant. Organic matter in and on the substrate was a food source for the Oligochaeta, Dubiraphia, and many of the Chironomids. The filter feeders Simulium and Cheumatopsyche were well established at this site, as might be expected with an extended period of flow.

The rate of drift was small in the Belle Fourche River near Moorcroft. The average rate was 8.4 invertebrates per hour, based on 7 drift samples. The most common invertebrates were chironomids, water boatmen (Corixidae), and terrestrial insects.

Dead Horse Creek

The sample-collection site is located at streamflow-gaging station 06313700 on Dead Horse Creek, an ephemeral tributary to the Powder River. The flow-duration curve for the station is shown in figure 12. Contrary to the expected flow pattern, the creek flowed on all sample dates but at a relatively small rate, averaging 0.09 cubic feet per second. Aquatic habitat at the site consisted primarily of pools. The most distinguishing feature of the site was the absence of emergent or submerged macrophytes, or visible periphyton. Cottonwood leaves lined the channel and pools. The substrate of the pools and riffles was a mixture of sand and gravel, with a large proportion of clay.

On each sample visit, water-quality measurements consisted of onsite determinations and samples collected for analysis of turbidity. Dissolved-oxygen concentrations ranged from 5.3 to 12.0 milligrams per liter on the sample dates. Specific conductance was variable, ranging from 1,800 to more than 8,000 microsiemens per centimeter at 25 °Celsius. The median pH was 7.8. The maximum water temperature measured was 17.0 °Celsius, which was less than that at other sites. The water was slightly murky, reaching a maximum of 25 nephelometric turbidity units in a sample collected 1 day after a small flood during August 1980.

The pools in Dead Horse Creek were unproductive. Invertebrate densities ranged from 0 to 206 invertebrates per square foot (fig. 15) and averaged 58 invertebrates per square foot. Although the maximum values occurred during the spring, a seasonal trend was not confirmed. The median diversity was 0.94, which indicates stress on the community. The small benthic invertebrate diversities may be interrelated with the absence of aquatic vegetation and periodic flooding at the site.

