Downstream Effects of
Placer Mining
in the Birch Creek Basin, Alaska

by
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EXECUTIVE SUMMARY

The effects of placer mining effluent on downstream water quality and aquatic macroinvertebrate populations were investigated in the east side of the Birch Creek watershed, which includes Crooked Creek and Birch Creek. We sampled along a 130 km continuum from the headwaters of Porcupine Creek, a tributary stream above mining, to Crooked Creek at the confluence with Birch Creek, and Birch Creek at the Steese Highway bridge. The study encompassed sites above mining, directly below mining, below mining effluent from tributary streams, and far downstream from mining input.

Placer mining in the Birch Creek watershed resulted in profound changes in water quality and invertebrate densities that persisted far downstream from mining input. We found:

(1) Invertebrate densities that were reduced by 87% between a clearwater site above mining and the site 2 km downstream below mining effluent;

(2) Invertebrate densities were at low levels throughout Crooked Creek below mining. Densities in Birch Creek, 92 km below all mining, were only 25% of the densities found in clear water;

(3) Turbidity and total suspended sediment levels increased from a background average of 0.27 NTU and 0.7 mg/L, respectively, above mining to an average of 243 NTU and 224 mg/L below the second mine on Porcupine Creek. Birch Creek, 92 km below active mining and 80 km below all mining input, had an average turbidity of 32 NTU and TSS of 48 mg/L; and

(4) Fine sediment and sand deposited on the substrate were more prevalent downstream from active mining than directly below mining or above mining.

We compared invertebrate densities in the Birch Creek system with densities reported by other researchers for mined and unmined systems. Invertebrate populations in Birch Creek far below mining were similar to densities found in the Chatanika River, a river of comparable size and stream order that is also a receiving water for placer mining effluent. Densities in clear water Porcupine Creek above mining were similar to densities found in clear water streams in Interior Alaska.

Our study demonstrated that the effects of increased siltation from placer mining effluent are not restricted to the

zone of or immediately below active mining. the cumulative effects of sediment input and deposition from numerous placer mines were evident in the lower reaches of Crooked and Birch creeks where aquatic invertebrate populations were low and stream bottom substrates were embedded in fine silt and sand.

This study is a component of the Tri-Agency placer studies project. Water quality and stream hydrology data were collected by the Alaska Department of Natural Resources, Division of Mining and Geology and by Dames and Moore, consultants to the Alaska Department of Environmental Conservation, with the assistance of the Alaska Department of Fish and Game. Biological data were collected by the Alaska Department of Fish and Game.

INTRODUCTION

Placer gold is often found in the alluvial gravel layer overlaying the bedrock of existing or ancient stream channels. Large earth moving equipment, including dozers, backhoes, and draglines, are commonly used to remove vegetation, soils, and gravels above the placer gold deposits. Once the gold-bearing gravel is uncovered, it is washed with water to separate the gold. The washwater, which is heavily laden with gravel and sediment, is usually held in one or more settling ponds, then discharged to a nearby stream. Well-designed settling ponds remove heavier particles that settle during the retention time limit of the pond. Settling ponds alone are not effective for removing all the suspended solids.

The effects of placer mining effluent on downstream water quality and aquatic habitat have been investigated by a number of researchers and resource agencies in Alaska (e.g., Chang 1979, Yang 1979, Madison 1981, Lloyd 1985, Bjerklie and LaPerriere 1985, Wagener and LaPerriere 1985, Weber and Post 1985, Mack 1986, Van Nieuwenhuyse and LaPerriere 1986). These studies have documented an often dramatic increase in turbidity, suspended solids and total metals resulting from placer mining. Increased sediment loads are known to alter channel morphology by sediment deposition (Dames and Moore 1986), to limit subsurface and surface water exchange (Bjerklie and LaPerriere 1985), and to decrease the average particle size of the stream bottom substrate (Weber and Post 1985). Effects of altered water quality from placer mining are usually greatest directly below the zone of active mining (Mack 1986, Weber 1986). Eventually turbidity decreases because fine particles settle downstream in quiescent pools and edges of the stream channel. Furthermore, dilution from clear water tributary streams decreases sediment concentrations.

Biological effects of increased sediment levels include loss of habitat for fish and other aquatic species (Weber and Post 1985, Dames and Moore 1986), decreased survival of fish in the egg and young-of-the-year stages (Reynolds 1985), decreased populations of aquatic macroinvertebrates and alterations in macroinvertebrate community structure (Weber and Post 1985, Wagener and LaPerriere 1985), and decreased algal production (Lloyd 1985, Van Nieuwenhuyse and LaPerriere 1985).

