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THE EFFECTS OF IRON ON THE MACROINVERTEBRATES OF SODA BUTTE CREEK

by

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in

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Approved:

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ABSTRACT

The response of the macroinvertebrate community of Soda Butte Creek to an effluent from a mill tailings was studied from June, 1972 to June, 1973. Physical and chemical parameters were measured and numbers, diversity, and ordinal composition of macroinvertebrates from artificial substrate samplers (Hester-Dendy plates) were obtained at one station upstream and four stations downstream from the effluent. The effluent increased the sulfate and iron concentrations considerably and decreased the pH slightly in Soda Butte Creek. The increased total iron concentration and heavy deposition of ferric hydroxide caused a drastic reduction in numbers and diversity of macroinvertebrates and an ordinal shift from Ephemeroptera and Plecoptera to Diptera immediately below the tailings. Partial recovery and complete recovery of the macroinvertebrate community occurred 2.4 and 15.1 kilometers, respectively, downstream from the tailings.

INTRODUCTION

Mining is an important segment of the economy in Montana. It provided the third largest source of income to the state in 1965 (Montana Department of Planning and Economic Development, 1968), with the mining of heavy metals accounting for approximately one-half of this (Montana Department of Planning and Economic Development, 1970). The mining of metals and the operation of mills to process the metallic ore often have undesirable side effects on the surrounding surface waters. A by-product of the milling of metallic ore from mining operations is the formation of tailings piles. Water percolating through the piled tailings often acquires chemical characteristics that pollute nearby waters.

Short-term, superficial surveys have indicated drainage from the McLaren Mill tailings near Cooke City has adversely affected Soda Butte Creek. In 1967 Mills and Sharpe (1968) found smaller numbers of aquatic insects in the stream immediately below the tailings than above it or farther downstream. In 1969, the tailings were leveled, shaped, covered with topsoil and planted with grass, and Soda Butte Creek was diverted around them (Hill, 1970 and Duff, 1972). However, Hill (1970), sampling within a year of the reclamation, found the stream had about the same chemical qualities as it had prior to reclamation efforts. Duff (1972) also found Soda Butte Creek had been degraded by seepage from the tailings and reported a progressive increase of benthic

DESCRIPTION OF STUDY AREA

Soda Butte Creek is located in southcentral Montana and the northeast portion of Yellowstone National Park (Figure 1). U. S. G. S. maps and U. S. Forest Service aerial photographs indicate Soda Butte Creek originates about 1.6 kilometers east of Cooke City, Montana and flows in a southwest direction approximately 40.2 stream kilometers before emptying into the Lamar River. Approximately 28 kilometers of the stream are within Yellowstone National Park.

Soda Butte Creek drains an area of approximately 260 square kilometers. The predominate rock types of the drainage are granite and breccia with some outcrops of limestone and basalt dikes present (U. S. Department of the Interior, 1930). Major tributaries are Woody, Amphitheater, and Pebble Creeks. The stream originates at an elevation of about 2,365 meters above mean sea level and has an average drop of 9.1 meters per stream kilometer. Flows in Soda Butte Creek were up to twenty times greater in some areas during the spring runoff than during the fall (Table 1).

Five sampling stations were established on the stream (Figure 1). Station 1 was approximately 151 meters above the area of the reclaimed tailings. Station 2 was 21 meters below the visual point of entry of seepage from the tailings area. Station 3 was 2.4 kilometers below the tailings area and below the entrance of Woody Creek. Station 4 was approximately 15.1 kilometers below the tailings and just inside

