MOUNT EMMONS
AQUATIC ECOLOGY BASELINE STUDIES
1978 - 1979

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1979

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Mount Emmons Project
Aquatic Ecology Studies

INTRODUCTION

Aquatic ecology data were collected in the upper Gunnison River watershed during 1978 and 1979 to provide baseline information for areas that might potentially be impacted by project development.

Objectives of the aquatic ecology program were to provide a detailed description of the aquatic habitat of the project area, provide baseline data on the existing aquatic environment, and identify any aquatic organisms that have been classified by State or Federal agencies as rare, endangered or threatened. Elements of the aquatic biota studies in 1978 and 1979 included periphyton*, benthic invertebrates, and fish.

Periphyton includes all aquatic organisms that grow on submerged substrate and includes attached algae, bacteria, protozoans, and small invertebrates. Most ecological studies of periphyton are concerned with algal components because attached algae have been shown to be a useful indicator of water quality (U.S. EPA 1973).

The benthic invertebrate and fish communities were studied because of the importance of these organisms in aquatic ecosystems and their sensitivity to natural or man-induced disturbances.

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*All underlined words in the Executive summary except species names are defined in the Glossary.

REGIONAL SETTING

The composition and abundance of aquatic biota in the project area are influenced by water quality. Presently, the major source of water quality degradation within the watershed is mine drainage from abandoned coal and base metal mining operations. These mines were active in the late nineteenth and early twentieth centuries. Mine drainage from these areas is characteristically acidic and contains high concentrations of iron, lead, zinc, copper, manganese, and cadmium.

The largest source of acid mind drainage in the project area is the Keystone Mine on Coal Creek. Drainage from this abandoned mine has nearly eliminated all aquatic life and has clouded the waters and stained the substrate of Coal Creek from the discharge downstream to the Slate River. Drainage from active and abanooned mines in other areas of the watershed and natural sources such as an iron bog and springs tend to elevate metal concentrations, especially zinc, and reduce the pH of waters in the project area.

Other sources of water quality degradation within the project area include wastes from both domestic sources and livestock. The major point source of domestic waste is the waste water treatment plant for the Town of Crested Butte. Domestic wastes from Mt. Crested Butte, which enter the Slate River via Washington Creek, also affect water quality, especially during the winter months when domestic waste loading to the treatment facility is highest and treatment efficiencies are, characteristically, lowest. Cattle pastured in the project area during the summer impact the streams by introducing wastes and by disturbing the bed and banks of streams.

OESCRIPTION OF PROJECT AREA

PROJECT AREA

Oata on the aquatic ecology of the project area were collected at a total of 16 stations (Figure 1) on eight streams. Four stations were located on Coal Creek and five stations were located on the Slate River to collect baseline data for the area that might be affected by the proposed mine development. Three sampling stations were located on the Ohio Creek and Carbon Creek to collect baseline data on streams that might be affected by construction, use, and maintenance of major transportation corridors for the project. Oata from two stations on the East River and one on Alkali Creek provide baseline information on streams near the proposed mill/tailing site in Alkali Basin. One station on Tomichi Creek was established to provide baseline data near the altenative tailing site in Chance Gulch and on Cabin Creek.

A summary of the aquatic and riparian habitats in the project area are included in Table 1. Oata on fish, benthic invertebrates, and periphyton collected in the Mount Emmons Project area during 1978 and 1979 are shown in Tables 2, 3, and 4, respectively.

MINE AREA

Coal Creek (Stations 2a, 3, 4, and 5)

Coal Creek flows south from its headwaters in Independence Basin through the Settlement of Irwin and then turns to the east and flows toward the Town of Crested Butte. Near Kebler Pass, Coal Creek meanders through a willow covered subalpine meadow that contains a series of beaver ponds. Oata from electrofishing surveys in this vicinity (Station 2a) indicate a population of brook trout (Table 2). Population estimates based on mark-recapture data (Everhart et al. 1975) collected during the fall of 1978 and 1979 indicated over 1,250 fish per kilometer (2,000 fish per mile) in this section of

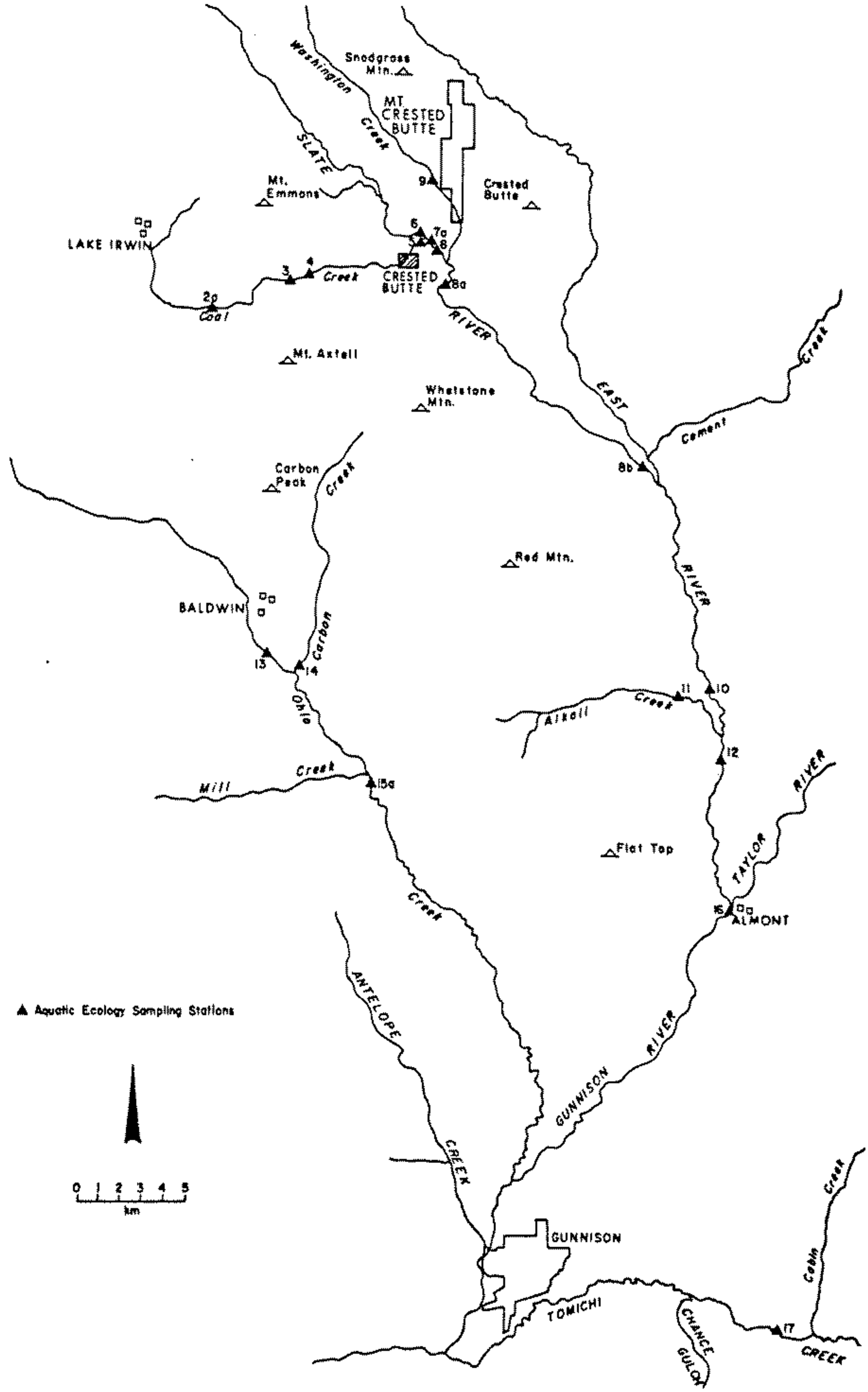

Figure 1 Location of aquatic ecology sampling stations, 1978 and 1979.

Table 1 Summary of the stream habitat at aquatic ecology sampling stations in the Mount Emmons Project study area, fall 1979

Station	Width (ft)	Depth (ft)	Stream Gradient (%)	Bottom Composition (%) 12"	3-11"	1-3"	.1-1"	Sand	Silt	Pool: Riffle Ratio (%)	Dominant Bank Cover
2a	3-6	0.5-2	2	5	40	25	15	5	10	50:50	Shrubs and Grass
3	5-10	0.5-1.5	4	30	30	20	10	10		30:70	Grass, Shrubs, Rocks
6	10-20	0.8-3	0.2		5	80		5	10	70:30	Gravel, Grass
7a	20-40	0.5-2	0.2	5	30	30	20		15	20:80	Rubble, Shrubs
8	20-30	1-6	0.1			30			70	70:30	Grass
8a	30-70	0.5-5	0.1	5	30	30		5	30	70:30	Grass
8b	40-80	0.5-3	2	10	60	15	10		5	40:60	Shrubs, Trees
10	40-80	0.5-4	1	10	60	10	10	5	5	30:70	Rock, Trees
11	2-5	0.2-2	-	5	5		10		80	50:50	Soil, Grass
12	50-90	0.5-2.5	1	5	40	20	20		15	20:80	Shrubs and Grass
13	12-20	0.5-3.5	2	10	50	20	10	5	5	55:45	Trees,Grass
14	4-12	0.2-3		5	40	20	10	5	20	55:45	Grass
15a	10-20	0.5-2	0.8	5	40	30		5	15	35:65	Trees, Grass
17	20-40	1-4	0.1	10	25	25	10	10	20	50:50	Grass, Shrub

Table 2 Comparison of number and species composition of fish collected during the fall of 1978 and 1979

	Number of Fish[a]													
	Brook Trout		Brown Trout		Rainbow Trout		White Sucker		Longnose Sucker		Fathead Minnow		Longnose Dace	
Station	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
2[b] Coal Creek	171	98	-	-	-	-	-	-	-	-	-	-	-	-
3 Coal Creek	57	56	-	-	-	-	-	-	-	-	-	-	-	-
6 Slate River	39	88	54	48	2	1	2	12	-	-	-	-	-	-
7[c] Slate River	44	21	3	-	-	-	8	15	-	-	-	-	-	-
8 Slate River	8	148	4	4	2	-	5	170	-	-	-	-	-	-
8A Slate River	-	32	-	9	-	-	-	75	-	-	-	-	-	-
8B Slate River	-	23	-	28	-	1	-	-	-	-	-	-	-	-
9 WashingtonCreek	66	-	-	-	-	-	-	-	-	-	-	-	-	-
10 East River	-	-	60	66	1	1	-	-	-	-	-	-	-	-
12 East River	-	-	60	51	4	-	-	-	-	-	-	-	-	-
13 Ohio Creek	23	29	17	5	5	10	-	-	-	-	-	-	-	21
14 Carbon Creek	207	210	3	0	3	-	-	-	-	-	-	-	-	-
15[b] Ohio Creek	8	12	15	2	2	1	-	1	48	6	-	-	75	42
17 Tomichi Creek	-	1	-	21	-	-	-	67	-	30	-	7	-	175

[a] Number of fish collected in 91 m (300 ft) of stream at each station

[b] Station 2 was moved approximately 0.05 km (150 ft) downstream and Station 15 was moved approximately 0.1 km (300 ft) upstream for the fall survey in 1979 because habitat at the former locations had been altered.

[c] Station 7 was moved approximately 0.2 km (600 ft) downstream and was designated 7a for the 1979 aquatic ecology sampling because flows from Coal Creek and the Slate River had not completely mixed at the previous location of Station 7.

Table 3 Comparison of number of taxa, mean density, and diversity of benthic macroinvertebrates collected in riffle samples during the fall of 1978 and 1979

Station	Location	No. of Taxa 1978	No. of Taxa 1979	Mean density (No/sq m) 1978	Mean density (No/sq m) 1979	Diversity[a] 1978	Diversity[a] 1979
2	Upper Coal Creek	35	42	2,196	2,195	3.66	3.64
3	Upper Coal Creek	18	25	377	936	3.24	3.44
4	Lower Coal Creek	0	1	0	11	0	0
5	Lower Coal Creek	2	5	11	26	0	1.16
6	Upper Slate River	22	21	969	3,943	2.50	1.39
7	Lower Slate River	6	8	65	237	1.44	1.65
8	Lower Slate River	12	8	527	102	2.55	1.91
10	East River	19	24	1,604	1,302	2.18	2.74
11	Alkali Creek	10	26	366	4,885	1.87	2.55
12	East River	18	31	1,830	4,917	2.16	2.54
13	Upper Ohio Creek	20	29	1,044	2,610	3.23	3.00
14	Carbon Creek	22	45	3,143	3,788	2.00	3.94
15	Lower Ohio Creek	10	30	269	4,212	2.21	3.13
17	Tomichi Creek	-	51	-	6,726		3.36

[a]Diversity index based upon Lloyd et al. (1968).

Table 4 Comparison of mean and maximum organic weight (mg/sq m) and density of attached algae (organisms/sq m) on glass slides placed at eight stations, August and October 1979.

	Accumulated organic weight (mg/sq m)		Density of Attached Algae (organisms/sq m)	
Station	Mean[a]	Maximum	Mean[b]	Maximum
3	527	1,020	59,500	160,700
4	240	513	28	96
6	225	480	48,400	190,200
7a	150	300	1,520	4,950
10	755	2,153	282,000	1,161,000
12	523	1,867	73,800	141,600
14	857	1,667	123,000	547,500
17[c]	2,003	5,333	112,000	130,000

[a] Mean for 8 sampling periods in August/September and 7 dates in October 1979.
[b] Mean for 3 sampling periods in August/September and 2 dates in October 1979.
[c] Samples at Station 17 collected only during October 1979.

Coal Creek. Over 90 percent of the brook trout collected in Coal Creek and other small tributaries in the study area such as Carbon Creek, were less than 200 mm (8 in.) in length.

Coal Creek at Station 2a also supported dense growth of attached algae (Table 4) and a diverse community of benthic invertebrates (Table 3).

Downstream from Station 2a, Coal Creek flows from the subalpine meadow into a steep, forested valley. The stream gradient in this vicinity was approximately four percent, the channel was straighter and contained fewer pools than near Station 2a. Water quality data collected in this vicinity (Station 3) indicated higher concentrations of zinc than at Station 2a. The source of this zinc may have been mine drainage, iron bog, or springs.

Fewer trout were collected in this section of Coal Creek in both 1978 and 1979 than at Station 2a (Table 2). Estimated population of brook trout at Station 3 was 880 fish per kilometer (1,420 fish per mile) based upon data collected during the fall of 1978 and 1979.

Density of benthic invertebrates (Tables 3) and periphyton (Table 4) were also lower at Station 3 for most sampling periods compared to data from Staton 2a; however, during March 1979, mean density of benthic invertebrates was over 11,000 organisms/sq m (1,000/sq ft) in samples from both pool and riffle habitats at Station 3 due to large numbers of Chironomidae (midges) in the samples. Midges constituted approximately 90 percent of the total taxa collected during the spring survey in 1979. Chironomids were also the dominant taxa in July 1978.

Discharge from the Keystone Mine enters Coal Creek approximately two miles upstream from the Town of Crested Butte. Below the discharge, the substrate of Coal Creek is stained orange by deposits of ferric hydroxide, and the creek is nearly devoid of plant and animal life due to the high concentrations of zinc, iron, copper, lead, cadmium, and other metals. Figure 2 illustrates the effects of the Keystone Mine discharge on the density of fish benthic invertebrates, and attached algae. Average concentrations of these metals near Station 4 on Coal Creek for the period from April 1978 to March 1979 were 15.1 mg/l Zn, 25.9 mg/l Fe, 0.58 mg/l Cu, 0.20 mg/l Pb, and 0.23 mg/l Cd (AMAX 1980a).

No fish were collected during fishery surveys in 1978 on lower Coal Creek downstream of the Keystone Mine discharge or near the confluence of Coal Creek with the Slate River. Benthic invertebrate populations in lower Coal Creek were nearly eliminated (Table 3). The few organisms collected in lower Coal Creek probably drifted into the area from upstream and were not permanent residents of this portion of the stream.

Data on attached algae indicated low density immediately downstream of the discharge at Station 4 (Table 4). Biomass measurements based on the amount of organic matter accumulated on artificial substrates placed at Station 4 was similar, however, to that at Stations 6 and 7a. This organic matter may have been nonliving detritus. Another explanation is related to the selective toxicity of metals. Review of literature on the toxicity of metals to algae (Gaechther 1976, Bartlett et al. 1974) indicates that the average concentrations of copper (0.58 mg/l) and zinc (15.1 mg/l) recorded at Station 4 on Coal Creek are toxic to most algal species. Weitzel (1979) reports that these metals are more toxic to algae than to bacteria and other heterotrophic organisms. Thus, it is possible that algal growth was inhibited by the heavy metals but that bacteria were not adversely affected.

Oata collected in 1978 showed that the attached algal community had recovered at Station 5 near the confluence with the Slate River (Table 4). The dominant taxa of algae collected on lower Coal Creek in 1978 was *Achnanthes minutissima*. Lowe (1974) describes *A. minutissima* as a species with wide tolerance to pH, salinity, and current. The taxon was also common at stations on the Slate and East rivers.

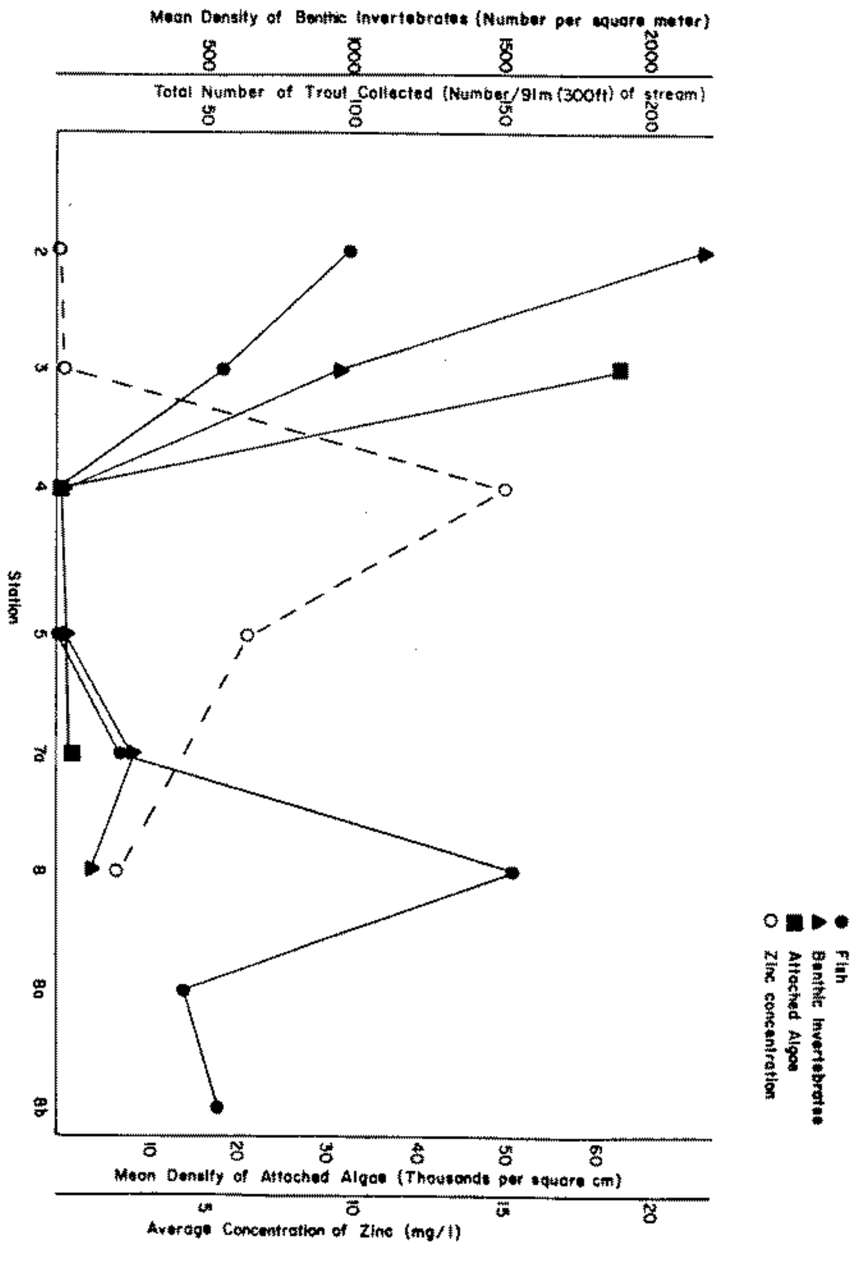

Figure 2. Comparison of the Density of Attached Algae, Benthic Invertebrates, and Fish With the Zinc Concentration at Aquatic Ecology Sampling Stations on Coal Creek and the Slate River.

As part of the "Clean Up Coal Creek Project", AMAX is constructing a water treatment facility to reduce concentrations of metals in the Keystone Mine discharge. It is anticipated that water quality will improve to the point that lower Coal Creek will once again support aquatic biota. Sampling of drifting invertebrates was conducted upstream of the mine discharge in 1979 to determine if an adequate number and variety of organisms were being carried downstream by the current to recolonize lower Coal Creek. Similar studies were conducted on the Slate River upstream of the Coal Creek confluence.

The mean density of drifting organisms collected in this survey ranged from 45 to 145 organisms/100 cu m (1.3 to 4.1 organisms/cu ft) of flow on Coal Creek and from 11 to 103 organisms per 100 cu m (0.3 to 2.9 organisms/cu ft) on the Slate River. Sixty-eight different taxa of organisms were collected in drift samples at the two locations. Data from the drift survey and from the literature (Waters 1962, Herrick 1973, and others), indicate that lower Coal Creek and the Slate River downstream of the Coal Creek confluence can be recolonized by benthic macroinvertebrates within a few months if water quality improves and ferric hydroxide deposits are flushed from the substrate.

Slate River (Stations 6, 7a, 8, 8a, and 8b)

The Slate River near Crested Butte flows through a wide alluvial valley. The streamside vegetation is primarily grasses and sedges with interspersed stands of willows.

The gradient of the Slate River upstream of the Coal Creek confluence is gentle (approximately 0.2 percent) and the stream channel meanders across the flood plain. The substrate of the upper Slate River is predominantly composed of flat, shale gravel and rubble. Due to the gentle gradient, the habitat of the Slate River in this vicinity, is dominated by 0.6-1.2 m (2-4 ft) deep pools.

Electrofishing data collected on the Slate River upstream of the Coal Creek confluence (Station 6) show that three species of trout, brook (Salvelinus fontinalis), brown (Salmo trutta), and rainbow (Salmo gairdneri) and white suckers (Catostomus commersoni) were collected during the fall surveys in both 1978 and 1979 (Table 4). A cutthroat trout (Salmo clarkii) was among the fish collected at Station 6 during the spring survey in 1978.

Density and diversity of benthic invertebrates collected at Station 6 were variable for the two years of the study. Density in samples from riffle areas ranged from a low of 27 organisms sq m (2.5 organisms/sq ft) in July 1978 to 3,943 organisms/sq m (369 organisms/sq ft) in September 1979. Diversity varied from 0.32 in July 1978 to 2.87 in September 1979. Taxonomic composition of the sample was also variable. Segmented worms (Oligochaeta) comprised 98 percent of the organisms collected in pools during the July 1978 survey, but were less than 2 percent of the organisms collected in pools and riffles for the other three sampling dates. In 1979, mayflies (Ephemeroptera) were the dominant taxa in samples from riffle areas and chironomids (midges) were numerically dominant in pools. Comparison of water quality data collected at Station 6 shows no significant changes for the two years of study (AMAX 1980a, 1980b). Thus, the temporal differences in diversity and species composition were not the result of changes in water quality, but probably resulted from sampling of different microhabitats in July 1978 compared to the other three sampling dates.

The density of attached algae at Station 6 was similar in 1979 to the density collected on upper Coal Creek (Station 3, Table 4). The dominant taxa of algae at Station 6 in 1978 and 1979 was the diatom, Achnanthes minutissima.

Coal Creek flows into the Slate River approximately 0.1 km (300 ft) downstream of Station 6. A yellow cloud forms in the Slate River at the Coal Creek confluence due to precipitation of dissolved iron from Coal Creek. Ferric hydroxide covers the substrate, especially in pools.

Fish were collected immediately below the confluence of the two streams (Station 7) in 1978 and approximately 0.5 km (0.3 mi) downstream from the confluence (Station 7a) in 1979. Brook trout and white suckers were the dominant taxa collected (Table 2). Reduction in the number of brown trout and rainbow trout in the Slate River below Coal Creek compared to the Slate River upstream of that point may be due to the greater sensitivity of brown and rainbow trout to zinc toxicity as compared to brook trout. Holcombe and Andrews (1978) report the toxic concentration of zinc to be 2.7 times higher for brook trout than for other trout species. For brook trout, the maximum allowable toxicant concentration (MATC) of zinc is reported to be between 0.5 and 1.3 mg/l (hardness 45 mg/l) (Holcombe and Andrew 1978). Average zinc concentration in the Slate River downstream of Coal Creek was 2.0 mg/l (hardness 71 mg/l), (AMAX 1980a, 1980b). Thus, the brook trout have either acclimated to the higher zinc concentration or possibly are not permanent residents of this section of the stream.

The benthic macroinvertebrate and attached algal community in the Slate River were also affected by the metal-laden discharge from Coal Creek. Density, diversity, and number of benthic invertebrate and algal taxa in 1979 were lower at Station 7a than at other stations in the study area except those on lower Coal Creek (Stations 4 and 5).

The discharge from the waste water treatment plant for the Town of Crested Butte enters Coal Creek approximately 0.05 km (150 ft) downstream from Station 7a. The Slate River from this point downstream is affected by both domestic wastes and high metal concentrations.

The gradient of the Slate River downstream of the waste water treatment plant was less than 0.1 percent. One to two meter (3-6 ft) deep pools occupied approximately 70 percent of the stream habitat. The substrate of these pools was covered with silt and the surface of the stream in backwater areas was blanketed by mats of filamentous algae during the summer and fall of both 1978 and 1979.

In the fall of 1978, only 19 fish were collected in a 91 m (300 ft) section of the Slate River downstream from the waste water treatment plant (Table 2). Sampling at the same location in the fall of 1979 yielded 322 fish including 148 brook trout and 170 white suckers (Table 2).

All of the brook trout and white suckers collected in the fall of 1979 were small: average lengths were 76 mm (3.0 in.) and 84 mm (3.3 in.), respectively.

The difference in the number of fish collected in this portion of the Slate River may have been due to differences in water quality. Comparisons of water quality data at this location show that zinc concentrations were over 2.6 times higher in September 1978 (2.8 mg/l) than in September 1979 (1.05 mg/l) (AMAX 1980a, 1980b). As previously discussed, zinc concentrations in excess of 1.3 mg/l are potentially toxic to brook trout (Holcombe and Andrew 1978).

In addition to direct toxicity of metals to fish and other aquatic organisms, certain metals, including cadmium, copper, iron, lead, molybdenum, and zinc, accumulate in tissues of exposed aquatic organisms.

Concentrations of these metals were measured in fish tissues in both 1978 and 1979 and in <u>sediment</u> samples in 1979. In 1978, the highest concentrations of copper (6,530 μg/g) and iron (10,320 μg/g) were found in white suckers collected on the Slate River below the waste water treatment plant (Station 8). Highest concentrations of zinc (4,050 μg/g) and cadmium (43 μg/g) reported in 1978 were found in rainbow trout also collected at Station 8.

Results from both 1978 and 1979 indicate that the concentrations of cadmium, copper, and zinc were higher in fish collected in the Slate and East rivers than in other streams in the study area. Analysis of metals content of sediment samples conducted in 1979 yielded similar results; concentrations of cadmium, copper, lead, molybdenum, and zinc were higher in sediment samples from the East River drainage (Coal Creek, Slate River, and East River) than in samples from the Ohio Creek drainage (Ohio Creek and Carbon Creek) as shown in Table 5.

The mean density of benthic invertebrates at Station 8 downstream of the waste water treatment plant was lower in 1979 than all areas except lower Coal Creek (Stations 4 and 5; Table 3). The density of benthic invertebrate organisms at Station 8 in 1978 was variable and ranged from 44 organisms/sq m to 1,307/sq m (4.1 to 122 organisms/sq ft). Mean density was 527 organisms/sq m (49 organisms/sq ft).

The habitat of the Slate River, approximately 3.0 km (1.8 mi) downstream of the Town of Crested Butte (Station 8a), was similar to that near the waste water treatment plant (Station 8). Slow flowing pools occupied the majority of the stream habitat. Filamentous algae covered the substrate in shallow portions (less than 0.6 m or 2 ft deep) of the pools and in the riffles.

Fewer brook trout and white suckers were collected at Staton 8a than at Station 8 during the Fall 1979 survey (Table 2). Population estimates based on the mark-recapture data collected in the fall of 1979 indicate approximately 2,200 brook trout per kilometer (3,600 brook trout per mile) and over 7,700 white suckers per kilometer (12,000 white suckers per mile).

The aquatic habitat of the Slate River changed near its confluence with the East River. The gradient of the stream at this point (Station 8b) was approximately two percent and 0.5-0.6 m (1.5 to 2 ft) deep riffles were the dominant habitat type. The substrate was composed of

Table 5 Concentrations of trace metals (in $\mu g/gm$) in fluvial sediment samples from the Mount Emmons study area, Spring 1979

Station	Location	Cadmium	Copper	Iron	Lead	Molybdenum	Zinc
3	Coal Creek	8.4	40	21,700	124	1.0	9.3
4	Coal Creek	2.1	474	32,100	176	1.3	382.0
5	Coal Creek	18.0	262	29,000	155	1.9	2,250.0
6	Slate River	4.1	58	29,100	136	2.5	659.0
8a	Slate River	39.0	390	28,500	230	1.8	4,250.0
8b	Slate River	11.0	127	34,500	146	2.3	2,750.0
10	East River	16.0	73	20,900	53	1.3	4,100.0
12	East River	3.0	19	20,700	28	0.8	702.0
13	Ohio Creek	<0.4	8	30,150	7	<0.3	63.0
14	Carbon Creek	<0.4	6	14,200	6	<0.3	37.0
15	Ohio Creek	<0.4	8	26,500	7	<0.3	59.0

rounded rubble. Sediment deposits and filamentous algae covered less than five percent of the substrate at this location.

A total of 23 brook trout, 28 brown trout, and one rainbow trout were collected in a 91 m (300 ft) section of the Slate River near its confluence with the East River during the fall survey in 1979. Average lengths of brook trout and brown trout were 178 mm (7.0 in.) and 202 mm (8.0 in.), respectively. Approximately five percent of the fish collected in this vicinity were less than 130 mm (5 in.) in length.

The Slate River in this vicinity contains gravel substrate suitable for trout spawning. It is possible that adult brook and brown trout collected during the fall of 1979 had moved into this section of stream to spawn.

In 1979, a fish tagging program was instituted to determine migration patterns of adult trout in the project area. A total of 120 trout were tagged during 1979. To date, data have been returned on 11 fish (9 percent) Seven of these recaptured fish were originally tagged at Station 8b. Of the fish tagged at Station 8b, all were recaptured within one mile of the tagging point except a 240 mm (9.5 in.) brown trout that was collected on the East River approximately eight miles downstream from Station 8b.

MILL/TAILING POND AREA

East River (Stations 10 and 12)

Sampling of aquatic biota was conducted on the East River both upstream and downstream of Alkali Creek. The stream habitat at the two East River stations was similar to that at the Slate River near its confluence with the East River (Station 8b). Riffles, 0.3-0.8 m (1-2.5 ft) deep, occupied 70 to 80 percent of the habitat, pools were confined to areas behind boulders and other obstructions. Brown trout composed over 96 percent of the fish collected at the two East River stations; rainbow trout, the only other fish species collected in the East River, comprised the remaining four percent.

The East River is stocked annually with rainbow trout by the Colorado Division of Wildlife. A total of 8,460 catchable size (greater than 150 mm, 6 in.) rainbow trout were stocked in the East River in 1978 (Colorado Division of Wildlife, 1979b) and a total of 7,800 catchable size rainbow trout were scheduled to be stocked in the East River in 1979 (Colorado Division of Wildlife 1979c). Limited creel census data for 1978 (Colorado Division of Wildlife 1979a) indicate that 58 percent of the trout caught on the East River were rainbow trout. The high percentage of rainbow trout caught by fisherman and the low percentage of rainbow trout collected in the electrofishing surveys suggest that most of these stocked fish are rapidly caught by fishermen. Natural mortality and emigration from the area may also contribute to the low number of rainbow trout collected in electrofishing surveys on the East River near Alkali Creek.

Data on the invertebrate and periphyton of the East River indicate diverse and productive benthic communities (Tables 3 and 4). The dominant taxa of benthic invertebrates in riffle samples collected in the East River were mayflies (Ephemeroptera). Chironomids (midges) were numerically dominant in pool samples.

The highest density of attached algae (1,161,000 organisms/sq cm, 7,490,000 organisms/sq in.) collected in 1979 was at Station 10. The dominant taxa at both East River stations were the blue green alga, *Chamaesiphon* spp., and the diatom, *Achnanthes minutissima*.

Alkali Creek (Station 11).

Alkali Creek is a small, spring-fed tributary that flows through the sagebrush-covered basin between Flat Top and Red Mountain (Figure 1). Although Alkali Creek does not have sufficient flow to support a fish population, a relatively dense and diverse community of benthic invertebrates was collected in 1979 at the sampling station on lower Alkali Creek (Station 11), as compared with the other stations in the study area (Table 3). Chironomidae (midges) were the most common group of organisms in riffle and pool samples at Station 11.

ORE HAULAGE AND TRANSPORTATION CORRIOOR AREA

Ohio Creek (Station 13 and 15)

Ohio Creek flows in a southeasterly direction from Ohio Pass and drains an alluvial valley which is used for hay production.. Although several abandoned coal mines are present in the Ohio Creek drainage, water and sediment quality data (AMAX 1980a) showed that metal concentrations were lower in this drainage than in the East River drainage. Ohio Creek, from approximately one mile upstream of Carbon Creek (Station 13) to downstream of the Mill Creek confluence (Station 15a) is from 3 to 9 m (10 to 30 ft) wide and is lined with cottonwoods and willows along much of its length. The substrate is predominantly rubble. The amount of silt in the substrate increased in the downstream direction.

Fish were collected at two stations on Ohio Creek during both 1978 and 1979. Brook trout, brown trout, rainbow trout, and longnose dace (*Rhinichthyes cataracte*) were collected at both locations in 1978 and 1979 (Table 2). Longnose suckers (*Catostomus catostomus*) were collected at the lower station on Ohio Creek (Station 15a) in both 1978 and 1979.

Population estimates for brook trout and brown trout based on data collected at Station 13 in the fall of 1979 indicate over 900 brook trout and 88 brown trout per kilometer (1,400 brook trout and approximately 140 brown trout per mile). The average length of brook trout, 140 mm (5.5 in.), was similar to that for brook trout in upper Coal Creek.

More rainbow trout (10) were collected at Station 13 in the fall of 1979 than at any other station in the project area. Although all were reported as rainbow trout, one of the trout collected at Station 13 appeared to be a hybrid between a rainbow and cutthroat trout.

Data on the benthic invertebrate community of Ohio Creek are shown in Table 3. Caddisflies (Tricoptera), true flies (Diptera), beetles (Coleoptera), and mayflies (Ephemeroptera) were the dominant taxa, constituting 87 percent of the sample in 1979.

Data on the attached algae collected at Station 13 in 1978 indicated similar density and taxonomic composition to that collected at the two East River stations (Table 4).

<u>Carbon Creek (Station 14)</u>

Carbon Creek drains the south face of Mt. Axtell and is less than 3.6 m (12 ft) wide in most places. Lower Carbon Creek contains several 0.6-1.5 m (2-5 ft) deep pools that provide cover for trout, especially during low flow periods in the fall and winter.

Carbon Creek supports a population of brook trout, over 200 were collected in a 91 m (300 ft) section of Carbon Creek (Station 14) in the fall of both 1978 and 1979. Average length of brook trout collected on lower Carbon Creek in 1978 and 1979 was 130 mm (5 in.) but brook trout up to 289 mm (11.4 in.) were collected.

Due to the low flow that occurred during the fall of 1978 and 1979, all of the fish were isolated in pools. Approximately 20 to 30 percent of the fish captured at Station 14 during the fall survey in 1979 were infected by a fungus, Saprolegnia spp. The four brook trout sacrificed in the fall of 1979 for metal and gastrointestinal analysis had no food material in either their stomachs or intestines. Stress due to lack of food and crowded conditions probably increased the susceptibility of the fish to disease.

The high productivity of lower Carbon Creek was indicated by the dense populations of benthic invertebrates (Table 3) and attached algae (Table 4 and 5) in both 1978 and 1979 and the high accumulation of organic matter on artificial substrates at Station 14 (Table 4) in 1979.

ALTERNATIVE MILL/TAILING SITE

Other mill/tailing sites under consideration include sites on Carbon Creek, Cabin Creek, Chance Gulch, and Antelope Creek. The aquatic ecology of Carbon Creek has been previously discussed. The other three drainages have intermittent or ephemeral flow, thus, no aquatic ecology samples were collected on these drainages. Cabin Creek and Chance Gulch drain into Tomichi Creek, a major tributary in the upper Gunnison River watershed. A station on Tomichi Creek was added to the sampling program prior to the fall of 1979 sampling period to collect baseline information near the mill/tailings sites on Cabin Creek and Chance Gulch.

Tomichi Creek (Station 17)

Tomichi Creek flows west from its headwaters near Monarch Pass to its confluence with the Gunnison River south of the City of Gunnison. The gradient of Tomichi Creek is less than one percent and the stream channel meanders through hayfields and pastures.

The banks of Tomichi Creek downstream of Cabin Creek are lined with grasses and shrubs. The substrate in the riffles is rubble and coarse gravel, but is covered with silt and sediment in pools.

Aquatic ecology sampling was conducted at Tomichi Creek only during the fall of 1979.

Twenty-one brown trout up to 420 mm (16.5 in.) in length were collected in a 91 m (300 ft) section of Tomichi Creek at Station 17. A single brook trout was the only other trout species collected, but large numbers of nongame fish including longnose dace (175), white sucker (67), and longnose sucker (30) were collected (Table 2). Fathead minnows were also collected at Station 17 (Figure 8). This was the only location in the project area where this minnow was captured during 1979, but fathead minnows are common in the lower portion of the Gunnison River drainage (Wiltzius 1978).

Water quality data collected in August 1979 on Tomichi Creek near Station 17 showed concentratons of ammonia nitrogen and total phosphate of 0.35 mg/l and 0.07 mg/l, respectively. These nutrient levels were higher than all other locations in the project area except downstream from the Town of Crested Butte waste water treatment plant (AMAX 1980a, 1980b). The high productivity of Tomichi Creek was reflected by the density of benthic invertebrates and the accumulation of organic matter, which were higher at Station 17 than at other stations in the fall of 1979 (Table 3 and 4). The highest number of taxa of benthic invertebrates (51) and attached algae (25) were also collected at Station 17.

METHODS

The location and dates of the various aquatic ecology sample collections are shown in Table 6. A summary of the sampling and analytical methods is included below.

Habitat Evaluation

A detailed evaluation of the aquatic and riparian habitat was made at each sampling station in late September and early October 1979. Visual estimates were made for average width and depth of the stream, flow velocity, pool to riffle ratio, and substrate composition. The habitat description also included measuring the slope of the stream channel, assessing bank composition and stability, and describing riparian and aquatic vegetation.

Periphyton

In 1978, periphyton samples were collected from a known area of natural rock substrates at 14 stations in July and September. In 1979, periphyton samples were collected using vertically oriented glass slides (U.S. EPA 1973) as an artificial substrate. In the laboratory, periphyton was identified and enumerated using the inverted microscope method (Lund et al. 1958) and the burnt mount technique (U.S. EPA 1973). The biomass of periphyton was determined by measuring the ash-free dry weight accumulated on the artificial substrate samplers (U.S. Geological Survey 1977). Periphyton densities were calculated and expressed as units per square centimeter. The Shannon-Weaver Diversity Index (Lloyd et al. 1968) and evenness (Pielou 1966) were calculated from these data.

Table 6 Locations and Dates of Aquatic Ecology Sampling in the Mount Emmons Project Area, 1978-1979.

Station[a]	Location	Habitat Evaluation	Periphyton				Benthos: Surber				Benthos: Microhabitat		Drift			Fish				Sediments	
		10/79	7/78	9/78	8/79	10/79	7/78	9/78	3/79	9/79	3/79	9/79	4/79	8/79	10/79	7/78	10/78	4/79	10/79	4/79	9/79
2a	Upper Coal Creek	X	X	X	X	X	X	X	X	X	X	X				X	X		X		X
3	Upper Coal Creek	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
4	Lower Coal Creek		X	X	X	X	X	X	X	X	X	X				X	X			X	X
5	Lower Coal Creek		X	X			X	X	X	X	X	X				X	X	X	X	X	X
6	Upper Slate River	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
7a	Lower Slate River	X	X	X	X	X	X	X	X	X	X	X				X	X		X		X
8	Lower Slate River	X	X	X			X	X	X	X	X	X				X	X		X		
8a	Lower Slate River	X																X	X	X	
8b	Lower Slate River	X																X	X	X	
9	Washington Creek		X	X			X	X								X	X				
10	East River	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	
11	Alkali Creek	X	X	X			X	X		X	X	X							X		
12	East River	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	
13	Upper Ohio Creek	X	X	X			X	X	X	X	X	X				X	X	X	X	X	
14	Carbon Creek	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	
15a	Lower Ohio Creek	X	X	X			X	X	X	X	X	X				X	X	X	X	X	
16	Upper Gunnison River										X	X									
17	Tomichi Creek	X				X				X		X							X		

[a] Letter subfix (e.g. 2a, 8b) indicates stations that were added or moved for 1979 survey

Benthos

Samples of benthic invertebrates were collected in July and September 1978 and in April and September 1979. Two samples were collected in pools and in riffles at each station using a modified Surber sampler with 595 m mesh net (U.S. EPA 1973).