The correlation of increased sediment levels with decreased macroinvertebrate populations has been well-documented for stream reaches below the zone of active mining (Weber and Post 1985, Wagener and LaPerriere 1985). It has not been documented if effects of placer mining to aquatic populations persist further downstream in receiving waters. The aim of this study was to investigate the effects of placer mining on water quality downstream from mining and to determine whether changes in water quality correspond to changes in stream bottom substrate conditions and changes in macroinvertebrate populations.

METHODS AND MATERIALS

Description of Study Area

Our study was conducted in the Birch Creek watershed, which contains both Crooked Creek and Birch Creek. The Birch Creek watershed has been mined for placer gold since 1894 (Cobb 1973) and continues to be one of the most active placer gold districts in interior Alaska. In summer 1985, there were two active placer mines on Porcupine Creek, 4 active placer mines on Bonanza Creek, 5 in the Mammoth Creek drainage, and 3 on Crooked Creek. Deadwood Creek, which flows into Crooked Creek about 5 river km below the headwaters, also contributed sediment laden water to this system. There were about ten active placer mines on Deadwood Creek in 1985. Fig. 1, shows the extent of past placer mining and locations of mines operating in 1985.

During summer 1985, we sampled eight stations in the Crooked Creek drainage (Fig. 1), from the headwaters of Porcupine Creek above mining, to Crooked Creek at the confluence with Birch Creek, and Birch Creek at the Steese Highway bridge. Total river distance along this reach was approximately 130 river km from the first site on Porcupine Creek to Birch Creek at the Steese Highway.

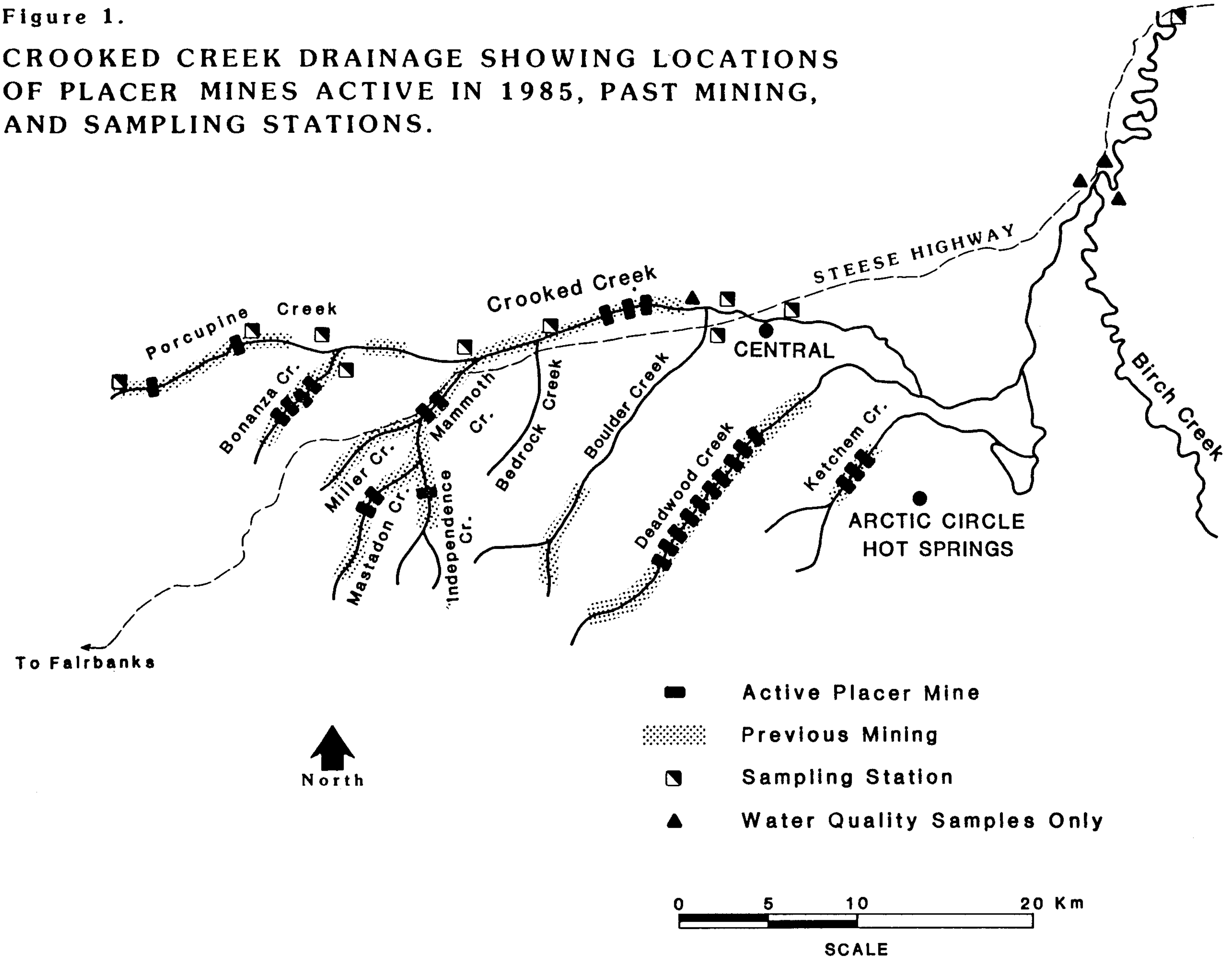
Porcupine Creek was sampled above mining, below mining, at the road near Bonanza Creek, and above the confluence with Mammoth Creek. Crooked Creek was sampled below the confluence of Bedrock Creek, a clear water tributary, at the confluence of Boulder Creek, also a clear water tributary, and at the town of Central. Crooked Creek was also sampled for water quality above the confluence with Birch Creek.

