CHAPTER 8
BENTHIC MACROINVERTEBRATES

8.1 INTRODUCTION

This chapter presents the determination of injury to benthic macroinvertebrate resources of the Coeur d'Alene basin, focusing on the South Fork Coeur d'Alene River, the Coeur d'Alene River, and tributaries to the South Fork Coeur d'Alene and Coeur d'Alene rivers. Information is also presented on the benthic macroinvertebrate community of Coeur d'Alene Lake. Benthic macroinvertebrates are invertebrates that live on stream or lake bottoms. Many are the larval stages of insects that emerge from the stream as flying or terrestrial adults. They are essential to decomposition and nutrient cycling in aquatic systems, and are a primary food source for fish, including trout (Stolz and Schnell, 1991). Healthy aquatic systems of Rocky Mountain montane rivers typically support complex and diverse macroinvertebrate communities that include mayflies, stoneflies, caddisflies, and craneflies. They fill various food web roles, including herbivorous shredders and scrapers that consume algae and biofilm that grows on stream bottoms, filterers and gatherers that consume detritus, and carnivorous engulfers that consume other invertebrates (Merritt and Cummins, 1984).

Benthic macroinvertebrate resources have been injured in the South Fork Coeur d'Alene, the Coeur d'Alene River, Coeur d'Alene Lake, Canyon Creek, and Ninemile Creek, as well as other stream/river reaches affected by releases of hazardous substances from mining and mineral processing operations. Specifically, the information presented in this chapter demonstrates the following:

- Benthic macroinvertebrates in the South Fork Coeur d'Alene, the Coeur d'Alene River, Coeur d'Alene Lake, Canyon Creek, and Ninemile Creek, as well as other tributary reaches, are exposed to elevated concentrations of cadmium, lead, and zinc in surface water, sediment, and biofilm.

- The metal concentrations to which benthic macroinvertebrates of the South Fork Coeur d'Alene, the Coeur d'Alene River, Coeur d'Alene Lake, Canyon Creek, and Ninemile Creek are exposed are well above concentrations shown to cause toxicity.

- Toxicity tests using water and sediment demonstrate that surface water and sediment downstream of mining activity are toxic to invertebrates under controlled laboratory conditions.

- Benthic macroinvertebrate communities in the South Fork Coeur d'Alene, Canyon Creek, Ninemile Creek, and other stream/river reaches are adversely affected by metals. Specifically, metal-sensitive species are largely absent from the invertebrate communities of these waterways downstream of mining activity. Historical data also demonstrate that the invertebrate communities in the mainstem Coeur d'Alene River and Coeur d'Alene Lake have been adversely affected in the past. Recent data on the communities in these areas are not available to confirm that the effects are continuing, but hazardous substance concentrations in surface water and sediment of the Coeur d'Alene River and Lake remain elevated. In addition, chironomid mouthpart deformities resulting from metals exposure may be ongoing in the South Fork and mainstem Coeur d'Alene rivers.

- The adverse effects on the invertebrate community have been occurring since at least the 1930s. Reductions in metals concentrations over time have resulted in an improvement in the benthic macroinvertebrate community, but the communities of the South Fork Coeur d'Alene River, Canyon Creek, and Ninemile Creek remain adversely affected.

8.2 BACKGROUND: EFFECTS OF HAZARDOUS METALS ON BENTHIC MACROINVERTEBRATES

8.2.1 Exposure Pathways

Benthic macroinvertebrates can be exposed to hazardous metals in surface water, sediment, sediment pore water, and food items (Figure 8-1). Metals in surface water or sediment pore water can be assimilated through direct uptake across the gill surface and other external body parts (Dodge and Theis, 1979; Hare et al., 1991).

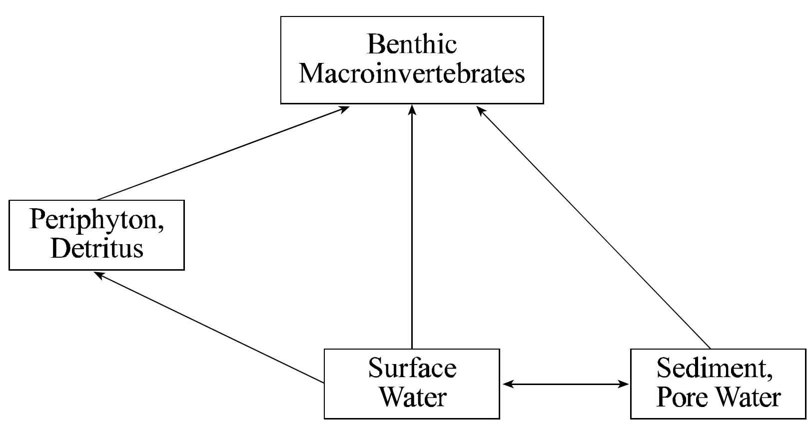

Figure 8-1. Pathways of metal exposure for benthic macroinvertebrates in the Coeur d'Alene River basin.