Samples were preserved in buffered formalin. Oligochaetes and chironomids were mounted on slides for identification under a compound microscope. Other organisms were identified and counted under a dissecting microscope.

Benthic macroinvertebrate densities were calculated in numbers per square meter. The Shannon-Weaver Oiversity Index (Lloyd et al. 1968) and evenness (Pielou 1966) were calculated.

Duplicate samples of drifting invertebrates were collected in March, August, and October 1979 at Station 3 on Coal creek and at Station 6 on the Slate River using a 0.14 sq m (1.5 sq ft) drift net. Velocity of flow passing through the net was measured with a Price-Gurley pygmy type current meter or Marsh-McBirney electronic current meter.

Invertebrates collected in drift samples were identified according to the methods described above. Oensities were calculated and expressed in organisms per 100 cu m of flow.

Benthic invertebrates were also identified in gastrointestinal contents of 73 fish collected in April and September/October 1979. Organisms were examined and identified under a dissecting microscope. After the organisms had been identified, the gastrointestinal contents were composited, frozen, and sent to the analytical laboratory for metals analysis.

Fish

Fish were collected by electroshocking a 91 m (300 ft) stretch of stream at each station. Each fish was identified according to species, weighed, and measured (total length). The condition factor (K) of each fish was calculated (Carlander 1969).

Additional sampling to estimate fish populations in the study area was conducted during the fall of 1978 and 1979. A mark-recapture technique (Everhart et al. 1975) was utilized to estimate number and biomass of fish per unit length of stream (kilometer or mile).

In 1978, 83 fish were retained for metals analysis. Whole body homogenates of each fish were analyzed via atomic absorption for total lead, zinc, molybdenum, copper, iron, and cadmium. In 1979, analysis for these metals was conducted on specific tissues (muscle, liver, and kidney) and stomach contents of 73 fish using atomic absorption techniques (U.S. EPA 1979a).

Sediments

Sediment samples were collected in the project area during the spring and fall of 1979. Sediment samples were processed according to methods described in Thurman and Runnells (1978) and were analyzed using atomic absorption techniques (U.S. EPA 1979b).

1.0 INTRODUCTION

The Mount Emmons project area lies within the Gunnison River watershed (Figure 1-1) and the Colorado mineral belt region which was subjected to intensive coal and base metal mining in the late nineteenth and early twentieth centuries. Although mining activity is presently underway in the project area, its intensity is low compared to that near the turn of the century. Coal Creek and the Slate River, two of the streams in the project area, exhibit elevated metal content in the water as well as ferric hydroxide deposits on the stream substrate as a result of past mining activities.

The proposed site for the mine portal is located on the south slope of Mount Emmons. The immediate watershed affected is Coal Creek, which flows into the Slate River after passing through the Town of Crested Butte.

Aquatic ecology studies in the vicinity of the Mount Emmons Project commenced in July 1978. The objectives of this program were to provide a detailed description of the aquatic habitat of the project area, provide baseline data on the existing aquatic environment, and identify any aquatic organisms that have been classified by state or federal agencies as rare, endangered, or threatened species.

The fundamental aquatic biota studied in 1978 and 1979 included periphyton, benthic macroinvertebrates, and fish. The study of the periphyton and benthic macroinvertebrate communities included determining species composition, density, diversity, and evenness. In 1979, the periphyton sampling included productivity estimates of the periphyton community. Sampling of benthic macroinvertebrates in 1979 included collection of drift organisms and qualitative benthos sampling in various microhabitats. Fisheries investigations included determination of species composition and abundance, species

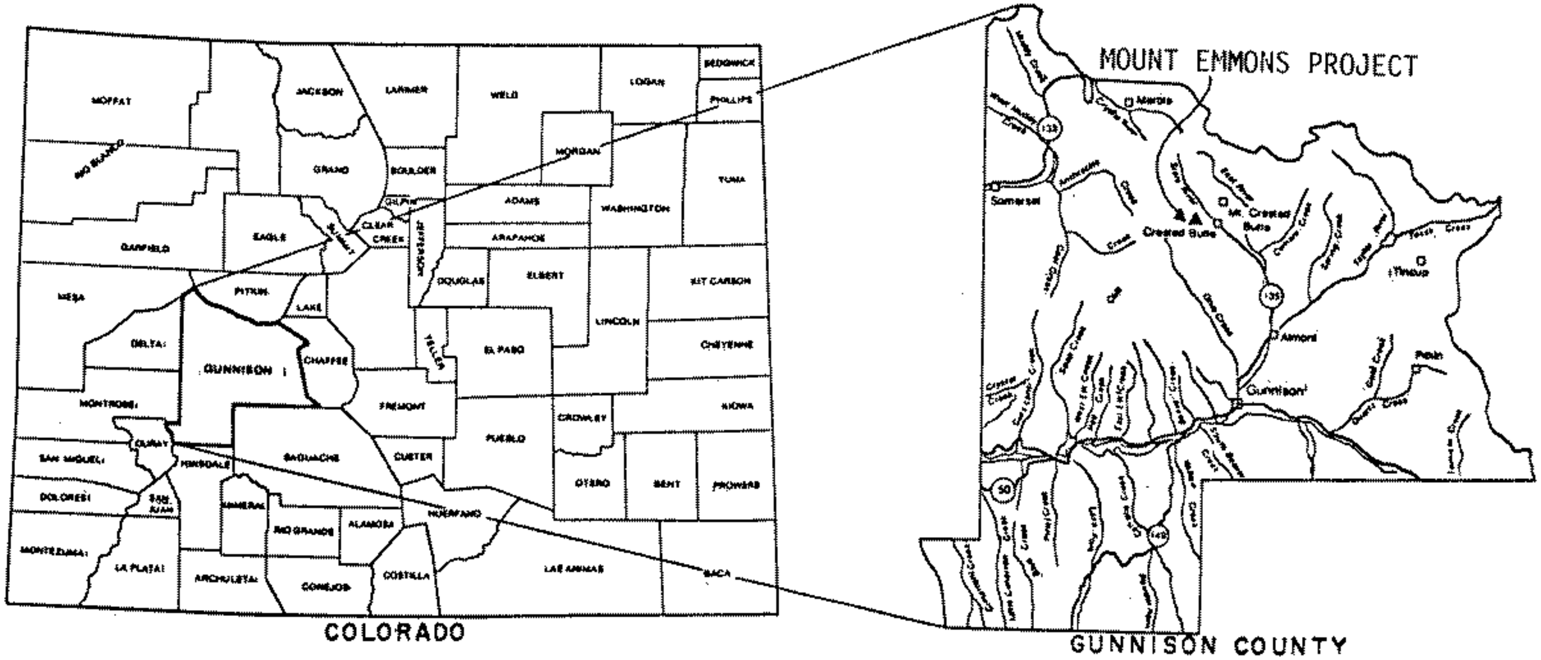

Figure 1-1. Index Map of Colorado and Gunnison County.

length-frequency distribution, stream fishing pressure, and metal concentrations in fish tissue. A fish tagging program was instituted in 1979 to determine migration patterns of fish in the project area. The accumulation of metals in fluvial sediment was also included in the 1979 studies to aid in determining the transport mechanism and ultimate reservoir of metals in the aquatic ecosystem of the project area.

Initially, mill/tailing sites under consideration included those on Washington Gulch, Carbon Creek, and Alkali Creek. Washington Gulch was eliminated from future consideration and sampling was discontinued in December 1978, while a location on Cabin Creek east of the City of Gunnison was added as a potential mill/tailing site. Since Cabin Creek is an intermittent stream, no biological samples were collected on this drainage. Nevertheless, Cabin Creek flows into Tomichi Creek, a major tributary of the Gunnison River watershed, therefore a station on Tomichi Creek was added downstream of the Cabin Creek confluence prior to the Fall, 1979 sampling period. The locations of sampling stations for the 1979 Mount Emmons Project aquatic ecology studies are shown in Figure 1-2.

This report presents the aquatic ecology data collected during 1978 and 1979 by Camp Dresser & McKee Inc., Environmental Consultants (CDM) for the Mount Emmons Aquatic Ecology Baseline Study near Crested Butte, Colorado. The report is divided into four major sections. The next section, Section 2.0, contains field and laboratory methods for collecting and analyzing aquatic ecology data. Section 3.0 contains results and discussion of the 1979 program including comparisons with similar data collected in 1978 as well as with data published in previous studies. This section also includes a description of the aquatic habitats in the project area in addition to a presentation, comparison and analysis of data on periphyton, benthic macroinvertebrates, and fish. Section 4.0 lists the references used.

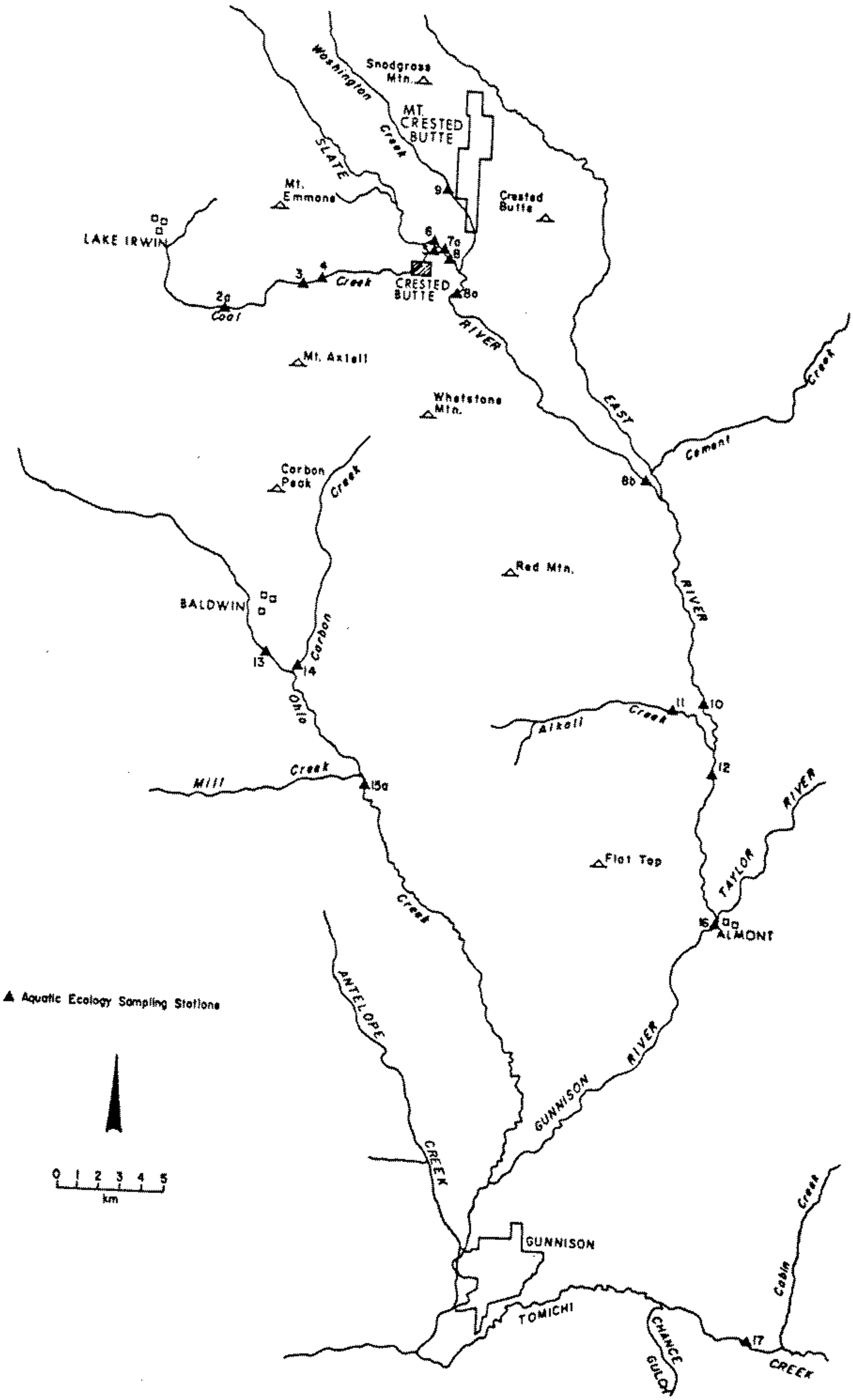

Figure 1-2 Location of aquatic ecology sampling stations, 1978 and 1979

2.0 METHODS

The 1979 Mount Emmons Aquatic Ecology field study addressed three principal aquatic ecology components: periphyton, benthos, and fish. The objective of the second year of field studies was to continue monitoring of the three ecological components to provide additional baseline information.

The locations of sampling stations for the 1979 Mount Emmons Aquatic Ecology Baseline Studies are shown in Table 2-1. Table 2-2 lists the frequency of sampling and the stations at which samples were collected for each subtask of the 1979 sampling program.

2.1 Periphyton

During the 1978 study (CDM 1979) periphyton samples were collected from natural rock substrates to determine the natural species composition, distribution, and relative abundance. Artificial substrate samplers were used for the collection of periphyton in 1979 to obtain more accurate estimates of the standing crop of periphyton (biomass) within the project study area.

Duplicate samplers, one on each side of the stream, were placed at seven stations during the summer and at eight stations during the fall sampling period (Table 2-2). Each sampler contained 20 to 30, 25 x 75 mm glass microscope slides. Sampling duration was approximately 32 d. During that period, glass slides were collected on the 4th, 8th, 12th, 16th, 20th, 24th, 28th, and 32nd day. Two slides were taken from each sampler at each station to determine the biomass of periphyton. Each slide was placed in an appropriately labeled glass jar and returned to the AMAX field office for further processing.

Table 2-1. 1979 aquatic ecology survey sampling stations for the Mount Emmons Molybdenum Project, Gunnison County, Colorado.

Station No.	Description
2a	Coal Creek near the summit of Kebler Pass approximately 6 mi (10 km) upstream of the Town of Crested Butte
3	Coal Creek approximately 0.7 mi (1 km) upstream of the Keystone mine discharge
4	Coal Creek 100 yd (0.1 km) downstream of the Keystone mine discharge
5	Coal Creek 30 yd (0.03 km) upstream of the confluence with the Slate River
6	Slate River 100 yd (0.1 km) upstream of the confluence with Coal Creek
7	Slate River 50 yd (0.05 km) downstream of the confluence with Coal Creek
7a	Slate River 0.3 mi (0.5 km) downstream of the Coal Creek confluence
8	Slate River 0.3 mi (0.5 km) downstream from the Crested Butte municipal waste treatment plant
8a	Slate River at first bridge on Colorado Highway 135 1.8 mi (2.1 km) south of Town of Crested Butte
8b	Slate River approximately 100 yd (0.1 km) upstream of the East River confluence
10	East River 1.2 mi (2.0 km) upstream of the confluence with Alkali Creek
11	Alkali Creek 1.5 mi (2.5 km) upstream of the confluence with East River
12	East River 0.5 mi (0.8 km) downstream of the confluence with Alkali Creek
13	Ohio Creek 1.0 mi (1.6 km) upstream of the confluence with Carbon Creek
14	Carbon Creek 0.2 mi (0.3 km) upstream of the confluence with Ohio Creek

Table 2-1. (Concluded)

Station No.	Description
15a	Ohio Creek 0.2 mi (0.3 km) downstream of its confluence with Mill Creek
16	Gunnison River 100 yd (0.1 km) downstream of Almont
17	Tomichi Creek 1 mi (1.7 km) downstream of Cabin Creek confluence at bridge on Long Gulch Road

Table 2-2. 1979 aquatic ecology sampling stations for the Mt. Emmons Molybdenum Project and the types of sampling programs conducted at each station.

Station	Electroshock		Fish Metals		Fish Stomach Contents I.D.		Benthos Surbers		Benthos Microhabitat		Benthos Drift			Sediments		Periphyton	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Summer	Fall	Spring	Fall	Summer	Fall
2		X		X		X		X	X	X					X		X
3		X		X		X		X	X	X	X	X	X	X	X	X	X
4								X						X	X	X	X
5								X			X	X	X	X	X	X	X
6	X	X	X	X	X	X		X			X	X	X	X	X	X	X
7									X	X					X		
7a		X		X		X		X								X	X
8		X		X		X		X	X	X							
8a	X	X	X	X	X	X								X			
8b	X	X	X	X	X	X								X			
10	X	X	X	X	X	X		X	X	X				X		X	X
11		X						X									
12	X	X	X	X	X	X		X	X	X				X		X	X
13	X	X	X	X	X	X		X	X	X				X			
14	X	X	X	X	X	X		X	X	X				X		X	X
15	X	X	X	X	X	X		X	X	X				X			
16									X	X							
17		X		X		X		X									X

At the AMAX field office, all sample bottles were placed in the drying oven at 105°C for 24 hr to prevent decomposition. After this initial drying, the samples were shipped to CDM's Denver office for biomass determination.

One additional glass slide was collected from each sampler on the 16th, 24th, and 32nd day to determine species composition and mean density of benthic algae. This slide was placed in an appropriately labeled container, preserved with fixative (Meyer 1971), and returned to the laboratory for analysis.

Periphyton samples returned to the laboratory for species identification were processed using both the inverted microscope technique (Lund et al. 1958) and the burnt mount procedure (Weber 1973). Slide preparations using the inverted microscope were examined until at least 100 individuals of the most numerous taxon were counted (Lund et al. 1958). All unicellular and colonial (multicellular, including filamentous) periphyton were tallied as single units.

The burnt mount procedure (U.S. EPA 1973) was used for diatom identification. One hundred individual diatoms were identified and counted in randomly selected microscope fields. The percentage of each diatom taxon on the burnt mounts was multiplied by the total diatom count from the inverted microscope counts to yield concentrations of each diatom taxon in the sample.

Periphyton were identified to the lowest practical taxon with the aid of the following taxonomic keys: Geitler (1932), Huber-Pestalozzi (1938, 1941), Huber-Pestalozzi and Hustedt (1942), Huber-Pestalozzi and Fott (1968), Hustedt (1930), Patrick and Reimer (1966, 1975), Prescott (1962), Skuja (1948, 1956, 1963), Smith (1920, 1950), Weber (1966), and Willen (1963).

Periphyton densities were calculated and expressed as reporting units per square centimeter (units/sq cm). The Shannon-Weaver Diversity Index (Lloyd et al. 1968) and evenness (Pielow 1966) were calculated from these data.

CDM maintains a reference collection of all periphyton samples collected.

The consultant used for periphyton verification was

Dr. Mathew Hohn
Department of Biology
Central Michigan University
Mount Pleasant, Michigan

2.2 Benthic Macroinvertebrates

Duplicate benthic macroinvertebrate samples were collected from pool and riffle areas at 13 stations in March and at 14 stations in September (Table 2-2). Samples were collected with a standard one square foot (D.D9 sq m) Surber sampler fitted with a U.S. Standard No. 3D mesh (595 m) net. Samples were preserved in the field with buffered formalin and returned to the laboratory for analysis.

Duplicate drifting macroinvertebrate samples were collected near Stations 3 and 6 during March, August, and October. Samples were collected with drift nets which measured 1 x 1.5 ft (D.3 x D.5 m) at the opening and were equipped with nitex netting. Current velocity was measured at the opening of each net with either a Marsh McBirney Electronic Current Meter or a Price-Gurley Pygmy Type current meter. Sampling durations were recorded. Drift samples were collected four times during a 24-hr cycle at approximately sunrise, noon, sunset, and midnight. The material retained in the net was transferred to a labeled container, preserved with buffered formalin, and returned to the laboratory for analysis.

Benthic macroinvertebrates were also collected from selected microhabitats. Field notes were taken to describe the different microhabitats sampled. Organisms from these specific microhabitats were placed in labeled vials containing buffered formalin and were returned to the laboratory for analysis.

In the laboratory, each macroinvertebrate sample was placed on a U.S. Standard No. 60 mesh (250μm) sieve and washed with tap water to remove the preservative. All organisms were removed from each sample (subsample) under a dissecting microscope. Oligochaetes were placed in a clearing solution of Ammon's lactophenol. All other organisms were placed in vials containing a solution of 70 percent ethanol and 5 percent glycerin. Oligochaetes and chironomids (midges) were mounted on slides for identification under a compound microscope.

Other organisms were identified and counted under the dissecting microscope. Benthic macroinvertebrates, other than chironomids and oligochaetes, were subsampled using the Folsom splitter.

All identifications were made to the lowest taxon using the following taxonomic keys and papers: Beck and Beck (1966, 1969), Brinkhurst and Jamieson (1971), Burch (1972), Edmondson (1959), Edmunds, Jensen, and Berner (1976), Hamilton and Saether (undated), Hamilton et al. (1969), Hilsenhoff (1975), Hiltunen (1967, 1973), Holsinger (1972), Johannsen (1934, 1935, 1937a, 1937b), Kenk (1972), Klemm (1972), Mason (1973), Merritt and Cummins (1978), Pennak (1953), Roback (1957), Saether (1969, 1971, 1976, 1977, undated), Sawyer (1972), Sperber (1948), Sublette and Sublette (1965), Townes (1945), Usinger (1968), Wiggins (1977), and Williams (1972).

Benthic macroinvertebrate densities for Surber samples were calculated as organisms per square meter (organisms/sq m). Drift densities were reported in organisms per 100 cubic meters (organisms/100 cu m). The Shannon-Weaver Diversity Index (Lloyd et al. 1968) and evenness (Pielow 1966) were also calculated for Surber and drift samples.

COM maintains a reference collection of all organisms which it gathered in the Mount Emmons Project area. A taxon which had not been previously collected by CDM in the project area was sent to one or more of the following outside experts for taxonomic verification.

Dr. Richard Bauman
Oepartment of Zoology
Brigham Young University
Provo, Utah

Dr. James Sublette
Oepartment of Biological Sciences
Eastern New Mexico University
Portales, New Mexico

Or. William Hilsenhoff
Department of Entomology
University of Wisconsin
Madison, Wisconsin

Jarl Hiltunen
Great Lakes Fishery Laboratory
U.S. Fish & Wildlife Service
Ann Arbor, Michigan

Dr. Glenn Wiggins
Department of Zoology
University of Toronto
Toronto, Ontario

All organisms sent for verification were returned to CDM and retained as part of the reference collection.

2.3 Fisheries

Surveys to collect adult and juvenile fish were conducted at eight stations during the spring sampling trip (April, 1979, Table 2-2). Sampling in the fall (September and October 1979) was conducted at 14 stations (Table 2-2). Fish were collected by electroshocking a 300 ft. stretch of stream at each sampling station. Electrofishing was conducted in the upstream direction at each station. The electrofishing unit consisted of a Coffelt model VVP-2C or VVP-15 variable voltage pulsator powered by a 230/115 volt gasoline powered generator. Pulsed direct current output was used and the electrofishing unit was adjusted as necessary to shock the fish while minimizing permanent damage.

Each fish was identified to species, weighed, and measured (total length) in mm. The fish were either kept for heavy metal and stomach content analysis or released. The data were recorded on computer formatted field data forms to facilitate data entry and analysis using existing computer programs. The condition factor (K) of each fish was calculated as a ratio of weight to length ($K = \text{weight } 10^5/\text{length}^3$). This factor serves as a comparative indication of the condition of each fish (Carlander 1969).

A total of 73 fish were sacrificed for heavy metals and stomach content analysis. Gastrointestinal contents from each fish were examined under a dissecting microscope and the organisms present were identified to the lowest practical taxon (Order, in most cases). Samples of dorsal muscle tissue, liver, kidney and stomach contents were removed from each specimen. These samples were composited by species, frozen, and returned to CDM's analytical laboratory in Denver for metals analysis. Processing and analysis of tissue samples and gastrointestinal contents was according to U.S. EPA procedure (1979).

Population estimates were computer calculated using Petersen's formula as presented in Everhart et al. 1975). In conjunction with the electrofishing surveys, CDM also implemented a fish tagging program during 1979. Tagging was done using small plastic Floy tags and a tagging gun. Each tag was inserted in the fleshy tissue at the base of the dorsal fin. Only the larger fish were tagged because tagging may cause permanent injury to small fish. A fish tagging form supplied by the Colorado Division of Wildlife was used to record information on the species tagged, size, and location of capture. When a fish was recaptured in a subsequent sampling trip or by angler the same information was recorded. Copies of all information obtained on tagging and recapture were sent to the Colorado Department of Wildlife.

2.4 Sediment Analysis

Sediment samples were collected from 11 stations during the spring survey and from 6 stations during the fall survey (Table 2-2). Sediment samples were digested according to the procedure described by Thurman and Runnels (1978). Digested sediment samples were analyzed for total copper, lead, zinc, iron, cadmium, and molybdenum according to the procedures listed in Table 2-3.

Table 2-3 Sediment sample analysis for the 1979 Mount Emmons aquatic ecology baseline studies

Metal	Analytical	Reference	Detection Limit (mg/l)
Copper	Graphite furnace atomic absorption	U.S.EPA (1979)	0.01
Lead	Graphite furnace atomic absorption	U.S.EPA (1979	0.01
Zinc	Graphite furnace atomic absorption	U.S.EPA (1979)	0.005
Molybdenum	Graphite furnace atomic absorption	Federal Register (1976)	0.005
Iron	Graphite furnace atomic absorption	U.S.EPA (1979)	0.01
Cadmium	Graphite furnace atomic absorption	U.S.EPA (1979)	0.002

2.5 Field Water Quality

Field data on water quality were also collected at each station immediately prior to the biological sampling. Water quality data included pH, temperature, conductivity, and dissolved oxygen. The following instruments were used for field water quality measurements:

Instrument	Parameter
Horizon Ecology Model 5999	pH
YSI model 51A	temperature
Chemtrix Type 70	conductivity
YSI Model 51A	dissolved oxygen

In addition to the analysis of these parameters, AMAX has conducted an extensive monthly and quarterly water quality sampling program. Results this study are presented in a separate report (AMAX 1980).

3.0 RESULTS AND DISCUSSION

3.1 Habitat Description

Detailed evaluation of the aquatic habitat at each sampling station was conducted in late September and early October 1979. Visual estimates were made for average width and depth of the stream, flow velocity, pool to riffle ratio, and substrate composition along the 300 ft section of stream surveyed at each station. The slope of the stream channel was measured at each station using a hand-held Locke level and stadia rod. The habitat description also included assessments of bank composition and stability, in addition to details of riparian and aquatic vegetation. The location of each station is shown in Figure 1-1 and described in Table 2-1. Habitat data are summarized in Table 3-1.

Coal Creek

Stations 2a and 3 were located on Coal Creek. Coal Creek flows generally south from its headwaters in Independence Basin through the settlement of Irwin and the Town of Crested Butte to its confluence with the Slate River.

Station 2a

Situated near Kebler Pass, Coal Creek flows through a subalpine meadow which contains a series of beaver ponds. Station 2 was located near the downstream border of this willow-covered meadow (Photo 1). The width of the stream in this vicinity was 3-6 ft (0.9-1.8 km) and water depth ranged from approximately 0.5 ft (0.15 m) in the riffles to 1.5 ft (0.45 m) in the pools.

Table 3-1 Summary of the stream habitat at aquatic ecology sampling stations in the Mount Emmons Project study area, fall 1979

Station	Width (ft)	Depth (ft)	Stream Gradient (%)	Bottom Composition 12"	3-11"	1-3"	.1-1"	Sand	Silt	Pool: Riffle Ratio (%)	Dominant Bank Cover
2a	3-6	0.5-2	2	5	40	25	15	5	10	50:50	Shrubs and Grass
3	5-10	0.5-1.5	4	30	30	20	10	10		30:70	Grass, Shrubs, Rocks
6	10-20	0.8-3	0.2		5	80		5	10	70:30	Gravel, Grass
7a	20-40	0.5-2	0.2	5	30	30	20		15	20:80	Rubble, Shrubs
8	20-30	1-6	0.1			30			70	70:30	Grass
8a	30-70	0.5-5	0.1	5	30	30		5	30	70:30	Grass
8b	40-80	0.5-3	2	10	60	15	10		5	40:60	Shrubs, Trees
10	40-80	0.5-4	1	10	60	10	10	5	5	30:70	Rock, Trees
11	2-5	0.2-2	-	5	5		10		80	50:50	Soil, Grass
12	50-90	0.5-2.5	1	5	40	20	20		15	20:80	Shrubs and Grass
13	12-20	0.5-3.5	2	10	50	20	10	5	5	55:45	Trees,Grass
14	4-12	0.2-3		5	40	20	10	5	20	55:45	Grass
15a	10-20	0.5-2	0.8	5	40	30		5	15	35:65	Trees, Grass
17	20-40	1-4	0.8	10	25	25	10	10	20	50:50	Grass, Shrub

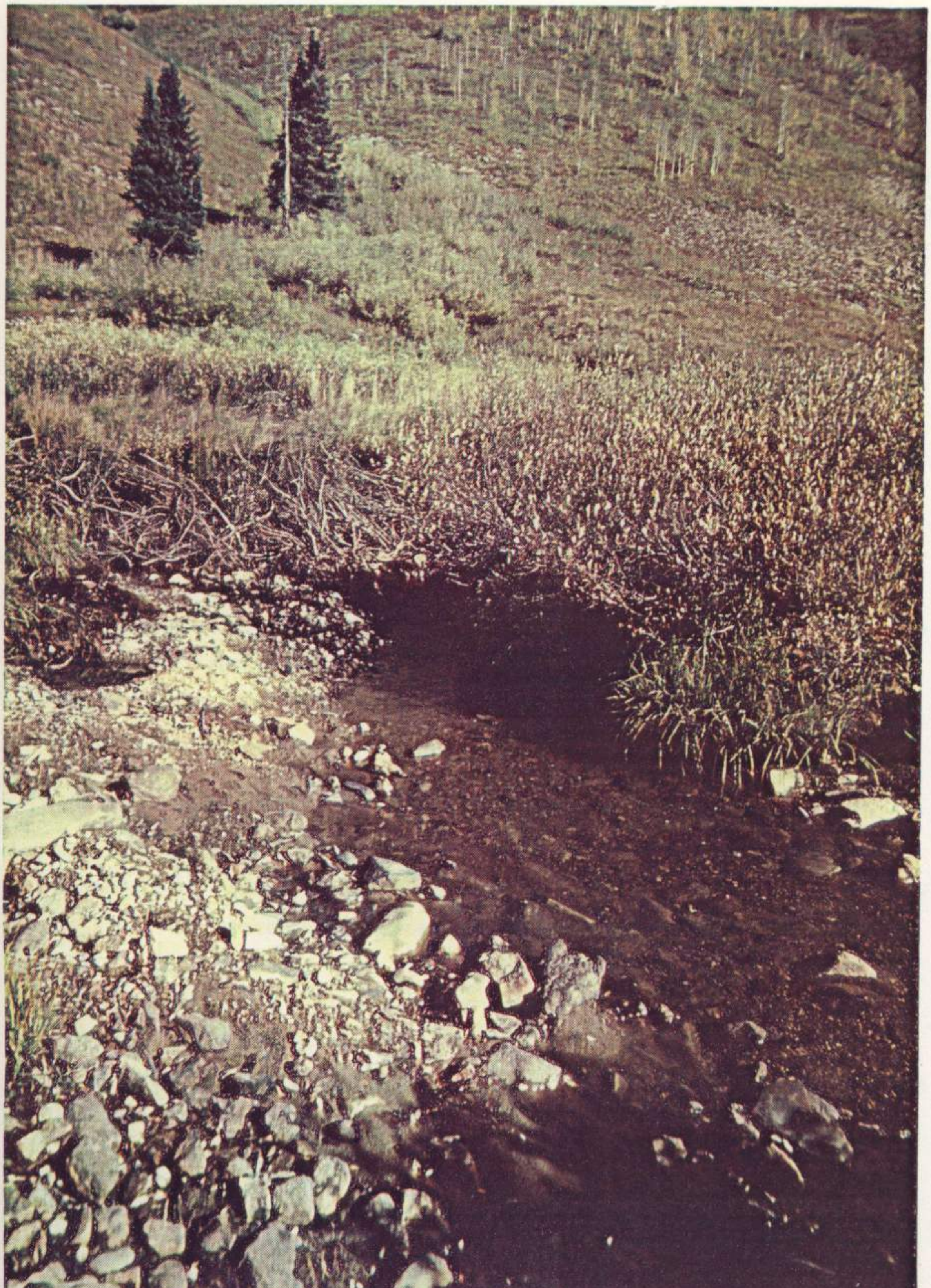

Photo 1. Coal Creek at Station 2a. Note beaver dam in background.

Pools and riffles occupied approximately equal proportions of the stream. All pools were shallow (less than 2 ft or 0.6 m deep). Overhanging willows and undercut banks provided cover along approximately 20 percent of the creek at Station 2a. Adequate flow occurred in the riffles to allow movement of fish up and down the stream. Flow patterns at the station had been altered by the recent construction of a beaver dam immediately upstream of the station. The beaver dam was not present at that location approximately two weeks prior to the fishery survey.

Since it is very difficult to sample fish populations of beaver ponds accurately using electrofishing equipment, the upper boundary of Station 2 was relocated for the Fall 1979 fishery survey to immediately downstream of the beaver dam. This new location, designated Station 2a, was 50 ft (15 m) downstream of the previous location, but due to the shift in boundaries of the station, the habitat of the station was different. The creek near the lower boundary of the station had a steeper gradient, less cover, and fewer pools than the upstream section.

The banks of the stream were 2-3 ft (0.6-0.9 m) high along approximately one-half of the length of Station 2a and were unstable with undercutting of the banks and other evidence of erosion along approximately 25-30 percent of the bank.

The substrate of the stream was primarily composed of 3-11 in. (7-28 cm) rubble and coarse to fine gravel. Some siltation occurred in the pool areas and along the banks. Aquatic vegetation at the station was limited, however, some periphyton were present on large rocks.

Station 3

Station 3 was located on Coal Creek approximately 0.7 mi (1.2 km) above the Keystone Mine discharge. The stream in this vicinity was bordered by steep, timbered slopes. The gradient of the stream at Station 3 is approximately four percent. This steep gradient and the confining terrain cause the stream channel to be straighter than at Station 2a.

The average stream width at Station 3 was approximately 12 ft (2.5 m). Average depth ranged from 0.5 ft (0.15 m) in riffles to approximately 1.3 ft (0.4 m) in pools. Although stream velocity was not measured, it appeared to be higher in both pools and riffles than at Station 2a due to the steeper gradient. Pools which constituted less than 30 percent of the stream habitat, were generally confined to areas behind large boulders and were shallow (less than 2 ft or 0.6 m) deep.

The banks along the upstream portion of Station 3 were lined with willow. This vegetation provides cover and helps stabilize the banks. Some undercutting of the bank occurred in this section. The banks at the lower end of Station 3 were lined with rocks and grass. More extensive growth of periphyton was present on the substrate than at Station 2; approximately 60 percent of the substrate was covered by diatoms or mats of algae.

The substrate was approximately 60 percent rubble and boulders. The shallow, fast-flowing riffles provide productive areas for benthic invertebrates. Gravel substrate suitable for trout spawning was also present.

Slate River

Stations 6, 7a, 8, 8a, and 8b were located on the Slate River. The Slate River flows through a wide alluvial valley. The grass-covered meadows in this valley are extensively used in the summer as pasture for cattle. The streamside vegetation is primarily grasses and sedges with interspersed stands of willows.

Station 6

Station 6 was located on the Slate River approximately 100 yd (0.1 km) upstream of the Coal Creek confluence. The gradient of the stream at this station was very gentle (approximately 0.2 percent).

The average width of the Slate River at Station 6 in late September was approximately 15 ft (4.5 cm), and average depth was 1.5-2.0 ft (0.5-0.6 m). Oue to the low gradient, pools occupied approximately 80 percent of the aquatic habitat at Station 6. The stream in this vicinity was comprised of long pools separated by short, fast-flowing riffles. Several small side channels were present and some undercutting of the banks occurred along the west side of the stream. The west bank was 2-3 ft (0.6-1.0 m) high and was lined with grasses and willows. The east bank was covered with flat shale gravel and was nearly devoid of vegetation.

The shifting substrate prevented vegetation from establishing along the east bank and also inhibited the growth of aquatic vegetation, little evidence of periphytic growth was seen in the main channel. Mats of algae were seen, however, in pools and side channels. This shale substrate was poor habitat for macroinvertebrates and for spawning of fish because of its instability.

Station 7a

Station 7a was located on the Slate River between the confluence of Coal Creek and the outfall from the Crested Butte waste water treatment plant. The river at Station 7a was considerably wider and shallower than at Station 6. Average width and depth of the stream at Station 7a in September 1979 were 30 ft (9 m) and 1.5 ft (0.5 m) respectively. The overall gradient at Station 7a was 0.2 percent and was uniform throughout the section. Thus, instead of having a series of pools and riffles, the stream at Station 7a was essentially a long shallow riffle with little diversity in habitat and limited cover. The metal-laden waters from Coal Creek clouded the water and ferric hydroxide deposits covered over half of the substrate. The ferric hydroxide deposits filled the interstitial spaces of the substrate and dramatically reduced the amount and quality of habitat for benthic macroinvertebrates.

The west bank at Station 7a was bordered by the access road for the Crested Butte waste water treatment plant. This steep bank was composed of rock and gravel and supported limited vegetation. The bank on the east side of the river was 4-6 ft (1.2-2.4 m) high and showed signs of erosion and instability along approximately 80 percent of its length at Station 7a.

The substrate at Station 7a was predominantly 3-11 in. (8-28 cm) rubble; the flat shale gravel that covered the substrate at Station 6 was absent.

Station 8

Station 8 was located on the Slate River, 0.3 mi (0.5 km) below the outfall from the Crested Butte waste water treatment plant.
The gradient of the stream at Station 8 was less than 0.1 percent. A slow-flowing pool covered the central two-thirds of the station and ranged from 1.5 ft (0.5 m) to over 6 ft (1.8 m) deep. Riffle areas were restricted to the upstream and downstream margins of the station.

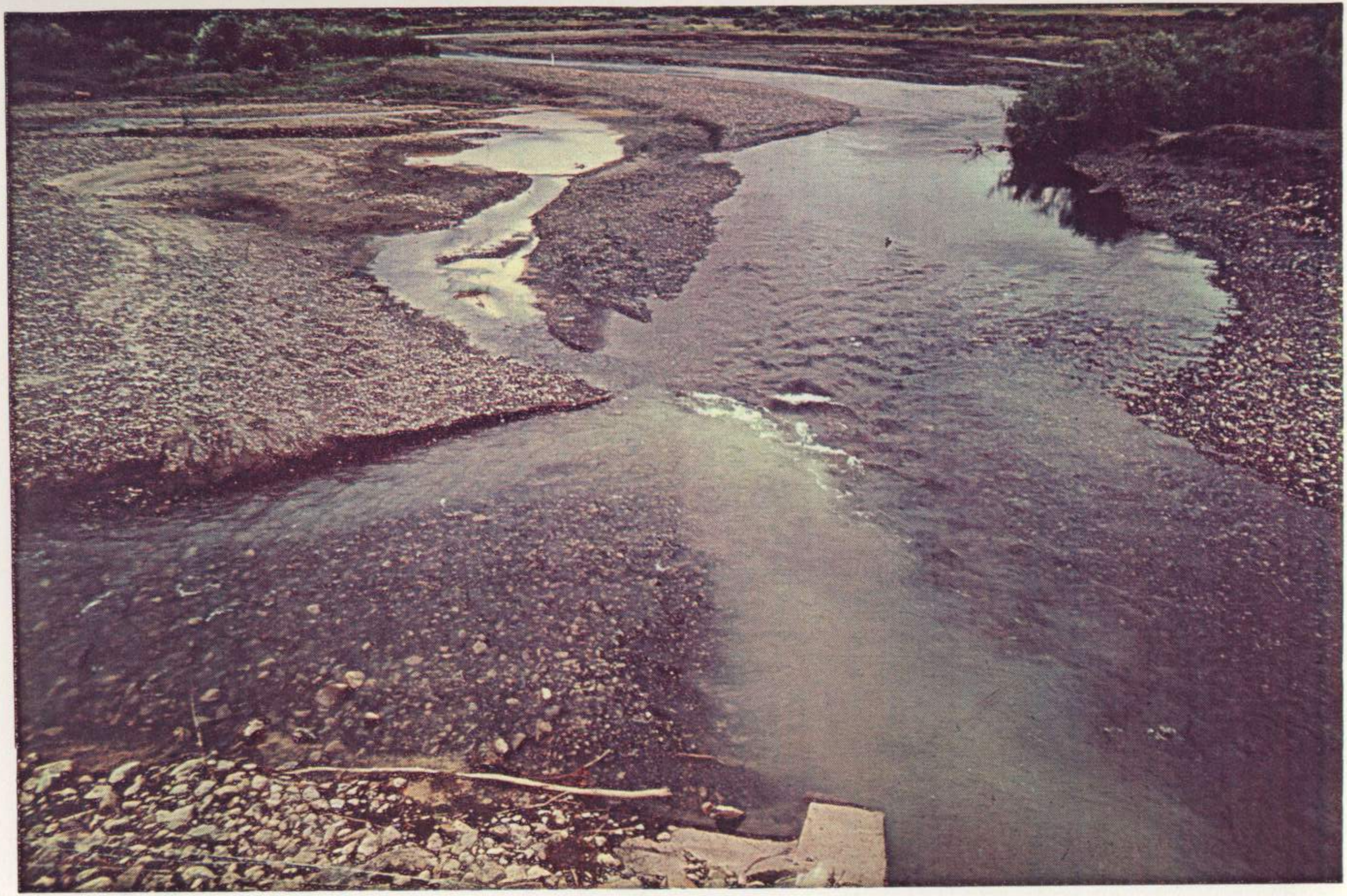

Photo 2. Slate River at Coal Creek confluence. Note turbidity due to precipitation of ferric hydroxide from Coal Creek. (Coal Creek is on the left side of the photo.)