Birch Creek was sampled near the Steese Highway bridge, approximately 30 river km downstream from the confluence with Crooked Creek. Two tributaries to the Crooked Creek system were also sampled: Bonanza Creek (mined) and Boulder Creek, a clearwater stream that had been previously mined in the headwaters.

Discharge and water quality were monitored by ADF&G and the Alaska Department of Natural Resources, Division of Geological and Geophysical Survey (DGGS) during the open water seasons in 1984 and 1985 (Weber 1986, Mack 1986). In 1985, ADF&G, DGGS and Dames and Moore, consultants to the Alaska Department of Environmental Conservation (ADEC), conducted intensive water quality and quantity monitoring of these streams during the same three day period that macroinvertebrates were sampled. With two exceptions, water quality

Figure 1.

CROOKED CREEK DRAINAGE SHOWING LOCATIONS OF PLACER MINES ACTIVE IN 1985, PAST MINING, AND SAMPLING STATIONS.



samples were collected in the same reaches sampled for invertebrates and substrates. Crooked Creek at the mouth was too deep to sample for macroinvertebrates. Water quality in Crooked Creek at Boulder Creek was sampled above the confluence of Boulder Creek, which is unmined and a major source of clear water. Macroinvertebrates and substrates were sampled below the confluence of Boulder Creek. Because invertebrate samples were collected in a reach with possibly lower turbidity and TSS levels than the water quality samples, data from this site were omitted from comparisons of macroinvertebrates and stream bottom substrate conditions with water quality parameters.

Stream reaches of 100 m length were established at each sampling station. Each reach was sampled for discharge, water quality, stream bottom substrate conditions, and macroinvertebrates.

Hydrology and Water Quality

Discharge was measured with Marsh-McBirney and Swoffer flow meters and stage was measured with staff gauges and instantaneous recording data pods. Water samples were taken at 6 hour intervals with ISCO automatic water samplers for the entire three day period and intermittently by grab samples. Water quality samples were analyzed for turbidity, total suspended solids (TSS) and settleable solids according to standard methods (Amer. Pub. Health Assoc. 1985).

Average summer turbidity levels, measured from June through September 1985, were compared among the study sites to determine differences in water quality conditions. Turbidity levels in July 1985, were also compared among sites to determine water quality conditions during the time of invertebrate sampling.

Stream Bottom Substrates

The stream bottom substrate inside the box sampler was evaluated when macroinvertebrates were collected. The median size of the particle length, width, and depth of each substrate particle greater than 3 cm was measured and recorded. Substrate material surrounding particles greater than 3 cm was classified as silt, sand, or gravel and was not measured. Embeddedness of particles greater than 3 cm was estimated by the percent of particle buried in sand or silt.

Benthic Macroinvertebrates

Locations for macroinvertebrate samples were selected by coordinates determined from a table of random numbers. We used a 0.1 m^2 portable box sampler to collect aquatic invertebrates. Five samples were taken at each site between July 23 and July 25, 1985. Macroinvertebrates were sorted from organic debris, identified to the lowest practical taxonomic level, and counted.

Macroinvertebrate densities were compared among the stream sites using the Kruskal-Wallis non-parametric analysis of variance test and the Scheffe' test for multiple comparisons (Zar 1974). The Spearman rank correlation test was used (Zar 1974) to correlate macroinvertebrate densities with each water quality and stream bottom substrate characteristics.