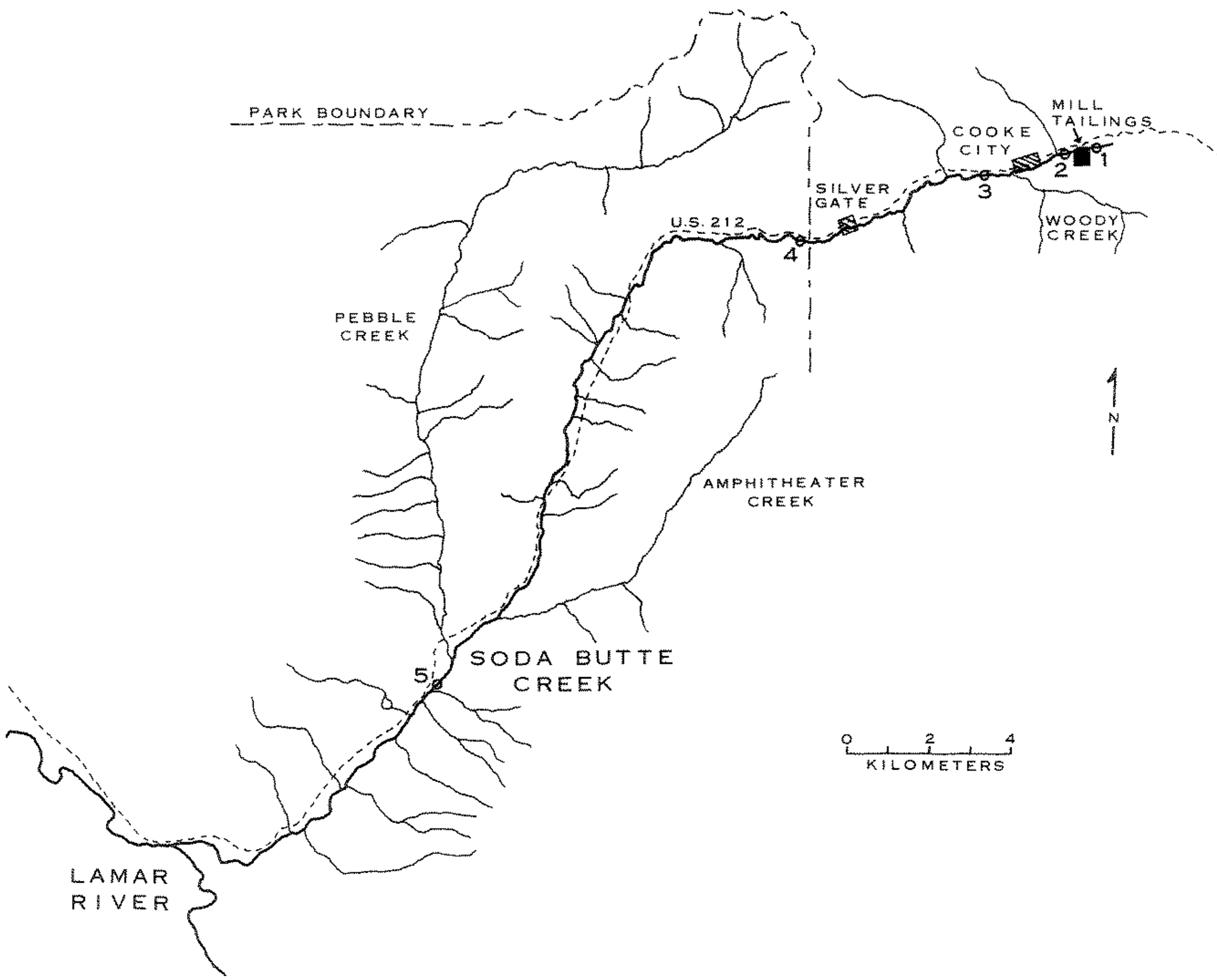

Figure 1. Map of Soda Butte Creek showing location of the sampling stations and the Yellowstone National Park boundary.

Table 1. Flows (m^3/sec) of Soda Butte Creek.

	Date					
	1972					1973
Station	June 24	July 22	Aug. 18 & 19	Sept. 18	Nov. 11	June 2
1	1.33	0.40	0.14	0.10	0.07	0.54
2	1.99	0.37	0.12	0.08	0.09	1.01
3	7.55	1.80	0.49	0.62	0.29	3.95
4		2.62	1.00	1.06	0.48	6.55
5			1.53	2.39	1.80	

the boundary of Yellowstone National Park. Station 5 was approximately 32 kilometers below the tailings and below the entrance of Pebble Creek. Sampling stations were located in riffle areas where bottom materials consisted primarily of gravel, with some boulders and rubble occurring at Stations 1 and 2. The substrate at Station 2 was covered by large deposits of a red material which is often called "ferric hydroxide" but which Stumm and Morgan (1970) indicate is more likely a poorly crystallized FeOOH. However, since it is commonly called ferric hydroxide this terminology will be used in this paper.

METHODS

Benthic macroinvertebrates were collected using Hester-Dendy samplers. These multi-plate, artificial substrate type samplers have a surface area of 930 square centimeters each and are described in "Standard Methods" (A. P. H. A., 1971). Three samplers were placed near the substrate with their plates parallel to the substrate at each station. Benthos samples were collected from all five stations at about monthly intervals from July 22, 1972 to November 11, 1972. Weather and stream conditions precluded collecting benthos from December, 1972 through May, 1973, and samples from only two stations were obtained on June 2, 1973. Samples were preserved in 10% formalin in the field and taken to Montana State University where organisms were separated from debris and identified to the lowest taxon practical using keys by Usinger (1971) and Ward and Whipple (1959).

The diversity parameters of the composite monthly benthos sample from each station were calculated using formulae for diversity ($\overline{H}$) and maximum community diversity (H_{max}) from Pielou (1969) and minimum community diversity (H_{min}) and redundancy (R) from Mathis and Dorris (1968). Data were analyzed at the Montana State University Computer Center utilizing a computer program written by personnel of the Math Department, M. S. U.

Selected chemical-physical parameters were sampled at each station on each date invertebrates were collected and also, during a portion of the study, at more frequent intervals. Stream temperature, pH, and dissolved oxygen were measured in the field, and water samples were collected from the stations at two week intervals from May 27, 1972 through October 17, 1972 and at monthly intervals from October 17, through June 2, 1973 as weather and stream conditions permitted. Water samples were taken to Montana State University where chemical analyses were conducted on them by Mr. Frank Pickett.

Six measurements of the flow at most stations were made between June 24, 1972 and June 2, 1973. Five of the six were made on dates the benthos were sampled. All flows were calculated using velocity measurements made with a Gurley current meter type AA.

To estimate the rate of deposition of iron a single 232 square centimeter plexiglass plate was placed parallel to and near the stream bottom at each station on August 31, 1972. These plates were collected on September 30, 1972 and the material deposited on them removed and subjected to a standard iron analysis using Hach reagents. A 61 meter section of stream at each sampling station was electrofished on September 8, 1972 to determine the presence or absence of fish. All fish collected were identified to species and measured. Cage bioassays of 48 hour duration were initiated on October 3, 1972 at Stations 1, 2, and 4 with fingerling cutthroat trout taken from the Yellowstone River near Yellowstone Lake.