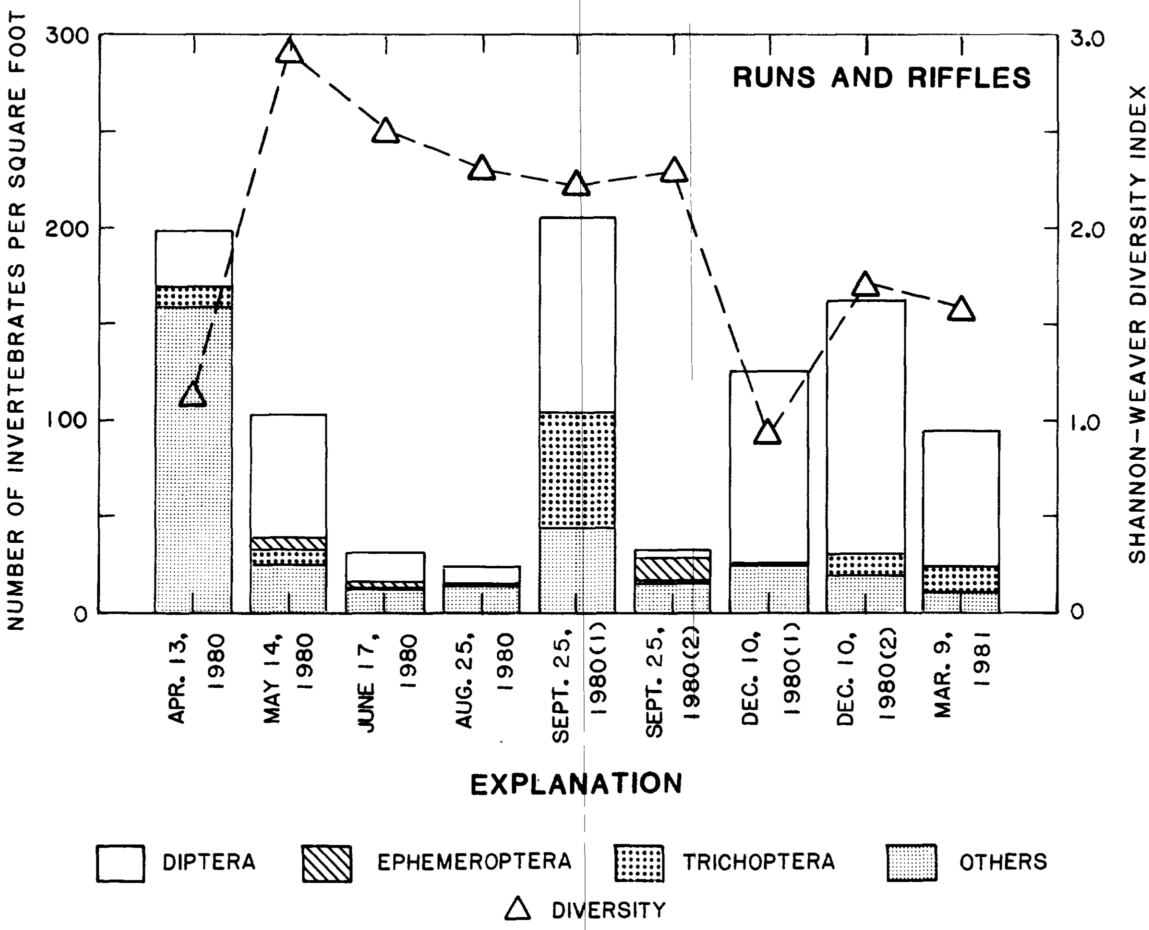


Figure 14.--Composition, density, and diversity of benthic invertebrates from runs and riffles in the Belle Fourche River near Moorcroft (station 06426500). Number in parentheses after date distinguishes duplicate samples.