The faunal lists from each sampling site were compared by using a simple index of similarity (Odum 1971), appropriate for faunal lists of macroinvertebrates identified to different taxonomic levels (Erman 1981):

$$S = \frac{2w}{a+b} \times 100$$

where $\underline{a}$ is the number of taxa from site A; $\underline{b}$ is the number of taxa from site B; and $\underline{w}$ is the number of taxa in common.

RESULTS

Water Quality

Mining inputs to the Crooked Creek drainage had profound effects on water quality during the period June through September 1985 (table 1). The average background turbidity level in Porcupine Creek above mining was only 0.27 NTU (values available for July only); however, the average turbidity measured downstream of the lowermost placer mine (2.4 km downstream) was 336 NTU in July and 243 NTU for the season. Turbidities in Porcupine Creek decreased with downstream distance from mining input; the average summer turbidity in Porcupine Creek at the road crossing (7.9 km below placer mining) was 86 NTU. The average summer turbidity measured in Porcupine Creek above the confluence with Mammoth Creek (16.5 km below placer mining in Porcupine Creek and about 8 km below the confluence with mined Bonanza Creek) was 52 NTU.

The average July turbidity in Crooked Creek below the input of mined Mammoth Creek (measured below the confluence with Bedrock Creek) was 148 NTU. This is about two times higher than the average in Porcupine Creek just above the confluence with Mammoth Creek. In fact, the average turbidity in Crooked Creek below the confluence on Mammoth and Porcupine creeks was approximately half way between the average turbidities of Porcupine Creek above the mouth (average = 85 NTU) and Mammoth Creek (average = 259 NTU). Seasonal averages cannot be compared because data from Crooked Creek below Bedrock Creek are only available for July.

Effluent from three placer mines located on Crooked Creek between the sampling stations at Bedrock and Boulder creeks resulted in July turbidity levels that were 2.4 times higher below the mines than above: from 148 NTU in Crooked Creek below Bedrock Creek, above the three mines, to 356 NTU in Crooked Creek above Boulder Creek, below the placer mines. Seasonal averages were not compared.

Average summer turbidity levels decreased in Crooked Creek downstream from Central: from 390 NTU in Crooked Creek at Central to 102 NTU in Crooked Creek above the confluence with Birch Creek, 57 km downstream. Average turbidity in Birch Creek above the confluence with Crooked Creek was lower than in Crooked Creek: average for July (the time of the invertebrate sampling) was only 9 NTU and for the summer, 11 NTU. Turbidities in Birch Creek below the confluence of Crooked Creek, measured at the Steese Highway 29 km downstream from the confluence, were 23 NTU for July and 32 NTU for the summer.

Table 1. Average turbidity levels from study sites in the Birch Creek Drainage, 1985. All values in NTU.

Sites from Porcupine Cr. to Birch Cr.	June	July	August	Sept.	Mean	n
Porcupine Cr. above mining		0.27			0.27	4
Porcupine Cr. below mining	151	336	12	30	243	16
Porcupine Cr. at road	88	105	57	11	86	45
Porcupine Cr. above mouth	311	85	410	26	234	52
Crooked Cr. at Bedrock Cr.		148			148	6
Crooked Cr. at Boulder Cr.		356	215	155	332	14
Crooked Cr. at Central	236	484	390	181	390	49
Crooked Cr. at mouth	105	95	172	59	105	22
Birch Cr. above Crooked Cr.	27	9	14	10	11	19
Birch Cr. at Steese Hwy	48	23	37	18	32	36
Tributary Streams						
Bonanza Cr.	63	308	1060	30	341	21
Mammoth Cr.	285	259	368	370	309	36
Boulder Cr.	10	0.5	0.8	0.6	1.6	20

Data from Dames & Moore 1986, Mack 1986, and ADF&G 1985.

The relationships of TSS levels and downstream distance from mining effluents were similar to the above relationships of turbidity with distance from mining effluent (table 2). Average background TSS levels in Porcupine Creek above mining were only 0.7 mg/L; however, average July TSS levels in Porcupine Creek below mining had increased to 276 mg/L. (Average summer values were not compared because TSS values for Porcupine Creek above mining were only measured in July.) As with turbidity levels, TSS levels in Porcupine Creek were lower at the road crossing, 8 km below mining, (summer average = 77 mg/L) than directly below mining (summer average = 224 mg/L).

July TSS averages for Porcupine Creek at the mouth (76 mg/L, measured about 8 km below the confluence of mined Bonanza Creek) were similar to July averages in Porcupine Creek above Bonanza Creek (79 mg/L, measured at the road crossing); however, the average summer TSS level measured in Porcupine Creek at the mouth (159 mg/L) was about two times higher than the summer average above the confluence of Bonanza Creek (77 mg/L).