RESULTS

Benthos

The numbers of benthic macroinvertebrates collected from three samples at each station are presented by sampling date and taxon in Table 2. A total of 6,329 invertebrates were collected during the study, of which 6,254 or approximately 99% were aquatic insects.

The total number of insects collected from each station differed considerably. Aquatic insects were collected from all five sampling stations on four dates (Table 2). Station 4 produced 38% of the total number of insects collected on these dates. Stations 5, 3, and 1 accounted for 27, 21, and 14%, respectively, of the total. Station 2, situated 21 meters below the visual point of entry of the pollutant, yielded less than 0.01% of the total number of aquatic insects collected on these dates.

Aquatic insects belonging to four orders were collected during the study. Ephemeroptera comprised approximately 40% of the total number of insects collected, Plecoptera and Diptera accounted for 29 and 26%, respectively, and Trichoptera contributed only 5% of the total. This ordinal composition is similar to that found by Mills and Sharpe (1968). They reported Ephemeroptera made up about 49%, Diptera 30%, Plecoptera 13%, and Trichoptera 8% of the total number of aquatic insects they collected on Soda Butte Creek.

Table 2. Numbers and kinds of benthic macroinvertebrates obtained from three 930 square centimeter samples taken monthly at each station on Soda Butte Creek.

	1972													
	July 22				August 18 & 19					September 19				
Station	1	2	3	4	1	2	3	4	5	1	2	3	4	5
Taxa														
Ephemeroptera														
Baetis	11	2	44	5	6	–	8	7	35	2	–	13	68	17
Centroptilum	10	–	1	2	3	1	10	–	–	–	–	–	–	–
Ephemerella	3	–	7	53	9	–	–	33	53	3	–	1	4	55
Cinygmula	23	–	37	28	24	–	6	4	5	27	–	58	235	3
Epeorus	–	–	4	2	–	–	–	4	62	–	–	10	6	29
Rithrogena	–	–	1	–	–	–	–	–	–	1	–	1	5	10
Ameletus	–	–	–	–	–	–	–	–	–	1	–	–	–	–
Plecoptera														
Alloperla	4	–	1	5	–	–	1	1	1	2	–	2	–	–
Brachyptera	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nemoura	41	–	58	180	87	–	28	142	21	81	–	103	318	70
Peltoperla	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Arcynopteryx	4	–	–	–	–	–	–	–	–	1	–	1	2	11
Isoperla	2	–	3	1	3	–	–	–	–	1	–	–	–	–
Pteronarcella	–	–	–	–	–	–	–	–	14	–	–	–	–	–
Trichoptera														
Brachycentrus	–	–	–	–	–	–	1	–	–	–	–	–	–	2
Glossosoma	–	–	–	2	–	–	–	–	–	–	–	–	1	2
Arctopsyche	–	–	–	–	–	–	1	–	2	–	–	–	62	4
Parapsyche	–	–	7	4	1	–	–	6	18	–	–	2	3	31
Drusinus	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Neothremma	4	–	–	–	2	–	–	–	–	15	–	–	–	–
Radema	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhyacophila	5	–	11	26	4	–	2	29	3	1	–	3	29	2

Table 2. Continued.

	1972										1973	
	October 17					November 11					June 2	
Station	1	2	3	4	5	1	2	3	4	5	1	2
Taxa												
Plecoptera (continued)												
Arcynopteryx	1	–	–	9	6	3	–	–	2	6	1	–
Isoperla	1	–	1	2	–	–	–	1	–	–	–	
Pteronarcella	–	–	–	–	–	–	–	–	–	6	–	–
Trichoptera												
Brachycentrus	–	–	–	–	1	–	–	–	–	–	–	–
Glossosoma	–	–	–	8	–	–	–	–	5	1	1	–
Arctopsyche	1	–	–	3	–	1	–	–	3	–	1	–
Parapsyche	–	–	–	–	6	–	–	2	–	1	–	–
Drusinus	–	–	–	–	–	–	–	1	–	–	–	–
Neothremma	4	–	–	–	–	–	–	–	–	–	1	–
Radema	–	–	–	2	–	–	–	1	–	1	–	–
Rhyacophila	1	–	2	7	1	2	–	–	2	–	1	2
Diptera												
Palpomyia	–	–	–	–	–	–	–	–	–	–	–	–
Simulium	–	–	–	–	193	–	–	–	–	11	2	–
Tendipedidae	112	3	55	15	160	7	–	69	26	68	5	5
Antocha	–	–	–	–	–	–	–	–	–	–	–	–
Atherix	–	–	–	–	–	–	–	–	–	–	–	–
Turbellaria	8	–	–	1	–	1	–	–	–	–	–	–
Total	255	3	240	554	560	125	–	361	329	234	169	9

The ordinal composition at individual stations is given in Table 3. At Station 1 four orders of aquatic insects were present in a fairly diverse community not overly dominated by any one order. The trichopteran *Neothremma* sp. was collected only at this station.

Table 3. Ordinal composition (in percent) of aquatic insects collected at sampling stations on Soda Butte Creek.