The water at Station 8 had a milky appearance. This turbidity was due to the effluent from the waste water treatment and the metal-laden discharge from Coal Creek. The substrate at Station 8 was covered with silt, especially in the pools. Ferric hydroxide deposits were also present in backwater areas. As at Station 6, approximately 90 percent of the substrate in the riffle areas was composed of flat shale gravel.

The banks of the streams were covered with willows and grasses. Evidence of grazing was apparent, especially along the east bank. Banks were 4-6 ft (1.2-2.4 m) high and showed considerable signs of erosion and instability, especially on the west side of the stream. An artificial dike of rock and gravel had been constructed on the west bank at the downstream end of the station.

Although nutrient levels were high due to the inflow of wastes, aquatic vegetation attached to the substrate at Station 8 was limited. The shifting nature of the shale restricted periphytic growth in the riffle areas and the depth and turbidity of the water restricted light penetration in the pools. Floating mats of algae covered approximately 20 percent of the pool and backwater areas. The shale substrate in the riffles was poor habitat for benthic macroinvertebrates. Extensive silt deposits in the pools, however, provided habitat for taxa such as oligochaetes (aquatic worms).

Station 8a

Station 8a was located at the bridge on Colorado Highway 135 approximately 1.8 mi (2.9 km) south of the Town of Crested Butte. The physical habitat at Station 8a was similar to that at Station 8 and included a slow-flowing pool bordered on either end by riffle areas (Photo 3). The depth of water in the pool was from 2-5 ft (0.6-1.5 m) during the fall survey in 1979. The pool was 75-100 ft (23-30 m) wide

Photo 3. Slate River at Station 8a showing slow-flowing pool near center of station.

at the upstream and downstream margins and was constricted in the center to approximately 50 ft (15 m) by the abutments of the bridge.

The water at this point had a milky appearance. Thus, light penetration in the deeper parts of the pool was limited and little periphytic growth was present in these areas. Filamentous algae were present and covered the substrate in the shallower portion (less than 2 ft or 0.6 m) of the pool and in the riffles along the west bank of the stream.

The substrate varied from coarse gravel and rubble in the riffles to silt and sand in the pool area.

Station 8b

Station 8b was located at the bridge approximately 6 mi (10 km) south of Crested Butte on Colorado Highway 135.

The aquatic habitat at Station 8b was different from that at Stations 8 and 8a. The gradient of the stream at this point had increased to approximately two percent and the stream was clear. The habitat at Station 8b was mainly 1.5-2 ft (0.5-0.6 m) deep riffles. Small pools were interspersed behind boulders in the stream channel.

The banks of the stream at Station 8b were lined with willows and mature alder and Douglas-fir. Several of these trees were over 50 ft (15 m) tall. The banks were mainly covered with 1-3 ft (0.3-1 m) rocks or bare ground; understory vegetation occupied less than 20 percent of the bank. The rocks and the gradual slope of the bank stabilized the shoreline.

The substrate was composed of well-rounded rubble with lesser amounts of coarse gravel. Essentially no silt was present in the pools. The substrate in the riffle had a film of periphytic growth; filamentous algae covered 10-20 percent of the rocks in pools and deeper riffles. The boulder and rubble substrate provided a variety of habitats for benthic invertebrates and cover for fish. The substrate also contained gravels suitable for trout spawning.

East River

Stations 10 and 12 were located on the East River, downstream of the confluence with the Slate River.

Station 10

Station 10 was located on the East River upstream of the Alkali Creek confluence. In late September, the East River at Station 10 was approximately 50 ft (15 m) wide and 2-3 ft (0.6-0.9 m) deep. Although the average gradient of the stream at Station 10 (one percent) was lower than at Station 8b, the habitat at the two stations was quite similar. Fast-flowing riffles predominate, but a slow-flowing pool was present adjacent to the pilings of the bridge that crosses the stream at Station 10.

The stream channel at Station 10 had been altered to reduce the possibility of flooding. Gravel and rubble had been piled to form a 6-10 ft (2-3 m) embankment to stabilize the channel and prevent flooding during peak flow periods. These altered banks supported little vegetation, although willows up to 15 ft (4.5 m) in height and alders to 60 ft (10 m) in height border the altered portions of the bank.

Rubble, 3-11 in. (8-18 cm), constitutes approximately 60 percent of the substrate; nearly equal volumes of coarse and fine gravels and lesser quantities of sand and silt made up the remainder of the substrate. A few 2-4 ft (0.6-1.2 m) boulders were present in the riffles. The substrate showed sparse growth of aquatic vegetation. Periphyton were present on the rocks and patches of filamentous algae grew in shallow areas (less than 2 ft or D.3 m) along the waterline. The substrate provided diverse habitat for benthic macroinvertebrates and contained gravel beds suitable for trout spawning.

Alkali Creek

Alkali Creek is a small intermittent, spring-fed tributary which flows through the sagebrush-covered basin between Flat Top and Red Mountain (Photo 4 Mtn. During low flow periods, the water in Alkali Creek is, as the name implies, quite alkaline. Alkalinity and hardness are several times higher than at any other stream or creek in the study area (AMAX 198D).

The flow and width of Alkali Creek tend to increase from the headwaters to the point where Alkali Creek flows onto the East River flooo plain. Downstream of this point, Alkali Creek diminishes in size due to loss of water to the alluvium and diversion of water for irrigation.

Station 11

Although Alkali Creek near Station 11 had several deep pools and undercut banks that could provide cover for fish, the flow, especially in the fall, between these pools was reduced to a trickle. The water was turbid and over half of the pools were covered by mats of filamentous, blue-green (Cyanophyta) algae. Because of the stagnant conditions and the copious algal growth, it is possible that dissolved oxygen concentrations in the creek are at times lower than the recommended guidelines for cold water biota (6 mg/l) (Colorado Department of Health 1979).

Photo 4. Alkali Creek near Station 11.

Since cattle graze along Alkali Creek, the banks of the stream at many locations have caved in as a result. Oue to extensive eroding and depositing of sediments, the substrate of Alkali Creek is predominantly silt and sediment.

Station 12

Station 12 was located on the East River adjacent to the Roaring Judy Trout Hatchery and downstream of the Alkali Creek confluence.

Ouring the fall of 1979, the stream at Station 12 was approximately 60 ft (18 m) wide. The lower half of Station 12 was shallow (1-1.5 ft deep) and fast-flowing. This riffle narrowed into a 2-3 ft (0.6-0.9 m) deep chute at the downstream border of the station. The upper half of the station was also shallow but was slower flowing. Gabions and concrete structures had been placed in the stream to improve the habitat for trout. Pools that were 2-3 ft deep (0.6-0.9 m) formed behind these structures. Approximately half of the east bank of the stream has been stabilized with riprap to reduce erosion. These riprapped structures, which extend about 10 ft (3 m) into the stream channel, deflected the flow and created shallow backwater areas along the shoreline. The west bank which was covered with shrubs, rocks, and grass, sloped gently away from the stream. The shrubs and rocks stabilized the bank as there was little evidence of erosion along the west bank of the river.

The substrate of the stream was predominately rubble with lesser quantities of coarse gravel, fine gravel, and sand, in that order. A few 2-3 ft (0.6-0.9 m) boulders were spaced throughout the riffle area. Silt covered the substrate in the backwater areas. Approximately 15-20 percent of the interstitial spaces in the substrate were filled with silt. The silt-free portions of the substrate provided good habitat for benthic macroinvertebrates.

Ohio Creek

Ohio Creek flows in a southeasterly direction from Ohio Pass and drains an alluvial valley used primarily for hay production. Although smaller than the East River, Ohio Creek has similar physical features such as fast flowing, high quality water; cobble bottom riffles, and deciduous trees which completely canopy the stream in many areas. Ohio Creek flows through private land for nearly all of its length and, therefore, is not subject to as much fishing pressure as the East and Slate Rivers.

Station 13

Station 13 was located on Ohio Creek approximately 1 mi (1.6 km) upstream from its confluence with Carbon Creek. In September, Ohio Creek was 12-20 ft (3.6-6 m). Depth ranged from about 1 ft (0.3 m) in the riffles to 3 ft (0.9 m) in the deeper pools. The section of stream at Station 13 had nearly equal quantities of pools and riffles. The banks along the lower half of the station were lined with alders which were up to 70 ft (21 m) tall. These large trees shaded much of this portion of the stream. Undercutting of the banks was found at the bends of the stream; gravel bars formed on the inside margins of these bends. Fallen trees, log jams, undercut banks, and exposed tree roots provided excellent cover for trout.

Station 15

Station 15 was located on Ohio Creek downstream from the confluence with Mill Creek. The location of Station 15 was changed for the fall 1979 survey because the area previously sampled had been altered by construction of a diversion structure (Photo 5). The altered section of stream was no longer representative of lower Ohio Creek and, for

Photo 5. Ohio Creek at Station 15. Note gravel bar to channel flow into diversion structure. Diversion headgate located near left margin of photo.

that reason, the location of the station was moved upstream approximately 0.1 mi (0.2 km) to the U.S. Geological Survey gaging station on Ohio Creek prior to the fall fishery survey and was designated as Station 15a.

Ohio Creek at Station 15a was approximately 15-20 ft (4.5-6 m) wide and 1-2 ft (0.3-0.6 m) deep. A shallow, boulder-strewn riffle covered the upper two-thirds of the station (Photo 6). The gradient of the stream in this stretch was approximately 0.9 percent, but decreased somewhat in the vicinity of the pool at the lower end of the station.

The banks of the stream were lined with alder and willow. Most of these overstory species were 10-30 ft (3-9 m) tall. Grasses and rocks covered and stabilized the banks. The substrate was composed of nearly equal proportions of rubble and coarse gravel. Silt covered the substrate in pools and in backwaters along the banks. Filamentous algae was observed in the shallow backwater areas.

Carbon Creek

Carbon Creek drains the south face of Mt. Axtell and flows into Ohio Creek. This creek, which is less than 12 ft (3.6 m) wide in most places, flows through a broad valley used for pasturing livestock and producing hay. The upper reaches of Carbon Creek have been reported to be dry during the spring and early summer, a result of agricultural diversions. Riparian vegetation consisted primarily of grasses and occasional stands of willows in the lower section of the stream.

Station 14

Station 14 was located on Carbon Creek approximately 1.2 mi (0.3 km) upstream of the confluence with Ohio Creek.

Carbon Creek at Station 14 contains three, 3-5 ft (0.9-1.5 m) deep pools. Overhanging willows and undercut banks provided cover during low flow periods.

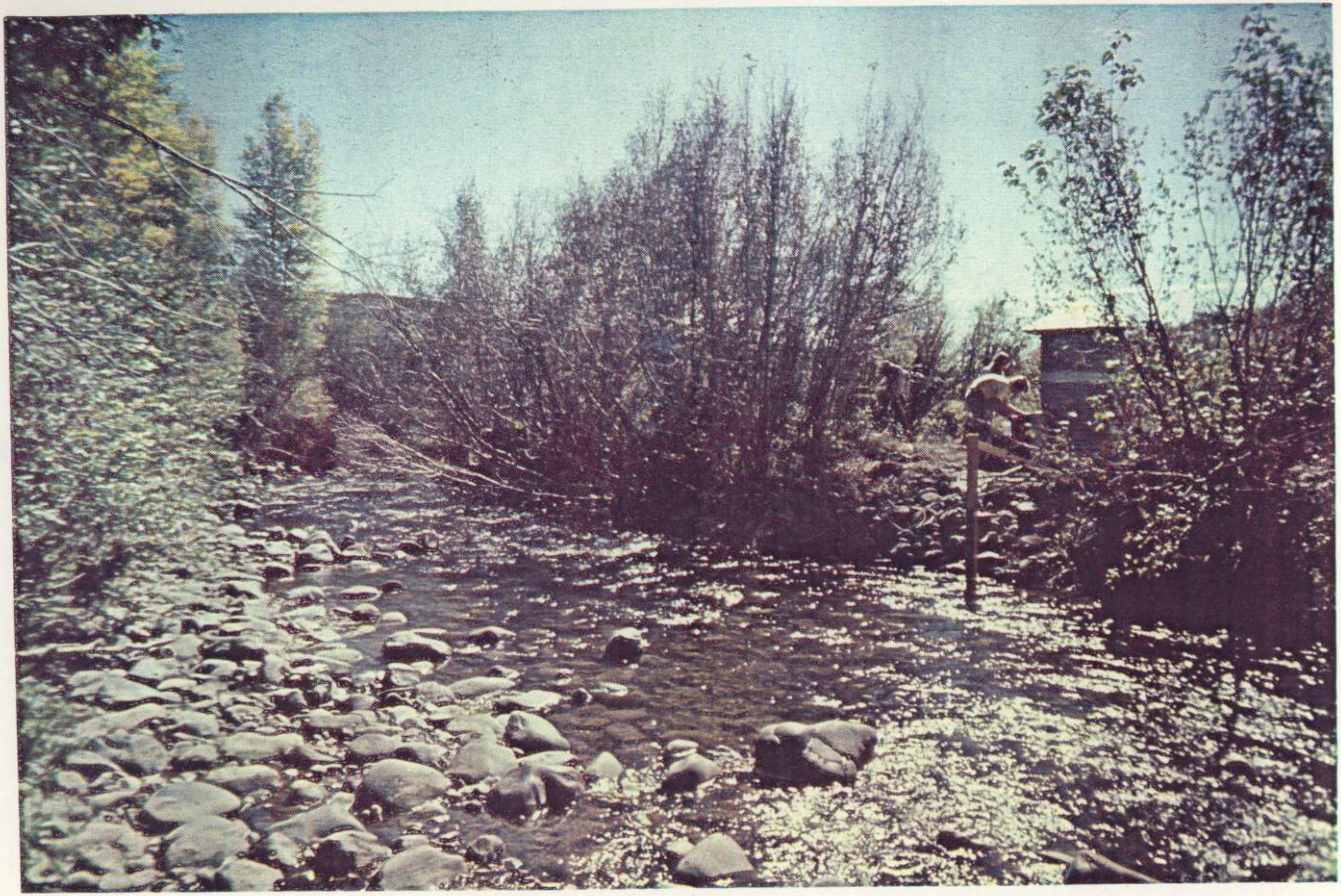

Photo 6. Ohio Creek at Station 15a. Note USGS gaging station on left side of photo.

In late September, Carbon Creek at Station 14 was 4-10 ft (1.2-3 m) wide and 0.3-3.0 feet (0.1-0.9 m) deep. Flow at this time of year was low. Most fish were confined to the pool areas because limited flow through the riffles restricted upstream or downstream movement. A log dam across the stream immediately below the bridge at Station 14 prevented upstream movement of fish during low flow periods and made passage difficult during higher flows.

The substrate at Station 14 was predominantly rubble with limited amounts of coarse gravel and sand. Much of the substrate in the pools was covered with silt. Disturbance of the banks and substrate by grazing cattle probably contributed to increased siltation.

Tomichi Creek

Tomichi Creek flows west from its headwaters near Monarch Pass to its confluence with the Gunnison River, just south of the City of Gunnison.

Tomichi Creek flows through a wide alluvial valley for much of its length. The gradient of the stream is low (0.1 percent) and the stream channel meanders back and forth through hayfields and pastures (Photo 7). The course of the stream is continually changing, numerous cutoffs, oxbow lakes, and abandoned channels which mark the former course of the creek are present.

Undercutting of the banks occured in bends of the stream, especially in the lower reaches. Filamentous algae and macrophytes covered the substrate in shallow riffles and along the shoreline of pools.

Station 17

Station 17 was on Tomichi Creek approximately 1 mi (1.6 km) downstream from the Cabin Creek-tomichi Creek confluence.

Photo 7. Meandering stream channel of Tomichi Creek near Station 17. Note evidence of former courses of the stream.

During the fall of 1979, Tomichi Creek at Station 17 was approximately 20-40 ft wide (6-12 m). A 2.5-4 ft (0.8-1.2 m) deep pool covered the central one-third of the station. A low dam and spillway, 3-4 ft (0.9-1.2 m) high and constructed of loosely piled rocks, was located 30-40 ft (9-12 m) upstream of the station.

The banks of Tomichi Creek at Station 17 were lined with shrubs and grasses. The banks were gently sloping and appeared to be very stable. A few willows were present along the stream. Fences prevented cattle from grazing along the creek.

The riffles were covered equally with rubble and coarse gravel. A few 2-4 ft (0.6-1.2 m) boulders and patches of sand and fine gravel occurred in the riffles. The substrate in the pools was covered with silt.

Periphyton was the dominant aquatic growth, but mats of aquatic macrophytes covered the substrate in shallow areas (less than 1 ft or 0.3 m) along the banks.

3.2 Periphyton

3.2.1 General Information

Periphyton consists of all aquatic organisms that grow on submerged substrates and includes algae, bacteria, protozoans, and small invertebrates. Most ecological studies of periphyton are concerned with the algal component because it has been shown to be a useful indicator of water quality. Literally translated, periphyton means "around plants" (Weitzel 1979), but periphyton also includes the attached microcommunity growing on rocks, sediments, animals, wood, and sand. Most studies of periphyton in flowing water systems have been concerned with periphyton growing on the surface of rocks or artificial substrates.

During 1978, periphyton samples were collected at 24 stations in the Mount Emmons Project study area to determine relative species composition and density on natural rock substrates. These data were presented in the 1978 Mount Emmons Aquatic Ecology Report (AMAX 1979). Although a substantial number of factors affect the standing crop of periphyton in flowing water systems, the single greatest variable, according to Pryfogle and Lowe (1979), is the substrate composition. In order to control this variable and to estimate primary productivity of the periphyton, samples were collected during the 1979 studies using artificial substrates.

Artificial substrates which have been used in periphyton studies include wood, concrete, slate, styrofoam, porcelain, plexiglass, and glass. None of these substrates yield results identical to those obtained from natural substrates, but in studies where the objectives are to compare relative abundance and/or relative biomass among a group of stations, it is not necessary to reproduce or attempt to reproduce the periphytic community that occurs on natural substrates (Hynes 1970).

In the 1979 Mount Emmons Aquatic Ecology Studies, microscope slides in specially designed slide trays were used as the artifical substrate. Detailed descriptions of the methods used for periphyton sampling and analysis are included in Section 2.1.

Artificial substrate samplers were placed at seven stations in mid-August and at eight stations in early October 1979. Samplers were located in similar habitats at each station to reduce the effect of variables such as current velocity, depth of exposure, sunlight, etc., on the growth of periphyton.

Periphyton productivity is routinely measured by determining the rate of accumulation of organic matter on artificial substrates (Weitzel 1979). The amount of organic matter accumulating on the artificial substrate was determined by measuring the ash-free dry weight of the material on the artificial substrate samplers. These data are shown in Figures 3-1 through 3-8 and are presented in tabular form in Appendix A.

Species composition and density of attached algae were also determined during the course of the two studies. Population indices and data on taxonomic composition and density of attached algae for each station are shown in Tables 3-2 through 3-9.

3.2.2 Periphyton Biomass Estimates

The organic matter measured on each slide included autotrophic and heterotrophic organisms, organic sediments, and detritus. Using gravimetric methods, it is not possible to distinguish between viable and nonviable organic matter. Nevertheless, patterns in the rate of accumulation of organic matter are evident within the study area. For both study periods, the accumulation rate of organic matter and the final organic weight at the end of each 32 day interval were lower at the two Slate River stations (Staton 6 and 7a) and at Station 4 on lower Coal Creek than at other locations in the study area. The greatest accumulation of organic matter was at Station 17 on Tomichi Creek.

Comparisons of accumulated organic matter and density of attached algae at each station (Table 3-10) do not show a direct relationship between the two parameters. The differences between the biomass estimates and the mean density of attached algae were most apparent for data from Station 4 on Coal Creek. The density of attached algae was lower at Station 4 than at other stations but accumulated organic matter at Station 4 was higher than that of the two Slate River stations (Table 3-10).

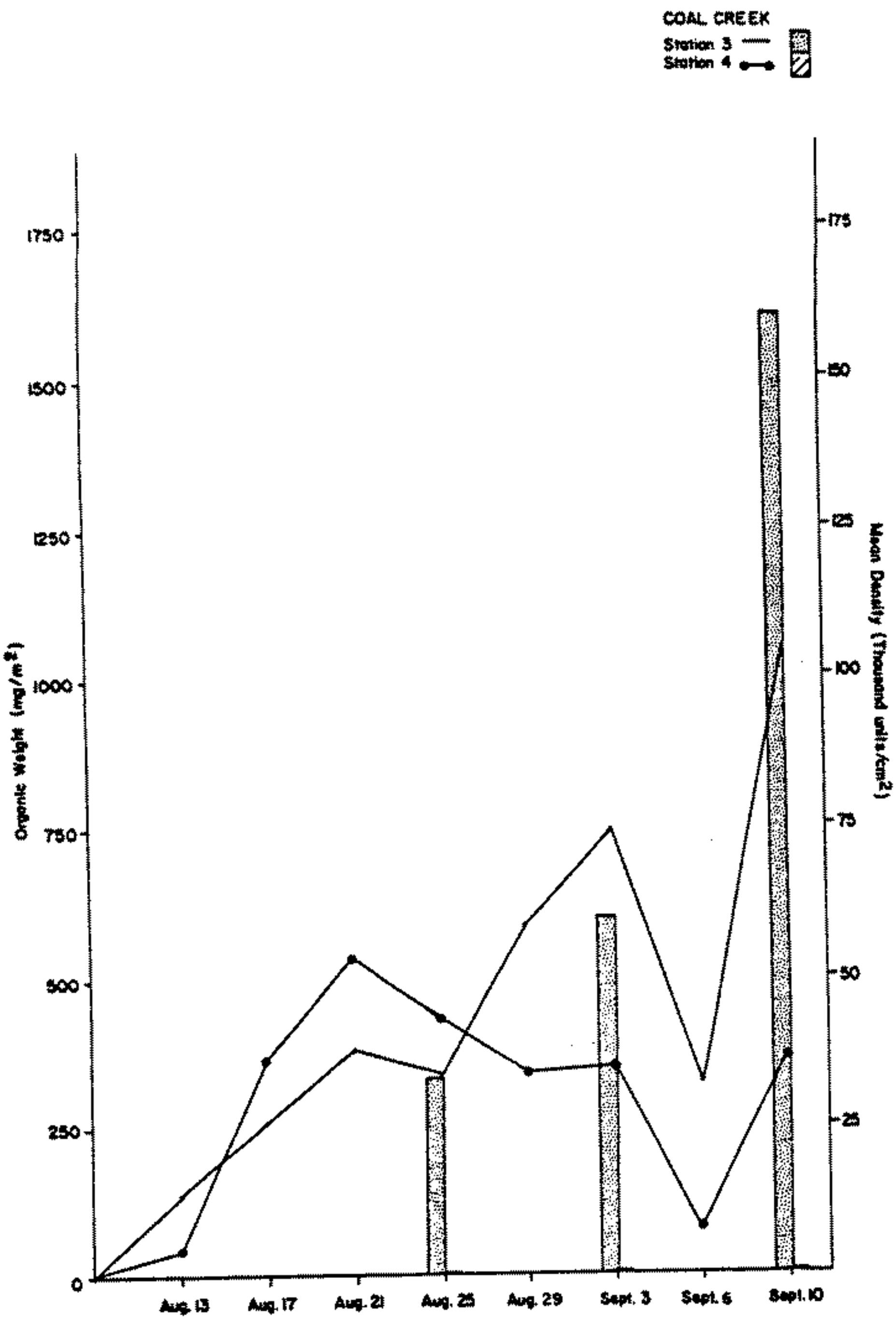

Figure 3-1. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae (units/cm^2) (bar graphs) on artificial substrates placed at Stations 3 and 4 on Coal Creek, August and September 1979.

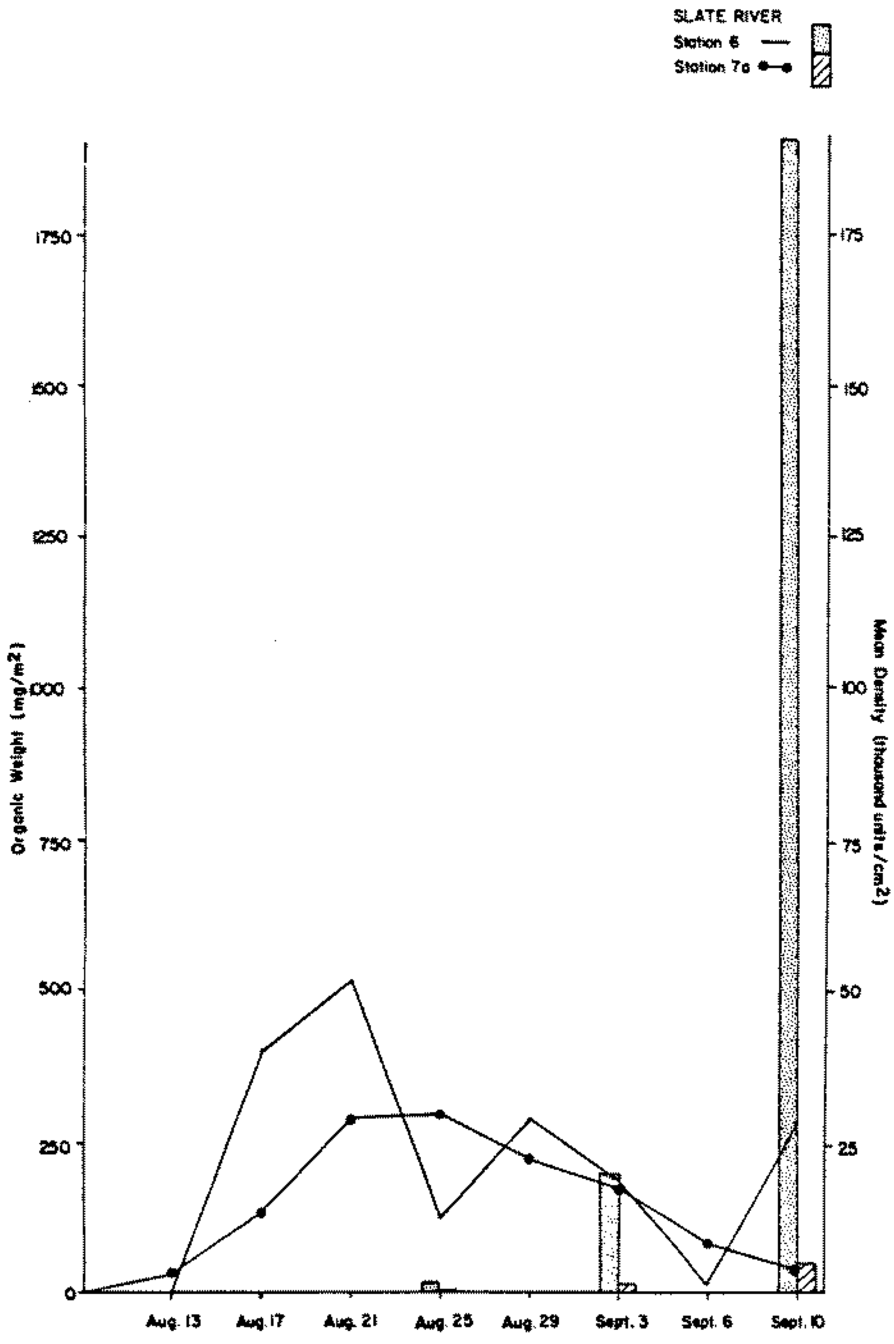

Figure 3-2. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae ($units/cm^2$) (bar graphs) on artificial substrates placed at Stations 6 and 7a on Slate River, August and September 1979.

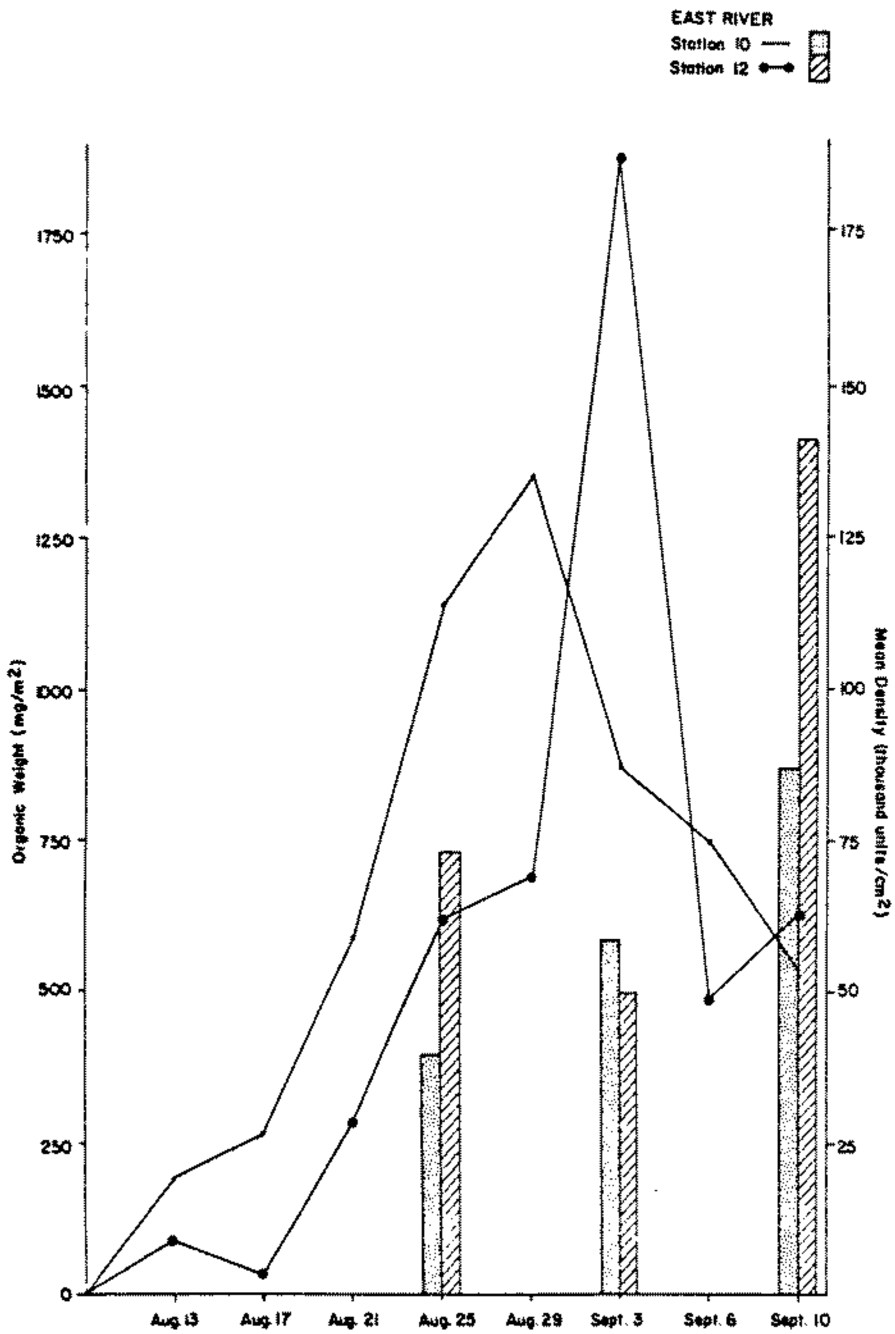

Figure 3-3. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae (units/cm^2) (bar graphs) on artificial substrates placed at Stations 10 and 12 on East River, August and September 1979.

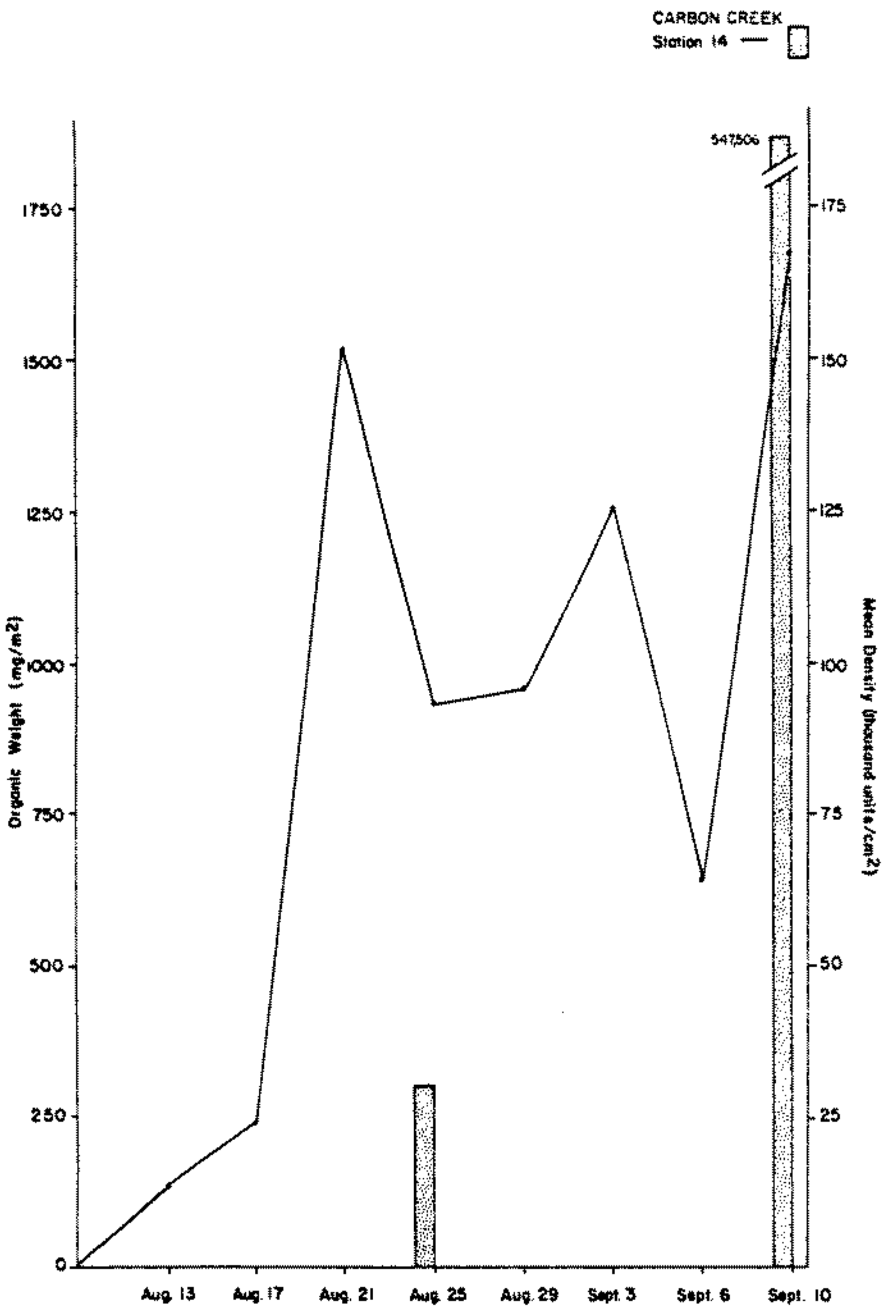

Figure 3-4. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae (units/cm^2) (bar graphs) on artificial substrates placed at Station 14 on Carbon Creek, August and September 1979.

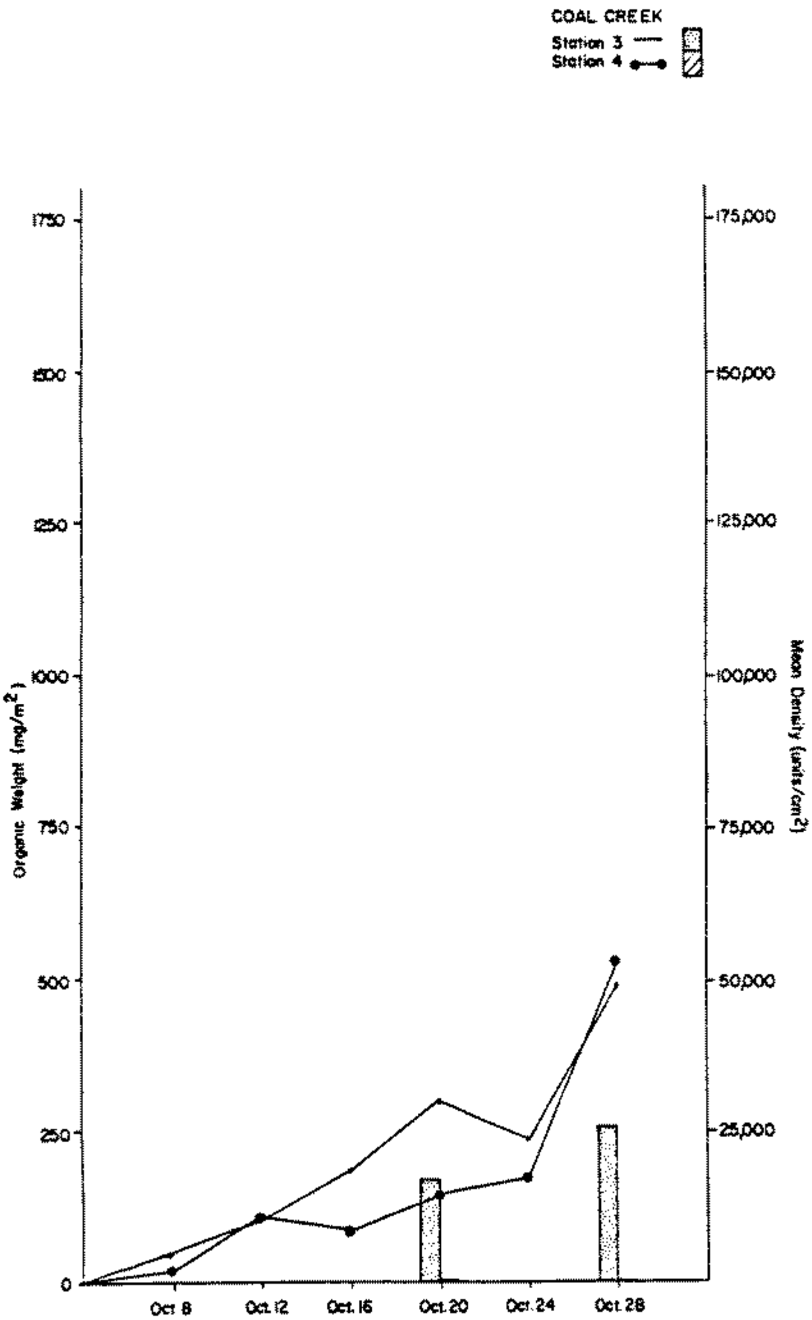

Figure 3-5. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae (units/cm^2) (bar graphs) on artificial substrates placed at Stations 3 and 4 on Coal Creek, October 1979.

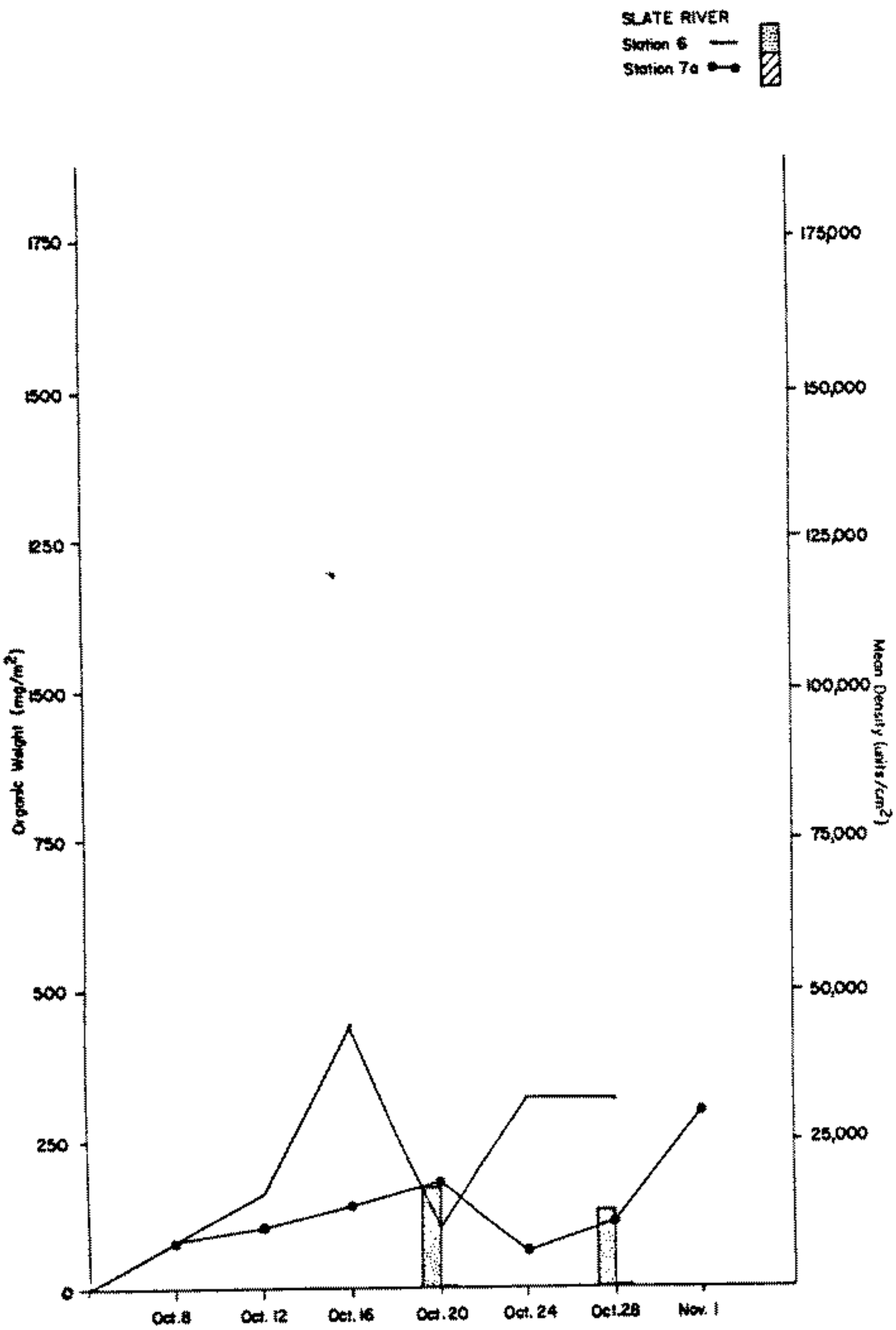

Figure 3-6. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae (units/cm^2) (bar graphs) on artificial substrates placed at Stations 6 and 7a on Slate River, October 1979.