Average July TSS levels in Crooked Creek below the input of mined Mammoth Creek (measured at the confluence of Bedrock Creek) were 116 mg/L. This is about 1.5 times higher than July TSS levels in Porcupine Creek above the confluence of Mammoth Creek. As with turbidity levels, TSS levels in Crooked Creek below the confluence of Mammoth and Porcupine creeks were between the TSS levels of these two tributary streams. Seasonal averages were not compared because TSS data for Crooked Creek at Bedrock Creek are only available for July.

Effluent from the 3 placer mines on Crooked Creek caused average July TSS levels to double: from 116 mg/L in Crooked Creek (above the mines) at Bedrock Creek (below the mines) to 252 mg/L in Crooked Creek at Boulder Creek. Seasonal averages were not compared.

Total suspended solids levels decreased in Crooked Creek downstream from Central. Average summer TSS levels were 375 mg/L in Crooked Creek at Central and 99 mg/L at the mouth (57 km downstream). Total suspended solids levels in Birch Creek above Crooked Creek were lower than in Crooked Creek: the seasonal average was 21 mg/L. Below the confluence with Crooked Creek, TSS levels in Birch Creek (measured at the Steese Highway) increased to 48 mg/L.

Although settleable solids were not measured at each site, the available data (table 3) show that for sites influenced

Table 2. Average total suspended solids levels from study sites in the Birch Creek Drainage, 1985. All values in mg/L.

Sites from Porcupine Cr. to Birch Cr.	June	July	August	Sept.	Mean	n
Porcupine Cr. above mining		0.7			0.7	4
Porcupine Cr. below mining	580	276	15	35	224	16
Porcupine Cr. at road	125	76	65	13	77	26
Porcupine Cr. at mouth	82	79	444	31	159	29
Crooked Cr. at Bedrock Cr.		116			116	
Crooked Cr. at Boulder Cr.		252	337	116	248	13
Crooked Cr. at Central	330	433	337	227	375	49
Crooked Cr. at mouth	135	87	136	80	99	22
Birch Cr. above Crooked Cr.	65	19	15	25	21	20
Birch Cr. at Steese Hwy	137	24	41	50	48	36
Tributary Streams						
Bonanza Cr.	71	393	1110	35	398	21
Mammoth Cr.	298	303	410	436	351	36
Boulder Cr.	14	3	2	0.9	3.3	22

Data from Dames & Moore 1986, Mack 1986, and ADF&G 1985. Averages are calculated from both measured TSS and estimated values based upon TSS:Turbidity regressions developed for each sample site (Dames & Moore 1986).

Table 3. Settleable solids levels in the Birch Creek drainage, 1985. All values in ml/L.

			DATE		
Sites from Porcupine Cr. to Birch Cr.	7-23	7-24	7-26	7-27	7-28
Porcupine Cr. below mining				nd	
Porcupine Cr. at road				nd	
Porcupine Cr. at mouth	0.15	2.2	0.3	0.3	0.3
Crooked Cr. at Central	0.15	0.35	nd	0.1	nd
Crooked Cr. above Birch		nd		nd	
Birch Cr. above Crooked Cr.		nd			
Birch Cr. at Steese Hwy.		nd			
Triburary streams					
Bonanza Cr.	4.0			3.5	
Mammoth Cr.	3.0	1.3	0.15	nd	nd

Data from Dames and Moore 1986, Mack 1986.
nd = not detectable

by mining effluent settleable solids levels are lowest in Porcupine Creek below mining and in the stream reaches farthest downstream from mining: Crooked Creek at the mouth, Birch Creek above Crooked Creek, and Birch Creek at the Steese Highway. Sites sampled below mining - Porcupine Creek above the mouth, Mammoth Creek, and Crooked Creek at Central - had settleable solids levels that exceeded state quality standards and federal effluent limitations.

Stream Bottom Substrates

Average particle size, embeddedness, and size of the surrounding material of stream bottom substrates were classified at each sample site (table 4). The largest substrate, including bedrock, was found in previously mined Porcupine Creek above mining and Porcupine Creek at the mouth. Particle embeddedness was greatest below mining, especially in Porcupine Creek at the mouth. Substrate particle size changed from predominately large gravel to predominately small cobble between Crooked Creek at Boulder Creek and Birch Creek at the Steese Highway. Fine silt and sand were more prevalent in the two sites farthest downstream from mining - Crooked Creek at Central and Birch Creek at the Steese Highway. Stream bottom substrates in these two downstream sites contained gravel and small cobble embedded (20-35%) in sand and silt.