Station	1	2	3	4	5
Order					
Ephemeroptera	38	9	41	43	36
Plecoptera	38	0	20	39	16
Trichoptera	5	3	2	8	5
Diptera	19	88	37	10	43

Station 2, established 595 meters downstream from Station 1 and below the tailings, had 76% fewer ephemeropterans, no plecopterans, and 463% more dipterans than Station 1. Roback and Richardson (1969) also found Ephemeroptera and Plecoptera were reduced by the products of acid mine drainage. Of the five Ephemeroptera collected from Station 2 during the study, three were *Baetis* (Table 2), a genus apparently more resistant to acid mine pollution than most other mayflies (Roback and Richardson, 1969). With the exception of one *Simulium*, all 52 Diptera collected at Station 2 were Tendipedidae (Table 2), a family Roback and Richardson (1969) and Koryak *et al.* (1972) found to be tolerant to zones of ferric hydroxide deposition.

A partial recovery of the insect community is indicated at Station 3. Ephemeropterans increased 456% and dipterans decreased 58% from the levels found at Station 2. Plecopterans were present at Station 3, but were not as abundant as they were at Station 1. Station 4 had an ordinal composition similar to that at Station 1 and showed no discernible effects of pollution on the aquatic insects. Station 5 had a lower percent of plecopterans and ephemeropterans and a higher percent of dipterans than Station 4. Tendipedidae comprised 98% of the dipterans collected at Station 1 through 4, but only 47% of the dipterans collected at Station 5 (Table 2). These faunal changes probably reflect the different physical parameters found at this station, such as higher water temperatures, greater flows, less shading, and decreased gradient, rather than the effects of a pollutant.

Seventy-five or approximately 1% of the benthic macroinvertebrates collected during the study were turbellarians. Of these about 87% were obtained during July, August, and September. Approximately 80% of them were collected at Station 1, 19% at Station 4, and 1% at Station 3. No turbellarians were collected at Stations 2 or 5.

Diversity Parameters

The total number of individuals (N), number of taxa (S), diversity ($\overline{H}$), and redundancy (R) of macroinvertebrates collected from Soda Butte Creek are presented by sampling date and station in Table 4. Significantly fewer organisms were collected from Station 2 than from

Table 4. Total number of invertebrates collected (N), number of taxa (S) present, diversity ($\overline{H}$), and redundancy (R) of invertebrate samples from Soda Butte Creek.

	7/22/72				8/19/72				9/19/72			
Station	N	S	$\overline{H}$	R	N	S	$\overline{H}$	R	N	S	$\overline{H}$	R
1	130	13	2.9	0.21	184	12	2.3	0.36	174	13	2.2	0.42
2	42	2	0.2	0.87	5	3	0.9	1.00	0	0	---	----
3	345	14	2.3	0.40	130	9	1.8	0.46	364	11	1.9	0.46
4	368	13	2.2	0.41	307	10	2.1	0.36	802	14	2.3	0.40
5	---	--	---	----	258	12	2.8	0.20	381	15	2.9	0.26

	10/17/72				11/11/72				6/2/73			
Station	N	S	$\overline{H}$	R	N	S	$\overline{H}$	R	N	S	$\overline{H}$	R
1	255	12	2.0	0.48	125	10	1.9	0.45	169	13	2.0	0.50
2	3	1	0.0	*	0	0	---	----	9	4	1.2	0.59
3	240	10	2.2	0.36	361	12	1.5	0.62	---	--	---	----
4	554	15	2.2	0.46	329	10	2.3	0.32	---	--	---	----
5	560	12	2.5	0.31	234	14	2.8	0.26	---	--	---	----

*Undefined

Stations 1, 3, 4, and 5 on every sampling date. Total number of organisms collected from Station 2 per sampling date varied from 0 to 42, while the numbers at Stations 1, 3, 4, and 5 ranged from 125 to 802 organisms. Invertebrates per collection at Station 1 averaged 173 while invertebrates per collection at Station 2 averaged only 10. Stations 3, 4, and 5 averaged 288, 472, and 358 invertebrates per collection, respectively. On two of the six sampling dates no organisms were collected from Station 2. However, organisms were collected from Stations 1, 3, 4, and 5 on all sampling dates.

On all sampling dates, fewer taxa were present at Station 2 than at Stations 1, 3, 4, and 5. The numbers of taxa present at Station 2 varied from 0 to 4, while the numbers at Stations 1, 3, 4, and 5 ranged from 9 to 15.

On all sampling dates when macroinvertebrates were present at Station 2, diversity decreased considerably from Station 1 to 2. On the four dates when all stations were sampled diversity increased steadily from Station 3 through 5. Diversity varied from 0 to 1.2 at Station 2 and from 1.5 to 2.9 at Stations 1, 3, 4, and 5. At Station 1 diversity was highest during July (2.9) and declined steadily to a low of 1.9 in November. No consistent seasonal trend appeared to exist at Stations 2, 3, 4, or 5.

The redundancy figure theoretically varies from 0 to 1 with a value of 0 indicating that the organisms collected are distributed evenly among the taxa present. On no occasion was redundancy greater at Station 1 than Station 2 and, on three of the four dates all stations were sampled, redundancy steadily decreased downstream from Station 2 through Station 5. Redundancy varied from 0.59 to 1.00 at Station 2 and from 0.20 to 0.62 at Stations 1, 3. 4, and 5. Redundancy was lowest at Station 1 in July (0.21) and increased steadily to a high of 0.50 in early June. No seasonal trend in redundancy was apparent at Stations 2, 3, 4, or 5.