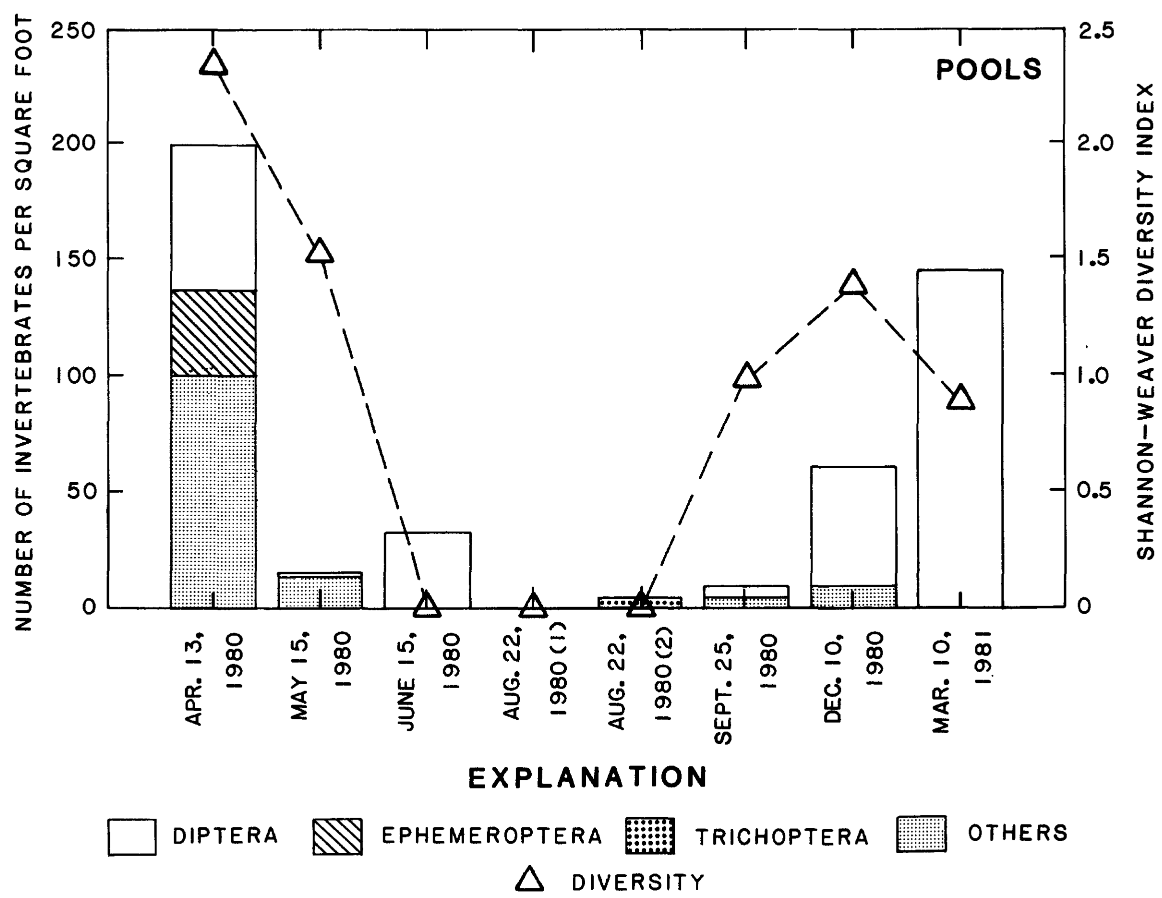


Figure 15.--Composition, density, and diversity of benthic invertebrates from pools in Dead Horse Creek (station 06313700). Number in parentheses after date distinguishes duplicate samples.

Dominant invertebrates in the pools were chironomids (Diptera) and snails (included in "others," fig. 15). The predominance of Diptera resulted from the numbers of chironomids and Heleidae (biting midges). The mayfly Callibaetis was common in some samples. Callibaetis is adapted to still waters (Edmunds and others, 1976, p. 166), as are snails and most of the chironomids. Invertebrates adapted to flowing water were present in the pools at small density during April and August. They probably were deposited in the pools during floods, rather than seeking the pool habitat. Water striders (Gerridae) were numerous on the surface of the pools.

Dead Horse Creek flowed between the pools, but at a small rate which limited the effectiveness of the Surber sampler. Therefore, the samples collected from the riffles are considered qualitative. Chironomids and snails were the most common invertebrates in the riffles. These invertebrates are not adapted to flowing water, but the small volume and slow velocity of water apparently did not restrict them. Simulium was found in small numbers, in four of the seven riffle samples. Oligochaeta and predaceous diving beetles (Dytiscidae) also were common.

Miscellaneous Ephemeral Streams

Four sites in ephemeral streams were sampled on a miscellaneous basis. The sites (fig. 1) were: Raven Creek at streamflow-gaging station 06425950, Box Creek at miscellaneous site 430609105163901, Little Thunder Creek at station 06375600, and Lodgepole Creek at station 06378300.

Raven Creek contained isolated pools along a dry stream channel. Aquatic vegetation was sparse or absent in the pools. A qualitative sample collected from several pools contained many invertebrate taxa not found in samples elsewhere in this study; most notably Conchostraca (clam shrimp) and Anostraca (fairy shrimp). Pennak (1978, p. 326) notes that these are among the most characteristic inhabitants of temporary pools. One of their adaptations to life in pools that dry up every year is thick-shelled eggs that remain viable after drying and freezing. Also present were the mayfly Callibaetis, the mosquito larvae Culiseta, and numerous zooplankton. Some of the invertebrate taxa collected in Raven Creek also were collected from pools at other sites such as the snail Physa, backswimmers and water boatmen (Hemiptera), and chironomid larvae.