Macroinvertebrate density

The macroinvertebrate density was significantly different among sample sites (Kruskall-Wallis one way analysis of variance, p less than 0.001, table 5). Macroinvertebrate densities were highest in Porcupine Creek above mining (mean = 96.8 inverts/0.1 m^2), then dropped to low levels below active mining in Porcupine Creek (mean = 7.4 inverts/0.1 m^2). Invertebrate densities were even lower in Porcupine Creek at the road crossing (8 km below mining, mean = 4.6 inverts/0.1 m^2), then increased in Porcupine Creek at the mouth, 16.5 km below mining (mean = 32.2 inverts/0.1 m^2). Densities of macroinvertebrates decreased from Porcupine Creek at the mouth to Crooked Creek below the confluence of mined Mammoth Creek (sampled below Bedrock Creek, mean = 8 inverts/0.1 m^2).

Macroinvertebrate densities in Crooked Creek below three placer mines (sampled below the confluence of Boulder Creek) were slightly higher (mean = 14.8 inverts/0.1 m^2) than in Crooked Creek above the placer mines; however, the difference between these two sites is not significant (Scheffe' test, p greater than 0.05). Macroinvertebrate densities were similar in Crooked Creek at the confluence of Boulder

Table 4. Average stream bottom substrate conditions in Birch Creek drainage, 1985.

Sites from Porcupine Cr. to Birch Cr.	Average Particle size, mm	Dominant substrate	Surrounding substrate	Embed. percent
Porcupine Cr. above mining	119	small cobble	gravel, sand	0-20
Porcupine Cr. below mining	94	small cobble	gravel, sand	0-20
Porcupine Cr. above road	71	large gravel	sand, silt	35-60
Porcupine Cr. above mouth	168	large cobble	sand, silt	60-85
Crooked Cr. below Bedrock	127	small cobble	gravel, sand	0-20
Crooked Cr. at Boulder	74	large gravel	gravel, sand	20-35
Crooked Cr. at Central	89	small cobble	sand, silt	20-35
Birch Cr. at Steese Hwy	81	small cobble	sand, silt	20-35
Tributary Streams				
Bonanza Cr. above mouth	84	small cobble	sand, silt	0-20
Boulder Cr. above mouth	76	large gravel	gravel, sand	0-20

Table 5. Density and median number of taxa of benthic invertebrates. Birch Creek drainage, 1985.

Sites from Porcupine Cr. to Birch Cr.	mean	s.d.	# taxa	n
Porcupine Cr. above mining	96.8	19.5	6	5
Porcupine Cr. below mining	7.4	2.6	3	5
Porcupine Cr. at road	4.6	2.3	2	5
Porcupine Cr. at mouth	32.2	47.2	3	5
Crooked Cr. at Bedrock	8.0	3.0	2	5
Crooked Cr. at Boulder	14.8	12.8	3	5
Crooked Cr. at Central	10.4	7.6	4	5
Birch Cr. at Steese Hwy.	24.6	14.1	6	5
Tributary Streams				
Bonanza Cr.	12.4	3.7	3	5
Boulder Cr.	60.2	26.1	7	5

Creek, and Crooked Creek at Central, a distance of about 5 km. Invertebrate densities were higher in Birch Creek at the Steese Highway, 92 km below mining than in any of the mining influenced sites. Averages in the Birch Creek site was 27.8 inverts/0.1 m^2.

Boulder Creek, a clear water tributary to Crooked Creek, had the highest macroinvertebrate density of any of the sites sampled (60.2 inverts/0.1 m^2), except for Porcupine Creek above mining, previously reported (also a clear water site). Densities in mined Bonanza Creek, a tributary that enters Porcupine Creek below the sampling site at the road crossing, had an average macroinvertebrate density of 12.4 inverts/0.1 m^2.

Macroinvertebrate densities were significantly and negatively correlated with both turbidity and TSS levels (Spearman rank correlation, p less than 0.05). Sites with high turbidity and TSS levels contained the lowest macroinvertebrate densities and, conversely, sites with clear water contained the highest densities. Figure 2 illustrates the relationship of invertebrate density with turbidity and TSS.

Invertebrate density was not correlated with substrate particle size. Further, there was no consistent correlation between turbidity levels and particle embeddedness at a given site (Spearman's rank correlation, p greater than 0.05). Generally, stream bottom substrates were more embedded farther downstream from mining input rather than at the mining discharge site.