Chemical-Physical

The determinations of the physical-chemical factors measured in the field, water temperature, pH, and dissolved oxygen, are listed in Table 5. Water temperatures varied from a low of 0.0° C in November, 1972, and March, 1973, to a high of 13.7° C on August 5, 1972. Temperatures increased in a downstream direction from May through October, 1972, and in May and June, 1973. In November, 1972, and March, 1973, temperatures were lower at Stations 3 and 4 than at stations above or below them, perhaps indicating a different pattern during these months. Recorded temperatures at Station 4 were more extreme than those at Stations 1, 2, and 3. Since the invertebrate community at Station 4 was similar to that of Station 1, it appears temperature did not cause the faunal changes seen at Stations 2 and 3.

The pH values ranged from 6.95 to 8.85. Differences in pH between adjacent stations did not exceed 0.93 units on any sampling date and

Table 5. The temperature (T) in ° C, pH, and dissolved oxygen (DO), total iron (Fe), and sulfate (SO_4) concentrations in parts per million of water samples taken from Soda Butte Creek.

Station	5/27/72 T	pH	DO	Fe	SO_4	6/9/72 T	pH	DO	Fe	SO_4	6/24/72 T	pH	DO	Fe	SO_4
1	3.1	8.84	10.0	0.24	--	2.0	8.30	9.3	0.70	6.0	3.4	8.17	--	0.23	6.5
2	3.5	8.08	10.0	3.03	--	2.2	8.09	9.1	0.80	11.4	3.9	8.20	--	0.68	14.0
3	2.8	8.28	10.3	2.12	--	2.3	8.22	9.1	1.16	2.0	5.1	8.27	--	0.60	4.0
4	5.9	8.60	10.2	2.02	--	3.4	8.19	9.1	2.44	2.0	5.0	8.18	--	1.00	3.8
5	7.3	8.85	10.4	1.37	--	6.2	8.44	9.2	4.88	4.0	6.6	8.48	--	1.26	3.5
	7/8 & 9/72					7/21 & 22/72					8/4 & 5/72				
1	5.2	8.34	8.3	0.16	6.0	4.5	8.40	9.9	0.08	5.5	4.8	8.64	9.7	0.07	5.4
2	6.5	7.98	8.4	0.90	18.8	6.7	7.86	9.2	2.32	35.0	6.8	8.05	8.8	3.30	57.6
3	8.7	8.07	8.6	0.50	4.8	8.8	8.22	9.0	0.79	7.3	9.0	8.24	9.2	1.24	9.0
4	9.5	8.13	8.6	0.45	3.8	9.1	8.39	9.0	0.59	6.3	11.3	8.66	9.0	0.60	7.0
5	10.1	8.39	8.3	0.78	3.5	10.0	8.45	8.8	0.49	4.8	13.7	8.49	8.4	0.40	5.5
	8/18 & 19/72					8/31/72					9/18 & 19/72				
1	6.0	8.47	9.6	0.07	6.8	5.0	8.40	9.6	0.11	5.9	5.0	8.24	10.2	0.16	8.4
2	6.0	7.61	8.7	4.22	60.0	6.7	7.71	8.7	5.86	70.0	5.9	7.69	8.8	8.64	68.0
3	7.9	7.61	9.4	1.24	10.0	7.1	8.18	9.8	1.30	10.0	5.9	8.08	10.0	2.21	13.4
4	8.6	8.17	9.2	0.85	9.0	9.0	9.37	9.5	1.09	10.6	6.8	----	10.1	1.70	12.2
5	10.5	8.29	9.0	0.05	11.8	13.0	8.43	9.2	1.28	7.9	8.6	----	9.9	0.37	10.5

Table 2. Continued.

	Date														
	9/29 & 30/72					10/17/72					11/11/72				
Station	T	pH	DO	Fe	SO_4	T	pH	DO	Fe	SO_4	T	pH	DO	Fe	SO_4
1	3.5	8.49	10.5	0.03	7.0	2.8	8.06	10.2	0.15	7.0	1.3	8.42	10.5	0.08	6.8
2	5.0	7.76	9.4	7.10	58.0	4.0	7.78	9.0	6.36	59.0	1.3	7.92	9.0	8.54	66.2
3	3.0	8.05	10.9	1.69	11.0	4.0	7.98	10.8	1.49	11.0	0.0	8.09	10.8	2.06	15.5
4	6.0	8.47	10.3	0.96	11.2	4.1	8.09	10.4	0.86	9.6	0.0	8.44	11.0	0.83	12.2
5	7.5	8.35	10.0	0.33	8.3	6.1	8.13	9.8	0.32	6.8	1.0	8.45	10.8	0.81	8.0
	1/20/73					3/22/73					5/5/73				
1	0.5	7.88	----	0.12	6.0	1.3	8.09	10.8	0.12	8.0	2.0	8.53	10.6	0.08	5.0
2	0.5	6.95	----	13.80	112.0	1.2	7.62	6.8	21.45	191.0	3.0	7.88	6.8	21.45	182.0
3	---	----	----	----	----	0.0	----	11.0	2.52	12.5	1.3	8.47	10.8	2.24	8.0
4	---	----	----	----	----	0.0	----	11.2	0.16	11.0	3.9	8.48	10.2	0.85	10.0
5	---	----	----	----	----	2.0	----	11.2	0.12	6.5	8.0	8.56	9.2	0.22	7.0
	5/20/73					6/2/73									
1	1.6	7.87	10.6	0.27	6.0	2.7	8.23	10.2	0.28	6.0					
2	1.8	7.56	10.3	2.40	12.0	3.0	7.85	9.8	3.04	16.0					
3	1.1	7.58	10.8	5.05	4.5	3.5	7.90	10.2	2.00	6.0					
4	3.1	7.95	10.4	3.18	4.5	4.3	7.95	10.2	1.34	4.5					
5	5.0	7.93	10.0	1.55	2.5	5.7	8.16	10.2	0.71	2.5					