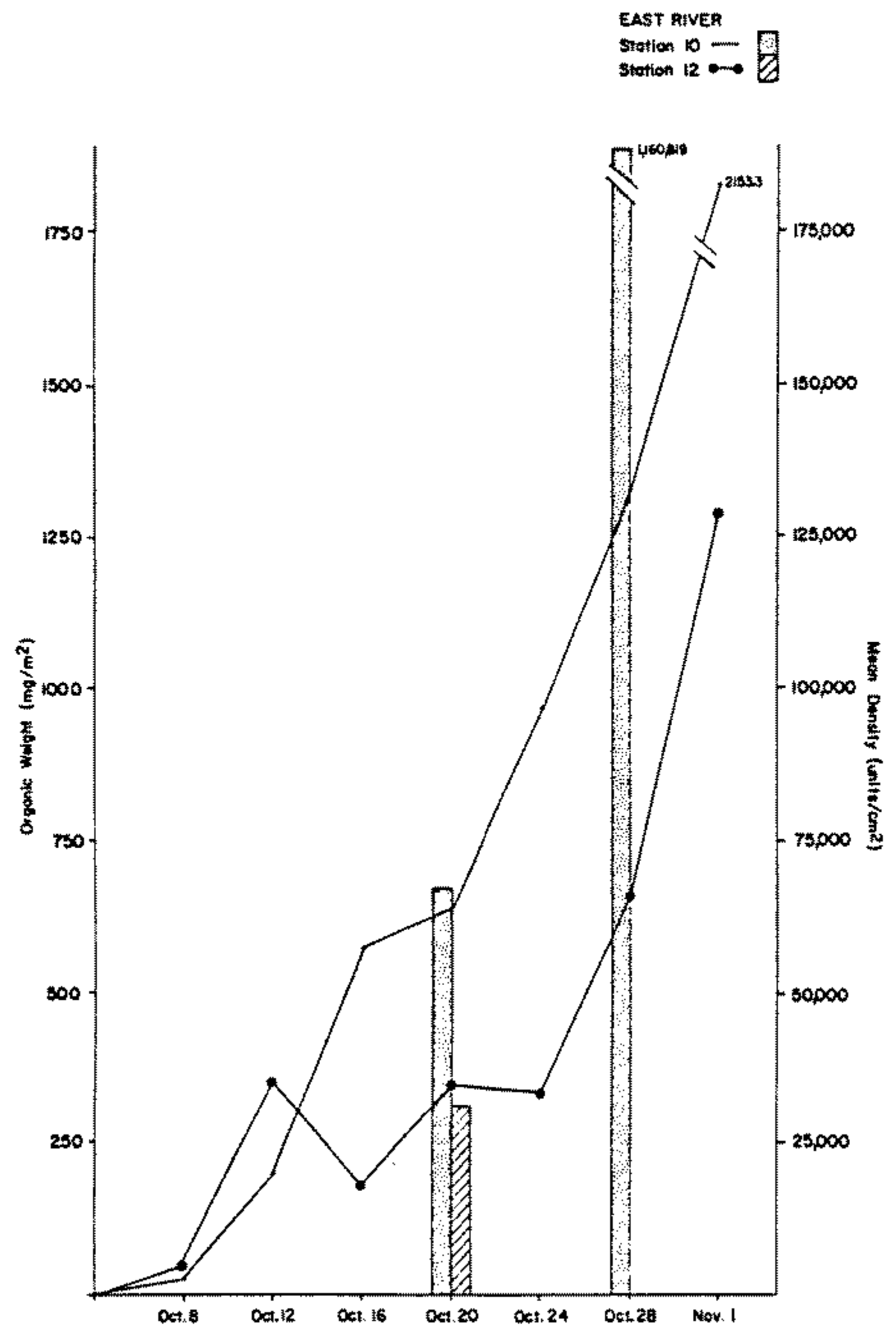

Figure 3-7. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae ($units/cm^2$) (bar graphs) on artificial substrates placed at Stations 10 and 12 on East River, October 1979.

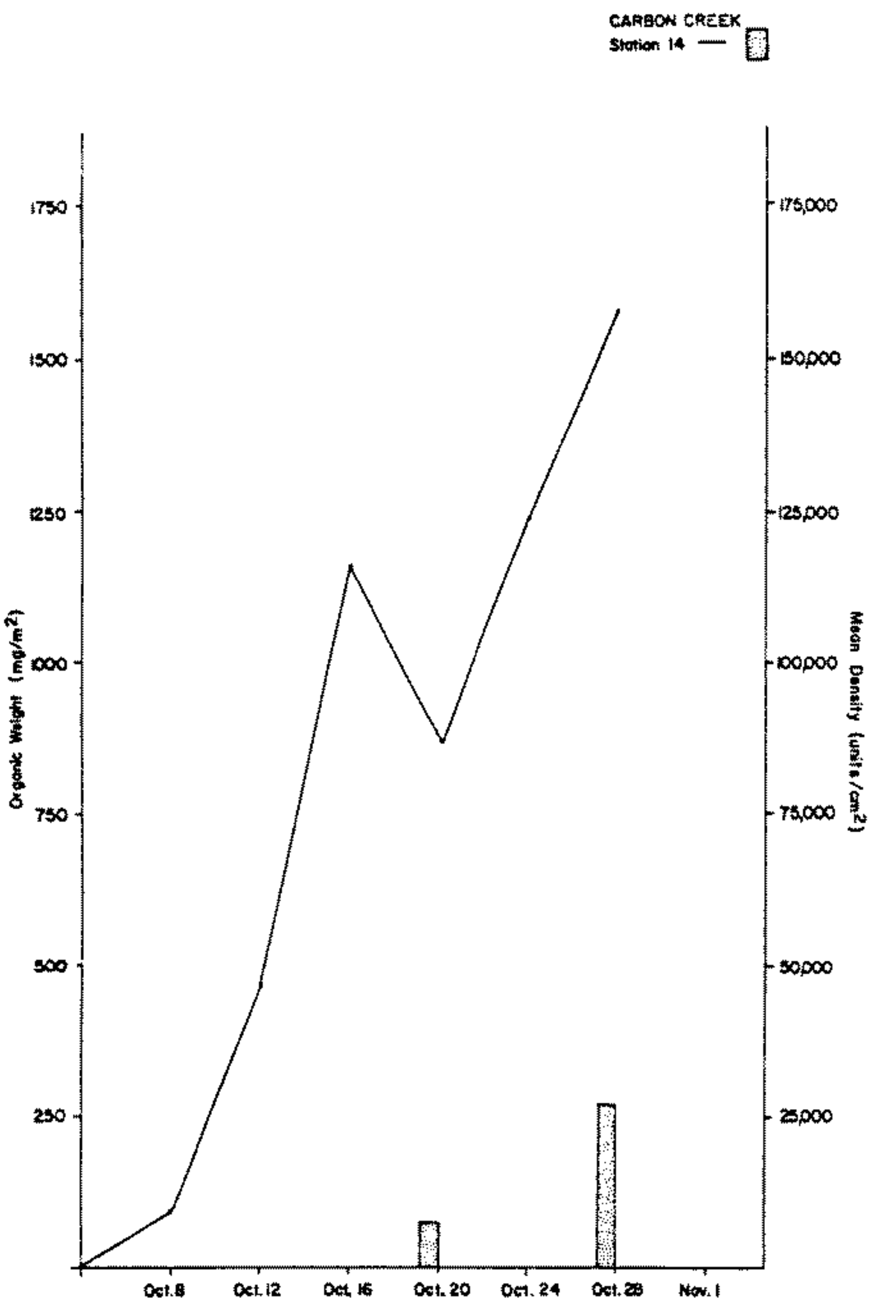

Figure 3-8. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae (units/cm^2) (bar graphs) on artificial substrates placed at Station 14 on Carbon Creek, October 1979.

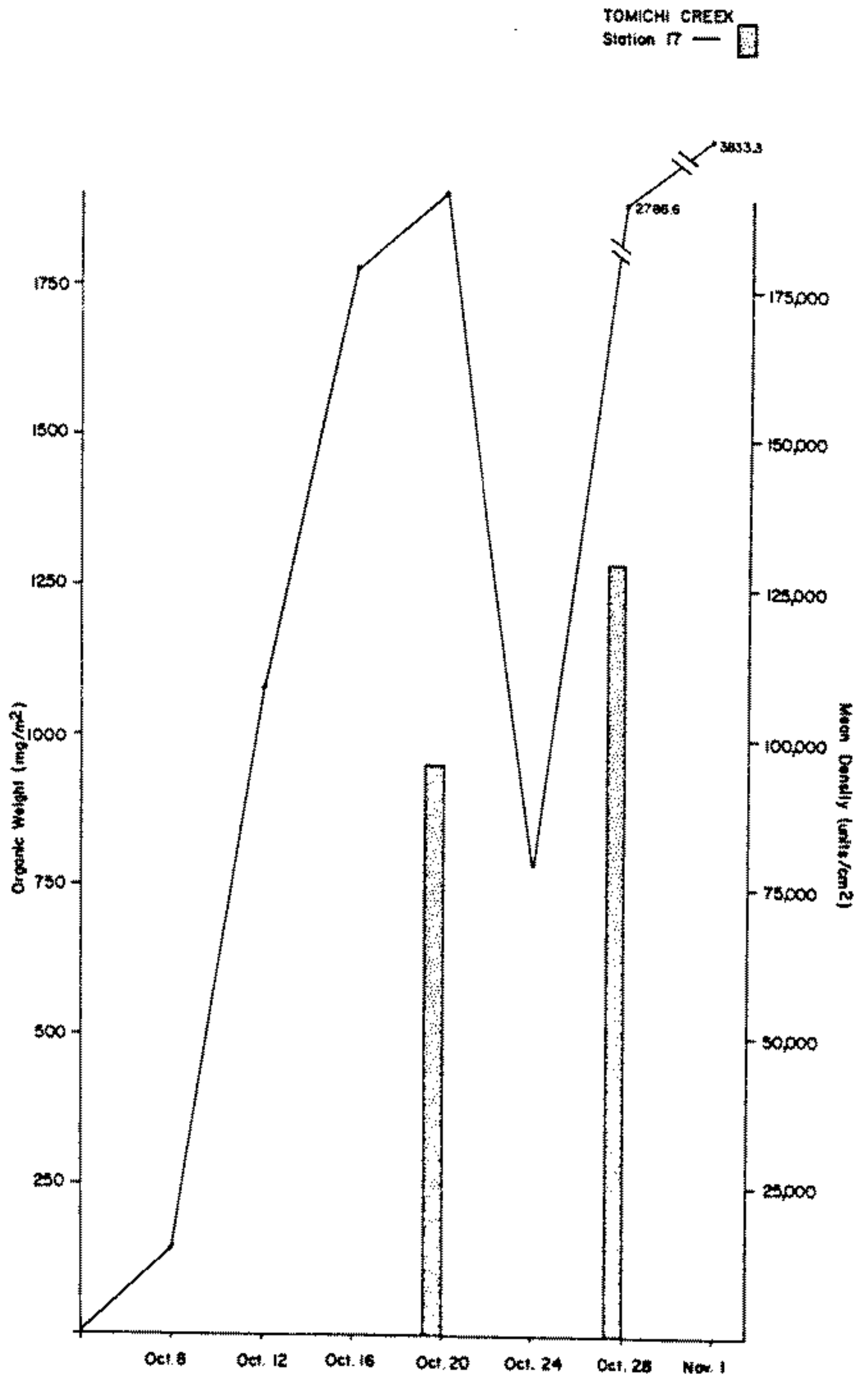

Figure 3-9. Accumulation of organic matter (mg/m^2) (linear graphs) and mean density of attached algae ($units/cm^2$) (bar graphs) on artificial substrates placed at Station 17 on Tomichi Creek, October 1979.

Table 3-2 Summary of attached algal data collected at Station 3 on Coal Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 3				
	Summer[a]			Fall[b]	
Time of Exposure (days)[c]	16	24	32	16	24
Total No. of Taxa	11	16	10	19	15
Mean Density (units/cm^2)	32,911	60,518	160,732	17,100	26,253
Percent Diatomaceae	29.9	41.6	64.6	72.2	33.1
Percent Euglenophyta	0.0	0.0	0.0	0.0	0.0
Percent Cyanophyta	0.6	8.5	19.1	7.6	1.8
Percent Chlorophyta	1.2	0.4	0.6	6.9	3.7
Percent Chrysophyceae	67.6	47.7	15.7	11.8	61.4
Percent Unidentified Unicellular	0.0	0.0	0.0	0.0	0.0
Diversity (Lloyd 1968)	1.18	1.71	1.45	2.08	1.43
Evenness (Pielou 1966)	0.49	0.62	0.63	0.71	0.53

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.
[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.
[c]Total days after periphyton sampler placed in streams.

Table 3-3 Summary of attached algal data collected at Station 4 on Coal Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 4				
	Summer[a]			Fall[b]	
Time of Exposure (days)[c]	16	24	32	16	24
Total No. of Taxa	0	2	0	1	1
Mean Density (units/cm^2)	0.0	96	0.0	32	12
Percent Diatomaceae	0.0	0.0	0.0	100.0	0.0
Percent Euglenophyta	0.0	33.3	0.0	0.0	0.0
Percent Cyanophyta	0.0	0.0	0.0	0.0	0.0
Percent Chlorophyta	0.0	66.7	0.0	0.0	0.0
Percent Chrysophyceae	0.0	0.0	0.0	0.0	100.0
Percent Unidentified Unicellular	0.0	0.0	0.0	0.0	0.0
Diversity (Lloyd 1968)	0.0	0.64	0.0	0.0	0.0
Evenness (Pielow 1966)	0.0	0.92	0.0	0.0	0.0

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

Table 3-4 Summary of attached algal data collected at Station 6 on Coal Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 6				
	Summer[a]			Fall[b]	
Time of Exposure (days)[c]	16	24	32	16	24
Total No. of Taxa	9	9	9	17	20
Mean Density (units/cm^2)	2,404	18,691	190,230	17,396	13,089
Percent Diatomaceae	99.0	100.0	98.0	88.0	81.7
Percent Euglenophyta	0.0	0.3	0.0	0.0	0.0
Percent Cyanophyta	0.0	0.0	0.9	2.3	1.6
Percent Chlorophyta	1.0	0.0	0.0	7.5	6.4
Percent Chrysophyceae	0.0	0.0	0.0	2.3	9.6
Percent Unidentified Unicellular	0.0	0.0	0.2	0.0	0.8
Diversity (Lloyd 1968)	1.67	1.42	0.46	2.21	1.85
Evenness (Pielow 1966)	0.76	0.64	0.22	0.78	0.62

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

Table 3-5 Summary of attached algal data collected at Station 7a on Coal Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 7a				
	Summer[a]			Fall[b]	
Time of Exposure (days)[c]	16	24	32	16	24
Total No. of Taxa	8	6	10	4	5
Mean Density (units/cm^2)	125	1,870	4,949	357	319
Percent Diatomaceae	68.0	98.1	97.1	90.9	75.0
Percent Euglenophyta	0.0	1.0	0.0	0.0	12.5
Percent Cyanophyta	18.3	0.0	1.9	0.0	0.0
Percent Chlorophyta	0.0	1.0	0.0	9.1	3.1
Percent Chrysophyceae	0.0	0.0	0.0	0.0	0.0
Percent Unidentified Unicellular	13.7	0.0	1.0	0.0	9.4
Diversity (Lloyd 1968)	1.81	0.49	0.72	0.99	1.33
Evenness (Pielow 1966)	0.87	0.27	0.31	0.71	0.82

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

Table 3-6 Summary of attached algal data collected at Station 10 on Coal Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 10				
	Summer[a]			Fall[b]	
Time of Exposure (days)[c]	16	24	32	16	24
Total No. of Taxa	11	7	14	14	15
Mean Density (units/cm²)	39,935	58,661	80,727	67,751	1,160,819
Percent Diatomaceae	91.9	93.8	45.2	95.2	90.2
Percent Euglenophyta	0.8	0.0	0.0	0.0	0.0
Percent Cyanophyta	1.6	6.2	53.1	0.0	2.7
Percent Chlorophyta	0.0	0.0	0.0	4.8	2.7
Percent Chrysophyceae	3.2	0.0	1.7	0.0	1.8
Percent Unidentified Unicellular	2.4	0.0	0.0	0.0	0.9
Diversity (Lloyd 1968)	1.52	1.36	1.27	1.69	1.95
Evenness (Pielow 1966)	0.63	0.70	0.48	0.64	0.72

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

Table 3-7 Summary of attached algal data collected at Station 12 on Coal Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 12				
	Summer[a]			Fall[b]	
Time of Exposure (days)c	16	24	32	16	24
Total No. of Taxa	15	15	11	16	No sample taken
Mean Density (units/cm2)	73,309	49,298	141,600	31,191	
Percent Diatomaceae	92.1	88.6	24.8	91.1	
Percent Euglenophyta	0.6	0.0	0.0	0.9	
Percent Cyanophyta	0.6	10.7	73.3	1.8	
Percent Chlorophyta	6.8	0.8	0.0	4.4	
Percent Chrysophyceae	0.0	0.0	1.9	0.0	
Percent Unidentified Unicellular	0.0	0.0	0.0	1.8	
Diversity (Lloyd 1968)	1.68	1.56	0.93	1.91	
Evenness (Pielow 1966)	0.62	0.58	0.39	0.69	

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

Table 3-8 Summary of attached algal data collected at Station 14 on Carbon Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 14				
Time of Exposure (days)[c]	Summer[a]			Fall[b]	
	16	24	32	16	24
Total No. of Taxa	9	d	9	20	25
Mean Density (units/cm^2)	30,942	d	547,506	7,449	27,915
Percent Diatomaceae	72.2	d	37.9	97.1	89.4
Percent Euglenophyta	0.0	d	0.0	0.0	0.9
Percent Cyanophyta	26.4	d	56.0	0.0	0.0
Percent Chlorophyta	0.0	d	0.0	1.0	3.5
Percent Chrysophyceae	1.4	d	6.0	1.0	0.9
Percent Unidentified Unicellular	0.0	d	0.0	0.0	3.5
Diversity (Lloyd 1968)	1.44	d	1.35	2.44	2.79
Evenness (Pielow 1966)	0.65	d	0.61	0.82	0.86

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

[d]Sample lost during shipping.

Table 3-9 Summary of attached algal data collected at Station 17 on Tomichi Creek, Gunnison County, Colorado during the summer and fall sampling periods of 1979

	Station 17				
	Summer[a]			Fall[b]	
Time of Exposure (days)[c]	16	24	32	16	24
Total No. of Taxa				25	25
Mean Density (units/cm^2)				95,265	129,958
Percent Diatomaceae				96.2	92.6
Percent Euglenophyta				0.0	0.9
Percent Cyanophyta				0.0	0.9
Percent Chlorophyta				3.8	0.9
Percent Chrysophyceae				0.0	2.8
Percent Unidentified				0.0	0.9
Diversity (Lloyd 1968)				2.87	2.62
Evenness (Pielow 1966)				0.89	0.82

[a]Samplers placed in stream for 32 days from 9 August to 10 September 1979.

[b]Samplers placed in stream for 27 days from 4 October to 1 November 1979.

[c]Total days after periphyton sampler placed in streams.

Table 3-10 Comparison of mean and maximum organic weight (mg/sq cm) and density of attached algae (organisms/sq cm) on glass slides placed at eight stations, August and October 1979.

	Accumulated organic weight (mg/sq m)		Density of Attached Algae (organisms/sq m)	
Station	Mean[a]	Maximum	Mean[b]	Maximum
3	527	1,020	59,500	160,700
4	240	513	28	96
6	225	480	48,400	190,200
7a	150	300	1,520	4,950
10	755	2,153	282,000	1,161,000
12	523	1,867	73,800	141,600
14	857	1,667	123,000	547,500
17c	2,003	5,333	112,000	130,000

[a] Mean for 8 sampling periods in August/September and 7 dates in October 1979.
[b] Mean for 3 sampling periods in August/September and 2 dates in October 1979.
[c] Samples at Station 17 collected only during October 1979.

One explanation for this apparent discrepancy is that the organic material accumulating on the glass slides might have been primarily nonliving matter. Another possible explanation is related to the selective toxicity of heavy metals. As discussed later in this section, Coal Creek at Station 4 contains concentrations of zinc and other heavy metals toxic to nearly all attached algae. Williams and Mount (1979) reported that the toxicity of zinc was apparently selective for the algal portion of the periphyton community. Similar results have been reported by Weitzel (1979) for other heavy metals. Thus, it is possible that the growth of algae was inhibited by heavy metals but bacterial growth was relatively unaffected. This may also explain the marked difference between the mean density of attached algae and the biomass estimates at Station 7a, where zinc concentrations as high as 3.4 mg/l were reported in 1979 (AMAX 1980).

Based on the shapes of the curves in Figures 3-1 through 3-9, it appears that the periphyton communities at many of the stations went through two or more growth cycles during the course of each 32 d study. such a cyclic pattern for accumulation of organic matter on natural substrates is quite common (Weitzel 1979). Periphyton often accumulates to the point where it either dies and sloughs off or is swept away by the current. The periphyton then begins to accumulate and the cycle is repeated.

3.2.3 Species Composition and Mean Density of Attached Algae

Detailed taxonomic data are included in Appendix A. These data are summarized in Tables 3-1 through 3-9.

Station 3 - Upper Coal Creek

The periphyton collected on artificial substrates at Station 3 was comprised mainly of diatoms (Diatomaceae), blue-green algae

(Cyanophyta), and yellow-brown algae (Chrysophyceae). Data on the taxonomy and density of periphyton collected between mid-August and mid-September 1979 indicate that the proportion of diatoms and blue-green algae increased and the proportion of yellow-brown algae decreased between days 8 and 24 of the 32 day period.

This pattern was reversed for the October sampling period and may reflect the normal seasonal cycle of periphyton dominance.

Station 4 - Coal Creek

Station 4 was located on Carbon Creek downstream of the Keystone Mine discharge. The density and absolute numbers of benthic algae at Station 4 were low. No algae were seen on slides collected on 25 August and 10 September 1979. Two taxa were collected on 3 September 1979 (Table 3-3); they were Chlorococcales spp., a green algae, and Trachelonas spp., a euglenophyte. Neither of these species were collected upstream at Station 3 on Coal Creek. This suggests that these taxa were residents of the stream at Station 4 and were not taxa which had drifted downstream and settled on the substrate. The absence of algae in the 10 September 1979 sample may indicate that these two taxa were eliminated by the high metal concentration or that these taxa were rare.

For the October sampling period, two different taxa of algae were collected. These two taxa, Achnanthes minutissima and Chrysocapsa spp., were common in samples collected at Station 3 a fact which may indicate that these taxa had simply drifted downstream and settled on the substrate. The dramatic reduction in the number of taxa and density of benthic algae is due to the effect of acid mine drainage. Metal toxicity and ferric hydroxide siltation from the acid mine drainage created an unfavorable habitat for periphyton. The siltation dramatically reduced light penetration in the stream and covered the substrate, thereby preventing colonization. High levels of heavy metals probably eliminated many species and inhibited the growth of the algae. Gaechther (1976) found that heavy metals inhibit the photosynthetic rate of algae and that copper was most toxic followed in order by cadmium, zinc, and lead. Although there were considerable differences in the tolerance of various algal species to heavy metals, development and growth of the green algae *Selenastrum capricornutum*, were adversely affected in laboratory tests by concentrations of 0.30 mg/l copper, 0.70 mg/l zinc, or 0.65 mg/l cadmium (Bartlett et al. 1974).

Average concentrations of these metals in water samples collected near Station 4 were 0.58 mg/l copper, 15.1 mg/l zinc, and 0.23 mg/l cadmium for the period from April 1978 to March 1979 (AMAX 1980). Thus, it appears that zinc and copper concentrations in Coal Creek near Station 4 are primarily responsible for the absence of attached algae at Station 4.

Station 6 - Upper Slate River

Diatoms were the most abundant group of attached algae collected during 1979 at Station 6. *Synedra* spp. and *Achnanthes minutissima* were the dominant taxa of attached algae collected at Station 6 for all sampling periods except 28 October 1979, when the diatom, *Fragillaria* spp. was the most prevalent taxa. These dominant taxa are pennate diatoms and are cosmopolitan in distribution across North America. Lowe (1974) describes *A. minutissima* as a species with wide tolerance to pH, salinity, current, and temperature conditions.

The density of benthic algae at Station 6 increased over ten-fold between 3 September and 20 September 1979. This dramatic increase was primarily due to a bloom of the diatom, *Achnanthes minutissima*. This species constituted over 91 percent of the attached algae collected on 10 September 1979.

Station 7a - Lower Slate River

Water quality and the aquatic biota of the Slate River at Station 7a were adversely affected by the metal-laden discharges from Coal Creek. Although the dominant taxa of algae were similar for Station 6 and 7a, the density of attached algae at Station 7a was lower (Tables 3-4 and 3-5). This reduction in mean density of the attached algae was probably due to the effects of metals entering the Slate River from Coal Creek.

Station 10 - East River

Diatoms constituted over 90 percent of the attached algae at this station during all of the sampling periods except 10 September 1979, when a blue green alga, Chamaesiphon spp., represented over half of the algal density. This blue green alga was the dominant taxa at Stations 10, 12, and 14 in 1978 (AMAX 1979). Many taxa of blue green algae are characteristically found in nutrient enriched waters, however, Kann (1975) reports that Chamaesiphon spp. grow best in oligotrophic (low nutrient) waters. Water quality data collected during 1978 and 1979 (AMAX 1980) indicated that nutrient levels were low at Station 10. The density of attached algae on slides collected at Station 10 was not substantially greater than at some of the other stations (e.g., Station 6 and 3) during the August to September 1979 survey. Densities were much higher, however, during the October sampling period. An algal density of 1,161,000 units/sq cm was reported at Station 10 on 28 October 1979. This dramatic increase was caused by an apparent bloom of the diatoms, Synedra spp. and Synedra ulna.

Station 12 - East River

Station 12 had aquatic habitat similar to that at Station 10. The taxonomic composition of periphytic algae at Station 12 was also similar. Oiatoms were the dominant taxa in the samples collected on 25 August and 3 September but were replaced by the blue green alga Chamaesiphon spp. in the samples collected on 10 September 1979. Chamaesiphon spp. was also the dominant taxa collected at Station 12 during September 1978.

Station 14 - Carbon Creek

Station 14 was located on Carbon Creek near its confluence with Ohio Creek. Diatoms were the most common group of attached algae present at Station 14 for all sampling dates except 10 September 1979 when the blue green alga, Chamaesiphon spp., was the most abundant taxa. This blue green algae was numerically dominant in both the July and September samples collected at Station 14 in 1978.

The mean density of attached algae at Station 14 (Table 3-8) was similar to those at Stations 10 and 12 on the East River.

Station 17 - Tomichi Creek

Periphyton samples were collected on Tomichi Creek only in October 1979. Diatoms were the most common group of attached algae collected at Station 17. No single taxa of Diatomaceae predominated, Diatoma vulgare, Fragillaria pinnata, Ephithemia sorex, Nitzchia palea, and Navicula cryptocephala were common at Station 17.

The mean density of attached algae and the accumulation of organic matter was greater at Station 17 than at other stations in the study area. This was probably due to the nutrient levels in Tomichi Creek. Concentrations of ammonia and total phosphate were higher at Station 17 than that at other stations in the study area except Station 8 downstream of the Crested Butte municipal waste water treatment plant (AMAX 1980).

3.2.4 Comparison of Periphyton Oata for 1978 and 1979

A total of 69 different taxa of algae were collected from artificial substrates during 1979 (Table 3-11). Comparison of the number of taxa collected in August and September 1979 with a similar list compiled for attached algae collected in September 1978 (Appendix A) shows that 44 taxa were collected on artificial substrate from mid-August to mid-September in 1979 compared to a total of 55 taxa collected from natural substrates in September 1978. Twenty-three of the taxa were collected in both September 1978 and September 1979.

A comparison of the dominant taxa (taxa constituting more than 10 percent of the total mean density at a station) for September 1978 and 1979 are shown in Table 3-12.

These data show that the diatoms Achnanthes minutissima and the blue-green algae, Chamaesiphon spp. were the dominant taxa in the study area in both September 1978 and September 1979. Dominant taxa were the same or similar in 1978 and 1979 at all stations except Stations 3 and 4 on Coal Creek. The taxa collected at Station 3 in 1978 and 1979 are all characteristically found in waters of good quality or have a wide range of environmental tolerance [Lowe (1977), Kann (1975)]. Water quality data collected at Station 3 are similar for 1978 and 1979 (AMAX 1980). Thus, the differences in dominant species at Station 3 for 1978 and 1979 may have been due to differences in physical habitat such as current velocity or amount of sunlight at sampling points.

Comparison of dominant taxa at Station 4 is not meaningful due to the low density of attached algae collected at this station in both 1978 and 1979.

Table 3-11 Periphyton Species List for the 1979 AMAX Mount Emmons Aquatic Ecology Studies.

TAXA	August-September			October	
	8-25	9-3	9-10	10-20	10-28
Chlorophyta					
Ankistrodesmus spp.				X	X
Ankistrodesmus falcatus					X
Chaetophorales spp.		X		X	X
Chlamydomonas spp.	X				
Chlorococcales spp.					X
Closterium spp.				X	X
Gloeocystis spp.					X
Mougeotia spp.		X	X	X	
Palmodictyon spp.	X				
Pediastrum spp.			X		
Staurastrum spp.		X		X	X
Scenedesmus spp.				X	
Spondylosium spp.					X
Tetraedron minimum				X	
Tetraedron muticum	X				
Ulothrix spp.					X
Euglenophyta					
Euglena spp.	X				
Lepocinclis spp.				X	X
Trachelomonas spp.		X			
Chrysophyta					
Chrysocapsa spp.	X	X	X	X	X
Dinobryon spp.					X
Diatomaceae					
Achnanthes spp.	X	X	X	X	X
Achnanthes lanceolata	X		X	X	X
Achnanthes minutissima	X	X	X	X	X
Cocconeis pediculus				X	X
Cocconeis placentula	X	X	X	X	X
Cyclotella spp.				X	
Cyclotella meneghiniana				X	
Cymbella spp.	X	X	X	X	X
Cymbella ventricosa	X	X	X	X	X
Cymbella sinuata					X
Denticulata tenuis				X	
Diatoma hiemale	X	X		X	
Diatoma vulgare				X	X
Epithemia sorex				X	X
Eunotia spp.				X	X
Fragilaria spp.	X	X	X	X	X
Fragilaria arcus	X	X		X	X
Fragilaria leptostauron				X	
Fragilaria pinnata		X	X	X	X
Fragilaria vaucheriae	X	X	X		
Gomphonema spp.	X	X	X	X	X

Table 3-11 (Continued)

TAXA	August-September			October	
	8-25	9-3	9-10	10-20	10-28
Gomphonema olivaceum	X				
Gomphonema parvulum		X	X		X
Gomphonema ventricosum				X	X
Meridion circulare	X			X	
Navicula spp.	X	X	X	X	X
Navicula capitata					X
Navicula cryptocephala				X	X
Nitzschia spp.	X			X	X
Nitzschia acicularis	X	X	X	X	X
Nitzchia dissipata				X	X
Nitzchia hungarica					X
Nitzschia linearis			X	X	X
Nitzschia palea	X	X	X	X	X
Rhicosphenia curvata				X	X
Surirella spp.				X	
Surirella angustata	X				
Synedra spp	X	X	X	X	X
Synedra ulna	X		X	X	X
Tabellaria flocculosa					X
Tabellaria fenestrata	X				
Cyanophyta					
Chamaesiphon spp.	X	X	X	X	
Chroococcus spp.	X				
Nostocales spp.					X
Oscillatoria spp.	X	X	X	X	
Oscillatoria pseudogeminata	X				X
Oscillatoria tenuis		X		X	X
Phormidium spp.	X		X	X	X
Unidentified flagellates					
5-10 microns	X			X	X
>10 microns					X
Unidentified unicellular					
5-10 microns	X	X	X	X	X

Table 3-12 Comparison of dominant taxa (greater than 10 percent of total mean density) of attached algae collected in the Mount Emmons project area in September 1978 and August-September 1979

	1978 [a,c]	1979 [b,c]
Station 3	Phormidium spp. Chamaesiphon spp. Chlorophyta spp.	Synedra spp. Chrysocapsa spp. Achnanthes minutissima Chamaesiphon spp.
Station 4	Achnanthes minutissima	Trachelomas spp. Chlorococcales spp.
Station 6	Achnanthes minutissima Chamaesiphon spp.	Achnanthes minutissima
Station 7a	Achnanthes minutissima	Achnanthes minutissima
Station 10	Chamaesiphon spp.	Achnanthes minutissima Chamaesiphon spp.
Station 12	Chamaesiphon spp. Achnanthes minutissima	Chamaesiphon spp. Achnanthes minutissima
Station 14	Chamaesiphon spp.	Chamaesiphon spp. Cocconeis placentula Achnanthes minutissima

[a] Samples in 1978 collected from natural substrates.
[b] Samples in 1979 collected from artificial substrates (glass slides).
[c] Taxa listed in order of dominance at each station.

3.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are animals that live at least part of their life cycles within or upon available substrate in a body of water. They are an important component of the aquatic ecology and are sensitive to stress caused by natural or introduced contaminants. Because they are relatively immobile and have long life spans, benthic invertebrates can be used to detect both long and short term changes in the aquatic community (U.S. EPA 1973).

3.3.1 Benthic Macroinvertebrates Collected in Surber Samplers

Table 3-13 presents the taxa that were collected during benthic macroinvertebrate, drift, and microhabitat studies in 1979. Tables 3-14 and 3-17 summarize data on the benthic macroinvertebrate densities, percent composition of the major groups, number of taxa, diversity and evenness. Additional data on benthic macroinvertebrates are presented in Appendix B.

A total of 153 taxa of benthic macroinvertebrates were collected in Surber samples. Drift and microhabitat samples yielded 68 and 79 taxa, respectively. Of the dominant major groups collected, Diptera (midges and flies) were represented by 53 taxa; Trichoptera (caddisflies), 27 taxa; Plecoptera (stoneflies), 19 taxa; and Ephemeroptera (mayflies), 17 taxa.

3.3.1.1 Temporal and Spatial Distribution of Benthic Macroinvertebrates

Spatial patterns in mean densities (organisms/sq m), diversity, and total number of taxa of benthic invertebrates occurred in the study area in 1979.

Total number of taxa, mean density, and diversity of benthic macroinvertebrates was consistently lower at Stations 4 and 5 on lower Coal

Table 3-13 Macroinvertebrate taxa collected during the benthic, drift, and microhabitat studies, Gunnison County, Colorado

TAXA	Benthic Macroinvertebrate	Drift	Microhabitat Qualitative
Turbellarie	X		X
Planariidae spp.	X		X
Nematode spp.	X	X	
Coelenterata			
Hydra spp.	X	X	X
Oligocheeta spp.	X		
Tubificidae			
Immature without capilliform chaetae	X	X	
Immature with capilliform chaetae	X		
Limnodrilus hoffmeisteri	X		
Tubifex tubifex	X		
Naididae			
Chaetogaster diaphanus	X		
Nais spp.	X		
N. behningi	X		
N. bretscheri	X		
N. communis	X		X
N. simplex	X		
Pristina spp.	X		
P. aequiseta	X		
P. foreli	X		
Aeolosomatidae spp.	X	X	
Enchytraeidae spp.	X	X	X
Glossoscolecidae spp.	X	X	
Hirudinea			
Helobdella stagnalis	X		
Hydracarina			
Hydracarina spp.	X	X	X
Ephemeroptera			
Baetidae spp.	X	X	
Baetis spp.	X	X	X
Pseudocloeon spp.	X		
Ephemerellidae			
Ephemerella spp.	X	X	
E. (Ephemerella) spp.	X		
E. (Drunella) spp.	X	X	X
E. (Serratella) spp.	X		X
E. (Timpanoga) spp.	X		
Heptageniidae spp.	X	X	
Heptagenia spp.	X	X	

Table 3-13 (Continued)

TAXA	Benthic Macroinvertebrate	Drift	Microhabitat Qualitative
Ephemeroptera (Continued)			
Cinygmula spp.	X	X	
Epeorus spp.	X		X
E. (Ironopsis) spp.		X	X
Rhithrogena spp.	X	X	X
Leptophlebiidae spp.	X		
Paraleptophlebia spp.	X	X	X
Siphlonuridae			
Ameletus spp.	X	X	X
Tricorythidae			
Tricorythodes spp.	X		
Coleoptera spp.	X		
Dytiscidae spp.	X		X
Agabus spp.			X
Elmidae spp.	X	X	
Heterlimnius spp.	X		X
Larsia spp.			X
Narpus spp.	X		
Optioservus spp.	X		X
Zaitzevia spp.	X		
Hydrophilidae spp.	X		
Noteridae spp.			X
Plecoptera spp.	X	X	X
Capniidae spp.	X	X	X
Perlidae			
Hesperoperla pacifica	X		
Claassenia spp.	X		
C. sabulosa	X		X
Nemouridae spp.	X	X	X
Malenka spp.		X	X
Podmosta spp.	X		
Prostoia spp.	X		X
Zapada spp.	X	X	X
Perlodidae spp.	X		X
Cultus spp.	X		
Diura spp.	X		
Isoperla spp.	X	X	X
Megarcys spp.	X		
Skwala spp.	X		
Pteronarcidae			
Pteronarcella spp.	X		
P. badia	X	X	X
Taeniopterygidae spp.		X	
Taenionema spp.	X	X	
Chloroperlidae	X	X	X
Alloperla spp.	X		

Table 3-13 (Continued)

TAXA	Benthic Macroinvertebrate	Drift	Microhabitat Qualitative
Hemiptera			
Corixidae spp.			X
Trichoptera spp.		X	X
Trichoptera pupa	X		
Brachycentridae spp.	X		
Brachycentrus spp.	X	X	X
B. pupa	X		
Micrasema spp.	X	X	
Glossosomatidae			
Glossosomatidae pupa	X		
Agapetus spp.	X		
Glossosoma spp.	X		X
Protoptila spp.	X		
Helicopsychidae spp.			
Helicopsyche spp.	X		
Hydropsychidae spp.	X		X
Arctopsyche spp.	X	X	X
Cheumatopsyche spp.	X		
Hydropsyche spp.	X	X	X
Hydroptilidae	X	X	X
Agraylea spp.	X		
Hydroptila spp.	X		
Neotrichia spp.	X		
Stactobiella spp.	X		
Lepidostomatidae			
Lepidostoma spp.	X		X
Leptoceridae			
Oecetis spp.	X		
Limnephilidae spp.	X		X
Amphicosmoecus canax		X	
Ecclisomyia spp.	X		X
Hesperophylax spp.	X		X
Oligophlebodes spp.	X	X	X
Psychomyiidae spp.			
Psychomyia spp.	X	X	
Rhyacophilidae			
Rhyacophila spp.	X	X	X
Collembola spp.	X	X	
Diptera	X		
Diptera pupa	X		
Athericeridae			
Atherix spp.	X		X

Table 3-13 (Continued)

TAXA	Benthic Macroinvertebrate	Drift	Microhabitat Qualitative
Diptera (cont.)			
Anthomyiidae spp.	X		
Blephariceridae spp.	X		X
Ceratopogonidae spp.	X	X	X
Deuterophlebiidae			
Deuterophlebia spp.		X	
Empididae spp.	X	X	X
Psychodidae spp.	X	X	
Pericoma spp.	X	X	X
Simuliidae spp.		X	
Simuliidae pupa	X		X
Simulium spp.	X	X	X
Prosimulium spp.	X	X	
Stratiomyidae spp.	X		
Tipulidae spp.	X	X	
Chironomidae			
Chironomidae pupa	X	X	X
Brillia spp.	X	X	X
Cardiocladius spp.	X		
Chironomus spp.		X	X
Cladotanytarsus spp.	X		
Corynoneura spp.	X		X
Cryptochironomus spp.	X		
Cricotopus spp.	X	X	
C. *bicinctus*	X	X	
C. (Isocladius)			
laricomalis	X		
C. *triannulatus*	X		
Diamesa spp.	X	X	X
Diplocladius spp.	X		
Eukiefferiella spp.	X	X	X
Heterotrissocladius spp.	X	X	X
Hydrobaenus spp.		X	
Larsia spp.			X
Micropsectra spp.	X	X	X
Microtendipes spp.	X		
Monodiamesa spp.	X		
Orthocladiinae spp.	X	X	
Orthocladius spp.	X	X	X
Odontomesa spp.	X		
O. fulva			X
Paracladopelma spp.	X		X
Parakiefferiella spp.		X	X
Paralimnophyes spp.	X		
Parametriocnemus spp.	X		
Paraphaenocladius spp.	X		
Phaenopsectra spp.	X		X
Polypedilum spp.	X		X

Table 3-13 (Concluded)

TAXA	Benthic Macroinvertebrate	Drift	Microhabitat Qualitative
Diptera (Continued)			
Polypedilum (fallax group) spp.	X		X
P. (tripodura group) spp.	X		X
Potthastia spp.	X		X
Psectrotanypus spp.	X	X	
Pseudodiamesa spp.	X	X	
Rheocricotopus spp.			X
Rheotanytarsus spp.	X	X	
Smittia spp.	X		
Stempellinella spp.		X	
Stictochironomus spp.	X		
Syncricotopus spp.	X		
Synorthocladius spp.		X	X
S. semivirens	X		
Tanytarsus spp.	X	X	X
Tanytarsini spp.	X		
Thienemaniella spp.	X		X
Thienemannimyia group spp.	X	X	X
Trissocladius spp.	X		
Sphaeriidae			
Sphaeriidae spp.	X		
Pisidium spp.	X		
Daphnia pulex			X
Immature Copepoda			X
Total number of taxa	153	69	77

Table 3-14 Total number of taxa, mean density (organisms/sq m), diversity, evenness, and percentage composition of each major group collected in riffle areas during the spring benthic macroinvertebrate survey (March) in Gunnison County, Colorado

	RIFFLE													
Station	2	3	4	5	6	7	8	10	11	12	13	14	15	17
Total No. of Taxa	27	21	1	0	10	3	2	14	-	21	18	20	21	-
Mean Density (no/m^2)	2039	11405	5	0	350	21	32	716	-	1201	543	215	1991	-
Diversity	3.11	2.36	0.0	0.0	2.36	0.46	0.46	2.17	-	2.71	2.94	3.23	2.43	-
Evenness	0.74	0.65	0.0	0.0	0.85	0.46	0.46	0.69	-	0.70	0.81	0.92	0.63	-
Coleoptera (%)	4.2	0.8	100.0	0.0	0.0	0.0	0.0	0.0	-	0.0	10.9	20.0	2.2	-
Diptera (%)[a]	67.3	94.9	0.0	0.0	16.9	0.0	33.3	33.8	-	56.9	3.0	45.0	9.7	-
Chironomidae (%)[b]	62.0	94.2	0.0	0.0	16.9	0.0	0.0	26.3	-	55.1	1.9	45.0	6.5	-
Ephemeroptera (%)	10.3	1.9	0.0	0.0	58.5	50.0	0.0	57.1	-	21.1	39.6	17.5	58.4	-
Hydracarina (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	-	0.0	0.0	2.5	0.0	-
Oligochaeta (%)	2.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	-	15.8	2.0	2.5	0.0	-
Plecoptera (%)	8.4	1.7	0.0	0.0	23.1	50.0	66.7	4.5	-	2.2	2.0	2.5	12.4	-
Trichoptera (%)	7.7	0.0	0.0	0.0	1.5	0.0	0.0	4.5	-	4.0	38.6	10.0	17.3	-

[a] Percent Diptera includes Chironomidae.