Box Creek was sampled in an ephemeral reach located downstream from the intermittent reach described earlier in this report. Aquatic vegetation, both submerged and emergent, was abundant and provided food and shelter for a considerable variety of invertebrates. Samples collected during August and September 1980 contained invertebrate taxa adapted to standing waters that were common in pools at other sites in this study. The most common invertebrates were snails, scuds (Hyallela azteca), dragonfly nymphs, and beetle larvae. During September, the water level of the pool was lower than during August, and many of the invertebrates and minnows appeared distressed and reacted slowly. The dissolved-oxygen concentration was 4.2 milligrams per liter, and the pool had a strong odor of rotting organic matter. Decomposition of organic matter during the night, when photosynthesis was not occurring, may have depressed the dissolved-oxygen concentrations, thereby stressing the invertebrates or causing death. The benthic-invertebrate density was smaller during September than during August.

Little Thunder Creek was sampled in a reach with numerous unconnected pools. The pools were turbid, and deeper than 3 feet. Submerged macrophytes were sparse. Invertebrate density in a sample collected during September was quite small. Beetle and chironomid larvae were the only invertebrates collected. The lack of macrophytes may have limited productivity at this site.

Isolated pools in Lodgepole Creek contained periphytic algae on macrophytes in shallow areas, but the macrophytes generally were sparse. The pools were very turbid and greater than 3 feet deep. The pool sediments were anoxic immediately below the sediment surface. A sample collected during August contained only a few phantom midge larvae Chaoboris. Zooplankton were observed in the pools, in addition to small numbers of minnows, water striders and backswimmers (Hemiptera), damselfly nymphs, and whirligig beetles (Gyrinidae). These taxa are adapted to standing water. The small invertebrate density probably is related to the lack of macrophytes.

COMPARISON OF INVERTEBRATE COMMUNITIES

Invertebrate densities varied greatly between the sites, based on average benthic densities (fig. 16) calculated from the sum of riffle, run, and pool samples at each site. The average density of benthic invertebrates was largest in a perennial stream, the Little Powder River at Highway 59, which contained an average of 1,040 invertebrates per square foot in samples from riffles, runs, and pools. Perennial streams contained relatively large average densities, with the exception of Salt Creek. The smallest average densities occurred in Salt Creek (3.4 invertebrates per square foot) and the Cheyenne River (16.6 invertebrates per square foot). Invertebrate communities in these two streams were stressed by degraded water quality or inadequate substrate or both.

The invertebrate communities also can be compared to each other through a nonparametric coefficient of community similarity. The Jaccard coefficient of community similarity (Sneath and Sokal, 1973, p. 131) was computed as follows:

$$S_j = \frac{a}{a + b + c}, \qquad (2)$$

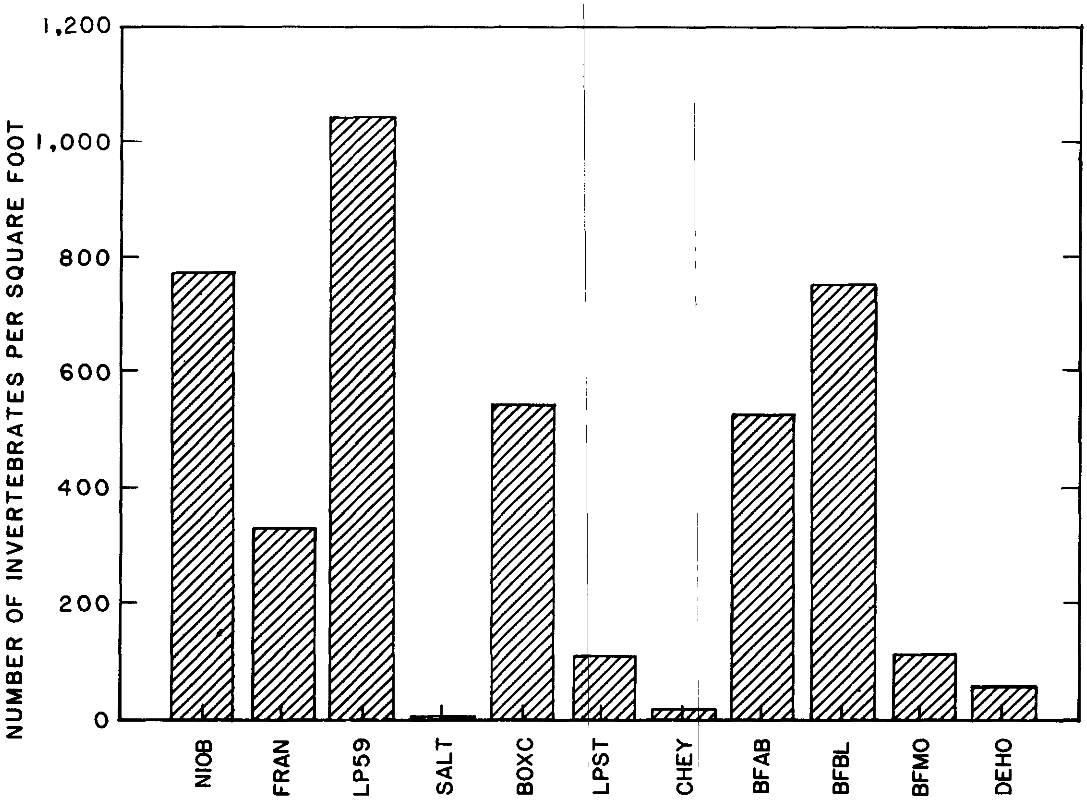
where S_j is the Jaccard coefficient;