did not cause the faunal changes seen between stations. However, on nine of the 14 dates that the pH of all five stations was measured, a general downstream pattern of progressively increasing pH values was apparent. The pH was higher at Station 1 than at Station 2 on 15 of the 16 dates pH was sampled. On the one remaining date, flow from spring runoff was at a maximum (Table 1) and erased the usual pH difference between Stations 1 and 2. On 12 of the 16 dates, Stations 3 through 5 had higher pH values than Station 2.

Dissolved oxygen concentrations ranged from 6.8 to 11.2 ppm and were at or near air saturation values on all but two sampling dates. On March 22 and May 5, 1973, dissolved oxygen concentrations of approximately 70% of the air saturation values were recorded at Station 2.

The results of the chemical analyses conducted by Mr. Frank Pickett (unpublished data) on water samples taken throughout the study period are presented in the Appendix. A review of these analyses showed a sharp increase in sulfate and total iron concentrations at Station 2 over the levels found at Station 1 and only slight changes in other chemical parameters. These potential chemical pollutants are therefore included in Table 5.

Sulfate levels at Stations 1, 3, 4, and 5 ranged between 2.0 and 15.5 ppm. Concentrations at Station 2 ranged between 11.4 and 70.0 ppm from June through November, 1972, and in late May and early June, 1973, and from 112.0 to 191.0 ppm from January to early May, 1973. Little has apparently been published about the toxicity of sulfate ions to macroinvertebrates. However, Roback and Richardson (1969) found a diverse and well balanced aquatic insect community established in areas with sulfate levels comparable to or higher than those recorded during this study. Sulfate was not considered to be influential in the reduction in the fauna seen at Station 2.

The concentration of total iron measured in water samples ranged from 0.03 to 21.45 ppm (Table 5) with the concentration present varying between stations and with conditions of stream flow. The lowest concentrations of total iron occurred at Station 1. Concentrations varied from 0.03 ppm during September of 1972 to 0.70 ppm during June of 1972 and appeared to have a direct relationship with flow. The widest range of concentrations occurred at Station 2 where total iron was approximately 0.70 ppm during June, 1972, then increased steadily to the highest level recorded, 21.45 ppm, during May, 1973, in an apparent inverse relationship with flow. Concentrations at Stations 3 through 5 ranged from 0.05 to 5.05 ppm. On all 17 sampling dates, the concentration of total iron was higher below the tailings than at Station 1. On 13 of the 17 dates concentrations of total iron generally decreased downstream from Station 2. However, on the two sampling periods in June of 1972 and the one on May 20, 1973, higher concentrations were recorded at stations downstream from Station 2. This reversal of pattern is probably the result of the increased flows (Table 1) during these time periods resuspending ferric hydroxide deposited below Station 2 and carrying it downstream. Although little information is apparently available on the toxicity of total iron to macroinvertebrates, Warnick and Bell (1969) have shown concentrations below those found at Stations 2 and 3 to be toxic to some aquatic insects in static bioassay experiments. Since other physical and chemical parameters measured do not explain the reduction in fauna seen at Stations 2 and 3, total iron was considered to be the primary pollutant.

Totals of 0.24, 46.50, 1.16, 0.37, and 0.03 g/m^2 of iron, primarily as ferric hydroxide, were deposited on plates located at Stations 1 through 5, respectively, from August 31 to September 30, 1972. Stations 2 and 3 received the greatest deposition of iron and are also the stations with the lowest diversity of macroinvertebrates. On September 8, 1972, electrofishing yielded no fish at Stations 1 and 2. Three cutthroat trout *(Salmo clarki)*, each over 19 centimeters in total length, were collected at both Stations 3 and 4; two cutthroat, one 15.6 centimeters and one 7.2 centimeters in total length, were taken at Station 5. In a 48 hour field bioassay test initiated on October 3, 1972, cutthroat trout ranging in length from 4.5 to 6.0 centimeters in total length suffered a 14, 80, and 11% mortality at Stations 1, 2, and 4, respectively. Water samples (Table 5) taken about four days prior to and 12 days after the bioassays indicated the total iron concentration was approximately 6.5 ppm at Station 2 and less than 1 ppm at Stations 1 and 4 during the test period. Total iron concentrations of 6.5 ppm or greater existed at Station 2 approximately nine months of the year.

DISCUSSION

The pollutional effect of the effluent from the McLaren Mill tailings extended at least 2.4 kilometers and not as far as 15 kilometers downstream during stable water conditions on Soda Butte Creek. The macroinvertebrate community at Station 2 immediately below the tailings exhibited a low diversity, contained very low numbers, and was dominated by tendipedids. This community structure is similar to those found by Roback and Richardson (1969) and Koryak *et al.* (1972) in areas having ferric hydroxide deposition and pH levels below 3.8. Since acidic pH levels did not occur in this study, it appears the deposition of ferric hydroxide alone is sufficient to cause a community structure similar to the one they reported.