[b] Chironomidae (midges) are in Order Diptera.

Table 3-15. Total number of taxa, mean density (organisms/sq m), diversity, evenness, and percantage composition of each major group collected in pool areas during the spring benthic macroinvertebrate survey (March) in Gunnison County, Colorado

	POOL													
Station	2	3	4	5	6	7	8	10	11	12	13	14	15	17
Total No. of Taxa	19	34	0	0	13	2	7	9	-	19	12	21	26	-
Mean Density (no/m^2)	328	11879	0	0	2604	16	70	506	-	823	124	533	554	-
Diversity	3.30	3.50	0	0	2.44	0.50	1.87	1.84	-	2.84	2.39	2.74	3.30	-
Evenness	0.89	0.77	0	0	0.82	0.50	0.99	0.76	-	0.78	0.89	0.73	0.85	-
Coleoptera (%)	9.8	2.7	0.0	0.0	0.0	0.0	0.0	0.0	-	1.3	13.0	49.0	20.4	-
Diptera (%)[a]	36.1	83.7	0.0	0.0	90.5	0.0	100.0	51.1	-	49.7	0.0	16.2	9.7	-
Chironomidae (%)[b]	34.4	82.4	0.0	0.0	83.9	0.0	46.2	51.1	-	47.7	0.0	12.1	4.9	-
Ephemeroptera (%)	24.6	3.1	0.0	0.0	2.5	0.0	0.0	27.7	-	10.5	26.1	23.2	9.7	
Hydracarina (%)	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	1.0	-
Oligochaeta (%)	2.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	-	24.2	8.7	1.0	16.5	-
Plecoptera (%)	8.4	7.1	0.0	0.0	7.0	100.0	0.0	21.3	-	0.0	4.4	4.0	1.0	-
Trichoptera (%)	7.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	-	14.4	47.8	6.1	41.8	-

[a] Percent Diptera includes Chironomidae.

[b] Choronomidae (midges) are in Order Diptera.

Table 3-16 Total number of taxa, mean density (organisms/sq m), diversity, evenness, and percentage composition of each major group collected in pool areas during the fall benthic macroinvertebrate survey (September) in Gunnison County, Colorado

	POOL													
Station	2	3	4	5	6	7	8	10	11	12	13	14	15	17
Total No. of Taxa	30	25	4	0	20	2	10	32	34	27	27	27	37	48
Mean Density (no/m^2)	3718	1237	32	0	839	11	75	1996	3626	2233	807	737	1237	3868
Diversity	2.99	3.01	1.25	0.0	2.87	0.0	2.07	3.41	3.45	3.53	3.51	3.60	3.78	3.88
Evenness	0.67	0.74	0.97	0.0	0.78	0.0	0.94	0.75	0.77	0.81	0.86	0.87	0.80	0.76
Coleoptera (%)	11.6	37.4	33.3	0.0	0.0	0.0	14.3	0.8	0.0	1.9	18.7	16.1	23.5	3.2
Diptera (%)[a]	74.1	26.5	50.0	0.0	55.1	50.0	35.7	11.1	65.9	68.9	9.3	30.7	28.7	24.0
Chironomidae (%)[b]	66.3	18.3	0.0	0.0	39.1	50.0	21.4	8.4	61.7	63.1	0.7	23.4	25.7	22.6
Ephemeroptera (%)	2.5	6.1	0.0	0.0	14.7	50.0	14.3	17.8	2.4	6.0	8.0	13.1	6.1	16.0
Hydracarina (%)	0.3	1.3	0.0	0.0	3.2	0.0	21.4	8.9	0.6	2.2	10.0	2.2	2.6	0.3
Oligochaeta (%)	2.2	22.2	0.0	0.0	1.3	0.0	0.0	0.3	16.9	3.4	5.3	8.8	4.4	5.7
Plecoptera (%)	2.2	4.4	0.0	0.0	25.0	0.0	14.3	8.6	9.5	2.9	6.0	11.0	7.4	3.2
Trichoptera (%)	6.8	2.2	16.7	0.0	0.0	0.0	0.0	52.3	2.1	13.2	41.3	18.3	27.0	47.4

[a] Percent Diptera included Chironomidae.
[b] Chironomidae (midges) are in Order Diptera.

Table 3-17. Total number of taxa, mean density (organisms/sq m), diversity, evenness, and percentage composition of each major group collected in riffle areas during the fall benthic macroinvertebrate survey (September) in Gunnison County, Colorado

	RIFFLE													
Station	2	3	4	5	6	7	8	10	11	12	13	14	15	17
Total No. of Taxa	42	25	1	5	21	8	8	24	26	31	29	45	30	51
Mean Density (no/m^2)	2195	936	11	26	3943	237	102	1302	4885	4917	3610	3788	4212	6736
Diversity	3.64	3.44	0	1.16	1.39	1.65	1.91	2.73	2.55	2.54	3.00	3.94	3.13	3.36
Evenness	0.76	0.83	0.0	0.50	0.35	0.72	0.84	0.67	0.63	0.56	0.70	0.78	0.68	0.64
Coleoptera (%)	31.1	5.8	0.0	20.0	0.0	0.0	0.0	0.0	1.0	0.9	3.0	17.5	10.0	3.0
Diptera (%)[a]	16.2	29.3	0.0	40.0	19.5	13.6	31.6	16.1	60.0	8.1	37.6	25.1	8.6	11.1
Chironomidae (%)[b]	11.5	6.3	0.0	40.0	1.4	9.1	31.6	12.0	33.7	4.7	0.9	21.6	0.9	3.4
Ephemeroptera (%)	34.8	24.1	0.0	0.0	76.8	9.1	21.1	46.3	9.3	60.1	42.5	31.4	32.0	20.6
Hydracarina (%)	1.2	2.3	0.0	0.0	0.0	2.3	0.0	0.4	0.1	0.9	3.7	2.7	0.9	0.2
Oligochaeta (%)	1.0	17.2	100.0	0.0	0.1	0.0	0.0	0.0	1.8	17.5	1.6	0.4	0.1	0.4
Plecoptera (%)	9.3	5.8	0.0	0.0	2.7	0.0	5.3	6.6	26.8	3.7	1.6	9.0	5.1	7.4
Trichoptera (%)	5.2	15.5	0.0	40.0	0.8	75.0	42.1	29.8	0.4	7.3	7.9	13.2	43.3	57.4

[a] Percent Diptera includes Chironomidae.
[b] Chironomidae (midges) are in Order Diptera.

Creek and at Stations 7a on the Slate River below the Coal Creek confluence than at other stations in the study area (Tables 3-14 and 3-17). The depleted benthic macroinvertebrate communities at these stations were due to acid mine drainage in the Coal Creek watershed.

For the spring survey, the highest mean density (11,879 organisms/sq m) and number of taxa (34) of benthic macroinvertebrates were collected in the pool samples from Station 3 on upper Coal Creek (Table 3-14). A similar density (11,405 organisms/sq m) but fewer taxa (21) were collected in riffle samples at Station 3 (Table 3-14).

Data from the fall survey show that the highest mean density (6,736 organisms/sq m) and number of taxa (51) occurred in riffle samples at Station 17 on Tomichi Creek (Tables 3-16 and 3-17) (Surber samples were not collected on Tomichi Creek during the spring survey). Trichoptera (caddisflies) constituted over one-half of the organisms collected in pools and riffles at Station 17.

The other stations in the study area (Station 6 on the Slate River, Stations 10 and 12 on the East River, Stations 13 and 15 on Ohio Creek and Station 14 on Carbon Creek) had comparable densities, diversities and number of taxa. Oata indicate that the benthic macroinvertebrate community at these stations was stable, well balanced, and was apparently not adversely affected by mine drainage or other sources of water quality degradation such as nutrient inputs from domestic sources and livestock.

3.3.1.2 Comparison of Benthic Macroinvertebrate in Riffle and Pool Samples. Comparing percentage composition of major groups at each station showed that chironomids (midges) generally formed a greater portion of the benthic community in pool samples than in riffle samples (Figure 3-10).

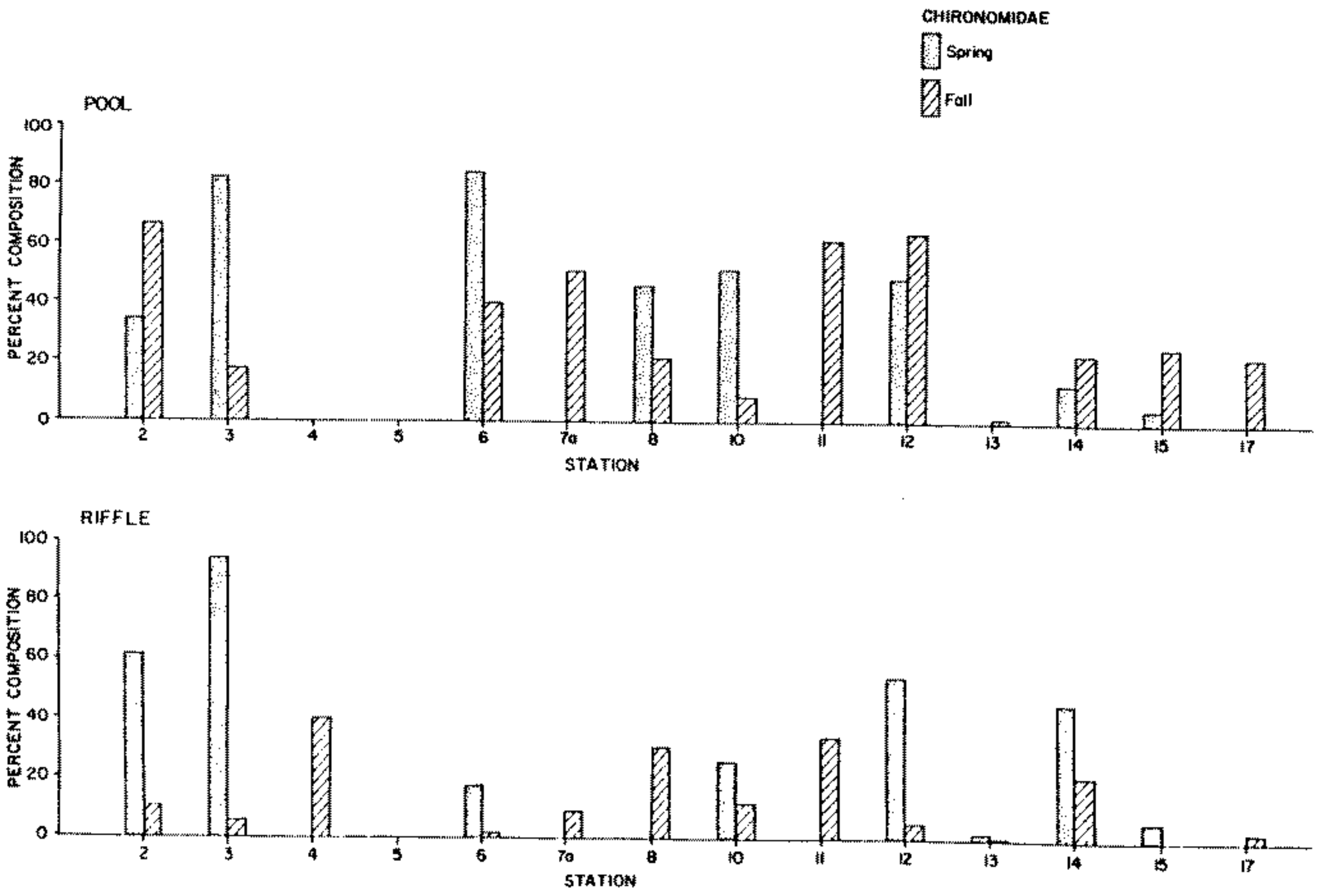

Figure 3-10 Percent composition of Chironomidae (midges) collected during the spring (March) and fall (September) surveys in pool and riffle samples.

Ephemeroptera were usually more abundant in riffles than in pools (Figure 3-11). Many of the individual mayfly taxa that were collected were rheophilic forms (characteristic of running water). No preference for pool or riffle habitats was evident for the other groups of organisms collected in the study area.

Generally, mean densities or organisms were higher for samples collected in the fall than in the spring. Notable exceptions to this pattern occurred, however, in pool and riffle samples from Station 3 and in pool samples from Station 6 where densities of organisms were much lower in the fall than in the spring. This is probably related to the life cycle pattern of chironomics (midges) that were the dominant organism collected at Station 3 during the spring survey. As spring approached, many larvae may have reached third or fourth instar stages and were large enough to be retained in the nets of the Surber samplers. During the fall survey, early instars of chironomids predominated. Many of these midges were too small to be retained in the nets of the samplers. Thus, the total density of organisms collected at Station 3 was higher in the spring than in the fall.

Trichoptera (caddisflies) wsere generally more abundant during the fall than the spring sampling in both riffle and pool samples (Figure 3-12). Exceptions to this general trend occurred at Station 13 in pool and riffle samples and in pool samples from Station 15. The presence of large numbers of Lepidostoma spp. and Brachycentrus spp. accounted for the higher densities of Trichoptera in the pool samples from Station 13 and 15 in the spring as compared to fall samples for 1979.

The mean density of the other groups of organisms (Plecoptera, Ephemeroptera, Coleoptera, Hydracarina, and Oligochaeta) were not consistently higher in either the spring or fall sampling periods.

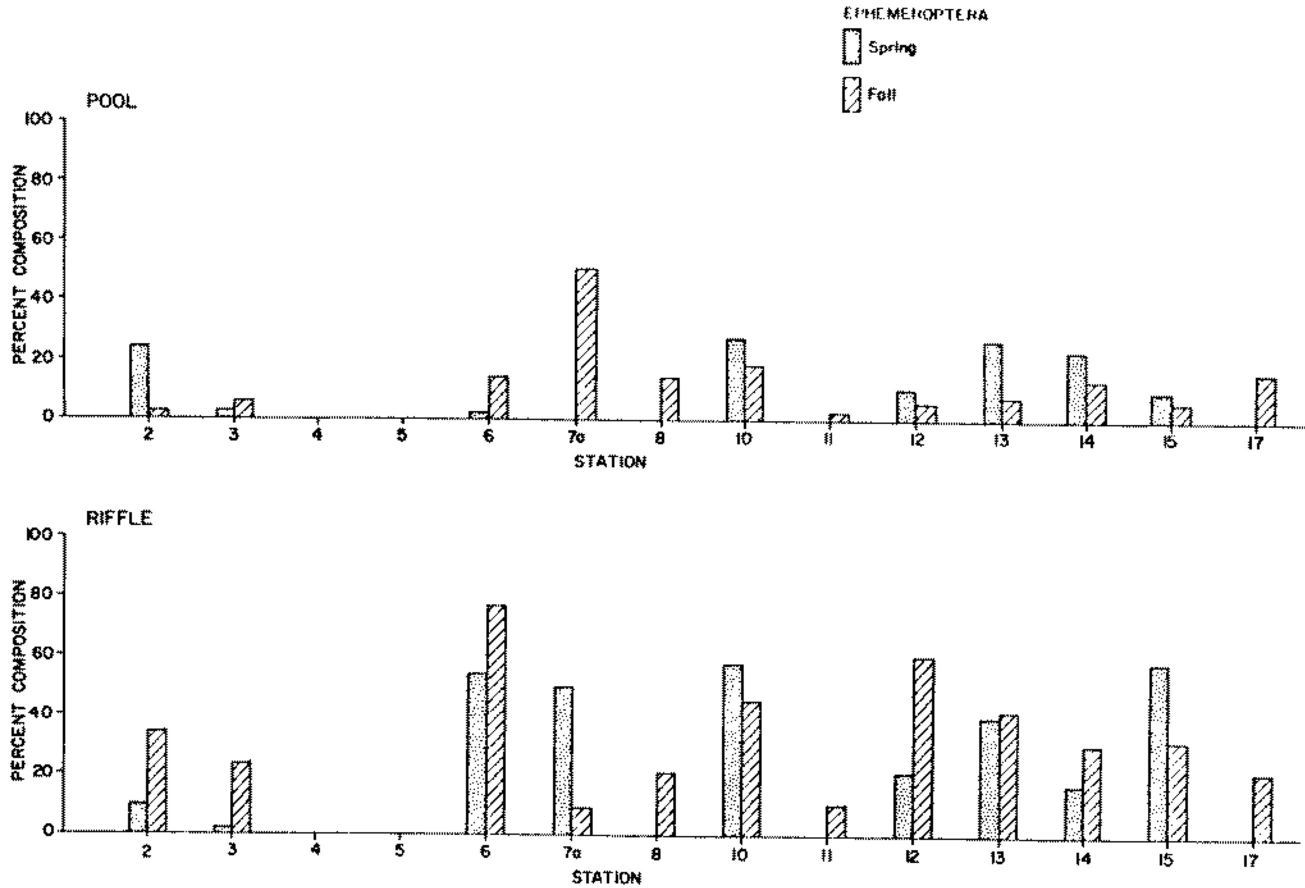

Figure 3-11 Percent composition of Ephemeroptera collected during the spring (March) and fall (September) survey in pool and riffle samples.

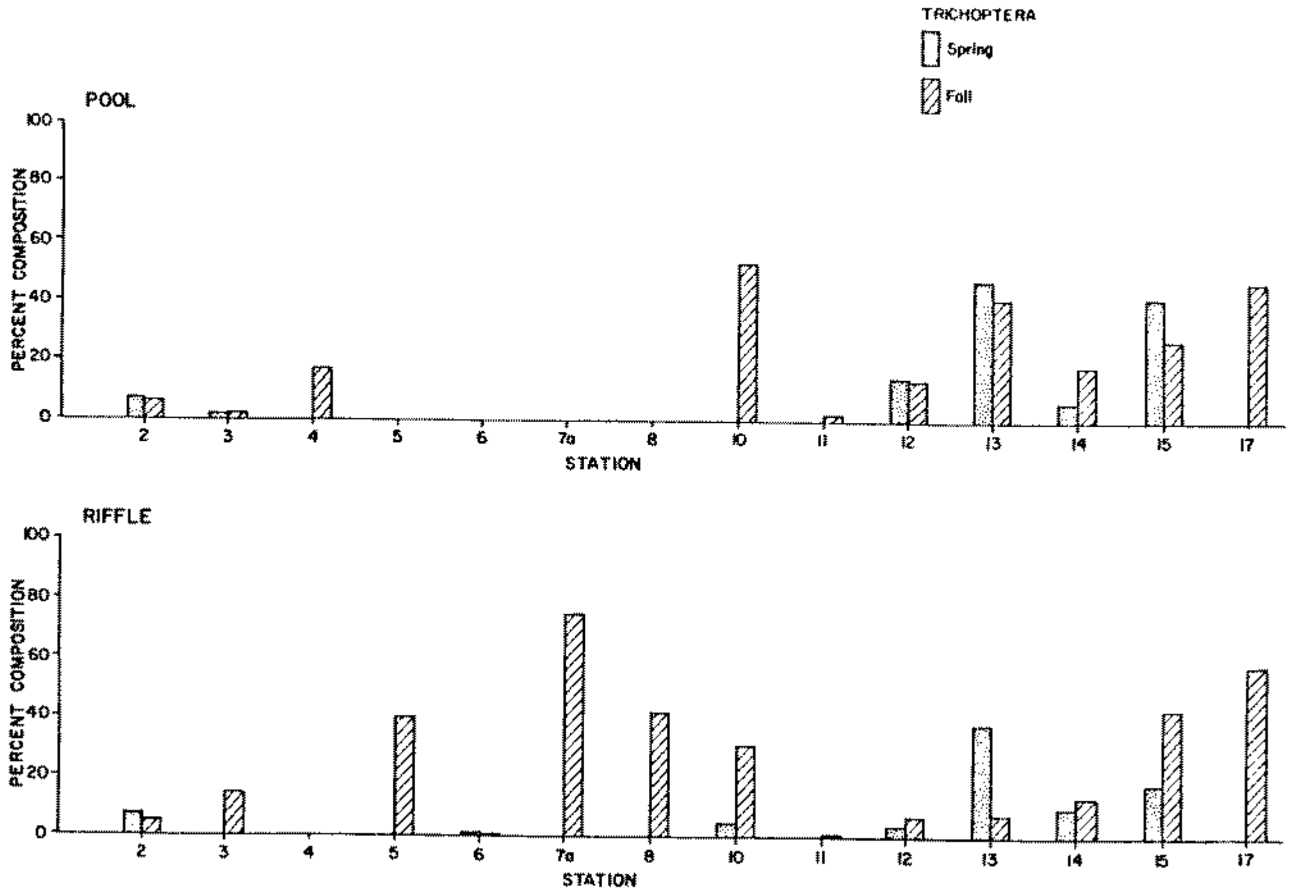

Figure 3-12 Percent composition of Trichoptera (coddisflies) collected during the spring (March) and fall (September) surveys in pool and riffle samples.

3.3.1.3 Drainage Area Information on Benthic Macroinvertebrates

Stations 2 and 3, Coal Creek

Stations 2 and 3 on Coal Creek above the Keystone mine discharge had relatively dense and diverse macroinvertebrate population during both sampling periods in 1979 (Tables 3-14 through 3-17). Mean densities were generally higher in riffle than in the pool areas.

Chironomids (midges) constituted nearly 95 percent of the organisms collected in riffle samples and over 82 percent of the organisms in samples from pool areas at Station 3 (Tables 3-14 through 3-17). Chironomids were also numerically dominant at Station 2 and formed 62 percent and 34 percent of the organisms collected in samples of pool and riffle habitats, respectively.

Ephemeroptera (mayflies), Chironomids (midges), Coleoptera (beetles) and Oligochaeta (aquatic worms) were the dominant orders in samples collected in the fall of 1979 at the two upper Coal Creek stations.

Stations 4 and 5 - Coal Creek

Statons 4 and 5 on lower Coal Creek downstream from the Keystone Mine discharge had an extremely depressed population of benthic invertebrates. Mean densities, diversity, evenness, and total number of taxa were substantially lower than at any other station in the study area. No organisms were collected in several of the pool and riffle samples. When organisms were collected, the mean densities were low and ranged from 15 to 32 organisms/sq m. The organisms that were found probably drifted into the area, they included Elmidae, Enchytracidae, Ceratopogonidae, and Simulium spp., all of which are reported to be intolerant of the type of conditions that exist at Staton 4 and 5 (U.S. EPA 1973).

Data in Warnick and Bell (1969) and Nehring (1976), indicate that the concentration of zinc, copper, and other metals in Coal Creek at Station 4 are sufficiently high to be toxic to benthic organisms.

In addition, benthic macroinvertebrates may be excluded from this section of stream if food sources are eliminated by metal toxicity.

As discussed in Section 3.2.2, attached algae, a major food source for many benthic macroinvertebrates, were found at extremely low densities at Station 4 and 5 on Coal Creek. Also, deposits of ferric hydroxides filled most of the interstitial spaces in the substrates and eliminated nearly all of the suitable habitat for benthic organisms. Morris (1974) found similar results in his study of lower Coial Creek in 1974. Koryak (1972) and Weed and Rutschky (1972) in studies of benthic invertebrate community of streams receiving acid mine drainage also found that benthic organisms were absent or existed in very low numbers directly below sources of acid mine drainage.

Station 6 - Slate River

Surber samples collected in pools and riffles at Station 6 on the Slate river immediately above the confluence with Coal Creek had much higher densities, total taxa, and greater diversity of benthic invertebrates as compared with lower Coal Creek (Tables 3-14 through 3-17). Ephemeroptera (mayflies) primarily Cinygmula spp. and Rithrogena spp. dominated riffle samples. Cinygmula spp. is one of the most common mayflies in the western mountain region. Both Cinygmula spp. and Rithrogena spp. prefer clean rocky bottomed streams with swift to moderate current (Edmunds 1976).

Chironomidae (midges) were numerically dominant in the pool samples during both the spring and fall sampling periods. Heterotrissoclodius spp. and Micropsectra spp., the two most abundant chironomids collected in pools at Station 6, both feed on detrital and other available non-living plant and animal matter (Merrit and Cummins 1978, U.S. EPA 1977). This type of food was readily available in the pool areas at Station 6 and probably accounted for the abundance of these two species.

Station 7a - Slate River

Station 7a, was located below the confluence of Coal Creek and the Slate River. Station 7a had lower mean densities, diversity, and total taxa of benthic macroinvertebrates as compared with that at Station 6 (Tables 3-14 through 3-17). Although the benthic invertebrate populations at Station 7a were not as severely depressed as at Stations 4 and 5 on Coal Creek, the effect of mine drainage and elevated metals concentrations on the benthic organisms was evident.

The caddisfly, Arctopsyche spp., was the most common organism collected in riffle samples during the fall, constituting 57 percent of the total assemblage. This caddisfly has been reported to be intolerant of degraded water quality conditions (Winget 1979). Water quality at Station 7a was degraded by the metal-laden flow entering the Slate River from Coal Creek. Zinc concentrations as high as 3.4 mg/l were reported near Station 7a in 1979 (Amax 1980b). Thus, it appears that Arctopsyche spp. was able to tolerate the high zinc concentrations which occur at Station 7a or was only a temporary resident of this portion of the stream.

Station 8 - Slate River

Station 8 was located on the Slate River below the Crested Butte waste water treatment plant. The benthic invertebrate population at Station 8 was, therefore, subjected to both nutrient enrichment from the treatment plant and high concentrations of metals from Coal Creek. Although the diversity values for the benthic macroinvertebrate community at Station 8 were generally higher than the values at Station 7a, the mean density of organisms remained very low (Tables 3-14 through 3-17).

Only two groups of organisms, Plecoptera and Diptera, were collected at Station 8 during the spring survey. The complete absence of other groups of benthic organisms, especially Ephemeroptera (mayflies) and Tricoptera (caddisflies), indicates a stressed environment.

Station 10 - East River

The benthic macroinvertebrate community at Station 10 showed no apparent effects from the metal-laden discharges or nutrient inputs in the upper portion of the watershed. The densities and diversities of macroinvertebrates indicated a balanced benthic community. Chironomidae (51.1 percent) dominated the pool samples collected during the spring of 1979. Ephemeroptera and Trichoptera constituted 27.7 and 21.3 percent of the benthic assemblage, respectively. The East River at Station 10 had limited pool habitats, although, deeper runs were present. The organisms obtained from the runs were both rheobiontic (characteristic of only running water) and rheophilic forms. Numerically dominant taxa collected in pool samples at Station 10 during the spring included the midges, Trissocladius spp., Orthocladius spp., and Miropsectra spp. Pool samples collected during the fall survey exhibited a change in composition. Trichoptera, primarily the genera, Brachycentrus spp., Lepidostoma spp., and

Oligophlebodes spp. were dominant. Riffle samples were dominated by Ephemeroptera, Diptera, and Trichoptera during the spring and fall surveys. The dominant taxa included Arctopsyche spp., Brochycentrus spp., Baetis spp, Rithrogens spp., Drthocladius spp, and Blephoriceridae spp.

Station 11 - Alkali Creek

Surber samples were not collected on Alkali Creek during the spring sampling period. During the fall, mean densities, number of taxa, diversity, and evenness were comparable to those at Stations 10 and 12 on the East River (Tables 3-16 and 3-17). The dominant taxa in riffle samples included members of the orders Plecoptera (Pteronarcella badia, Capniidae, and Chloroperlidae) and Diptera (Simulium spp., Eukiefferiella spp., and Diamesa spp.). Pool areas were dominated by Chironomidae and Dligochaeta, primarily Parametrocnemus spp., Diamesa spp., Enchytracidae, and immature oligochaetes.

Station 12 - East River

Station 12 was located on the East River below Alkali Creek. The composition of the invertebrate community at Station 12 during the spring and fall was very similar to that at Station 1D. Chironomidae and Ephemeroptera collectively constituted well over half of the organisms at each station. Oligochaetes (primarily Enchytraidae) also constituted between 15.8 and 17.5 percent of the riffle community for the spring and fall surveys, respectively. Station 12 had numerous 1-2 ft (D.3-D.6 m) deep pools that contained deposits of silt. Pool samples were dominated by Chironomidae during spring (47.7 percent) and fall (63.1 percent). Oligochaeta (primarily Enchytraeidae) formed 24.2 and 16.9D percent of the organisms in pool samples at Station 12 during the spring and fall, respectively.

Station 13 - Ohio Creek

Trichoptera and Ephemeroptera were the most common taxa collected in pool samples while Trichoptera, Ephemeroptera, and Diptera dominated riffle samples from Station 13 on Ohio Creek. The velocity of flow in the riffles at Station 13 was higher than at most other stations. Many of the organisms that were present including Simulium spp., Rithrogena spp, Oligoplebodes spp., and Brachycentrus spp. are considered clingers or anchorers which attach very securely to the substrate to maintain their position in fast currents (Merrit and Cummins 1978).

Station 14 - Carbon Creek

Riffle samples collected at Station 14 had higher diversity values than riffle samples from other stations in the study area during the spring and fall surveys. Although densities of macroinvertebrates were lower in the spring than at all other stations, except those affected by mine drainage (Station 4, 5, 7a, and 8), the high diversity and taxonomic composition indicated a well balanced, stable community. Coleoptera, primarily Elmidae (riffle beetles), Ephmeroptera, Diptera, and Trichoptera were found in nearly equal portions of the riffle and pool communities during both the spring and fall.

Station 15a - Ohio Creek

The taxonomic composition of benthic macroinvertebrates collected at Station 15a during the spring of 1979 was similar to that at Station 13 on Ohio Creek, but the density of organisms at Station 15a was higher (Tables 3-14 and 3-15). Total densities, diversity, and number of taxa at Station 15a increased in pool and riffle samples from spring to fall.

Station 17 - Tomichi Creek

As previously discussed, nutrient levels were higher at Station 17 than at other stations except Station 8 below the Crested Butte waste water treatment plant (AMAX 1980). Nutrient enrichment did not appear, howver, to adversely affect the benthic macroinvertebrate community at Station 17. The highest number of taxa (51) for any station in the study area was collected at Station 17 in the fall of 1979. Mean densities and diversity of organisms were also high (Tables 3-16 and 3-17).

The dominant groups in riffles and pools at Tomichi Creek included Trichoptera (47.4-57.4 percent), Ephemeroptera (16.0-20.6 percent) and Diptera (11.1-24.0 percent).

Many of the individual taxa collected were indicative of the type of habitat available at Tomichi Creek. Ephemerella, one of the dominant genera of mayflies collected at Station 17 is often associated with and found in submerged vegetation in slow flowing streams (Edmunds et al. 1978). Several caddisflies also associated with slow moving warmer waters include Cheumatopsyche spp. and Heliopsyche spp. (Wiggins 1978) were also present. Because Tomichi Creek had different aquatic habitat than other stations in the study area and was located in a different drainage basin, several organisms were found at Station 17 that were not found at other stations. They included the worms, Pristina aeqiseta, P. Foreli Na spp., N. simplex, N. behningi, and N. butscheri and the caddisflies Cheumatopsyche spp., Hydroptila spp., Neotrichia spp., Psychomyia spp., and Heliopsyche spp.

3.3.1.4 Comparison of Benthic Macroinvertebrate Data for 1978 and 1979. A comparison of data from benthic macroinvertebrate surveys conducted in 1978 and 1979 show similar spatial distributions for benthic macroinvertebrate density and composition for the two years (Table 3-18).

The benthic macroinvertebrate community at Station 2 and 3 on Coal Creek was relatively diverse and well balanced for both years.

Similar effects of the discharge from the Keystone Mine on the benthic macroinvertebrate community were seen at the lower Coal Creek and Slate River stations. Stations 4 and 5 on lower Coal Creek were nearly devoid of benthic organisms and Stations 7, 7a, and 8 had reduced numbers and diversities of organisms in both 1978 and 1979. The remaining stations were relatively unaffected by these two point sources of pollution and had similar compositions and density of taxa in 1978 and 1979. Diptera, Chironomidae, Coleoptera, Ephemeroptera, Plecoptera, Trichoptera, and Oligochaeta were the dominant groups. These groups were represented by 153 taxa in 1979, as compared to 128 in 1978. Riffle samples generally contained higher mean densities and more taxa than pool samples during both years. This trend is similar to that reported by Minshall and Minshall (1977). There was no generalized trend in the diversity values for the two years of study.

The composition of riffle samples in 1979 generally showed Ephemeroptera to be the dominant order with Dipterans, primarily Chironomidae, to be the most abundant group of organisms in riffle samples at most stations.

Pool samples collected during 1978 and 1979 showed Chironomidae to be the dominant group at a majority of stations during both sampling periods.

Other studies of benthic organisms in the vicinity of the study area have been conducted by the Colorado Department of Health (1975), Wiltzius (1978), Herricks (unpublished data), Allan (1978a, 1978b), and Morris (1974).

Table 3-18 Comparison of number of taxa, mean density, and diversity of benthic macroinvertebrates collected in riffle samples during the fall of 1978 and 1979

Station	Location	No. of Taxa 1978	No. of Taxa 1979	Mean density (organisms/sq m) 1978	Mean density (organisms/sq m) 1979	Diversity[a] 1978	Diversity[a] 1979
2	Upper Coal Creek	35	42	2,196	2,195	3.66	3.64
3	Upper Coal Creek	18	25	377	936	3.24	3.44
4	Lower Coal Creek	0	1	0	11	0	0
5	Lower Coal Creek	2	5	11	26	0	1.16
6	Upper Slate River	22	21	969	3,943	2.50	1.39
7	Lower Slate River	6	8	65	237	1.44	1.65
8	Lower Slate River	12	8	527	102	2.55	1.91
10	East River	19	24	1,604	1,302	2.18	2.74
11	Alkali Creek	10	26	366	4,885	1.87	2.55
12	East River	18	31	1,830	4,917	2.16	2.54
13	Upper Ohio Creek	20	29	1,044	2,610	3.23	3.00
14	Carbon Creek	22	45	3,143	3,788	2.00	3.94
15	Lower Ohio Creek	10	30	269	4,212	2.21	3.13
17	Tomichi Creek	-	51	-	6,726		3.36

Station locations, objectives, and sampling methods differed for these studies and thus direct comparison of data is not possible. General trends, however, did indicate that Diptera and Ephemeroptera were the dominant groups in the upper Gunnison River drainage.

3.3.2 Macroinvertebrate Drift

AMAX Inc. is presently constructing an advanced water treatment facility to treat the metal-laden discharge from the Keystone Mine. It is anticipated that water quality will improve in lower Coal Creek to the point that this segment of the creek will once again support aquatic biota.

Sampling of macroinvertebrates was conducted on Coal Creek and the Slate River to determine the supply of organisms available to recolonize lower Coal Creek and the Slate River below the Coal Creek confluence after the treatment facility begins operating.

Benthic fauna are subject to downstream movement or drift. This movement can have a significant influence on the benthic community. Existing populations can be enriched and areas with few benthic invertebrates can be replenished by these drifting organisms. Townsend and Hildrew (1976) reported that 82 percent of the recolonization of substrates in a small stream was by drift. Several factors (water depth, current, temperature, light, life cycle, and organism behavior) can influence the quantity as well as the composition of stream drift (Hynes 1970).

Sampling of drifting macroinvertebrates was conducted near Station 3 on Coal Creek and at Station 6 on the Slate River in the spring (April), midsummer (August), and fall (October) of 1979. Sampling during these periods was conducted four times a day at approximately 6 hr intervals to determine the diurnal variation in drift densities and to obtain daily estimates of drift density.

The densities and percentage composition of each drifting macroinvertebrate taxon identified is listed in Appendix B. A summary of these data including total number of taxa, mean density (organisms/100 cu m), diversity, evenness, and percent composition of major groups is shown in Table 3-19. Results of the drift sampling showed that 68 taxa were collected (Table 3-13).

Lehmkuhi and Anderson (1972) found that increased water depths and strong currents caused by flooding, resulted in increased numbers of drift organisms. They also found that the major effect of the drift was downstream dispersal of the populations. Periods of low flow generally produced low drift densities (Hynes 1970). Comparison of drift density for the April, August, and October surveys indicated that the number of organisms per 100 cubic meters was lower in April, a high flow period, than in August and October, when flows were much lower. Nevertheless, the number of organisms collected per unit time was much higher in April than in August or October because the volume of flow sampled per unit time was much higher in April than for the other two sampling periods.

Another factor that can affect drift densities is light. Diurnal variations in drift are found at all times of the year. A general pattern of peak densities of drifting organisms usually occurs a short time after sunset (Hynes 1970). This trend was evident in the study, the highest density of drifting organisms was usually encountered immediately after dusk and the lowest density was found in midday samples.

Mayflies (Ephemeroptera) were the most abundant order and constituted 37.3 percent of the total number of organisms collected in the drift samples. Chironomids (midges) totaled 21.4 percent; stoneflies (Plecoptera), 16.2 percent; and other Diptera (not including

Table 3-19 Mean density (organisms/100 cu m), percent composition, number of taxa, diversity and evenness for drifting macroinvertebrates collected at Station 3 on Coal Creek and at Station 6 on the Slate River in April, August, and October, 1979

	Station 3			Station 6		
	April	August	October	April	August	October
Total No. of Taxa	36	43	34	20	32	21
Mean Density (organisms/100cu m)[a]	45	113	145	11	103	65
Diversity (Lloyd et al 1968)	3.40	3.09	2.40	2.13	3.01	1.89
Evenness (Pielow 1966)	0.91	0.78	0.80	0.69	0.16	0.80
Percent Pleoptera	27.9	5.2	34.1	29.1	4.2	3.9
Number of Taxa	5	5	5	3	2	3
Percent Ephemeroptera	16.3	40.3	19.3	35.9	47.3	72.6
Number of Taxa	5	7	3	4	7	6
Percent Diptera[b]	10.4	21.9	5.8	6.8	5.1	0.8
Number of Taxa[b]	5	5	4	1	2	1
Percent Chironomidae	38.1	20.9	20.6	16.5	23.6	9.2
Number of Taxa	15	10	11	7	12	4
Percent Coleoptera	1.1	6.0	6.7	1.9	1.2	0.8
Number of Taxa	1	5	2	1	1	1
Percent of Hydracarina	1.1	2.8	5.8	2.9	10.3	4.5
Number of Taxa	1	1	1	1	1	1

[a] Densities (per 100 m^3) are means of 8 replicates collected during a 24 hr. period.