a is the number of taxa common to both sites;

b is the number of taxa that occur at the first site, but not the second; and

c is the number of taxa that occur at the second site, but not at the first.

The Jaccard coefficient ranges from 0 (no similarity) to 1 (complete similarity). The Jaccard coefficient is based on the presence or absence of taxa, not on the number of individuals in each taxon.



EXPLANATION

NIOB NIOBRARA RIVER

FRAN FRANK DRAW TRIBUTARY NUMBER 2

LP59 LITTLE POWDER RIVER AT STATE HIGHWAY 59

SALT SALT CREEK

BOXC BOX CREEK

LPST LITTLE POWDER RIVER NEAR WYOMING-MONTANA STATE LINE

CHEY CHEYENNE RIVER

BFAB BELLE FOURCHE RIVER UPSTREAM FROM CORDERO MINE

BFBL BELLE FOURCHE RIVER DOWNSTREAM FROM CORDERO MINE

BFMO BELLE FOURCHE RIVER NEAR MOORCROFT

DEHO DEAD HORSE CREEK

Figure 16.--Average density of benthic invertebrates.

Jaccard coefficients (table 1) indicate that the most similar invertebrate communities occurred in Box Creek and the Niobrara River, the Little Powder River at State Highway 59, and Frank Draw tributary number 2, because of the taxa adapted to flowing water. These sites also contained the largest numbers of taxa (table 1). The invertebrate communities at the three sites on the Belle Fourche River were relatively similar to each other and also to those in Box Creek and the Little Powder River at the Wyoming-Montana State line because of the invertebrate taxa adapted to standing water and vegetation in pools. The invertebrate communities were least similar between Salt Creek and the other three perennial streams because of the environmentally limited conditions of Salt Creek versus the relatively healthy conditions at the other perennial streams. Salt Creek contained the smallest number of taxa of all the sites.

A cluster diagram was generated through the computer statistical package SAS[1] (SAS Institute, Inc., 1982), based on the Jaccard coefficients (fig. 17). The cluster procedure recalculated the coefficients and grouped the sites, according to the similarity of invertebrate communities at each site to all the other sites. Minimally connected data sets (lesser similarity) give long, strung-out clusters, whereas fully connected data sets (greater similarity) are dense and compact (Sneath and Sokal, 1973, p. 198). The clustering method used was the hierarchial average linkage (squared Euclidean distance) between pairs of observations (SAS Institute, Inc., 1982, p. 423). Ward's method of clustering (SAS Institute, Inc., 1982, p. 420-424) also was tested with SAS and produced a diagram similar to that of the average linkage method.