A partial recovery of the macroinvertebrate community 2.4 kilometers below the tailings was probably due to the dilution of the stream by the entrance of Woody Creek, which contributes about 70% of the flow (Duff, 1972) at this location. The more balanced ordinal composition and increased diversity of the invertebrates at this site indicate improved conditions over those found immediately below the tailings, but still reflected the continued pollutional effect of the effluent. The increase in numbers of aquatic insects at this station to levels comparable to above the tailings is probably due to a low level of iron deposition and the indirect influence of a tenfold increase in orthophosphate levels (Appendix).

No effect of the pollution from the tailings on the macroinvertebrates of Stations 4 and 5 was observed during stable water conditions. The invertebrates at Station 4 exhibited a diversity and ordinal composition similar to that found above the tailings. At Station 5 decreased numbers of macroinvertebrates and a faunal change as exhibited by the Diptera appear to be the result of the altered physical parameters rather than the influence of pollution from the mill tailings.

The effluent from the tailings may, however, affect the fauna of Stations 4 and 5 during spring runoff. During high flows the concentration of total iron at Stations 4 and 5 reached levels of 2 ppm or higher and exceeded those recorded at Station 3 during stable low flow conditions. These concentrations may have persisted at Stations 4 and 5 for up to one month, but probably only lasted about one week. Although these levels did not appear to adversely effect the macroinvertebrate community, they probably did influence the fish present because they exceeded the 1 to 2 ppm total iron the U. S. Environmental Protection Agency (1971) has cited as being lethal to trout. Warnick and Bell (1969) indicate fish seem to be more sensitive than aquatic insects to pollution from heavy metals. These factors may explain the low numbers of trout found by electrofishing at Stations 4 and 5.

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Soda Butte Creek
Alkalinity (as ppm $CaCO_3$)

Date	Station 1	2	3	4	5
5/27/72	82.5	67.5	52.5	55.0	65.0
6/9	56.5	52.0	37.0	40.5	53.5
6/24	69.5	58.5	36.0	41.0	58.0
7/8	97.5	72.0	40.0	49.5	56.0
7/21	99.0	88.0	49.5	55.0	75.0
8/4	106.5	99.0	50.5	57.5	82.5
8/18	113.5	105.5	50.0	65.0	99.0
8/31	115.5	114.5	55.5	75.0	105.5
9/18	112.0	110.5	47.0	60.0	93.5
9/29	105.0	104.5	51.0	69.0	90.5
10/17	113.5	105.5	61.0	68.0	95.0
11/11	111.0	108.5	68.5	82.5	104.5
1/20/73	113.5	108.0	---	---	---
3/22	113.0	121.5	77.5	104.5	120.0
5/5	111.5	128.0	70.1	95.1	107.8
5/20	76.5	62.5	36.5	38.8	47.4
6/2	68.8	58.1	42.5	45.6	55.3

Soda Butte Creek
Total Hardness (as ppm $CaCO_3$)

Date	Station 1	2	3	4	5
5/27/72	92.0	105.0	59.0	60.0	63.0
6/9	62.0	60.0	39.0	41.0	71.0
6/24	79.0	80.0	26.0	41.0	54.0
7/8	99.0	87.0	39.0	42.0	53.0
7/21	44.4	170.0	49.0	54.6	72.0
8/4	114.0	140.0	49.0	57.6	79.4
8/18	117.0	163.0	49.0	66.0	90.0
8/31	115.6	165.6	55.2	73.8	96.8
9/18	116.0	166.6	44.2	57.8	91.8
9/29	121.4	169.2	56.8	74.6	98.4
10/17	114.4	155.8	58.2	68.0	90.0
11/11	114.8	169.0	73.8	86.4	105.8
1/20/73	116.4	204.4	---	---	---
3/22	---	---	---	---	---
5/5	120.4	119.6	71.8	104.2	114.0
5/20	87.8	80.0	38.0	38.4	48.6
6/2	76.4	81.0	47.0	47.0	57.0

Soda Butte Creek
Sulfate (mg/l as $SO_4^{=}$)

Date	Station 1	2	3	4	5
5/27/72	---	---	---	---	---
6/9	6.0	11.4	2.0	2.0	4.0
6/24	6.5	14.0	4.0	3.8	3.5
7/8	6.0	18.8	4.8	3.8	3.5
7/21	5.5	35.0	7.3	6.3	4.8
8/4	5.4	57.6	9.0	7.0	5.5
8/18	6.8	60.0	10.0	9.0	11.8
8/31	5.9	70.0	10.0	10.6	7.9
9/18	8.4	68.0	13.4	12.2	10.5
9/29	7.0	58.0	11.0	11.2	8.3
10/17	7.0	59.0	11.0	9.6	6.8
11/11	6.8	66.2	15.5	12.2	8.0
1/20/73	6.0	112.0	---	---	---
3/22	8.0	191.0	12.5	11.0	6.5
5/5	5.0	182.0	8.0	10.0	7.0
5/20	6.0	12.0	4.5	4.5	2.5
6/2	6.0	16.0	6.0	4.5	2.5