[b] Percentage composition and number of taxa of all Diptera taxa except Chironomidae.

Chironomidae) made up 10 percent of the total. Beetles (Coleoptera) and water mites (Hydracarina) composed 4.0 and 5.4 percent, respectively (Table 3-19).

Mean densities (organisms/100 cu m), total number of taxa, and diversity values for drifting invertebrates were higher at Station 3 than at Station 6 during all sampling periods.

Studies have been conducted to determine if correlations exist between the density and taxonomic composition of organisms in benthic samples and drift samples. Cowell and Carew (1976) reported that density influenced the drift rate of certain species but no correlation existed between the density of other taxa in the substrate and drift rate of that taxa.

A comparison of the percentage composition and density of taxa in Surber samples and drift samples at Stations 3 and 6 are shown in Tables 3-20 and 3-21, respectively, These data show that no pattern was evident for the percentage composition and density of taxa in drift and Surber samples at the two stations. Similar results have been reported by Hynes (1970).

This is due, in part, to differences in behavioral patterns of aquatic nymphs and larvae. Organisms such as baetid mayflies swim in short bursts from rock to rock and are often swept downstream by the current. Other organisms such as some caddisflies are "clingers" and attach themselves to the substrate by using hooks or by building fixed retreats (Merritt and Cummins 1978). Baetid and other mayflies with similar behavioral patterns often make up a large proportion of drift samples, but caddisflies and other attached or burrowing organisms are usually not as common in drift samples.

Also, the organisms collected in the drift samples may have drifted a considerable distance downstream from their former residence. The

Table 3-20 Comparison of the percentage composition and mean density of benthic invertebrates collected in drift and Surber samples at Station 3 on Coal Creek, spring and fall, 1979

	Station 3					
	Spring			Fall		
	DRIFT	SURBER		DRIFT	SURBER	
		Riffle	Pool		Riffle	Pool
Percent Plecoptera	27.9	1.7	7.1	34.1	5.8	4.4
Number of Taxa	5	4	8	5	4	5
Percent Ephemeroptera	16.3	1.9	3.1	19.3	24.1	6.1
Number of Taxa	5	5	7	3	5	3
Percent other Diptera[a]	10.4	0.8	1.3	5.8	23.0	8.1
Number of Taxa	5	1	3	4	2	3
Percent Chironomidae	38.1	94.2	82.4	20.6	6.3	18.3
Number of Taxa	15	8	9	11	7	6
Percent Coleoptera	1.1	0.8	2.7	6.7	5.8	37.4
Number of Taxa	1	1	1	2	2	3
Percent Hydracarina	1.1	0	0.2	5.8	2.3	1.3
Number of Taxa	1	0	1	1	1	1
Mean density[b]	45	11405	11879	145	936	1237

[a]Percentage composition and number of taxa of all Diptera taxa except Chironomidae.

[b] Mean density of organisms in drift samples and Surber samples expressed as organisms/100 cu m, and organisms/sq m, respectively.

Table 3-21 Comparison of the percentage composition and mean density of benthic invertebrates collected in drift and Surber samples at Station 6 on the Slate River, spring and fall, 1979

	Station 6					
	Spring			Fall		
	DRIFT	SURBER		DRIFT	SURBER	
		Riffle	Pool		Riffle	Pool
Percent Plecoptera	34.1	23.1	7.0	3.9	2.7	0.0
Number of Taxa	5	3	2	3	3	0
Percent Ephemeroptera	19.3	58.5	2.5	72.6	76.8	9.1
Number of Taxa	3	4	2	6	5	1
Percent other Diptera[a]	5.8	0.0	6.6	0.8	18.1	16.0
Number of Taxa	4	0	1	1	4	4
Percent Chironomidae	20.6	16.9	83.9	9.2	1.4	39.1
Number of Taxa	11	2	8	4	3	6
Percent Coleoptera	6.7	0.0	0.0	0.8	0.0	0.0
Number of Taxa	2	0	0	1	0	0
Percent Hydracarina	5.8	0.0	0.0	45	0.0	3.21
Number of Taxa	1	0	0	1	0	1
Mean density[b]	11	350	2604	65	3943	839

[a] Percentage composition and number of taxa of all Diptera taxa except Chironomidae.

[b] Mean density of organism in drift samples and Surber samples expressed as organisms/100cu m and no/sq m, respectively.

habitat of the stream may have been considerably different upstream when compared with that of the sampling location. Thus, it is not surprising that the composition of drift samples collected at a station is often quite different from that in benthos (Surber) samples collected at the same location.

As previously stated, one of the primary purposes for sampling drifting invertebrates was to determine if the composition and density of drifting organisms were adequate to reestablish populations of benthic invertebrates that are necessary for supporting a trout population in lower Coal Creek.

Herricks (1973) reports that the organisms most common in drift samples were the dominant organisms of the bottom fauna following recovery. Studies by Waters (1962) and others indicate that recolonizing of a section of stream can occur rapidly (e.g., within 1-3 mo) following removal or reduction of the stress.

Based on the composition and density of drifting organisms collected in 1979, it appears that Coal Creek below Station 3 and the Slate River downstream of Station 6 would be recolonized by benthic invertebrates if water quality conditions improve and the ferric hydroxide deposits in the substrates are removed. Ephemeroptera and Chironomidae will probably be the dominant groups of organisms in both locations following recovery.

3.3.3 Microhabitat Evaluation

The spatial distribution of aquatic invertebrates in semiarid regions has been studied by Minshall and Minshall (1977), Williams (1978), Rabeni and Minshall (1977), Lehmkuhi and Anderson (1972), Allan (1975a, 1975b), and Peckarsky (1979). In these studies, the response of benthic invertebrates to physical factors such as current velocity, water depth, substratum, particle size, detrital inputs, and light were evaluated. Rabeni and Minshall (1977) found that response to these factors differs considerably among species and even among life stages of the same species. Anatomical adaptions, i.e., flattening of the body, suckers, friction pads, hooks, and ballast also are factors which affect dispersal of benthic invertebrates (Hynes 197D).

The microhabitat study was designed to determine the occurrence and distribution of organisms in different habitat types (i.e., top versus bottom of rocks, algal mats versus bare rock, fast currents versus slow currents, etc.) The study was also designed to sample microhabitats that were generally not included in either the drift or Surber sampling, such as branches, logs, and submerged vegetation.

The general information obtained from this microhabitat evaluation will be used to determine if taxa exhibit a consistent preference for or absence from a particular microhabitat. This information will aid in designing future sampling programs for the Mount Emmons Project.

A summary of the taxa collected during the spring and fall sampling periods and brief descriptions of habitat type are listed in Appendix B. Table 3-12 lists the taxa collected during benthic invertebrate (Surber), drift, and microhabitat studies. Seventy-five taxa were collected during the spring and fall microhabitat surveys. A total of five taxa of benthic invertebrates were collected in the microhabit survey that had not previously been collected in Surber or drift samples. These taxa included three Coleoptera (beetle) taxa (*Agabus* spp., *Larsia* spp., and Noteridae) one Hemiptera - Corixidae, and one Dipteran larvae (*Rheocricotopus* spp.). The beetle taxa were primarily collected from detritus covered branches and other submerged vegetation; the Hemipteran taxon was collected at the surface of a pool, and the Dipteran taxon was collected on the side of a large rock.

The following is a discussion of the microhabitats of the most common taxa of benthic invertebrates collected in the microhabitat survey during 1979.

Baetis spp. (mayfly), the most common organism collected, exhibited a wide range of microhabitats. Microhabitats varied from the tops and bottoms of rocks located in torrential currents to silt deposits in slow moving pools. Similar varieties of habitat have been reported for baetid mayfly species (Edmunds et al. 1978).

The mayfly, Rithrogena spp., exhibited a preference for riffle habitats, and was found on both the upper and lower surface of rocks. This nymph has an anatomical adaption for living in riffle habitats. The body is extremely compressed and the abdominal gills form a disc which help the organism adhere to the rocks (Hynes 1970).

The mayflies, Ephemerella (Drunnella) spp., and E. (Serratella) spp., prefer different habitats. Ephemerella (Drunella) was found primarily in riffle areas on varying sized rocks; however, Ephemerella (Serratella) occurred only in silt or moss covered substrates in pools. Edmunds et al. (1978) described the habitat preferences of nymphs of the genus Ephemerella as variable, ranging from slow moving stagnant streams to swift streams with rapids. He further stated that certain forms of this genus often live on mats of moss.

Caddisflies also occupied a variety of microhabitats within pools and riffles. Rhyacophila spp. was collected only from riffle habitats, however, this genus occupied a variety of microhabitats within the riffle and was collected on the bottoms and tops of rocks and on submerged sticks. Wiggins (1978) found that although Rhyacophila (a free living predator) prefers lotic habitats, its distribution is usually dependent upon the presence or absence of prey organisms.

Arctopsyche spp., another of the more frequently encountered specimens, was found only in riffle areas, and was generally exposed to strong currents on the upper surface of larger rocks. This microhabitat selection is consistent with the larval habitat described by Wiggins (1978).

The caddisfly larva, Brachycentrus spp., was also a common inhabitant of riffle or faster flowing sections of streams throughout the study area. Brachycentrus spp. was found in several microhabitats on rocks and submerged branches.

Although not abundant in microhabitat samples, the stoneflies that were collected exhibited a variety of habitat preferences. The family Nemouridae, which includes the genera listed in Table 3-12 are often the dominant primary consumers in river ecosystems and act as shredders of heterotrophic material that enter the ecosystem (Bauman et al. 1977). Their micro-distribution within this study area was probably affected by the availability of food. In most instances, the members of the family Nemouridae were collected in riffle areas where plant materials and other detritus had accumulated.

The dipterans, Blephariceridae and Simulium spp., were very common in the study area and were collected in similar habitats. Both Simulium spp. (blackfly) and Blephariceridae were attached to surfaces of rocks in extremely swift current. Blackfly larvae feed on plankton and organic debris which they filter from the water via fan-like appendages (Pennak 1978).

Members of the family Chironomidae were abundant. The two most common genera were Orthocladius spp. and Eukiefferiella spp. Merritt and Cummins (197B) describe the general habitat type for both organisms as lotic erosional (i.e. riffles). In this study, most specimens of Eukiefferiella spp. and Orthocladius spp. were collected in riffle type areas. These organisms occupied a variety of microhabitats within the riffle areas and were collected on both the top and bottom surfaces of rocks, within algal or moss matts, and in silt deposits.

Although Eukiefferiella spp. and Orthocladius spp. showed no preference for a particular microhabitat, another chironomid, Chironomus spp., exhibited a marked preference. Chironomus spp. was collected immediately downstream from the Crested Butte waste water treament plant outfall in both the spring and fall microhabitat surveys. The U.S. EPA (1973 and 1977) consider Chironomus spp. to be very tolerant of organic enrichment indicates that this genera prefers any habitat where nutrient concentrations are high.

Interactions between physical factors, species preference, and anatomical adaptions all have some effect on the micro-distribution of aquatic macronvertebrates. The microhabitat preference of organisms discussed in this section generally agreed with the microhabitat descriptions in the literature. Observations also showed that the riffle areas generally supported a more diverse population than did pools. This is similar to the finding of Egglishaw (1967), Lehmkuhi and Anderson (1972), Rabeni and Minshall (1977) and others. The observations made during microhabitat studies indicate that future quantitative sampling efforts should be concentrated on riffle areas to obtain both maximum densities and composition of benthic invertebrates taxa.

3.4 Fisheries

Table 3-22 presents the total number of fish collected for the April and September 1979 surveys. Appendix C presents a summary of the physical water quality data and the fish catch data at each station during each sampling period. Length-frequency distributions for the numerically dominant species of fish collected in the fall of 1979 are also included in Appendix C.

3.4.1 Overview of 1979 Electrofishing Surveys

Fish were collected at all stations surveyed except Station 11 on Alkali Creek. Seven species of fish were collected in the study area.

Table 3-22 Number and species of fish collected during April, September, and October 1979 at aquatic ecology stations in the Mount Emmons Project study area

Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker	Longnose Sucker	Longnose Dace	Fathead Minnow
April 1979							
6	-	4	2	-	-	-	-
8a	9	1	-	1	-	-	-
8b	23	14	-	-	-	-	-
10	-	19	-	-	-	-	-
12	-	14	-	-	-	-	-
13	5	-	2	-	-	3	-
14	49	1	6	-	-	-	-
15	7	1	1	-	-	5	-
September and October 1979							
2	98	-	-	-	-	-	-
3	56	-	-	-	-	-	-
6	88	48	1	12	-	-	-
7a	21	-	-	15	-	-	-
8	148	4	-	170	-	-	-
8a	32	9	-	75	-	-	-
8b	23	28	1	-	-	-	-
10	-	66	1	-	-	-	-
12	-	51	-	-	-	-	-
13	29	5	10	-	-	-	-
14	210	-	-	-	-	-	-
15	12	2	1	-	6	42	-
17	1	21	-	67	30	175	7

Brook trout (Salvelinus fontinalis) was the most common species in the study area (Photo 8). It was collected at five of the eight stations in April and at 11 of the 13 stations in September and October (Table 3-22). Brook trout dominated the catch in the smaller tributary streams such as Carbon Creek and in the upstream areas of Ohio Creek. It was the only species collected from Coal Creek. Brook trout generally prefer a clear, cold water stream with a gravelly bottom and adequate pools and riffles (Beckman 1970). These trout have a tendency to migrate upstream and, thus, are often concentrated in the headwaters of drainages (Baxter and Simon 1970). The low productivity of headwater regions and intense competition for food due to overpopulation causes most brook trout in headwater regions to be slow growing. This was the case in the headwater areas in the study area (Station 2, 3, 13, and 14) where less than 10 percent of the brook trout exceeded 8 in. (200 mm) in length.

The presence of brook trout at other stations in the study area such as Stations 7a and 8 on the Slate River may be due, in part, to the greater tolerance of brook trout to metals pollution as compared to other trout species (Holcombe and Andrew 1978, Benoit et al. 1976; Holcombe and Benoit 1978).

Brown trout (Salmo trutta) was the second most abundant species captured. This fish was collected at seven of the eight sampling stations in April and at nine of thirteen sampling stations in the fall of 1979 (Table 3-22). Brown trout were more common at the downstream stations within the study area and was the only species of fish collected on the East River in the spring survey.

Brown trout are commonly found in slower flowing portions of the stream, especially in shaded pool areas that have abundant cover such as overhanging vegetation, rocks, or undercut banks. This type of habitat was abundant at Station 17 on Tomichi Creek and at Station 10

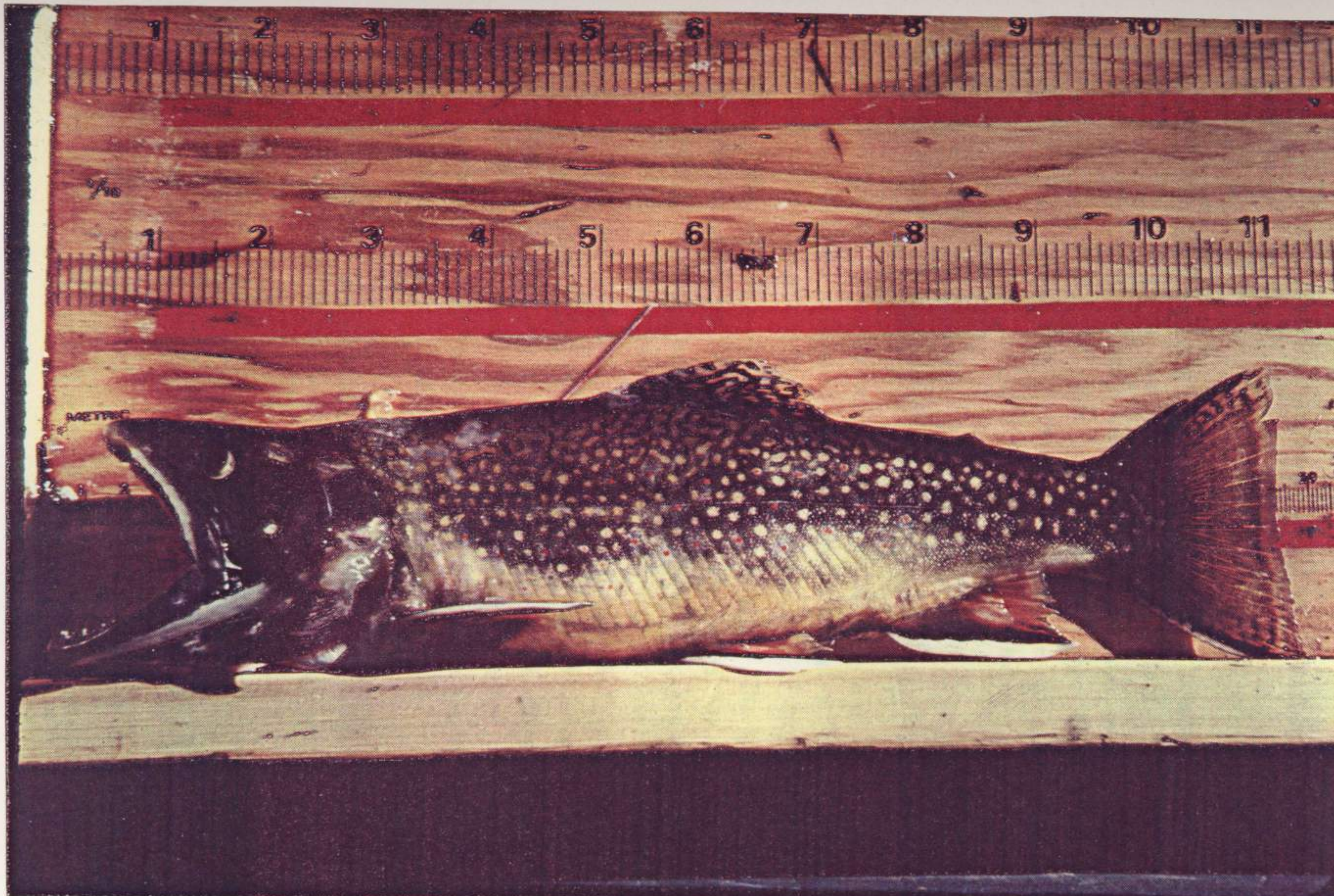

Photo 8. One of the larger male brook trout (Salvelinus fontinalis) collected in the study area. Note size of head in relation to body.

on the East River, two stations where brown trout dominated the trout population.

Rainbow trout (Salmo gairdneri) was the third most common trout species collected in the study area. Although collected at four of eight stations in April and five of thirteen stations in September, the number of fish in this species was less than that for either brook or brown trout (Table 3-22). This was the case in spite of the fact that rainbow trout was the only species that was extensively stocked in the study area.

The relatively low number of rainbow trout in the study area is probably due to the fact that most of the stocked fish are caught by fishermen. Stocked rainbow trout are considered easier to catch than all other trout except brook trout (Sigler and Miller 1963). Most rainbow trout are stocked on a put-and-take basis. The spawning success of hatchery-reared rainbow trout in the wild is low (Sigler and Miller 1963). The only evidence of natural reproduction of rainbow trout observed in the study area during 1979 was at Station 15, where a single juvenile rainbow trout measuring 67.5 mm (2.7 in.) in length was collected. Colorado Division of Wildlife stocking records for 1978 (CDOW 1979b) and the stocking schedule for 1979 (CDOW 1979c) indicate that only catchable size rainbow trout (greater than 6 in. or 150 mm) were stocked in Ohio Creek. Thus, this juvenile rainbow trout probably was the result of natural reproduction.

No cutthroat trout (Salmo clarkii) were collected in the study area in 1979. A trout that appeared to be a rainbow-cutthroat cross was collected, however, at Station 13 on Ohio Creek during the fall of 1979. Rainbow-cutthroat crosses are fairly common in Colorado.

Four species of nongame fish were collected in the study area. The most common was the white sucker (Catostomus commersoni). White suckers were present in the Slate River and Tomichi Creek in the fall, but were absent from all stations except Ba during the spring of 1979 (Table 3-22). White suckers tend to avoid rapid current (Baxter and Simon 1970). Thus, during the spring, these fish may have concentrated in backwater areas and in deep pools that were not sampled.

Historically, the white sucker was native only to the east slope drainages of Colorado and was probably introduced to the upper Colorado River drainage in the 1920's (Wiltzius 1978).

Longnose suckers (Catostomus catostomus) were captured at the lower Ohio Creek sampling station in September and at Station 17 on Tomichi Creek in October 1979 (Photo 9). None were collected, however, during the spring survey. It is possible that the longnose suckers also concentrated in deep, slow-flowing pools during the spring, and thus, were not available for sampling.

Like the white sucker, the longnose sucker was originally native to eastern slope drainages such as the Arkansas and Platte River basins, but the longnose is now established in many of the streams and impoundments of the upper Colorado River basin (Everhart and Seaman 1971).

Longnose dace (Rhinchthys cataracte) were collected at Station 13 and 15 in the spring and at Station 15 and 17 in the fall. Longnose dace was the most prevalent species collected at Station 17. This species is a bottom dweller and generally occupies riffle areas of streams (Baxter and Simon 1970). These minnows are usually 3-4 in. (80 to 100 mm) long at maturity and are an important forage fish for trout (Baxter and Simon 1970).

Fathead minnows (Pimephales promelas) were collected at Station 17 on Tomichi Creek. This small minnow is native to the east slope of

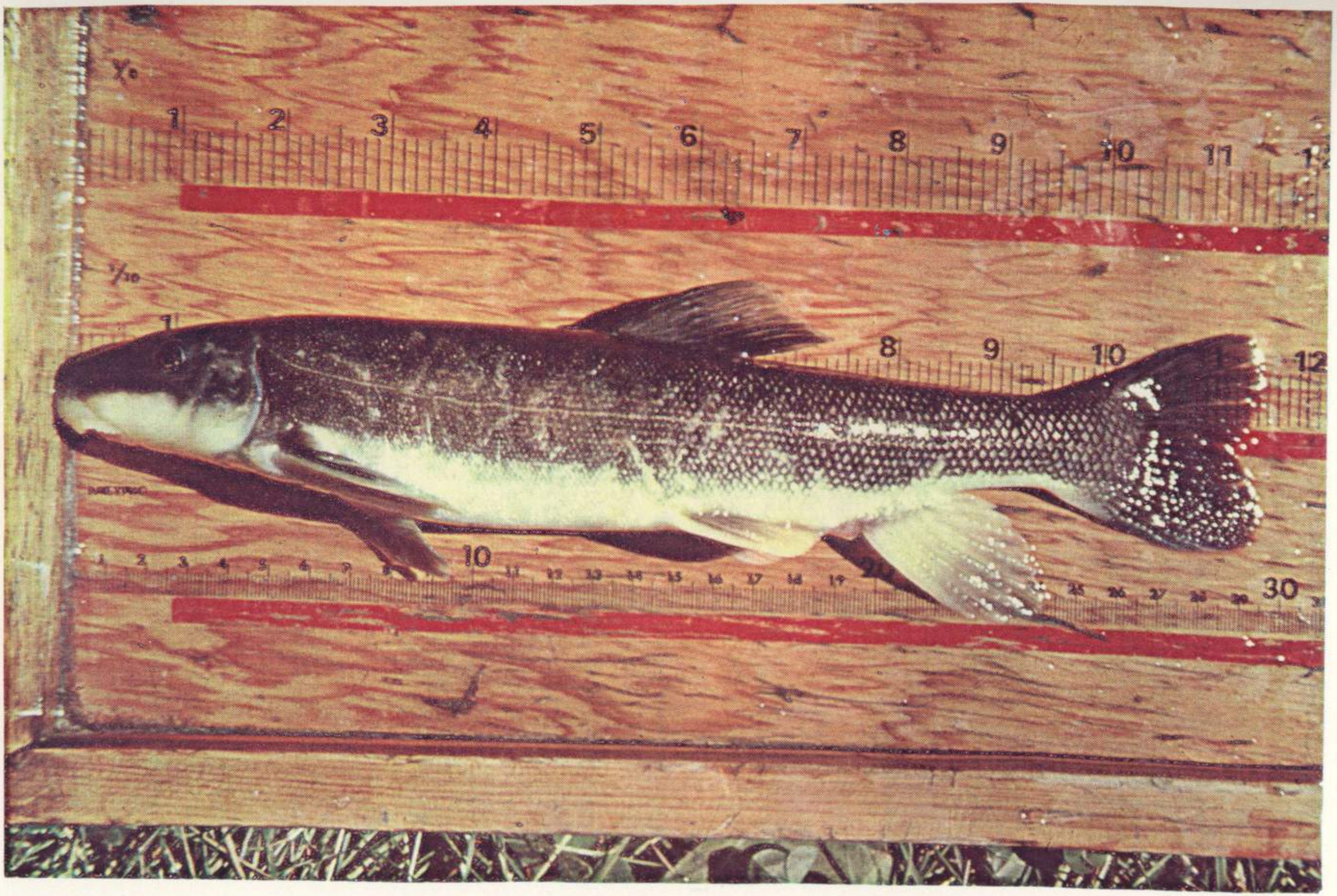

Photo 9. Longnose sucker collected from Ohio Creek.

Colorado, but has been widely introduced into the western part of the state (Everhart and Seaman 1971). Fathead minnows typically occupy deep, slow flowing pools which contain abundant vegetation (Everhart and Seaman 1971). This type of habitat was present at Station 17.

3.4.2 Orainage Area Information on Fisheries

Estimates of fish populations were calculated during the Fall 1979 survey were based on Petersen's mark-recapture method (Everhart et al. 1975) as described in Section 2.3. These data are presented in Tables 3-23 and 3-24.

Comparisons of fishery data for the first two years of the study are confined to data collected during the fall of 1978 and 1979. As previously stated, fish sampling during the spring was mainly qualitative and, thus, comparison of numbers of fish collected during the first two years of the study would not be meaningful. Lower flows during the fall permitted more quantitative sampling of fish. A comparison of numbers and species of fish collected during the fall of 1978 and 1979 are shown in Table 3-25. The average lengths, weights, and condition factors of these fish collected during 1979 are shown in Table 3-26 through 3-31.

Station 2 - Coal Creek

Electrofishing surveys were not conducted at Station 2 in April 1979 because of ice cover on Coal Creek (Photo 10).

During the fall survey, a total of 98 brook trout were collected. Most of the brook trout collected at Station 2a in the fall of 1979 were between 4 and 7 in. (100 and 180 mm) in length. Less than two percent of the fish collected in 1979 at Station 2a exceeded 8 in. (200 m) in length.

Oata from 1978 (AMAX 1979) indicated a somewhat higher estimated number and biomass of brook trout at Station 2 than at Station 2a in

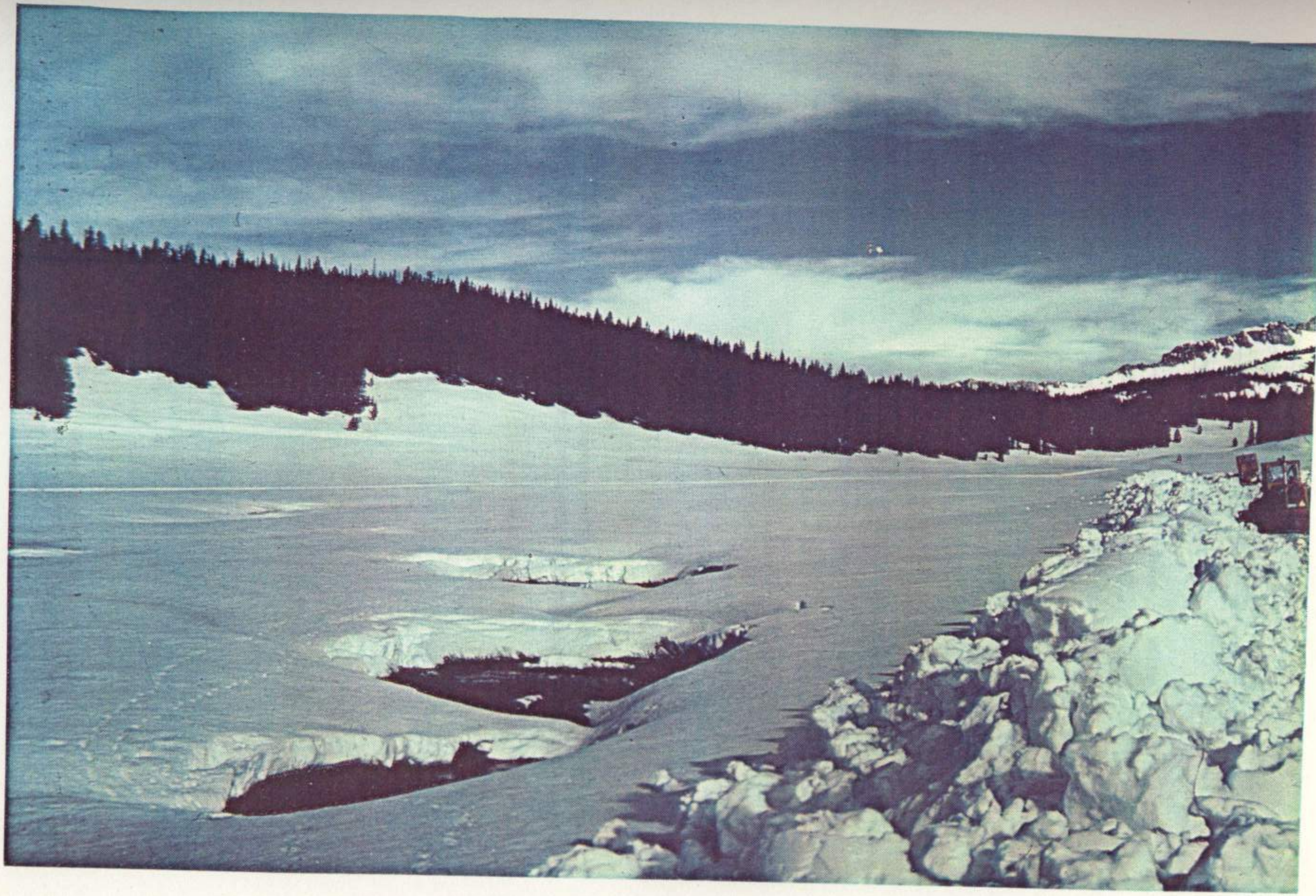

Photo 10. Upper Coal Creek during spring. Note depth of snow on roads and in valley.

Table 3-23 Estimated number of trout and suckers in the Mount Emmons Project study area, fall 1979

	Estimated Number per Kilometer[a,b]			
Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker
2a	1,257			
3	785			
6	2,221	676		204
7a	467			525
8a	1,844	219		7,713
8b	345	398	11	
10		862		
12		2,527		
13	901	88	192	

[a]Based on data collected during September and October 1979.
[b]Estimated biomass determined using Petersen's mark-recapture technique (Everhart et al. 1975).

Table 3-24 Estimated biomass of trout and suckers in the Mount Emmons Project study area, fall 1979

Estimated Biomass (grams) per Kilometer[a,b]

Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker
2a	35,191			
3	29,042			
6	35,533	52,016		11,231
7a	7,001			3,150
8a	85,331	29,756		362,496
8b	22,795	36,237	1,072	
10		84,429		
12		106,139		
13	30,624	15,666	18,762	

[a]Based on data collected during September and October 1979.
[b]Estimated biomass determined using Petersen's mark-recapture technique (Everhart et al. 1975).

Table 3-25 Comparison of number and species composition of fish collected during the fall of 1978 and 1979

	Number of Fish[a]													
	Brook Trout		Brown Trout		Rainbow Trout		White Sucker		Longnose Sucker		Fathead Minnow		Longnose Dace	
Station	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
2[b] Coal Creek	171	98	-	-	-	-	-	-	-	-	-	-	-	-
3 Coal Creek	57	56	-	-	-	-	-	-	-	-	-	-	-	-
6 Slate River	39	88	54	48	2	1	2	12	-	-	-	-	-	-
7[c] Slate River	44	21	3	-	-	-	8	15	-	-	-	-	-	-
8 Slate River	8	148	4	4	2	-	5	170	-	-	-	-	-	-
8A Slate River	-	32	-	9	-	-	-	75	-	-	-	-	-	-
8B Slate River	-	23	-	28	-	1	-	-	-	-	-	-	-	-
9 WashingtonCreek	66	-	-	-	-	-	-	-	-	-	-	-	-	-
10 East River	-	-	60	66	1	1	-	-	-	-	-	-	-	-
12 East River	-	-	60	51	4	-	-	-	-	-	-	-	-	-
13 Ohio Creek	23	29	17	5	5	10	-	-	-	-	-	-	-	21
14 Carbon Creek	207	210	3	0	3	-	-	-	-	-	-	-	-	-
15[b] Ohio Creek	8	12	15	2	2	1	-	1	48	6	-	-	75	42
17 Tomichi Creek	-	1	-	21	-	-	-	67	-	30	-	7	-	175

[a] Number of fish collected in 91 m (300 ft) of stream at each station

[b] Station 2 was moved approximately 0.05 km (150 ft) downstream and Station 15 was moved approximately 0.1 km (300 ft) upstream for the fall survey in 1979 because habitat at the former locations had been altered.

[c] Station 7 was moved approximately 0.2 km (600 ft) downstream and was designated 7a for the 1979 aquatic ecology sampling because flows from Coal Creek and the Slate River had not completely mixed at the previous location of Station 7.

Table 3-26 Average length of trout and suckers collected in the Mount Emmons Project study area during April 1979[a]

	Average Length (mm)			
Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker
6		158 (4)	338 (2)	
8a	142 (9)	181 (1)		100 (1)
8b	157 (23)	183 (14)		
10		218 (19)		
12		210 (14)		
13	123 (5)		282 (2)	
14	137 (49)	240 (1)	217 (6)	
15	153 (7)	280 (1)	189 (1)	

[a]Number of fish of each species is shown in parenthesis below corresponding average length.

Table 3-27 Average weight of trout and suckers collected in the Mount Emmons Project study area during April 1979[a]

	Average Weight (gm)			
Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker
6		39 (4)	342 (2)	
8a	31 (9)	44 (1)		5 (1)
8b	44 (23)	76 (14)		
10		122 (19)		
12		103 (14)		
13	22 (5)		206 (2)	
14	22 (49)	146 (1)	106 (6)	
15	37 (7)	200 (1)	59 (1)	

[a]Number of fish of each species is shown in parenthesis below the corresponding average weight.

Table 3-28 Average condition factor of trout and suckers collected in the Mount Emmons Project study area during April 1979[a]

Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker
	Average Condition Factor			
6		0.77 (4)	0.98 (2)	
8a	0.75 (9)	0.75 (1)		0.50 (1)
8b	0.82 (23)	0.85 (14)		
10		0.95 (19)		
12		1.13 (14)		
13	0.78 (5)		0.85 (2)	
14	0.62 (49)	1.06 (1)	0.92 (6)	
15	0.60 (7)	0.91 (1)	0.87 (1)	

[a]Number of fish of each species is shown in parenthesis below the corresponding average condition factor.

Table 3-29 Average length of trout and suckers collected in the Mount Emmons Project study area during September and October 1979a

	Average Length (mm)				
Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker	Longnose Sucker
2a	135 (98)				
3	153 (56)				
6	84 (88)	182 (48	233 (1)	139 (12)	
7a	86 (21)			80 (15)	
8	75 (148)	171 (4)		83 (170)	
8a	108 (32)	250 (9)		109 (75)	
8b	178 (23)	202 (28)	228 (1)		
10		192 (66)	229 (1)		
12		148 (51)			
13	140 (29)	248 (5)	205 (10)		
14	125 (210)				
15a	119 (12)	217 (2)	68 (1)		155 (6)
17	97 (1)	197 (21)		115 (67)	136 (30)

[a]Number of fish of each species is shown in parenthesis below the corresponding average length.

Table 3-30 Average weight of trout and suckers collected in the Mount Emmons Project study area during September and October, 1979[a]

	Average Weight (mm)				
Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker	Longnose Sucker
2a	28 (98)				
3	57 (56)				
6	16 (88)	77 (48	96 (1)	55 (12)	
7a	15 (21)			6 (15)	
8	16 (148)	53 (4)		13 (170)	
8a	30 (32)	136 (9)		47 (75)	
8b	66 (23)	91 (28)	98 (1)		
10		98 (66)	96 (1)		
12		42 (51)			
13	34 (29)	179 (5)	98 (10)		
14	28 (210)				
15a	24 (12)	106 (2)	4 (1)		40 (6)
17	6 (1)	134 (21)		39 (67)	42 (30)

[a]Number of fish of each species is shown in parenthesis below the corresponding average weight.

Table 3-31 Average condition factor of trout and suckers collected in the Mount Emmons Project study area during September and October, 1979[a]

	Average Condition Factor				
Station	Brook Trout	Brown Trout	Rainbow Trout	White Sucker	Longnose Sucker
2a	0.94 (98)				
3	0.96 (56)				
6	0.89 (88)	1.15 (48)	0.76 (1)	1.01 (12)	
7a	0.85 (21)			1.03 (15)	
8	1.40 (148)	0.84 (4)		1.31 (170)	
8a	0.85 (32)	0.99 (9)		1.04 (75)	
8b	0.99 (23)	1.00 (28)	0.83 (1)		
10		0.94 (66)	0.80 (1)		
12		1.02 (51)			
13	0.97 (29)	1.01 (5)	1.09 (10)		
14	1.03 (210)				
15a	1.04 (12)	1.03 (2)	1.27 (1)		1.03 (6)
17	0.66 (1)	1.03 (21)		0.96 (67)	0.94 (30)

[a]Number of fish of each species is shown in parenthesis below the corresponding average condition factor.

1979. For 1978, the estimated number and biomass of brook trout per kilometer was 2,009 and 44,187 gram, respectively. The difference in the trout population for the two years might be due, in part, to the relocation of Station 2 necessitated by the construction of a large beaver dam near the upstream boundary of Station 2 during the summer of 1979 (Photo 11). Alteration of the habitat at Station 2 due to this beaver dam is discussed in Section 3.1.

Nearly all brook trout at Station 2 were collected in pools that had overhead cover. Reduction in the amount of this type of habitat due to the change in the location of Station 2, probably affected the number of brook trout collected at the station.

Electrofishing surveys were also conducted by the Colorado Division of Wildlife in 1979 near Station 2a on Coal Creek. Sixty-seven brook trout were collected in August and 79 brook trout were collected in October 1979 in a 300 ft (91 m) section of the creek (COOW 1980). Less than one percent of the fish collected on these two dates were greater than 8 in. (200 m) in length (COOW 1980).

Station 3 - Coal Creek

Electrofishing surveys were not conducted at Station 3 in April 1979 because the creek was iced over at that time. A total of 56 brook trout were collected at Station 3 during the Fall 1979 survey. The average length and weight of the brook trout collected at Station 3 were 6 in. (153 mm) and 3.7 g, respectively. Approximately 5 percent of the trout collected at Station 3 were greater than 8 in. (200 mm) in length.

The estimated number and biomass of brook trout per kilometer at Station 3 was 785 and 29,042 g, respectively. Comparison of these estimates with similar population estimates from 1978 shows that the

Photo 11. Beaver dam on Coal Creek at Station 2.

estimated number of fish per kilometer was lower for 1979 but the estimated biomass of fish per kilometer was higher because the average size of the fish collected in 1979 was larger than in 1978.

Calculated condition factors for the fish at Station 3 were nearly identical for 1978 and 1979, 0.95 and 0.96 respectively.

The Colorado Oivision of Wildlife also conducted electrofishing surveys near Staton 3 in 1979. Thirty-nine brook trout were collected in August and 41 were collected in October 1979 from a 300 ft (91 m) section of the stream (COOW 1980). All fish collected by the COOW near Station 3 were less than 8 in. (200 mm) long.

Lower Coal Creek

As previously stated, fish sampling was not conducted on lower Coal Creek in 1979 because no fish were collected at the lower Coal Creek stations in 1978; furthermore, water quality conditions indicated that fish would continue to be absent from this area in 1979 (Photo 12).

Although only brook trout were collected at Stations 2 and 3 on Coal Creek during both 1978 and 1979 (Table 3-22) lower Coal Creek has, in the past, supported populations of several different trout species. According to Mr. Tony Verzuh, a lifetime native of Crested Butte, rainbow, native (cutthroat), eastern (brook), and German brown (brown) trout once populated Coal Creek (AMAX 1978).

Mr. Verzuh referred to the portion of the creek downstream of the Keystone Mine. Oischarge from this mine has completely eliminated fish from lower Coal Creek, a condition which has persisted for over 30 years.