The cluster diagram (fig. 17) indicates that invertebrate communities in perennial streams are similar to each other, and that invertebrate communities in ephemeral streams are similar to each other, with some exceptions. Group 1 indicates similarity in invertebrate communities between the Little Powder River at State Highway 59, the Niobrara River, Frank Draw tributary number 2, and Box Creek. Group 1 contains sites with many taxa adapted to flowing water; streamflow was perennial at three of the sites and intermittent at one site. Group 2 indicates similarity in invertebrate communities between three sites on the Belle Fourche River and the Little Powder River at the Wyoming-Montana State line. Group 2 contains sites with many taxa adapted to standing water; streamflow was ephemeral at three sites and intermittent at one site. Salt Creek shows little connection with other sites, as a result of limitations to the invertebrate community described earlier. Intermittent streams did not form a group, because their invertebrate communities are intermediate to those of perennial and ephemeral streams. The two sites in the Cheyenne River and Dead Horse Creek are grouped together because the invertebrate communities at these sites are more similar to each other than to those at other sites.

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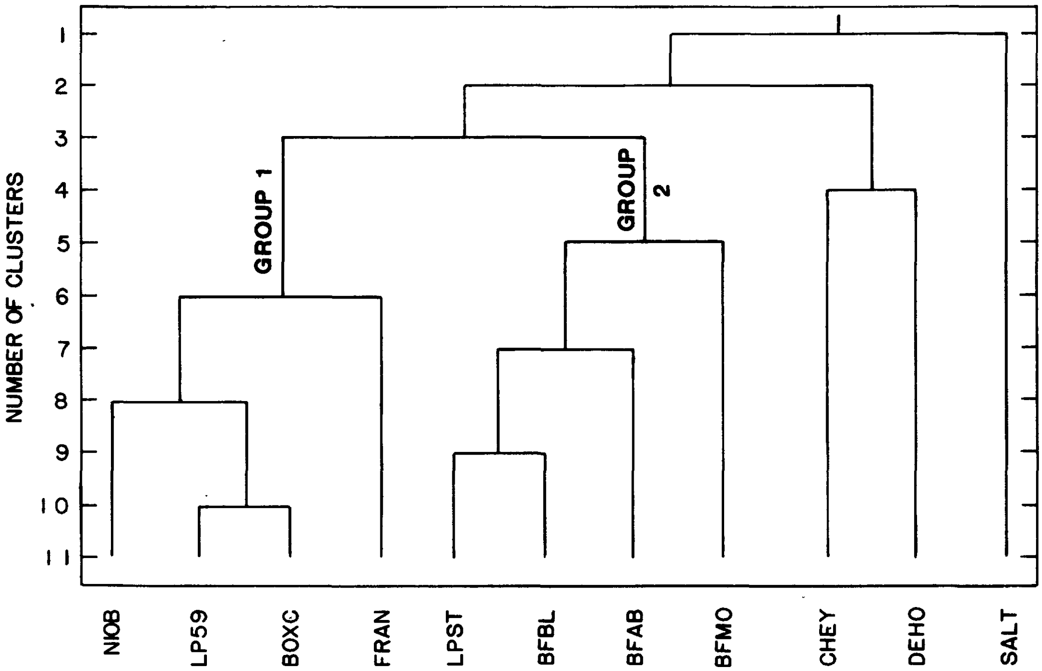
[1] Use of the brand name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 1.--Jaccard coefficients of community similarity between sites

Stream and sampling-site number	Number of taxa	Niobrara River (06454000)	Frank Draw tributary No.2 (430245-105420901)	Little Powder River (06324790)	Salt Creek (06313400)	Box Creek (430433-105234301)	Little Powder River (06324970)	Cheyenne River (06365900)	Bell Fourche River (06425720)	Bell Fourche River (06425780)	Bell Fourche River (06426500)
Niobrara River (06454000)	61										
Frank Draw tributary No. 2 (430245-105420901)	59	0.263									
Little Powder River (06324790)	64	.289	0.268								
Salt Creek (06313400)	10	.076	.062	0.072							
Box Creek (430433-105234301)	49	.410	.350	.395	0.135						
Little Powder River (06324970)	43	.209	.186	.305	.128	0.296					
Cheyenne River (06365900)	19	.176	.130	.186	.115	.214	0.216				
Belle Fourche River (06425720)	31	.227	.233	.267	.139	.311	.298	0.190			
Belle Fourche River (06425780)	39	.250	.225	.338	.114	.333	.367	.184	0.321		
Belle Fourche River (06426500)	26	.192	.164	.200	.200	.316	.255	.216	.295	0.250	
Dead Horse Creek (06313700)	40	.188	.269	.253	.136	.290	.221	.255	.224	.215	0.245