Soda Butte Creek
Orthophosphate (as mg/l $PO_4^{\equiv}$-P)

Date	Station 1	2	3	4	5
5/27/72	-----	-----	-----	-----	-----
6/9	0.001	0.004	0.026	0.028	0.033
6/24	-----	-----	-----	-----	-----
7/8	0.004	0.002	0.038	0.037	0.038
7/21	0.000	0.000	0.035	0.035	0.035
8/4	0.005	0.005	0.042	0.040	0.040
8/18	0.003	0.003	0.038	0.038	0.038
8/31	0.002	0.004	0.044	0.024	0.023
9/18	0.008	0.008	0.045	0.058	0.044
9/29	0.003	0.001	0.027	0.038	0.033
10/17	0.000	0.000	0.020	0.029	0.018
11/11	0.000	0.000	0.020	0.027	0.035
1/20/73	0.004	0.005	-----	-----	-----
3/22	0.001	0.001	0.034	0.030	0.035
5/5	0.013	0.000	0.036	0.025	0.032
5/20	0.003	0.001	0.022	0.032	0.032
6/2	0.000	0.000	0.061	0.024	0.025

Soda Butte Creek
Total Iron (mg/l)

Date	Station 1	2	3	4	5
5/27/72	0.24	3.03	2.12	2.02	1.37
6/9	0.70	0.80	1.16	2.44	4.88
6/24	0.23	0.68	0.60	1.00	1.26
7/8	0.16	0.90	0.50	0.45	0.78
7/21	0.08	2.32	0.79	0.59	0.49
8/4	0.07	3.30	1.24	0.60	0.40
8/18	0.07	4.22	1.24	0.85	0.05
8/31	0.11	5.86	1.30	1.09	1.28
9/18	0.16	8.64	2.21	1.70	0.37
9/29	0.03	7.10	1.69	0.96	0.33
10/17	0.15	6.36	1.49	0.86	0.32
11/11	0.08	8.54	2.06	0.83	0.81
1/20/73	0.12	13.80	---	---	---
3/22	0.12	21.45	2.52	0.16	0.12
5/5	0.08	21.45	2.24	0.85	0.22
5/20	0.27	2.40	5.05	3.18	1.55
6/2	0.28	3.04	2.00	1.34	0.71

Soda Butte Creek
Copper (mg/l)

Date	Station 1	2	3	4	5
5/27/72	T	T	T	0.00	0.00
6/9	T	0.04	0.04	0.05	0.05
6/24	0.04	T	T	T	0.04
7/8	0.00	0.04	0.00	0.00	T
7/21	0.00	T	0.00	0.05	0.00
8/4	0.00	0.04	T	0.00	T
8/18	0.00	T	0.00	0.00	0.00
8/31	0.00	0.00	T	0.04	T
9/18	0.00	0.00	0.00	0.00	0.00
9/29	0.04	0.07	0.00	0.00	0.00
10/17	0.10	T	0.00	0.00	0.00
11/11	0.05	0.04	0.00	0.00	0.04
1/20/73	0.00	0.00	---	---	---
3/22	0.00	0.00	0.00	0.00	0.00
5/5	0.00	0.05	0.00	0.00	0.00
5/20	0.00	0.00	T	0.00	0.00
6/2	0.04	0.00	0.04	0.00	0.00

T = $<$ .04

Soda Butte Creek
Zinc (mg/1)

Date	Station 1	2	3	4	5
5/27/72	0.030	0.030	0.030	0.000	0.000
6/9	0.035	0.000	0.025	T	0.040
6/24	T	T	0.000	T	0.000
7/8	T	T	T	T	0.000
7/21	T	T	T	T	T
8/4	0.000	0.000	0.000	0.000	0.000
8/18	T	0.035	0.035	0.000	0.000
8/31	0.000	T	0.000	0.000	0.000
9/18	T	T	0.030	T	0.000
9/29	0.000	T	0.000	0.000	0.000
10/17	0.000	T	T	T	0.000
11/11	0.000	0.000	T	0.000	0.000
1/20/73	T	0.030	----	----	----
3/22	T	T	0.000	0.000	0.000
5/5	0.000	0.035	T	0.000	0.000
5/20	0.000	T	0.000	0.000	0.000
6/2	0.000	0.000	0.000	0.000	0.000

T = $<$ .025

Soda Butte Creek
Magnesium (mg/1)

Date	Station 1	2	3	4	5
5/27/72	3.9	4.6	3.2	2.9	4.1
6/9	2.9	3.2	0.0	4.9	8.5
6/24	4.1	6.3	0.0	2.4	7.5
7/8	5.1	3.9	2.4	2.7	3.7
7/21	5.7	21.3	4.1	3.9	1.3
8/4	6.3	8.8	2.7	3.8	6.2
8/18	6.1	10.9	2.9	4.9	7.1
8/31	6.3	12.0	3.2	5.1	7.3
9/18	6.7	12.2	2.8	3.9	7.8
9/29	7.3	12.2	3.9	5.0	7.8
10/17	6.4	10.9	4.1	5.1	6.8
11/11	6.8	12.7	0.7	5.6	8.5
1/20/73	5.2	15.3	---	---	---
3/22	---	---	---	---	---
5/5	6.8	---	4.3	3.2	10.9
5/20	5.1	3.9	2.2	2.2	3.7
6/2	4.4	4.6	3.2	3.4	4.6