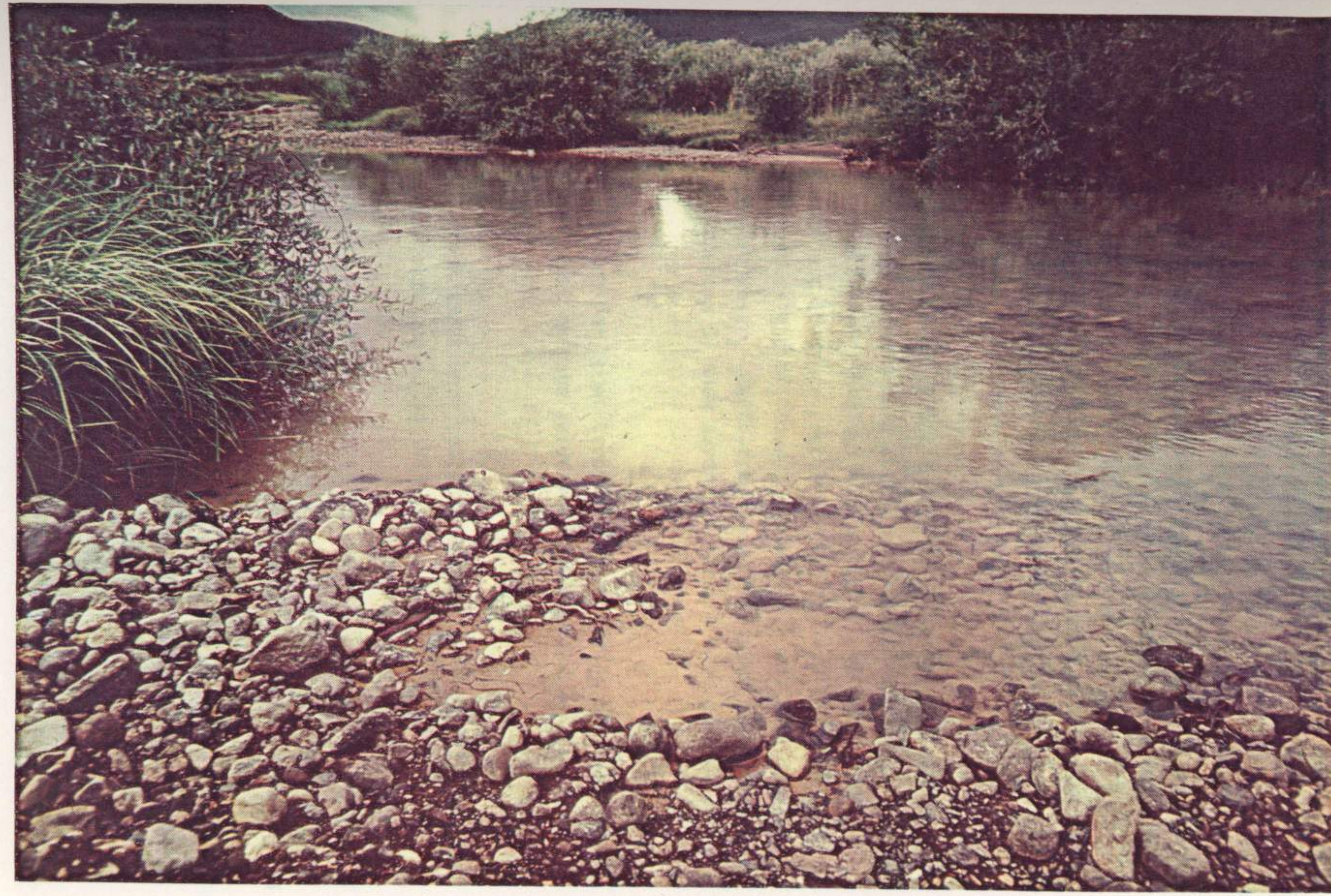

Photo 12. Lower Coal Creek near confluence with Slate River.
Note extensive "yellow boy" deposits.

Station 6 - Slate River

Fish were collected at Station 6 in April and September. Four brown trout and two rainbow trout were collected during qualitative sampling at Station 6 in April (Table 3-22). The two rainbow trout were adult fish and had probably moved into the riffle areas at Station 6 to spawn. The low number of fish collected may be due to the fact that most trout in high mountain streams concentrate in deeper pools during the early spring. No deep pools were present at Station 6.

In September, a total of 88 brook trout, 48 brown trout, 1 rainbow trout, and 12 white suckers were collected (Table 3-22). Most of the brook trout collected were small; average length and weight were 3.3 in. (84 mm) and 16 g, respectively (Tables 3-29 and 3-30). Average length and weight of brown trout were 7.2 in. (182 mm) and 77 g, respectively; however, length-frequency histograms for brown trout at Station 6 (Appendix C) show several different size classes at Station 6.

The condition factor for brown trout collected during the fall survey was 1.15, the highest average value for this species in the study area.

A total of 88 brook trout were collected in the fall of 1979 compared to 39 during the same period in 1978 (Table 3-25).

Station 7a - Slate River

Fish were not collected at Station 7a in April 1979 because snowdrifts prevented access to the area.

The electrofishing survey at Station 7a in September 1979 yielded a total of 21 brook trout and 15 white suckers (Table 3-22). Brook trout from Station 7a were small in size and averaged 3.4 in. (86 mm) in length and 15 g in weight (Tables 3-29 and 3-30). White suckers from Station 7a were also small; average length and weight were 3.1 in. (80 mm) and 6 g, respectively (Tables 3-29 and 3-30).

Fewer brook trout were collected at Station 7a in 1979 than in 1978. Here again, these differences may be due to the location of the station. Station 7 was moved approximately 200 yd (0.2 km) downstream for the 1979 survey because the previous location of Station 7 was not far enough below the confluence of Coal Creek and the Slate River for the flows to mix completely (Photo 12). During the 1978 survey, most of the flow from Coal Creek was channeled along the left bank of the stream at Station 7 and most of the trout were collected along the opposite side of the stream. Thus, most of the fish collected in 1978 were not subjected to the direct effects of the metal-laden discharge from Coal Creek.

Station 8 - Slate River

Large numbers of brook trout and white suckers were collected at Station 8 in the Fall 1979 survey (Table 3-22). Nearly all brook trout and white suckers were small (Tables 3-29).

The average condition factor for brook trout at Station 8 was high (1.40). This is probably a function of the small average size of these fish. Bagenal and Tesch (1978) state that direct comparison of condition factors is not possible if there are significant differences in the average lengths of the fish among stations.

The number of fish collected at Station 8 was dramatically higher in 1979 than in 1978. It is possible that differences are due in part to changes in water quality at Station 8. Comparison of water quality data collected near Station 8 during September 1978 and 1979 shows that the concentration of total zinc was substantially lower in 1979 (1.05 mg/l) than in 1978 (2.8 mg/l) (AMAX 1980). The zinc concentration of 2.8 mg/l is potentially toxic to salmonids. Holcombe and Benoit (1976) indicate that the LC50 (lethal concentration for 50 percent of the organisms) for zinc ranged from 1.38 mg/l to 2.50 mg/l (hardness 45 mg/l) for brook trout. Thus, it is probable that the high zinc concentrations in the water was the cause for the low number of fish collected at Station 8 in September 1978.

The absence of larger brook trout at Station 7a and 8 is difficult to explain. This section of the Slate River receives little fishing pressure. It is possible that larger brook trout were not present at Station 7a because cover for larger fish was limited, however, suitable habitat for larger fish was abundant at Station 8.

Selective toxicity to heavy metals does not appear to be a reasonable explanation because Holcombe and Andrew (1978) and others have demonstrated that juvenile, rather than adult, brook trout are generally more sensitive to heavy metal toxicity.

Since brook trout spawn in the fall and the substrate at Station 8 is not suitable for spawning, it is possible that the adult brook trout emigrate to other area to spawn.

Station 8a - Slate River

Fish were collected at Station 8a in both April and September. In April 1979, a total of 11 fish were collected at Station 8a including 9 brook trout, 1 brown trout, and 1 white sucker. In contrast, a total of 116 fish were collected in September 1979. This total included 32 brook trout, 9 brown trout, and 75 white suckers. The average length and weight of fish collected at this station during the fall survey were somewhat higher than at Station 8 (Tables 3-29 and 3-30). Population estimates for brook trout, brown trout, and white suckers based on Petersen's mark-recapture method (Everhart et al. 1975) are shown in Table 3-11 and 3-12). These estimates indicate that white suckers constituted over 71 percent of the total number and approximately 76 percent of the total biomass of fish at Station 8a in September 1979. Fish were not collected at Station 8a in 1978; however, the Colorado Division of Wildlife conducted an electrofishing survey in this vicinity in June 1977 (CDOW 1978). In this survey, a total of six fish including three white suckers, two brown trout, and one brook trout were collected from a 500 ft section of the stream. The reported fish biomass was 52 percent white sucker, 44 percent brown trout, and 4 percent brook trout.

Station 8b - Slate River

Trout were the only fish collected at Staton 8b in 1979. Twenty-three brook trout and 14 brown trout were collected in April. In September, the species composition was 54 percent brown trout, 44 percent brook trout, and two percent rainbow trout (Table 3-22).

Very few juvenile trout were collected at Station 8b, consequently, the average length and weight of trout collected during the fall survey at Station 8b was greater than at the other Slate River Stations (Tables 3-29 and 3-30). Since brook and brown trout in the study area spawn in the fall and the Slate River in the vicinity of Station 8b contains gravel substrate suitable for spawning, it is probable that many adult fish moved into this section of the stream to spawn.

Population estimates for the three trout species collected at Station 8b are shown in Table 3-23 and 3-24.

Fish were not collected at Station 8b in 1978. The Colorado Division of Wildlife, however, sampled near Station 8b in June 1977 (CDOW 1978) and collected a total of 19 fish, including 12 brook trout and 7 brown trout from 540 ft (165 m) of the stream. The low numbers of fish collected was partially due to reduced efficiency of electrofishing due to high flow during that time of year (COOW 1978). The low numbers may also have been due to habitat selection by the trout, during high flow periods most trout inhabit slow flowing, relatively deep pool areas. Station 8b contained no deep pools and thus fewer trout would occupy this section in the spring than in the fall of the year.

Station 10 - East River

All fish collected at Station 10 in 1979 were brown trout except for a single rainbow trout collected during the fall of 1979. A total of 19 brown trout was collected in April and 66 brown trout and 2 rainbow trout were collected in September.

The average length and weight of the brown trout collected at Station 10 are shown in Tables 3-29 and 3-20, respectively. The largest brown trout collected in the study area in 1979 was captured at Station 10. This fish was 18.2 in. (462 mm) long and weighed 2.3 lb (1046 g). Most of the larger brown trout collected at Station 10 were in the deep pool which bordered the bridge abutment.

Population estimates from the fall survey based on Petersen's mark-recapture method indicated that there were approximately 860 brown trout per kilometer in this section of the East River.

Station 11 - Alkali Creek

No fish were collected in Alkali Creek, however, fish were collected in a small irrigation canal into which Alkali Creek flows approximately one-half mile (0.8 km) upstream of the East River confluence. At the time of the survey, little flow was present in the irrigation canal and the fish were confined to isolated pools.

Qualitative sampling of these isolated pools yielded both brook trout and brown trout ranging in length from 5 to 13 in. (130 to 330 mm) and from 7 to 16 in. (180 to 400 mm), respectively.

Station 12 - East River

Although the East River in this vicinity is regularly stocked in the summer with rainbow trout, only brown trout were collected at Station 12 during both the spring and fall surveys. Fourteen brown trout were collected at Station 12 in the spring survey and 51 were collected during the fall. The average size of the brown trout collected at Station 12 in the fall survey was somewhat smaller than at Station 10. Average length was 5.8 in. (148 mm) compared to 7.6 in. (192 mm) at Station 10. The difference may be partially due to increased fishing pressure at Station 12, however, a more important factor for the difference in size may be the lack of suitable habitat for larger trout at Station 12 in the fall of the year. Larger brown trout tend to seek shaded pool areas with abundant cover. This type of habitat was limited to areas behind large (2-6 ft or 0.6-1.8 m) boulders at Station 12 during the fall. During the high flow periods in the spring, however, 2-4 ft (0.6-1.2 m) deep pools with adequate cover for larger trout were present at Station 12. The average size of the brown trout collected at Station 12 during the spring survey was 8.3 in. (210 mm).

Similar numbers of brown trout were collected at Station 12 in 1978 and 1979. In 1978, four rainbow trout were collected at Station 12, however, rainbow trout were collected, in 1979. The East River near Station 12 has been stocked with rainbow trout, a fact which may account for the presence of this species in September 1978. Colorado Division of Wildlife stocking records (CDOW 1979b) indicate that over 3,400 rainbow trout were stocked in the East River in August 1978.

Station 13 - Ohio Creek

The number and species of fish collected at Station 13 in the spring and fall of 1979 are shown in Table 3-22.

Brook trout were numerically dominant at Station 13, making up 67 percent of the fish collected during 1979. The average length and weight of the brook trout collected in the fall were 5.5 in. (140 mm) and 34 g, respectively. Brook trout constituted approximately 76 percent of the estimated trout population but, due to their small average size, only 47 percent of the estimated fish biomass (Tables 3-23 and 3-24).

More rainbow trout (10) were collected at Station 13 than at any other station in the study area during 1979. These rainbow trout ranged in length from 7.0 to 10.6 in (179 to 270 mm). Although all were reported as rainbow trout, one of the trout collected at Station 13 appeared to be a hybrid between a rainbow trout and cutthroat trout.

Five brown trout were collected at Station 13 during the fall. Although brown trout represented only seven percent of the estimated trout population at Station 13, they formed nearly one-fourth of the estimated fish biomass because of their larger average size.

The number of trout collected at Station 13 was similar for 1978 and 1979, however, the population of longnose dace was much lower in 1979 than in 1978. Twenty-one longnose dace were collected at Station 13 in 1978, but only three were collected in 1979. Longnose dace are an important forage fish for trout. It is possible that the numbers of longnose dace at Station 13 have been reduced due to predation by trout, especially the larger brown trout that often selectively feed on minnows and other small fish.

Station 14 - Carbon Creek

Carbon Creek at Station 14 supported a large brook trout population. A total of 210 brook trout were collected in the fall of in a 300 ft (91 m) section at Station 14. The length-frequency histograms (Appendix C) show that most brook trout at Station 14 were in the 3.0-4.0 in. (75-105 mm) size class.

During the survey in April 1979, a total of 49 brook trout, 1 brown trout, and 6 rainbow trout were collected at Station 14. The rainbow trout may have moved into Carbon Creek from Ohio Creek to spawn.

Average condition factor for the brook trout collected at Station 14 during the fall survey was relatvely high (1.03); however, stomach content analysis for four of the brook trout collected at Station 14 showed that none of these fish had food in either their stomachs or intestines (Section 3.4.5). Approximately 20-30 percent of the brook trout at Station 14 were infected by a fungal growth (Photo 13). Specimens of these diseased fish were frozen and sent to the U.S. Fish and Wildlife Service Fish Disease Control Center in Ft. Morgan, Colorado where it was confirmed that the fish were infected by a Saprolegnia spp. fungus (Janeke 1979). This disease is fairly common, especially during the spawning season (Janeke 1979). Adult trout, in forming the spawning redds, scrape the substrate with their tail and caudal peduncle. This removes the protective mucous layer from the skin and makes the fish more susceptible to topical infections such as Saprolegnia. The disease spread among the brook trout population at Station 14 because of high fish concentrations in the pools brought about by low flow conditions during the fall.

Many of the fish collected at Station 14 during the fall of 1979 were under severe stress due to the lack of food and the fungal infection. For this reason, electrofishing the stretch of stream for a second time was rejected, as it would subject the fish to additional undue

Photo 13. Brook trout infected with <u>Saprolegnia</u> spp. fungus. Fish collected at Station 14 on Carbon Creek.

stress. Thus, it was not possible to calculate population estimates for brook trout at Station 14 based on the Petersen's mark-recapture method (Everhart et al. 1975). Because nearly all fish were isolated in the pools, electrofishing efficiency was high.

Station 15a - Ohio Creek

In April 1979, a total of seven brook trout, one brown trout, one rainbow trout, and five longnose dace were collected at Station 15 on Ohio Creek.

The number and species composition of trout collected during the fall survey were similar to those collected in the spring survey. More longnose dace were collected, however, during the fall survey. Also, longnose suckers were collected at Station 15 during the fall survey. This was probably due to differences in the habitat sampled for the fall compared to the spring survey in 1979. As discussed previously, Station 15 was moved approximately 100 yd (0.1 km) upstream, prior to the Fall 1979 survey because the former location of Station 15 had been channeled. The water at the new location (Station 15a) was shallower and faster flowing than at the previous location (Station 15). Beckman (1970) states that longnose dace prefer the swifter parts of streams. Thus, more habitat for longnose dace was available at Station 15a than at Station 15 which probably accounts for the greater number of longnose dace collected during the fall survey.

Because of the low number of trout collected at Station 15, the trout population could not be estimated accurately. Estimates for longnose dace indicate a population of approximately 4,130 fish/mi (2,560 fish/km).

Comparison of data collected during the fall of 197B and 1979 shows that higher numbers of brown trout and longnose suckers were collected at Station 15 in 197B than in 1979 (Table 3-25). These differences were probably due to differences in the aquatic habitat at the two lower Ohio Creek stations. The location of Station 15 in 1978 contained a 3-4 ft deep (0.9-1.2 m) pool with overhanging vegetation and undercut banks. Most of the brown trout and suckers were collected from this deep pool. A similar habitat was not present at the location sampled during the fall of 1979 (Station 15a), thus, fewer of these species were collected.

Station 17 - Tomichi Creek

Data on fish were not collected at Station 17 prior to the fall of 1979.

In the fall, Tomichi Creek at Station 17 contained brown trout up to 16.5 in. (420 mm) in length. A single brook trout was the only other trout species collected but large numbers of non-game fish, such as longnose dace, white suckers, and longnose suckers were present (Table 3-22).

Tomichi Creek at Station 17 also contained fathead minnows. This was the only location in the study area where this minnow was collected during 1979. Fathead minnows, however, are common in the lower portion of the Gunnison River drainage and are numerically the most abundant fish in backwaters of the Gunnison River below the North Fork (Wiltzius 1978).

3.4.3 Fish Tagging

A fish tagging program was included in the 1979 aquatic ecology studies, to evaluate fish migration patterns in the study area. This program was implemented to determine if fish migration in the East and Slate rivers was affected by the acid mine drainage from Coal Creek or by the discharge of domestic wastes from the Crested Butte and Mt. Crested Butte municipal waste water treatment plants. The tagging program was also designed to determine if fish immigrate and emigrate seasonally or if most fish are year-round residents, moving only short distances during their life cycles.

A total of 60 trout were tagged during the fishery survey in April 1979 (Table 3-32). To date, information has been returned on 11 fish (Table 3-33). Seven of these fish were caught by fishermen and four were captured during the fall fishery survey.

The highest rate of return for tagged fish occurred at Station 8b on the Slate River approximately 0.2 mi (0.3 km) upstream of the East River confluence where 7 of the 13 tagged fish were recaptured. Four were caught by fishermen and three were captured during the fall fishery survey. Of the seven fish, five were recaptured at or near the point of tagging (Table 3-33). However, a 9-inch (229 mm) brook trout was recaptured approximately 1 mi (1.6 km) upstream, and a 9-inch (229 mm) brown trout was recaptured approximately 8 mi (13 km) downstream from Station 8b near the Roaring Judy Trout Hatchery (Table 3-33).

At other stations, the tagged fish that were recaptured were collected within 1 mi (1.6 km) of the location of tagging except for a brook trout tagged in Carbon Creek. This fish was caught in Ohio Creek approximately 2 mi (3.5 km) downstream from the point of tagging.

Eighty fish were tagged during the fall survey in 1979. To date, no information has been returned on these tagged fish. Because of the limited amount of data on returned fish, no conclusions regarding the migration patterns of fish in the study area can be made at this time. Data on tagged fish will continue to be compiled during 1980.

Table 3-32 Numbers of fish tagged and recaptured during 1979 for the Mount Emmons aquatic ecology baseline studies

Spring

Station	Location	No. of Fish Tagged	No. of Fish Recaptured
6	Slate River	3	0
8a	Slate River	3	1
8b	Slate River	13	7
10	East River	11	1
12	East River	9	1
13	Ohio Creek	2	0
14	Carbon Creek	19	1
		60	11

Fall

Station	Location	No. of Fish Tagged	No. of Fish Recaptured
6	Slate River	16	0
8a	Slate River	4	0
8b	Slate River	6	0
10	East River	31	0
12	East River	1	0
13	Ohio Creek	10	0
17	Tomichi Creek	12	0
		80	0

Table 3-33 Fish Tagged and Recaptured during 1979 for the Mount Emmons Aquatic Ecology Baseline Studies.

Station	Location	Species	Date of Tagging	Date of Recapture	Length at Tagging (in)	Length at Recapture (in.)	Net movement between tagging and recapture dates
8a	Slate River	Brown trout	4/18/79	7/26/79	7.4	8-9	None
8b	Slate River	Brook trout	4/18/79	9/27/79	9.8	10.2	None
8b	Slate River	Brown trout	4/18/79	9/27/79	11.4	11.4	None
8b	Slate River	Brown trout	4/18/79	7/16/79	9.3	9.5	Approx. 8 mi downstream
8b	Slate River	Brook trout	4/18/79	8/7/79	9.4	10.5	Approx. 0.3 mi upstream
8b	Slate River	Brook trout	4/18/79	9/27/79	9.4	9.7	None
8b	Slate River	Brook trout	4/18/79	7/29/79	9.3	9	Approx. 1 mi upstream
8b	Slate River	Brook trout	4/18/79	8/29/79	11.0	12	None
10	East River	Brown trout	4/18/79	10/2/79	13.9	14.8	None
12	East River	Brown trout	4/17/79	7/29/79	10.5	12	Approx. 0.7 mi upstream
14	Carbon Creek	Brook trout	4/19/79	8/20/79	10	13	Approx 1 mi downstream

3.4.4 Feeding Habits of Fish

As part of the 1979 fishery studies, the gastrointestinal contents of fish were examined and the organisms present were identified to the lowest practical taxa. The purpose of identifying stomach and intestinal contents was to determine the feeding preferences, if any, of the different species of fish collected.

In flowing streams, invertebrates generally are the most important and widespread component of a fish's diet (Hynes 1970). Rainbow trout (*Salmo gairdneri*) feed on a variety of animal life, but aquatic insects, terrestrial insects, and snails often make up the bulk of the diet (Pfleiger 1975). Although the diet of large brown trout (*Salmo trutta*) often consists mainly of smaller fish, most brown trout feed on insects including both aquatic and terrestrial organisms. Brook trout (*Salvelinus fontinalis*) are voracious feeders and feed on all types of aquatic insect nymphs and larvae (Baxter and Simon 1970).

White suckers(*Catastomus commersoni*) eat a wide variety of food organisms including crustacea, simple one-celled animals, rotifers, insect larvae, filamentous algae, and even vascular plants (Baxter and Simon 1970).

Allan (1975, 1978a, 1978b) conducted several studies relating macroinvertebrate abundance and nymph size to frequency of occurrence in salmonid stomachs. Allan found that salmonids feed most heavily on the most abundant prey. He also reported that salmonids are generally sight feeders as evi-denced by the predominance of larger prey size specimens in stomach contents and that brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) diets consist of similar prey. Differences that do occur in stomach contents are probably the result of the location of feeding rather than selective feeding patterns.

The invertebrates (including nymphs, larvae, and some adults) found in the stomachs and intestines of brook trout, brown trout, and rainbow trout were components of either the drift or Surber samples collected during this study (Appendix B). Several terrestrial invertebrates, including snout beetles (Curculionidae), ants (Hymenoptera), spiders (Arachnoidea), and grasshoppers (Orthoptera) were also present. In addition, trout eggs were found in the stomachs of two brook trout. Stomach contents of white suckers included invertebrate organisms, fish scales, microcrustaceans, and macrophytic material.

The evaluation of stomach contents was mainly qualitative, since taxonomic analysis of stomach contents was based largely on identification of detached parts. However, organisms were counted if the organism was intact and readily identifiable.

A list of the stomach contents of each of the 73 fish analyzed during 1979 is presented in Appendix C.

The results of this study were similar to those reported by Allan (1975, 1978a, 1978b), and indicated that the diets of rainbow, brook, and brown trout were very similar throughout the study area. Differences in stomach contents were probably due to the opportunistic nature of the feeding habits of the trout rather than a preference of that species for a particular organism.

The diet of the trout species examined was generally dependent on the type of habitat in which it was captured. For instance, the Slate River at Station 8b was fast-flowing and had rocky substrate that provided excellent habitat for clinging organisms such as *Brachycentrus* spp., Hydrosychidae, *Arctopsyche* spp., Deuterophlebiidae, and Simuliidae pupae and larvae (Wiggins, 1978, Merrit and Cummins 1978). These organisms were common in the stomach and intestinal contents of brown trout collected at Station 8b.

Stomach analysis also indicated that fish moved into the area near the Crested Butte waste water treatment plant to feed. During the fall benthic survey, it was noted that the effluent from the Crested Butte waste water treatment plant contained dense populations of Daphnia. These crustacea were not found in any other location in the project area and yet brook trout collected approximately 100 yd (0.1 km) upstream and 2 mi (3.2 km) downstream contained numerous Daphnia carapaces in their gastrointestinal contents.

Seasonal differences in feeding habitat were evident. Gastrointestinal contents of trout collected in the spring indicated that the trout were feeding on bottom dwellng and drifting organisms such as stoneflies, caddisflies, mayflies, and blackfly larvae.

In the fall, trout were primarily surface feeding, as evidenced by the presence of terrestrial Hymenoptera, Hemiptera, Coleopterans, and adult stages of aquatic organisms in the gastrointestinal contents. Thus, it appears that insect life cycles (both terrestrial and aquatic) have a major effect on the diet of the trout in the study area. No minnows or immature fish were found in the gastrointestinal contents of the fish examined.

3.4.5 Fish Stocking Records and Creel Census Data

Colorado Division of Wildlife stocking records (CDOW 1979) indicate that over 12,500 catchable size [6 inches (150 mm) plus] rainbow trout were stocked in the study area in 1978.

A total of 3,520 rainbow trout were stocked in the Slate River in 1978 (CDOW 1979b). The CDOW stocking schedule for 1979 shows that approximately half that number of catchable size rainbow trout were designated for the Slate River in 1979. Stocking was scheduled for June, July, and August and the location of stocking was designated as the Gunnison National Forest upstream of the Town of Crested Butte.

For the East River, a total of 8,460 catchable size rainbow trout were stocked in 1978. The fish stocking was concentrated in the vicinity of the Roaring Judy Trout Hatchery. The 1979 stocking schedule (CDOW 1978) indicated that approximately 2,700 fish were to be stocked in June and in July and 2,400 fish were to be stocked in August 1979, for a total of 7,800 fish.

The only other stream in the study area that was stocked by the Colorado Oivision of Wildlife during 1978 or 1979 was Ohio Creek. CDOW records (COOW 1979a) indicate that a total of 525 rainbow trout were stocked in Ohio Creek in July 1978.

Creel census data for the study area are limited. Data collected between 1973 and 1977 (COOW 1979a) are included in the 1978 Mount Emmons Aquatic Ecology Baseline Report. Creel census data for 1978 are shown in Table 3-22. Oata are inadequate to draw conclusions regarding the quality of fishing in the study area. It is interesting, however, to compare species composition of the creel data for the East River with data from the electrofishing surveys conducted for this study. Creel census data show that 58 percent of the total catch in 1978 were rainbow trout and only 42 percent were brown trout (Table 3-34). In contrast, only one rainbow trout was collected at the two East River stations during electrofishing surveys in 1979. For the two years of the study, rainbow trout have constituted only three percent of the fish collected at the two East River stations.

The section of the East River near the Roaring Judy Trout Hatchery is open for public fishing and is fished more heavily than any other section of stream in the project area during the summer. The low percentage of rainbow trout collected in electrofishing surveys indicates that nearly all of the rainbow trout stocked in the East River are caught or die within a short period of time after they are stocked or migrate out of the area.

Table 3-34 Census Data for the Mount Emmons Project study area, 1978 (CDOW 1979b)

	Coal Creek (Keystone Mine to Headwaters)	Slate River	East River	Ohio Creek
No. of Fishermen Surveyed	2	1	26	2
Hours Fished	9	1	55	1
Total Fish Caught	2	0	38	0
Catch per man-hour	.222	0	.691	0
Species caught/average size	Brook Trout - 6 in.	-	Rainbow trout - 11 in.	-
		-	Brown trout - 10 in.	-
Species Composition (percent)				
Brook Trout	100%	-	-	-
Rainbow Trout	-	-	58%	-
Brown Trout	-	-	42%	-

3.4.6 Accumulation of Metals in Fish Tissue

In general, detectable concentrations of potentially toxic elements in fresh waters occur only near sources of contamination (Photo 14). Contamination is evident, however, farther from the source in other segments of the ecosystems. Accumulation of nonessential trace elements by aquatic organisms can occur at distances removed from the source of contamination (McKim et al. 1976). Continued exposure of organisms to sublethal concentrations of metals may result in the accumulation of these metals in the tissue of the exposed organisms to concentrations that are lethal to or that have other adverse effects on the organisms. Accumulation of metals in the tissues of organisms may also be harmful to organisms consuming the affected organisms. This is of particular concern if the metals contaminated organism is consumed by man.

To determine the extent of metal accumulation in fish of the study area, representative specimens of fish were sacrificed and samples of dorsal muscle, kidney, liver, and gastrointestinal contents were collected for metals analysis. Pooled specimens of muscle, liver, and kidney tissue, and stomach contents were analyzed to determine concentrations of molybdenum, cadmium, zinc, copper, lead, and iron. Details of the analytical methods are included in Section 2.0, Methods. Cadmium, zinc, copper, lead, and iron were selected for analyses because of their tendency to accumulate in various tissues of aquatic organisms and because of the widespread distribution of these metals in the streams of the study area. Molybdenum was included in the analyses because of its role in the planned project. Results of these analyses are shown in Tables 3-35 through 3-40.

A total of 44 tissue samples were collected during the spring survey in 1979 at nine stations. Seventy-two tissue samples were collected during the fall survey at 11 stations.

Photo 14. Discharge from Keystone Mine entering Coal Creek.

Table 3-35 Concentrations of Cadmium in Samples of Fish Tissue from the Mount Emmons Project Study Area, Spring and Fall 1979.

Concentration of Metal (µg/g, wet weight)

SPRING

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
6	Brown trout	3	0.04	46	7.4	8.6
8a	Brook trout	3	<0.6	18	5.4	0.88
8b	Brown trout	3	0.07	28	6.6	3.2
8b	Brook trout	3	<0.08	28	5.6	8.1
10	Brown trout	3	<0.03	11	4.6	6.1
12	Brown trout	3	<0.06	25	4.5	5.4
13	Rainbow trout	2	<0.6	4.3	<0.09	<0.09
13	Brook trout	2	<0.05	<0.5	<0.2	<0.11
14	Brook trout	3	<0.16	0.3	0.08	0.15
14	Rainbow trout	3	<0.06	<0.2	<0.66	<0.08
15	Brook trout	3	<0.04	<0.4	0.15	<0.10

FALL

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
2	Brook trout	3	<0.16	0.94	0.53	0.63
3	Brook trout	2	0.19	25	9.8	1.4
6	Brown trout	2	<0.3	16	5.2	31
6	Brook trout	3	<0.2	1.9	<0.4	8.3
6	Rainbow trout	1	1	0.75	<0.3	0.62
7	Brook trout	4	<0.2	37	3.8	7.4
7	White sucker	4	<0.3	<5.4	<0.6	--
8a	Brown trout	2	<0.2	4.9	4.4	2.5
8a	Brook trout	2	<0.3	15	7.9	4.4
8a	White sucker	2	<0.2	0.8	2.7	8.1
8b	Brook trout	3	<0.1	4.2	2.9	1.9
8b	Brown trout	3	<0.2	22	16	4.0
10	Brown trout	1	<0.2	13	3.6	15
10	Rainbow trout	3	<0.2	0.4	<0.3	0.2
13	Brook trout	3	<0.1	<0.6	<0.2	<0.5
14	Brook trout	3	<0.2	<0.5	<0.2	<0.3
15	Brook trout	3	<0.4	<1.0	<0.2	0.4
17	White sucker		<0.3	0.8	0.2	0.4

[a]Number of specimens of each species analyzed.

Table 3-36 Copper Concentrations in Fish Tissue from the Mount Emmons Project Study Area, Spring and Fall 1979

Concentration of Metal (μg/g, wet weight)

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
			SPRING			
6	Brown trout	3	0.10	2.1	210	10
8a	Brook trout	3	1.3	11	110	3.4
8b	Brown trout	3	1.0	6.5	310	22
8b	Brook trout	3	1.2	16	91	16
10	Brown trout	3	0.6	3.4	340	21
12	Brown trout	3	0.9	4.2	370	26
13	Rainbow trout	2	1.0	1.9	23	4.7
13	Brook trout	2	0.8	5.4	22	4.0
14	Brook trout	3	0.9	2.8	25	5.1
14	Rainbow trout	3	1.1	4.1	34	2.9
15	Brook trout	3	0.8	5.4	29	5.5
			FALL			
2	Brook trout	3	0.6	2.4	5.3	1.3
3	Brook trout	2	0.8	6.3	49	7.4
6	Brown trout	2	1.2	2.5	110	8.1
6	Brook trout	3	0.6	3.0	25	13
6	Rainbow trout	1	0.6	2.8	270	5
7	Brook trout	4	0.9	25	94	41
7	White sucker	4	1.1	22	8.8	--
8a	Brown trout	2	0.8	3.6	190	9.9
8a	Brook trout	2	<0.6	5.1	36	9.6
8a	White sucker	2	0.3	0.8	15	52
8b	Brook trout	3	0.3	11	40	11
8b	Brown trout	3	0.9	10	280	20
10	Brown trout	3	0.3	3.8	140	22
10	Rainbow trout	1	0.7	6.0	63	3.8
13	Brook trout	3	0.2	1.2	6.5	6.1
14	Brook trout	3	0.5	0.9	10	1.8
15	Brook trout	3	<0.8	2.2	7.4	5.3
17	White sucker	3	<0.6	1.4	7.0	4.0

[a]Number of specimens of each species analyzed.

Table 3-37 Iron Concentrations in Fish Tissue from the Mount Emmons Project Study Area, Spring and Fall 1979

Concentration of Metal (μg/g, wet weight)

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
SPRING						
6	Brown trout	3	30	302	160	634
8a	Brook trout	3	12	124	92	131
8b	Brown trout	3	9.3	70	15	1490
8b	Brook trout	3	9.8	1260	102	990
10	Brown trout	3	6.5	73	64	1320
12	Brown trout	3	8.4	92	194	4262
13	Rainbow trout	2	10	65	264	2740
13	Brook trout	2	10	111	434	3140
14	Brook trout	3	30	101	233	4160
14	Rainbow trout	3	12	108	74	2390
15	Brook trout	3	8.6	98	47	4290
FALL						
2	Brook trout	3	13	256	300	44
3	Brook trout	2	9	128	233	178
6	Brown trout	2	12	183	245	400
6	Brook trout	3	16	284	380	2580
6	Rainbow trout	1	14	195	340	780
7	Brook trout	4	10	190	195	4120
7	White sucker	4	13	310	120	---
8a	Brown trout	2	10	190	177	89
8a	Brook trout	2	13	138	91	214
8a	White sucker	2	8	227	67	3220
8b	Brook trout	3	11	87	82	180
8b	Brown trout	3	5	135	168	174
10	Brown trout	3	6	150	108	2000
10	Rainbow trout	1	14	213	227	1120
13	Brook trout	3	6	140	260	840
14	Brook trout	3	20	134	216	152
15	Brook trout	3	15	193	151	490
17	White sucker	3	17	110		596

[a] Number of specimens of each species analyzed.

Table 3-38 Lead Concentration in Fish Tissue from the Mount Emmons Project Study Area, Spring and Fall 1979

Concentration of Metal (µg/g, wet weight)

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
SPRING						
6	Brown trout	3	<0.02	11	1.0	<0.1
8a	Brook trout	3	<0.03	0.2	0.20	0.2
8b	Brown trout	3	0.02	<0.04	0.06	3.6
8b	Brook trout	3	<0.04	1.7	<0.06	1.2
10	Brown trout	3	<0.02	<0.04	2.8	1.3
12	Brown trout	3	0.03	<0.09	0.9	0.2
13	Rainbow trout	2	<0.03	0.5	0.2	0.5
13	Brook trout	2	0.44	9.3	1.7	0.06
14	Brook trout	3	0.15	0.9	1.7	0.06
14	Rainbow trout	3	0.13	4.9	1.2	0.34
15	Brook trout	3	0.24	2	0.4	0.6
FALL						
2	Brook trout	3	0.2	0.2	0.07	0.2
3	Brook trout	2	<0.06	<0.2	0.07	0.3
6	Brown trout	2	<0.1	0.6	<0.2	1.7
6	Brook trout	3	0.2	0.3	0.2	16
6	Rainbow trout	1	0.2	0.5	0.4	1.9
7	Brook trout	4	0.2	1.8	1.6	34
7	White sucker	4	0.5	2	0.4	---
8a	Brown trout	2	0.2	0.3	0.2	0.5
8a	Brook trout	2	0.3	0.4	0.2	1.6
8a	White sucker	2	0.2	0.2	0.2	16
8b	Brook trout	3	0.2	0.4	0.1	1.4
8b	Brown trout	3	0.2	0.5	0.1	2.4
10	Brown trout	3	0.1	0.2	0.1	3.4
10	Rainbow trout	1	0.1	0.2	0.1	0.3
13	Brook trout	3	0.05	0.3	<0.1	0.4
14	Brook trout	3	0.2	<0.2	0.07	0.2
15	Brook trout	3	0.2	<1.0	<0.2	0.3
17	White sucker	3	0.2	0.1	0.1	0.7

[a] Number of specimens of each species analyzed.

Mount Emmons Project Study Area, Spring and Fall 1979

Concentration of Metal (µg/g, wet weight)

SPRING

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
6	Brown trout	3	< 0.04	< 2.5	< 0.24	< 0.33
8a	Brook trout	3	< 0.07	< 0.21	0.10	< 0.03
8b	Brown trout	3	< 0.04	0.16	0.12	0.11
8b	Brook trout	3	0.15	3.18	0.19	0.65
10	Brown trout	3	0.05	0.08	0.14	0.46
12	Brown trout	3	0.09	0.56	0.15	0.15
13	Rainbow trout	2	0.08	0.13	0.13	< 0.11
13	Brook trout	2	0.09	0.72	0.38	0.26
14	Brook trout	3	0.13	0.56	0.13	0.30
14	Rainbow trout	3	0.12	0.50	1.3	0.41
15	Brook trout	3	0.14	0.80	0.15	0.40

FALL

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
2	Brook trout	3	0.3	0.4	0.4	0.6
3	Brook trout	2	<0.1	<0.4	0.2	<0.3
6	Brown trout	2	<0.3	<0.3	<0.4	0.4
6	Brook trout	3	<0.3	<0.5	<0.4	0.7
6	Rainbow trout	1	<0.3	0.6	<0.4	<0.2
7	Brook trout	4	<0.2	<0.6	<0.6	<0.5
7	White sucker	4	<0.2	<5.0	<0.6	--
8a	Brown trout	2	<0.2	<0.2	<0.2	<0.3
8a	Brook trout	2	<0.3	<0.3	<0.1	<0.3
8a	White sucker	2	0.3	0.3	0.3	0.3
8b	Brook trout	3	0.1	<0.5	<0.2	0.2
8b	Brown trout	3	<0.2	<0.2	<0.2	<0.2
10	Brown trout	3	<0.2	0.3	<0.2	0.5
10	Rainbow trout	1	0.2	<0.5	<0.2	0.2
13	Brook trout	3	<0.1	<0.5	<0.2	<0.5
14	Brook trout	3	<0.2	<0.5	<0.2	<0.3
15	Brook trout	3	<0.3	<1.0	<0.2	0.9
17	White sucker	3	<0.4	0.2	0.3	0.3

[a] Number of specimens of each species analyzed.

Table 3-40 Zinc Concentrations in Samples of Fish Tissue from the Mount Emmons Project Study Area, Spring and Fall 1979

Concentration of Metal (μg/g, wet weight)

SPRING

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
6	Brown trout	3	7.0	73	33	106
8a	Brook trout	3	6.9	68	90	38
8b	Brown trout	3	10.1	56	44	490
8b	Brook trout	3	8.2	73	82	390
10	Brown trout	3	11	35	43	580
12	Brown trout	3	4.4	37	48	680
13	Rainbow trout	2	4.6	11	30	24
13	Brook trout	2	2.8	5.7	25	53
14	Brook trout	3	3.6	19	37	37
14	Rainbow trout	3	3.5	14	25	19
15	Brook trout	3	3.7	11	31	56

FALL

Station	Species	No.[a]	Muscle	Kidney	Liver	Gastrointestinal
2	Brook trout	3	9.7	24	23	39
3	Brook trout	2	10	51	54	88
6	Brown trout	2	7.8	47	28	91
6	Brook trout	3	7.1	41	37	137
6	Rainbow trout	1	8.8	23	29	57
7	Brook trout	4	9.0	108	116	460
7	White sucker	4	9.2	118	25	--
8a	Brown trout	2	6.9	34	34	44
8a	Brook trout	2	16	39	97	112
8a	White sucker	2	8.0	16	48	1040
8b	Brook trout	3	7.0	61	46	163
8b	Brown trout	3	9.4	32	62	140
10	Brown trout	3	7.8	49	35	750
10	Rainbow trout	1	8.1	29	27	35
13	Brook trout	3	5.6	27	26	64
14	Brook trout	3	5.2	21	27	25
15	Brook trout	3	11	26	22	40
17	White sucker	3	6.7	21	21	24

[a]Number of specimens os each species analyzed.

This discussion includes a brief survey of the literature on the accumulation of metals by fish and describes the biological fate and tissue distribution of metals in fish. Because fish are mobile and may only be temporary residents of the locale at which they were collected, it is difficult to make station to station comparisons. However, comparison of metal concentrations in fish from the different drainage basins was possible.