EXPLANATION

NIOB NIOBRARA RIVER

LP59 LITTLE POWDER RIVER AT STATE HIGHWAY 59

BOXC BOX CREEK

FRAN FRANK DRAW TRIBUTARY NUMBER 2

LPST LITTLE POWDER RIVER NEAR WYOMING-MONTANA STATE LINE

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SALT SALT CREEK

Figure 17.--Cluster diagram of invertebrate communities, based on Jaccard coefficients of community similarity.

RECOLONIZATION THROUGH DRIFT

Potential for recolonization of invertebrates in streams is of interest in reclamation of channels altered by mining and in maintenance of invertebrate communities in intermittent and ephemeral streams. Williams and Hynes (1976) found drift to be the most important source of recolonization, but noted that upstream migration within the water, migration within the substrate, and aerial sources are also important. A man-made channel of the Tongue River, flowing through a reclaimed surface coal mine in north-central Wyoming outside the study area, had invertebrate densities comparable to natural conditions within 70 days, whereas 90 days were required to achieve comparable diversities (Gore and Johnson, 1979).

Recolonization through drift can occur during behavioral and constant drift, such as noted during diel-drift sampling in this study. The largest rates of drift were noted in three perennial streams: the Little Powder River at State Highway 59, the Niobrara River, and Frank Draw tributary number 2. The large drift rates indicate that a disturbed reach in these three streams would be recolonized sooner than a disturbed reach of the other streams studied. Stream flooding and the density and diversity levels in undisturbed stream reaches and tributaries also are factors in the rate of recolonization.

Catastrophic drift during stream flooding may aid in recolonization of disturbed stream reaches, as well as intermittent and ephemeral streams. Flooding in the Little Powder River near the Wyoming-Montana State line caused catastrophic drift of many invertebrates not normally found in drift (Wangsness and Peterson, 1980). Catastrophic drift aids recolonization by transport of invertebrates that would not drift otherwise, but the flooding also scours the stream channels. Widespread flooding occurred in the Powder River basin a few days before the August 1980 sampling trip. Drift rates were moderate when sampled after the flood, but the benthic-invertebrate populations had not yet recovered from the effects of the flood and were at smaller densities than during other visits, particularly in the Cheyenne River. Decreases of benthic populations by floods were noted by Stehr and Branson (1938) in an intermittent stream of Ohio.

Specially adapted invertebrates are important in recolonization of dry intermittent and ephemeral streams (Hynes, 1970, p. 403-406). Williams (1977) reported that during drought, dormant invertebrates that burrowed into the substrate were the most important colonizers of two temporary streams in Canada. Larimore and others (1959) and Harrison (1966) considered dormant invertebrates in the substrate and aerial invertebrates migrating from nearby permanent waters to be important recolonizers of streams after the reappearance of flow. Abell (1984) and Stehr and Branson (1938) also noted that invertebrate life cycles coinciding with periods of flow are an important adaptation to intermittent streams.

USE OF DATA TO DEFINE ALLUVIAL VALLEY FLOORS

The regulations for the Surface Mining Control and Reclamation Act of 1977 provide for protection of alluvial-valley floors. Alluvial-valley floors are defined in part by their role in the local surface and ground-water system and also by their historical or potential use for agriculture, such as hay production. Identification of alluvial-valley floors through aquatic biology and streamflow type was considered in this study, but preliminary examination yielded negative results. A potential problem in application is the difficulty of correlating streamflow type and the invertebrate community with the presence or absence of potential agricultural activities, which has recently been emphasized in identification of alluvial-valley floors (U.S. Office of Surface Mining, 1983).