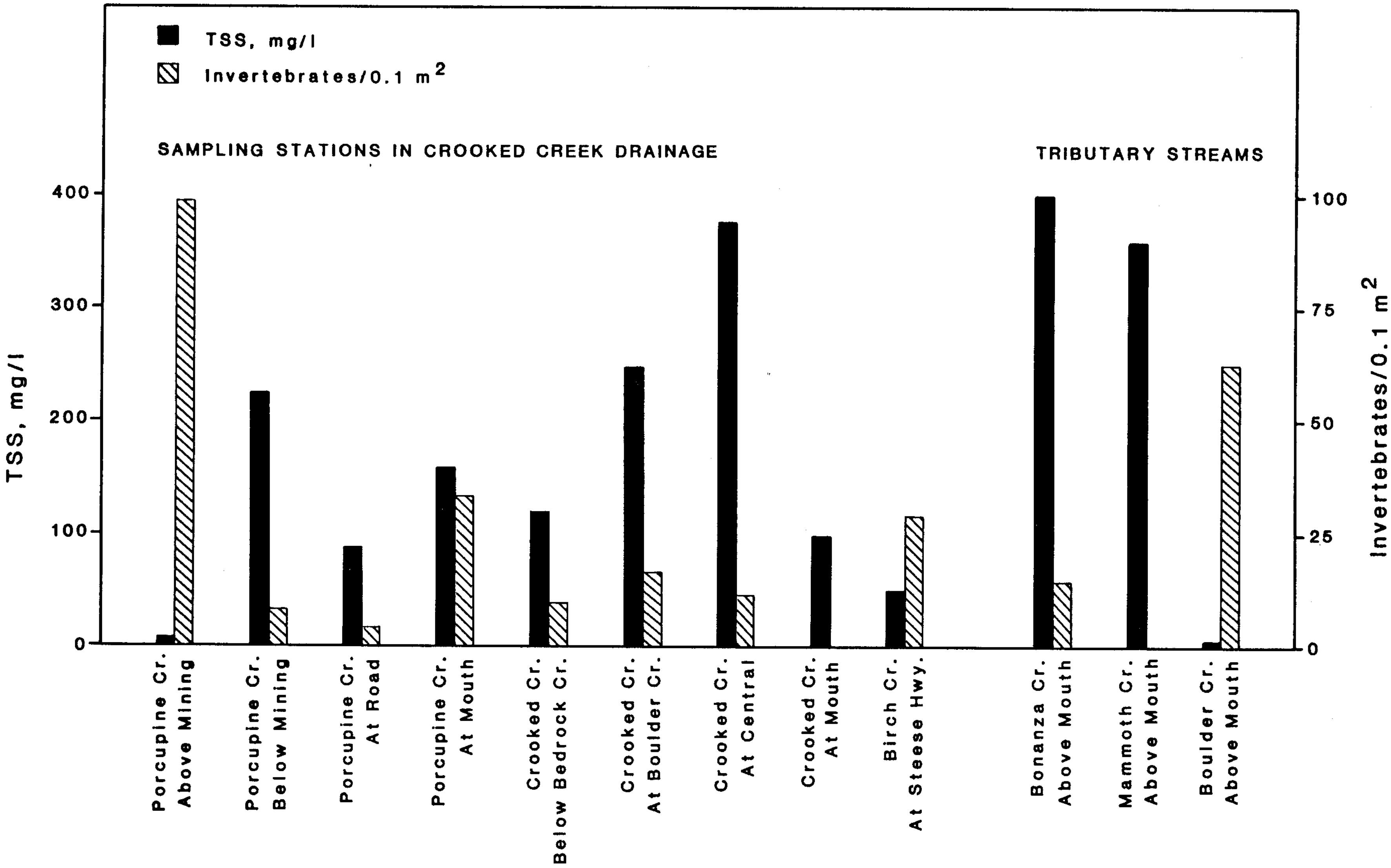
Macroinvertebrate Community Structure

Generally, mayflies, stoneflies, and black flies were most common in clear water Boulder Creek and Porcupine Creek above mining, and in Crooked Creek below the confluence of Boulder Creek. These families were rarest in sites directly below active mining (Porcupine Creek below mining and at the road, and Crooked Creek below the confluence of mined Mammoth Creek). The Diptera family Chironomidae was common in all sites.

The highest numbers of taxa per sample (taxonomic richness) were found in the clear water sites: Porcupine Creek above mining and Boulder Creek contained an average of 6 and 7 taxa per sample, respectively. Samples from Birch Creek at the Steese Highway, where the average turbidity was 23 NTU, contained an average of 6 taxa per sample. Except for Crooked Creek at Central, all other sites with turbidities greater than 23 NTU or TSS levels greater than 22 mg/L had 3 or fewer taxa per sample. Crooked Creek at Central had an

Figure 2.