Cadmium

Benoit et al. (1976), reported that cadmium is readily accumulated by freshwater organisms through both food and water uptake. A direct relationship is reported to exist between the concentration of cadmium in water and in fish tissues (Solbe and Flook 1975). For brook trout, the highest concentrations of cadmium accumulate in the kidney, followed by the liver and gills (Benoit et al. 1976). Accumulation in the kidney and liver is probably related to the presence of the cadmium-specific binding protein in these organs which detoxifies the metal (Benoit et al. 1976). Accumulation of high concentrations of cadmium in the liver occurs during chronic exposures but little cadmium is accumulated following short term exposure (i.e., 96 hr or less) (Mount and Stephan 1967). These authors suggest that concentrations of cadmium in excess of 300 μg/g in liver tissue indicate a history of chronically damaging cadmium exposure.

Data collected during the spring and fall of 1979 show that cadmium concentrations were generally higher in kidney samples than in samples of muscle, liver, or gastrointestinal contents. Muscle tissue had much lower concentrations of cadmium than the other tissue samples with the exception of the sample of rainbow trout muscle collected at Station 6 during the Fall 1979 survey (Table 3-35).

Cadmium concentrations in liver, kidney, and gastrointestinal samples tended to be higher for fish collected in the Slate-East River watersheds (Stations 2 through 12) than in the Ohio Creek drainage

(Stations 13 through 15; Table 3-35). Concentrations of cadmium were less than 1 μg/g for all tissue samples from fish collected at Stations 13, 14 and 15. Corresponding samples from stations 2 through 12 on the Slate and East rivers contained cadmium concentrations as high as 37 μg/g.

Copper

Copper tends to accumulate in the liver and gills of fish. The concentration of copper in these tissues reflects the relative copper exposure (Brungs et al. 1973). Trout have been shown to accumulate copper when exposed to as little as 3 μg/l Cu in the water (Goettl et al. 1974). Little harm results to humans from consuming copper-contaminated organisms because the toxicity of copper to humans is low. However, for fish, a good correlation exists between the onset of copper accumulation above background levels and the development of chronic symptoms of copper toxicity (Phillips and Russo 1978).

Goettl et al. (1972) report that the baseline concentration of copper in rainbow trout on a dry weight basis is 12.9 μg/g in kidney tissue and 1.7 μg/g for muscle. This corresponds to a wet weight concentration of approximately 2.6 μg/g and 0.3 μg/g, respectively, if it is assumed that fish tissue is approximately 80 percent water by weight (Phillips and Russo 1978).

Data for both the fall and spring sampling period show much higher concentrations of copper in liver samples than the other tissues sampled. Concentrations as high as 370 μg/g of copper were found in liver samples (Table 3-36). The highest concentrations (wet weight) for the other types of samples were 1.3 μg/g for muscle samples from brook trout collected at Station 8a, 25 μg/g for kidney samples from brook trout collected at Station 7a, and 52 μg/g for gastrointestinal samples from white suckers collected at Station 8a (Table 3-36).

These concentrations exceed the baseline levels reported by Phillips and Russo (1978) and indicate that chronic symptoms of copper toxicity may exist in certain trout in the Slate River downstream from Coal Creek. The accumulation of copper in fish tissue was much greater for fish collected from the Slate-East River drainage than for fish taken from the Ohio Creek drainage; the difference in concentrations was greatest for liver samples. Samples of liver from fish collected in the Slate and East Rivers (Station 6 through 13) had average copper concentrations of 150 μg/g compared to an average concentration of 18 μg/g for stations in the Ohio Creek drainage.

Iron

Because of the low toxicity of iron to humans, iron in freshwater fish does not constitute a hazard (Phillips and Russo 1978). Iron tends to concentrate in the gills of fish but iron levels in fish tissues do not appear to increase with age (Phillips and Russo 1978). For the samples analyzed, the gastrointestinal contents had much higher iron concentrations than did samples of kidney, liver, or muscle. Iron concentration as high as 4,160 μg/g were recorded in gastrointestinal samples. Iron concentrations ranged from 4.7 μg/g to 434 μg/g in liver samples and from 65 μg/g to 1,280 μg/g in kidney samples (Table 3-37).

Muscle tissue contained much less iron than did other samples; iron concentration was 30 μg/g or less in all samples of muscle tissue. Iron levels in fish collected in the Ohio Creek drainage (Stations 13 and 15) were similar to those collected at the Slate and East River stations (Stations 6 through 12). Iron content of sediment samples were also similar throughout the study area (Section 3.5).

Lead

Holcombe et al. (1976) reported that kidneys and gills of brook trout accumulate the highest concentration of lead, followed by the liver. Muscle tissue accumulates the least amount of lead (Holcombe et al. 1976).

Studies of the chronic toxicity of lead to rainbow trout (Hodson et al. 1978) demonstrated that waterborne lead was readily taken up by fish and resulted in physiological changes. In contrast, dietary lead was not taken up and did not affect the fish. Lead levels in excess of 10 μg/g (wet weight) in liver and above 36 μg/g (wet weight) in kidneys may indicate a "history of unacceptable lead exposure" (Phillips and Russo 1978).

Lead concentrations in kidney samples were generally higher than in liver, muscle, or gastrontestinal samples for fish tissues collected during the spring of 1979 survey (Table 3-38). Highest lead concentrations for the spring survey (11 μg/g) were found in kidney samples from brown trout collected at Station 6. Lead levels in muscle tissue were generally lower than in other tissue samples; the highest concentration of lead in muscle samples was 0.5 μg/g for samples from white suckers collected at Station 7 during the fall survey (Table 3-38).

For the fall survey, the highest lead concentration (34 μg/g) was recorded in a sample of gastrointestinal contents from brook trout collected at Station 7. Lead concentrations in kidney samples were lower for the fall survey than during the spring. The highest concentration in kidney samples for the fall survey was 2.0 μg/g compared to a maximum concentration of 11 μg/g for kidney samples collected during the spring survey (Table 3-38).

Sediment samples collected from the Ohio Creek drainage generally had lower lead concentrations than did those from the Slate and East River stations. A similar pattern, however, was not evident for the metals content of all fish tissues. Although lead levels in samples of gastrointestinal content were generally lower for the samples from Station 13, 14, and 15, two of the higher lead concentrations in kidney samples were recorded during the spring survey at Stations 13 and 14.

Molybdenum

Ward (1973) reported that the molybdenum concentration in samples of bone, kidney, and brain of rainbow trout increased with increasing concentration of molybdenum in the surrounding water. Molybdenum levels in muscle tissue were however, not affected by the concentrations of molybdenum in the water (Ward 1973).

Molybdenum in fish tissue presents little potential hazard to humans because molybdenum does not accumulate in the edible portion of the fish and is of relatively low toxicity to humans.

Molybdenum levels were near or below the detection limits for nearly half of the samples of fish tissue (Table 3-39).

A molybdenum concentration of 3.18 $\mu g/g$ was recorded in the kidney sample from brook trout collected at Station 8b (Table 3-39). The maximum detectable concentrations of molybdenum for liver samples was 1.3 $\mu g/g$ in rainbow trout collected at Station 14. All other samples of kidney, liver, and muscle tissue and stomach contents contained less than 1.0 $\mu g/g$ of molybdenum. Ward (1973) indicates that molybdenum accumulates in kidney tissue, but not in skin or muscle tissue.

Zinc

Studies by Bican and Orbal (1978) indicate several species of fresh-water fish accumulate the largest amount of zinc in the kidneys followed by the gills and spleen. Goettl et al. (1972), who measured zinc uptake in various tissues of rainbow trout, reported that the eye accumulated the highest concentration of zinc followed by gill, bone, intestine, liver, kidney, and skin. Baseline zinc levels (dry weight basis) for selected tissues from unexposed fish were: 150 μg/g for liver, 125 μg/g for kidney, and 20 μg/g for muscle (Goettl et al. 1972). These concentrations correspond to wet weight concentrations of approximately 30μg/g, 25 μg/g, and 4 μg/g, respectively.

Zinc is readily accumulated from both food and water (Phillips and Russo 1979). Accumulation of zinc up to 300 μg/g has occured in fish exposed to as little as 47 μg/l of zinc for 30 d (Spehar 1976).

Zinc also accumulates to high concentrations in aquatic invertebrates. Goettl et al. (1971) collected aquatic insects from Colorado streams near mining and milling sites and analyzed samples of the organisms for zinc, copper, and lead. On a dry weight basis, the samples contained 10,250 μg/g zinc, 6,440 μg/g copper, and 6000 μg/g lead.

Zinc concentration for fish tissue samples collected during 1979 was highest for samples of gastrointestinal contents. The highest zinc concentration (1,040 μg/g) was measured for samples from white suckers collected during the fall survey at Station 8a (Table 3-40). Gastrointestinal samples from fish at several other stations had zinc concentrations in excess of 300 μg/g (Table 3-40). These elevated concentrations may have been due to consumption of zinc-contaminated benthic macroinvertebrates by the fish.

Zinc levels in kidney and liver samples were similar. The maximum concentrations of zinc for kidney and liver samples were 118 μg/g and 116μg/g, respectively. Zinc concentrations were generally much lower in samples of fish muscle; the maximum concentration was 16 μg/g. These maximum concentrations are considerably in excess of the baseline zinc levels (wet weight) reported by Goettl et al. (1972).

Levels of zinc in fish tissues were substantially higher for samples collected in the Slate and East rivers than for those collected in the Ohio Creek drainage.

The highest concentrations of zinc in samples of kidney, liver, and gastrointestinal contents were all reported for samples collected at stations in the Slate and East River drainages. The average concentrations of zinc for kidney, liver, and gastrointestinal samples at Station 6 through 12 were 52 μg/g, 51 μg/g, and 300 μg/g, respectively. Concentrations of zinc for corresponding samples collected in the Ohio Creek drainage were 17 μg/g, 27 μg/g, and 38 μg/g, respectively (Table 3-40).

Zinc concentrations in sediment samples had a similar spatial distribution; levels of zinc were substantially higher in samples from Stations 6 through 12 than in sediment samples from Stations 13 through 15 (Section 3.5).

3.4.7 Comparison of 1978 and 1979 Data on Metals Concentrations in Fish Tissues

As previously noted, the metals analysis of fish tissues conducted during the 1978 program was performed on homogenates of the whole body of the specimens. Thus, direct comparison of metals concentration for the 1978 study with data presented in this report is not possible. Similar trends, however, were apparent.

In 1978, it was reported that fish collected at the Slate River stations (6, 7, and 8) had somewhat higher concentrations of metals than fish collected in the Ohio Creek drainage (AMAX 1979). As discussed previously, this trend was also seen in 1979 for all metals except iron, lead, and molybdenum.

3.5 Metals Content of Sediment Samples

Most metals are relatively insoluble in natural water and generally precipitate from solution and are deposited in the sediments near the source of the discharge. Thus, water samples collected downstream of a source of metal-laden discharge contain little or no detectable concentrations of metals but sediment samples collected in the same location contain higher concentrations of metals.

In the sediments, metals tend to concentrate on fine organic particulate matter (Gale et al. 1976) or are associated with hydrous iron and manganese oxides (Delfino 1977).

Transport of metal-laden sediments occurs especially during high flow periods and often results in a metal concentration gradient in sediments downstream from the source of metal pollution. Thus, the concentration of metals in sediments is often a more accurate indicator of the extent of contamination than the metals concentration of water samples.

Acidic, metal-laden drainage occurs in several locations in the study area. These discharges enter the stream via the iron bog, natural springs, and various effluents from active and inactive mining operations. The effects of these discharges are reflected in the metal concentrations of sediment samples collected in the study area.

The concentrations of cadmium, copper, iron, lead, molybdenum, and zinc were measured in sediment samples collected during June and September 1979. Sediment sampling was conducted at 11 stations during June and at six stations in September. Results of the sediment analyses are listed in Table 3-41.

The toxicity to aquatic organisms of metals in sediments is a function of the biological availability of the metal. For instance, metal ions that are loosely adsorbed onto organic matter may be metabolized by aquatic organisms, whereas metals that are part of the crystalline structure of a mineral probably cannot be incorporated into the tissues of aquatic organisms. The concentration of metals may be similar for two different sediment samples, but the toxicity of the sediments to aquatic organisms may be vastly different.

It is not possible using atomic absorption spectrometry to determine the biological availability of metals in sediments. The discussion of metal concentrations in sediments is, therefore, limited to discussing trends in metal concentrations rather than effects of a particular metal concentration on aquatic organisms.

The concentrations of trace metals in sediments of fluvial systems tend to have large temporal and spatial variations. The sediment sampling program conducted during 1979 did not permit detailed assessment of the metal concentrations of sediments in the study area. However, certain patterns were apparent.

Table 3-41 Concentrations of trace metals (μg/g) in fluvial sediment samples from the Mount Emmons study area

Station	Spring 1979					
	Cadmium	Copper	Iron	Lead	Molybdenum	Zinc
3	8.4	40	21,700	124	1.0	9.3
4	2.1	474	32,100	176	1.3	382.0
5	18.0	262	29,000	155	1.9	2,250.0
6	4.1	58	29,100	136	2.5	659.0
8a	39.0	390	28,500	230	1.8	4,250.0
8b	11.0	127	34,500	146	2.3	2,750.0
10	16.0	73	20,900	53	1.3	4,100.0
12	3.0	19	20,700	28	0.8	702.0
13	<0.4	8	30,150	7	<0.3	63.0
14	<0.4	6	14,200	6	<0.3	37.0
15	<0.4	8	26,500	7	<0.3	59.0

Station	Fall 1979					
	Cadmium	Copper	Iron	Lead	Molybdenum	Zinc
2	1.0	9	31,000	40	<0.5	114
3	11	24	31,200	80	<0.5	1,380
4	3	110	32,000	100	2.1	500
5	98	350	29,000	160	1.4	5,770
6	2	27	19,600	100	0.7	424
7	31	266	35,700	170	1.1	1,690

The Ohio Creek watershed receives little or no acid mine drainage. Metal concentrations in sediments from Stations 13, 14, and 15 were, therefore, lower than at other stations in the study area for all metals except iron (Table 3-41).

The level of trace metals in sediments from Station 2 was also lower because Station 2 is upstream of the mine discharges on Coal Creek.

Stations 3, 4, and 5 on Coal Creek and Stations 6 and 7 on the Slate River are all downstream of sources of mine discharge. As a result, the concentrations of cadmium, copper, lead, molybdenum, and zinc in sediment samples from these stations are all consistently higher than those in sediment samples from Station 2 on upper Coal Creek or from Station 13, 14, and 15 in the Ohio Creek Orainage. No major sources of acid mine drainage exist below Station 7 on the Slate River or on the East River. The concentrations of most metals in sediment samples tended to decrease downstream from Station 7. Sediment samples from Station 12, the most downstream station on the East River generally had lower concentrations of metals than did other stations in the East River drainage except Station 2.

Of the trace metals analyzed in sediment samples, only iron showed essentially no spatial pattern of concentration in the study area. Iron concentrations in sediments were similar for nearly all stations. The widespread distribution of iron in sediments is probably due to the natural sources of iron in the study area.

REFERENCES

Allan, J.O. 1975. The distributional ecology and diversity of benthic insects in Cement Creek, Colorado. Ecology 56:1040-1053.

Allan, J.O. 1978a. Trout predation and the size composition of stream drift. Limnol. Oceanogr. 23(6):1231-1327.

Allan, J.O. 1978b. Oiet of brook trout (Salvelinus fontinalis Mitchell) and brown trout (Salmo trutta L.) in an alpine stream. Verh. Internat. Verein. Limnol. Vol. 20 P. 2045-2050.

AMAX, Inc. 1978. Clean Up Coal Creek Project, AMAX Mount Emmons Project, Crested 8utte, Colorado.

AMAX, Inc. 1979. Mount Emmons aquatic ecology baseline report, 1978. Prepared by Camp Dresser & McKee Inc. 123 p.

AMAX, Inc. 1980. Mount Emmons water quality baseline report, 1978-1979. Prepared by Camp Oresser and McKee Inc. 88 p.

AMAX Inc. 1980b. Unpublished water quality data for the Mount Emmons Project Study Area, 1979.

American Public Health Association 1975. Standard methods for the examina tion of wastes and wastewaters. Washington, D.C.: Amer. Pub. Health Assoc; 14th Ed.

8ailey, R.G. 1966. Observations on the nature and importance of organic drift in a Oevon river. Hydrobiologia, 27:353-67.

8ailey, R.M. 1970. A list of common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. No. 6.

8agenal, T.B.; Tesch F.W. 1978. Age and growth. 8agenal, T.8. ed. Methods for assessment of fish production in fresh water. Oxford: 8lackwell Scientific Publishers, Handbook #3. 101-126.

8artlett, L. et al. 1974. Effects of copper, zinc, and cadmium on Selenastrum capricornutum. Water Res. (G.8.) 8:179.

8auman, R.W. 1978. Nearctic stonefly genera as indicators of ecological parameters (Plecoptera Insecta). Great 8asin Naturalist 39(3) 241-144.

8auman, R.W., Gaufin, A.R., Surdiek, R.F. 1977. The stoneflies (Plecoptera) of the Rocky Mountains. Memoire of Amer. Entomol. Soc. No. 31. 208 pp.

8axter, G.T.; Simon, J.R. 1970. Wyoming fishes. 8ull. #4. Cheyenne: Wyoming Game and Fish Oept., 168 p.

Beck, E.C.; 8eck,W.M. Jr. 1969. Chironomidae of Florida. III. The Harnsichia complex (Chironominae). 8ull. Fla. St. Mus. 13:277-313.

REFERENCES (Continued)

Beck, W.M. 1977. Environmental requirements and pollution tolerance of common freshwater Chironomidae. Washington, D.C.: Environmental Protection Agency; EPA 6D0/4-77-D024.

Beck, W.M., Jr.; Beck, E.C. 1966. Chironomidae (Diptera) of Florida. I. Pentoneurini (Tanypodinae). Bull. Fla. St. Mus. 10:305-379.

Beckman, W.C. 1970. Guide to the fishes of Colorado. Oenver: Colorado Oivision of Wildlife. Denver. 110 p.

Benoit, O.A. et al. 1976. Toxic effects of cadmium on three generations of brook trout. Trans. Amer. Fish Soc. 4:550.

Bican, J.; Orbal, K. 197B. The content of zinc in the tissues of some fish. Aquatic Sci. and Fish Abs. B:9682-1Q8.

Brinkhurst, R.O.; Jamieson, B.G. 1971. Oligochaeta of the world. New York: Oxford Press.

Brunes, W.A.; Leonard, E.N.; McKin, J.M. 1973. Acute and long term accumulation of copper by the brown bullhead. J. Fish. Res. Board. Can. 3D(4):5B3-5B6.

Burch, J.B. 1972. Freshwater sphaeriancean clams (Mullosca: Pelecypoda) of North America. U.S. Environmental Protection Agency. Biota of freshwater ecosystems. Washington, O.C.: U.S. EPA; Identification Manual No. 3.

Carlander, K.O. 1969. Handbook of freshwater fishery biology. Ames: Iowas State Univ. Press; Vol. 1.

Colorado Oepartment of Health (COH). 1975. The upper Gunnison River drainage. Oenver: Colo. Oept. Health, Water Quality Oiv. 7D p.

Colorado Oepartment of Health (COH). 1979. Regulations establishing basic standards and antidegradation standards and establishing a system for classifying state waters, for assigning standards, and for granting temporary modifications. Adopted: May 22, 1979. Effective: July 10, 1979.

Colorado Oivision of Wildlife. 1972. Survey and evaluation of Colorado's surface waters as a fishery resource (Computer printout data), Denver.

Colorado Oivision of Wildlife. 197B Results of electrofishing surveys in the upper Gunnison River drainage, June 1977. (Unpublished)

Colorado Division of Wildlife. 1979a. Creel census data. 1973-1978. (Unpublished)

Colorado Division of Wildlife. 1979b. Stocking records. 1973-1978. (Unpublished)

Colorado Division of Wildlife. 1979c. Stocking schedule, 1979. (Unpublished)

Colorado Division of Wildlife. 1980. Results of electrofishing survey on Coal Creek. 1979. (Unpublished).

Cowell, B.C.; Carew, W.C. 1976. Seasonal and diel periodicity in the drift of aquatic insects in a subtropical Florida stream. Freshwater Biol. 6:587-594.

Delfino, J.J. 1977. Effects of river discharge and suspended sediment on water quality in the Mississippi River. J. Environ. Sci. Health. 12:79.

Edmondson, W.T., editor. 1959. Freshwater biology. New York: John Wiley & Sons, Inc.

Edmunds, G.F., Jr., S.L. Jensen, and L. Berner 1976. The mayflies of North and Central America. Minneapolis: Univ. Minn. Press.

Egglishaw, J.H. 1967. The distribution of benthic invertebrates on substrata in fast flowing streams. J. of Anim. Ecol. 36:19-32.

Elliott, J.M. 1967. The life histories and the drifting of the Plecoptera and Ephemeroptera in a Dartmoor stream. J. Anim. Ecol. 36:343-362.

Everhart, W.H, Seaman R. 1971. Fish of Colorado. Denver: Colorado Game, Fish, and Parks Division.

Everhart, W.H., Eipper, A.W.; Youngs, W.D. 1975. Principles of fishery science. Ithaca, New York: Cornell University Press.

Federal Register. 1976. Guidelines for establishing test procedures for analysis of pollutants, Part 2, Dec 1, 1976. EPA Water Programs.

Gaechther, R. 1976. Heavy metals toxicity and synergism to natural phytoplankton in the eutrophic Lake Alpnach and the mesotrophic Horw Bay. Schweiz. Z. Hydrol (Ger.) 38:2, 97.

Gale, N.L., et al. 1976. Investigation of Clearwater Lake as a potential sink for heavy metals from lead mining in Southeast Missouri. Trace Subst. Environ. Health 10:187.

Geitler, L. 1932. Dr. L. Rabenhorst's Kryptogamenflora Cyanophyceae von Europa. Leipzig: Akademische Verlagsgesellschaft.

Goettl, J.P., Jr; Sinley, J.P.; Oavies P.H. 1971. Study of the effects of mineral mining and milling operations on high mountain streams. Colorado Oivision of Wildlife. Water pollution studies. Fort Collins: Colo. Div. of Wildlife, Job Prog. Rep., Fed. Aid Proj. F-33-R-6, pp. 1-48.

Goettl, J.P., Jr.; Sinley, J.R.; Davies, P.H. 1972. Study of the effects of metallic ions on fish and aquatic organisms. Baseline levels of zinc and copper in rainbow trout. Colorado Division of Wildlife. Water pollution studies. Fort Collins: Colo. Oiv. of Wildlife, Job Prog. Rep., Fed. Aid Proj. F-33R-7.

Goettl, J.P., Jr.; Sinley, J.R.; Davies, P.H. 1974. Water pollution studies. Fort Collins: Colorado Division of Wildlife, Job Prog. Rep., Fed Aid Proj. F-33-R-9.

Goettl, J.P., Jr.; Davies, P.H. 1977. Study of the effects of metallic ions on fish and aquatic organisms. Tissue molybdenum levels. Colorado Division of Wildlife. Water pollution studies. Fort Collins: Colo. Oiv. of Wildlife, Job Prog. Rep., Fed. Aid Proj. F-33-R-12.

Hamilton, A.L., Saether, O.A. Undated. Keys to larval Tanypodinae, Oiamesinae, Chironomini, and Tanytarsini. (Mimeograph of unpublished material.

Hamilton, A.L.; Saether, O.A.; Oliver, O.R. 1969. A classification of the nearctic Chironomidae. Winnipeg: Fish. Res. Bd. Can. Tech. Report No. 124.

Herricks, E.E. 1973. The recovery of stream macrobenthic communities from the effects of acid mine drainage. Blacksburg: Virginia Polytechnic Institute and State University. 279 pp.

Herricks, E.E. 1979. Benthic invertebrate sampling of the Gunnison River Basin, July 1979. (Unpublished)

Hilsenhoff, W.L. 1975. Aquatic insects of Wisconsin. Tech. Bull. No. B9. Madison, Wisconsin. Oept. of Nat. Res.

Hiltunen, J.K. 1967. Some oligochaetes from Lake Michigan. Trans. Amer. Microsc. Soc. B6:4BB-454.

Hiltunen, J.K. 1973. Keys to the tubificid and naidid Oligochaeta of the Greal Lakes region. Unpubl. manuscript. 2nd edition.

Hodson, P.V. et al. 197B. Chronic toxicity of water-borne and dietary lead to rainbow trout (<u>Salmo gairdneri</u>) in Lake Ontario Water. Water Res (G.B.). 12:B69.

Holcombe, G.W. et al. 1976. Long-term effects of lead exposure on three generations of brook trout. J. Fish. Res. Bd. Can. 33:1731.

Holcombe, G.W.; Andrew, R.W. 197B. The acute toxicity of zinc to rainbow and brook trout - comparisons in hard and soft water. Washington, D.C.: U.S. Environmental Protection Agency; EPA-6D0/3-78-D94. 17 pp.

Holcombe, G.W.; Benoit, D.A. 1976. Unpublished data available at the National Environmental Research Laboratory. U.S. Environmental Protecton Agency. Quality criteria for waters. Washington, D.C.: U.S. EPA.

Holcombe, G.W., Benoit, D.A., Leonard, E.W. 1979. Long-term effects of zinc exposures on brook trout (Salvelinus fontinalis). Trans. Amer Fish Soc. 1D8:76-B7.

Holsinger,J.R. 1972. The freshwater amphipod crustaceans (Gammaridae) of North America. U.S. Environmental Protection Agency. Biota of freshwater ecosystems. Washington D.C.: U.S. EPA; Identification Manual No. 5.

Huber-Pestalozzi, G. 1938. Die Binnengewasser. Band 16, Das Phytoplankton des Susswassers. Teil 1. Algemeiner Teil, Blaualgen, Bakterien, Pilze. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung.

Huber-Pestalozzi, G. 1941. Die Binnengewasser. Band 16, Das Phytoplankton des Susswassers. Teil 2, Chrysophyceen, farblose Flagellaten, Heterokonten. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlug,

Huber-Pestalozzi, G.; Fott, B. 1968. Die Binnengewasser. Band 16, Das Phytoplankton des Susswassers. Teil 3, halfte 2. Auglage. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung.

Huber-Pestalozzi, G.; Hustedt, F. 1942. Die Binnegewasser. Band 16, Das Phytoplankton Des Susswassers. Teil 2, Halfte 2. Diatomeen. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung.

Hustedt, F. 193D. Bacillariophyta. Pascher, A., ed., Die Susswasser-Flora Mitteleuropas, Heft 1U. Jena: Gustav Fischer. (University Microfilms, Ann Arbor, Mich.)

Hynes, H.B.N. 197D. The ecology of running waters. Toronto: Univ. Toronto Press.

Janeke, P.W. 1979. Personal communication with J.W. Ericson, Oct 23, 1979. USFWS Fish Disease Control Center, Ft. Morgan, Colo.

Johannsen, D.A. 1934. Aquatic Diptera. Part 1. Nemocera, exclusive of Chironomidae and Ceratopogonidae. N.Y. (Cornell) Agr. Expt. Sta. Mem. 164:1-171.

Johannsen, D.A. 1935. Aquatic Diptera. Part 11. Drthorrhapha Brachycera and Cyclorrhapha, N.Y. (Cornell) Agr. Expt. Stat. Mem. 177:1-62.

Johannsen, O.A. 1937a. Aquatic Oiptera. Part III. Chironomidae: subfamilies Tanypodinae, Oiamesinae, and Orrhocladiinae. N.Y. (Cornell) Agr. Expt. Stat. Mem. 210:1-84

Johannsen, O.A. 1937b. Aquatic Oiptera. Part IV. Chironomidae: subfamily Chironominae. N.Y. (Cornell) Agr. Expt. Sta. Mem. 210:1-52.

Kann, V.E. 1975. On the systematics and ecology of the genus Chamaesiphon (Cyanophyceae). Archiv F. Hydrobiologic (Ger.) Suppl. - Bd. 41:243-2B2.

Kenk, R. 1972. Freshwater planarians (Turbellaria) of North America. In: Biota of freshwater ecosystems. Washington, O.C.: U.S. EPA; U.S. Environmental Protection Agency, Identification Manual No. 1.

Klemm, O.J. 1972. Freshwater leeches (Annelida:Hirudinea) of North America. U.S. Environmental Protection Agency. Biota of freshwater ecosystems. Washington, O.C.: U.S. EPA: Identification Manual No. B.

Koryak, M.; Shapiro, M.A.; Sykora J.L. 1972. Riffle zoobenthos in streams receiving acid mine drainage. Water Research. 6:1239-1247.

Lagler, K.F., et al. New York: 1977. Ichthology. John Wiley and Sons, New York

Lehmkuhl, O.M.; Anderson, N.H. 1972. Microdistribution and density as factors affecting the downstream drift of mayflies. Ecology 53:661-667.

Lloyd, M.; Zar, J.H.; Karr,J.R. 1968. On the calculation of information theoretical measures of diversity. Amer. Midl. Natur 97:257-272.

Lowe, R.L. 1974. Environmental Requirements and pollution tolerance of freshwater diatoms. Washington, O.C.: U.S. Environmental Protection Agency; EPA 670/4-74-005. 334 pp.

Lund, J.W.; Kipling, G.C.; LeCren, E.C. 1958. The inverted microscope method for estimating algal numbers and statistical basis of estimation by counting. Hydrobiologia 11:143-170.

McKim, J.J.; Benoit, O.A. 1974. Ouration of toxicity tests for establishing "no effect" concentrations for copper with brook trout (Salvelinus fontinalis): J. Fish. Res. Board Can. 31(4):449-452.

McKim, J.M., et al. 1976. Long-term effects of methylmercuric chloride on three generations of brook trout (Salvelinus fontinalis): toxicity, accumulation, distribution, and elimination. J. Fish. Res. Board Can. 33(12):2726-2739.

Mason, W.T. 1973. An introduction to the identification of chironomid larvae. Cincinnati, Ohio: U.S. Environmental Protection Agency.

REFERENCES (Continued)

Merritt, R.W.; Cummins, K.W. (editors.). 1978. An introduction to the aquatic insects of North Ameria. Dubuque, Iowa: Kendall Hunt Publ. Co.

Meyer, R.L. 1971. A study of the phytoplankton dynamics in Lake Fayetteville as a means of assessing water quality. Arkansas Water Resource Res. Center Publ. 10. Fayetteville: Univ. of Arkansas.

Minshall, G.W.; Minshall, J.N. 1977. Microdistribution of benthic invertebrates in Rocky Mountain streams. Hydrobiologia 55:231-249.

Moran, R.E.; Wentz, D.A. 1974. Effects of metal mine drainage on water quality in selected areas of Colorado, 1972-1973. Colorado Water Resource Circular #25. 250 p.

Morris, A. 1974. Effect of Keystone Mine effluent on aquatic invertebrates. Rocky Mtn. Biological Lab. (Unpublished)

Mount, D.I.; Stephen, C.E. 1967. A method for detecting cadmium poisoning in fish. J. Wildl. Manage. 31(1):168-172.

Nehring, R.B. 1976. Aquatic insects as biological monitors of heavy metal pollution. Bull. of Environ. Contam. Toxicol. 15:147-154.

Patrick, R.; Reimer, C.W. 1966. The diatoms of the United States, exclusive of Alaska and Hawaii. Vol. 1: Fragilariaceae, Eunotiaciae, Achnanthaceae, Naviculaceae. Philadelphia: Acad. Natur. Sci. Monogr. 13,

Patrick. R.; Reimer, C.W. 1975. The diatoms of the United States, exclusive of Alaska and Hawaii. Vol. II. Part I. Entomoneidaceae, Cymbellaceae, Gomphonemaceae, Epithemiaceae. Philadelphia: Acad. Nat. Sci. Monogr. 22.

Peckarsky, B.L. 1979. 8iological interaction as determinants of distribution of benthic invertebrates within the substrate of stony streams. Limnol. Dceanogr. 24(1)59-68.

Pennak, R.W. 1953. Freshwater invertebrates of the United States. New York: Ronald Press Co.

Pennak, R.W. 1978. Freshwater invertebrates of the United States. New York: 2nd Edition. John Wiley and Sons.

Pflieger, W.L. 1975. The fishes of Missouri. Jefferson City: Missouri Department of Conservation. 343 pp.

Phillips, G.R.; Russo, R.C. 1978. Metal bioaccumulation in fishes and aquatic invertebrates: a literature review. Washington, D/C/. U.S. Environmental Protection Agency; EPA-6D0/3-78-103. 116 pp.

Pielow, E.C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13:131-144.

Prescott, G.W. 1962. Algae of the Western Great Lakes Area. Dubuque, Iowa: W.C. Brown.

Pryfogle, P.H.; Lowe, R.L. 1979. Sampling and interpretation of epilithic lotic diatom communities. Weitzel, R.L. ed. New York: American Society for Testing and Materials, Methods and measurement of periphyton communities: a review. ASTM STP 690.

Rabeni, C.F. and G.W. Minshall 1977. Factors affecting microdistribution of stream benthic insects. Oikos 29:33-43.

Roback, S.S. 1957. The immature tentipedids of the Philadelphia area. Philadelphia: Acad. Natur. Sci. Monogr. 9.

Rumburg, C.B.; Gery, B.H.; Butcher, K. 1978. Gunnison County stream water quality study. Oenver: U.S. Environmental Protection Agency, Water Oivision.

Saether, O.A. Undated. Key to known nearctic larvae of Procladius. (Mimeograph of unpublished material).

Saether, O.A. 1969. Some nearctic Ponominae, Diamesinae, and Orthocladiinae (Diptera: Chironomidae). Bull. Fish. Res. Bd. Canada 170.

Saether, O.A. 1971. Notes on general morphology and terminology of the Chironomidae (Oiptera). Can. Ent. 103:1237-1260.

Saether, O.A. 1976. Revision of Hydrobaenus, Trissocladius, Zalutschia, Paratrissocladius, and some related genera (Oiptera:Chironomidae). Bull. Fish. Res. Bd. Canada 195.

Saether, O.A. 1977. Taxonomic studies on Chironomidae:Nanocladius, Pseudochironomus, and the Harnischia complex. Bull. Fish. Res. Bd. Canada 196.

Sawyer, R.T. 1972. North American freshwater leeches, exclusive of the Priscicolidae, with a key to all species. Urbana, Illinois: Univ. of Illinois Press.

Sigler, W.F.; Miller, R.R. 1963. Fishes of Utah. Salt Lake City: Utah State Oepartment of Fish and Game. 203 pp.

Skuja, H. 1948. Taxonomie des Phytoplanktons einiger Seen in Uppland, Schweden. Symb. Bot. Upsal. Vol. IX.

Skuja, H. 1956. Taxonomische and biologische studien uber das phytoplankton schwedischer binnengewasser. Nova Acta Regiae Soc. Sci. Upsal. Ser. IV, 16(3):1-104.

Skuja, H. 1963. Grundzuge der algenflora and algenvegetation des fjeldgegenden um abisko. Nova Acta Regiae Soc. Upsal. Sci. Ser. IV, 18(3)1-344.

Smith, G.W. 1920. Phytoplankton of the inland lakes of Wisconsin. Wisc. Geol. and Nat. Hist. Surv. Bull. 57.

Smith, G.W. 1950. The freshwater algae of the United States. New York: McGraw Hill Co. Inc.

Solbe, J.F. de L.G.; Flook, V.A. 1975. Studies on the toxicity of zinc sulfate and of cadmium sulfate on stone loach Noemacheilus barbatulus (L.) in hard water. J. Fish Biol. 7:631-637.

Spehar, R.L. 1976. Cadmium and zinc toxicity to flat fish, Jordanella floridae. Jour. Fish Res. Bd. Can. 33:1939.

Sperber, C. 1948. A taxonomical study of the Naididae. Zool. Bidr. Upps. 28:1-296.

Sublette, J.E., Sublette, M.S. 1965. A catalogue of the Diptera of America north of Mexico. Family Chironimidae (Tendipedidae). U.S. Department of Agriculture, Handbook 276:1-1696.

Thurman, E.M; Runnells, D.D. 1978. Baseline study of the concentration of molybdenum in bottom sediments of major rivers in Colorado, U.S.A. J. Geochem. Explor.(in press).

Townes, H.K. 1945. The nearctic species of Tendipedini (Diptera, Tendipedidae, Chironomidae). Amer. Midl. Natur. 34: 207 p.

Townsend, C.R.; Hildrew, A.G. 1976. Field experiments on the drifting, colonization and continuous redistribution of stream benthos. J. of Anim. Ecol. 45:759.

U.S. Environmental Protection Agency 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. U.S. EPA (670/4-73-001).

U.S. Environmental Protection Agency 1979a. Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissues. U.S. EPA Environmental Monitoring and Support Laboratory.

U.S. Environmental Protection Agency 1979b. Methods for chemical analysis of water and wastes. Cincinnati: U.S. EPA. EPA/600/4-79-020.

U.S. Environmental Protection Agency. 1979c. EPA proposed guidelines establishing test procedures for analysis of pollutants. 44 FR 69464, Dec. 3, 1979.

U.S. Geological Survey 1977. Methods for collection and analysis of aquatic biological and microbiological samples. Washington, D.C.: U.S.G.S.; TW1-C4-8k5.

Usinger, R.L., editor. 1956. Aquatic insects of California. Berkeley: Univ. Cal. Press.

Ward, J.F. 1973. Molybdenum concentrations in tissues of rainbow trout (Salmo gairdneri) and kokanee salmon (Oncorhynchus nerka) from waters differing widely in molybdenum content. J. Fish. Res. Board Can. 30(6): 841-842.

Warnick, S.C.; Bell, H.L. 1969. Acute toxicity of some heavy metals to different species of aquatic insects. J. Wat. Poll. Cont. Fed. 41:280-284

Waters, T.F. 1962. Diurnal periodicity in the drift of stream invertebrates. Ecology 43:316-320.

Weed, C.E.; Rutschky, C.W., III 1972. Benthic macroinvertebrate community structure in a stream receiving acid mine drainage. Penn. Acad. of Science. Vol. 48. pg 41-47.

Weitzel, R.L., editor. 1979. Methods and measurement of periphyton communities: a review. New York: American Society for Testing and Materials; ASTM STP 690. 183 pp.

Weitzel, R.L.; Sanocki, S.L.; Holecek, H. 1979. Sample replication of periphyton collected from artificial substrates. Weitzel, R.L. Methods and measurements of periphyton communities: a review. New York: American Society for Testing and Materials. Weitzel, R.L. ed. ASTM STP 690.

Wiggins, G.B. 1977. Larvae of the North American caddisfly genera (Trichoptera). Univ. of Toronto Press.

Willin, T. 1963. Notes on swedish plankton algae. Nova hedwiga. Z. Kryptogamenkande 6:36-56.

Williams, D.D. 1980. Some relationships between stream benthos and substrate heterogeneity. Limnol. Oceanogr. 25(1) 166-172.

Williams, W.D. 1972. Freshwater isopods (Asellidae) of North America. U.S. Environmental Protection Agency. Biota of freshwater ecosystems. Washington, D.C.: U.S. EPA; Identification Manual No. 7.

Wiltzius, W.J. 1978. Some factors historically affecting the distribution and abundance of fishes in the Gunnison River. Ft. Collins. Colorado Division of Wildlife.

Winget, R.N.; Mangum, F.A. 1979. Biotic condition index: integrated biological, physical, and chemical stream management. U.S. Department of Agriculture Contract No. 40-84M8-8-524. 67 pp.

GLOSSARY OF TERMS

Alluvial - Earth, sand, gravel, or rock transported and deposited by flowing water.

Artificial substrate - A sampler made of glass, plexiglass, or other material placed in a body of water to collect periphyton or other small aquatic organisms.

Ash-free dry weight - The weight of a sample following combustion at 550°C for one hour (to oxidize the organic matter).

Attached algae - Microscopic and macroscopic aquatic plants growing on rocks, sediments, submerged vegetation, and sand.

Biomass - Mass of living matter, often expressed in weight of organic matter per unit area or volume.

Benthic invertebrates - Organisms without backbones that spend at least a portion of their life cycle on or in the substrate of a stream, river, or lake.

Boulder - Rocks greater than 30 cm (12 in) in diameter.

Condition factor - Comparative measure of the "plumpness" of a fish based on a ratio of length to weight.

Creel census - Survey of the number, species, and size of fish caught by fishermen.

Detritus - Decomposing plant and animal matter.

Deciduous - Trees that shed their leaves annually (willow, cottonwood).

Diversity - An index of the number of taxa and abundance of organisms in each taxa.

Electrofishing - A method of collecting fish by netting the fish after it has been momentarily disabled by an AC or DC electrical current.

Ephemeral - A drainage in which surface flow occurs only after a precipitation event or during snow melt. Little or no inflow of ground water is present.

Evenness - Statistical parameter expressing the observed diversity as a proportion of the maximum possible diversity.

Gravel - Rocks from .25 to 7.6 cm (0.1 to 3 in.) in diameter.

Heterotrophic - Organisms that must obtain their food from living or dead organic matter; consumers.

Intermittent - A stream that flows for only a portion of the year. Flow may be the result of surface runoff or ground water inflow.

Oligotrophic - Waters with a low supply of nutrients such as nitrogen and phosphorus.

Periphyton - All aquatic organisms that grow on submerged substrates including attached algae, bacteria, protozoans, and small invertebrates.

Protozoa - Microscopic unicellular animals in the Phylum Protozoa.

Productivity - The rate of producing organic matter by biological activity per unit area or volume (e.g., grams of organic matter per square centimeter per day).

Riffle - A shallow, fast-flowing portion of a stream or river where the surface of the water is broken by ripples or waves.

Riparian - Living or located on the banks of a stream, river, or lake.

Rubble - Rocks from 7.6 to 28 cm (3 to 11 in.) in diameter.

Substrate - The bottom or bed of a stream, river, or lake.

Sediments - Soil, sand, and/or rock covering the bottom of a stream, river, or lake.

Taxa - A taxonomic group or entity.