SUMMARY

Three of the four perennial streams in this study supported invertebrate communities which included many taxa adapted to flowing water. The Niobrara River supported an average density of 772 invertebrates per square foot in riffles and 773 invertebrates per square foot in runs. Average invertebrate density and diversity in runs at Frank Draw tributary number 2 were smaller (average density 328 invertebrates per square foot) than in the Niobrara River or the Little Powder River at State Highway 59, which supported an average density of 653 invertebrates per square foot in riffles and 2,260 invertebrates per square foot in pools. The fourth perennial stream, Salt Creek, supported an average density of 3.4 invertebrates per square foot in riffles and runs. Density and diversity in Salt Creek were small because of stress caused by degraded water quality or unstable substrate or both. Salt Creek was the only perennial-stream site lacking a well-defined community adapted to flowing water. Diel (24-hour) sampling of the drift in the other three perennial streams showed behavioral and constant drift patterns and yielded several uncommon species at each site. Drift in Salt Creek was not sampled on a diel basis.

Communities of intermittent streams contained some taxa adapted to flowing waters and other taxa adapted to standing water. Box Creek supported a relatively dense, diverse invertebrate community in riffles (average density 929 invertebrates per square foot), but pools were sparsely populated (average density 98 invertebrates per square foot). The average density in Box Creek was 541 invertebrates per square foot. The Little Powder River near the Wyoming-Montana State line supported many taxa in riffles and pools, at an average density of approximately 100 invertebrates per square foot in both environments. The Cheyenne River supported relatively few invertebrates (average density 16.6 invertebrates per square foot in runs), probably due to the unstable substrate.

Ephemeral-stream communities generally were composed of taxa adapted to standing water. Vegetation in the pools formed an important habitat for benthic invertebrates in the Belle Fourche River upstream and downstream from the Cordero Mine. Invertebrate density and diversity were smaller upstream from the mine (566 invertebrates per square foot) than downstream (884 invertebrates per square foot). Between the two sites, the river receives intermittent flow from a tributary, is diverted around the mine, and receives infrequent pumpage from the mine. Contrary to the ephemeral flow pattern expected on the basis of the flow duration curve, the Belle Fourche River near Moorcroft flowed on all sample dates; the samples contained some taxa adapted to flowing water and yielded an average density of 109 invertebrates per square foot. Dead Horse Creek supported a relatively small average density of 58 invertebrates per square foot in samples collected from pools.

The Jaccard coefficient of community similarity and a cluster diagram were used to compare the invertebrate communities. The most similar communities occurred in Box Creek, the Niobrara River, the Little Powder River at State Highway 59, and Frank Draw tributary number 2, because of the taxa adapted to flowing water. The communities at the three sites on the Belle Fourche River were relatively similar to each other and also to those in Box Creek and the Little Powder River at the Wyoming-Montana State line, because of the invertebrate taxa adapted to standing water and vegetation in pools.

Recolonization potential of streams was assessed through drift samples to gain understanding for reclamation of channels altered by mining and in maintenance of invertebrate communities in intermittent and ephemeral streams. The largest rates of drift were noted in three perennial streams--the Niobrara River, Frank Draw tributary number 2, and the Little Powder River at State Highway 59.

With further study, a method could be developed to determine streamflow type from qualitative samples of the invertebrates. The similarity of communities within perennial and ephemeral streams, demonstrated in this study, provides a basis for future study of this potential application. Traditionally, at least 5 years of streamflow record is required to plot a reliable flow-duration curve, which can be used to determine streamflow type. Development of a predictive method using aquatic-biologic samples would provide a comparatively quick indication of the streamflow type. Further work might include analysis of invertebrate samples from other perennial, intermittent, and ephemeral streams, taxonomic identifications to species level, and more detailed statistical analysis.

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* U.S. GOVERNMENT PRINTING OFFICE: 1990--774-681/25056