RELATIONSHIP OF AVERAGE INVERTEBRATE DENSITY AND AVERAGE TSS LEVELS AT EACH SAMPLE STATION, CROOKED CREEK DRAINAGE, 1985



average of 4 taxa per sample, an average turbidity of 488 NTU, and an average TSS of 312 mg/L.

The macroinvertebrate communities were compared with a coefficient of similarity (Odum 1971) between all pairs of sample sites to determine the number of taxa that were common to both sites. There was little similarity among macroinvertebrate communities in all pairs of sites. The highest degree of similarity occurred in samples from Porcupine Creek above mining and Bonanza Creek below mining where 75% of the taxa were common to both sites. Porcupine Creek above mining and Porcupine Creek below mining were somewhat similar; 50% of the macroinvertebrate taxa occurred at both sites. All other pairs of sample sites had less than 50% overlap in taxonomic groups. The average value for the coefficient of similarity for all pairs of comparisons was 26%, a low degree of similarity.

DISCUSSION AND CONCLUSIONS

We investigated changes in water quality and macroinvertebrate communities resulting from placer mining on Porcupine Creek and Crooked Creek, and from the effluent from Bonanza Creek (3 mines)and Mammoth Creek (at least 5 active mines). Our study showed that placer mining resulted in profound changes in water quality and invertebrate densities that persisted far downstream from mining input. We found:

1. Invertebrate densities were reduced by 87% between sites above and below mining in Porcupine Creek.

2. Invertebrate densities were at low levels throughout Crooked Creek, below mining. Densities in Birch Creek, 92 km below all mining, were only 25% of the densities found in clear water.

3. Turbidity and TSS levels increased from a background average of 0.27 NTU and 0.7 mg/L, respectively, above mining to an average of 243 NTU and 224 mg/L below the lowermost mine on Porcupine Creek. Birch Creek, 92 km below active mining and 80 km below all mining input, had an average turbidity of 32 NTU and TSS of 48 mg/L.

4. Fine sediment and sand deposited on the substrate were more prevalent downstream from active mining than directly below mining or above mining.

Our study demonstrates that the effects of increased siltation from placer mining effluent is not restricted to the zone of or immediately below active mining. Invertebrate populations were found to be significantly depleted in Birch Creek at the Steese Highway, the sample site farthest downstream from mining. Effects of placer mining effluent may extend even farther than 92 km downstream. The presence of large proportions of silt and sand in the stream bed in Birch Creek at the Steese Highway suggests that many fine sediments are being deposited far downstream from mining.

Aquatic invertebrate populations in Birch Creek at the Steese Highway were compared with data from other streams in Alaska to determine if the low population levels found at this site might be a natural occurrence in a stream of this size and gradient. Wagener and LaPerriere (1985) found densities in the Chatanika River, a stream of comparable size to Birch Creek, averaged 25 inverts/0.1 m^2 (compared to our average of 28 inverts/0.1 m^2 in Birch Creek). Water quality in the Chatanika River is degraded from placer mining in the upstream tributaries. Cowan and Oswood (1984) presented aquatic invertebrate data for 20 undisturbed streams in Alaska. Densities found in Birch Creek were lower than densities reported by Cowan and Oswood for all Alaskan streams of comparable size. McManus Creek, a clear water tributary to the Chatanika River, had invertebrate densities that were similar to densities found above mining in Porcupine Creek (91 inverts/0.1 m^2 in the upstream reaches of McManus Creek and 114 inverts/0.1 m^2 in the downstream reaches, (Woodward-Clyde 1980).

Water quality and substrate variables are themselves highly autocorrelated, and it is not possible to separate the effects of each variable on macroinvertebrates. Crooked Creek and its tributaries have been mined since the early 1900's, and fine sediments have been gradually washed both downstream and deeper into the gravel substrate.

Dames and Moore (1986) stated that the surface of the stream bottom gravels would probably be cleaned in a relatively short time (2-5 years) if inputs of sediment were stopped. They further stated that it would probably take a considerably greater period of time to remove fine sediments trapped within stream gravels. Bjerklie and LaPerriere (1985) demonstrated long term effects of sediment deposition in Birch Creek near the headwaters. They found that stream beds were sealed with fine sediments and that there was no longer an exchange between surface and subsurface water in the stream.

Cumulative effects of sediment input and deposition from numerous placer mines were evident in the lower reaches of Crooked and Birch creeks (up to 92 km downstream of mining) where aquatic invertebrate populations were low and stream bottom substrates were embedded in fine silt and sand. Our findings demonstrate the fact that effects of placer mining on aquatic communities are not localized to the immediate area of the mine, but extend far downstream from mining.

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