Benthic macroinvertebrates also can be exposed to metals via ingestion of contaminated food items. Invertebrates consume a variety of food items, including algae, periphyton, detritus, and other invertebrates (Merritt and Cummins, 1984). Several studies have documented that in riverine systems contaminated with metals from mining activities, invertebrate food items can become highly contaminated with metals (Kiffney and Clements, 1993; Lipton et al., 1995; Beltman et al., 1999). Benthic macroinvertebrates can also incidentally ingest contaminated sediment during feeding. The assimilation of metals ingested by invertebrates has been well documented (Burrows and Whitton, 1983; Smock, 1983; Gower and Darlington, 1990; Hare et al., 1991). Therefore, ingestion of contaminated food items and sediment is another mechanism by which benthic macroinvertebrates are exposed to metals.

8.2.2 Adverse Effects on Viability

Benthic macroinvertebrates have been used extensively to monitor the effects of metals contamination on aquatic systems. Benthic macroinvertebrates demonstrate individual level responses (e.g., mortality, reduced growth, reduced reproductive fitness) as well as community level responses (e.g., reduced density, reduced species richness, community shift to more tolerant species) to metals. Attributes that make benthic macroinvertebrates useful for evaluating ecological effects of hazardous substances include the following: (1) they are in intimate contact with sediments; (2) they exhibit a wide range of sensitivity to metals; (3) they occupy limited home ranges; (4) they are integral components of the aquatic food chain; (5) they integrate exposure conditions over their life spans, typically several months to a few years; and (6) they are relatively easy to monitor (Winner, 1972; Wiederholm, 1984; U.S. EPA, 1989; Voshell et al., 1989; Burton, 1992; Cairns and Pratt, 1993).

Metals have been shown to be toxic to benthic macroinvertebrates in laboratory toxicity tests (U.S. EPA, 1992), artificial laboratory streams (Selby et al., 1985; Clements et al., 1988, 1989, 1992; Kiffney and Clements, 1994), natural streams experimentally dosed with metals (Winner et al., 1975, 1980; Leland et al., 1989), and streams or rivers receiving metal pollution (Clements et al., 1992; Beltman et al., 1999).

Community level responses often are used to evaluate the effects of metals on benthic macroinvertebrates (Clements, 1991). Where metals concentrations are sufficiently high, benthic invertebrates may be entirely absent or their abundance greatly reduced (Clements, 1991). Where metals concentrations do not entirely eliminate the community, however, measures of taxa richness (e.g., total number of species present) or abundance of metals-sensitive taxa provide the most sensitive and reliable measure of community level effects (Barbour et al., 1992; Clements and Kiffney, 1995; Carlisle and Clements, 1999). Invertebrate taxa richness is reduced by exposure to metals, as metal-sensitive species are eliminated. For example, many mayfly species are sensitive to metals contamination (Warnick and Bell, 1969), and a reduction in the number of mayfly species present is an effective and reliable measure of metals impacts on benthic macroinvertebrate communities (Ramusino et al., 1981; Specht et al., 1984; Van Hassel and

Gaulke, 1986; Clements, 1991; Clements et al., 1992; Kiffney and Clements, 1994). Metal-exposed communities with reduced taxa richness thus are dominated by metal-tolerant species, fundamentally altering the community structure.

In contrast to community taxa richness or the presence of metals-tolerant species, other metrics such as total invertebrate density (or total abundance) provide a much less sensitive and reliable measure of metal effects on benthic macroinvertebrate communities (except in areas of extremely high metal concentrations). Some investigators have proposed using total invertebrate abundance in the determination of metal effects on benthic communities (e.g., Ginn, 1999). However, studies of invertebrate communities downstream of mining sites in the western United States have shown that total abundance is a poor measure of metals effects. For example, in the Arkansas River in Colorado, Clements (1994) found that at locations downstream of a mine site, metal-sensitive invertebrates were replaced with metal-tolerant ones in response to zinc exposure, and as a result there was no correlation between total abundance and zinc concentrations. Similar results have been reported for Panther Creek, Idaho (Beltman et al., 1999), and Eagle River, Colorado (Kiffney and Clements, 1994), downstream of mine pollution, where metals caused substantial shifts in the benthic community composition but not in the total number of invertebrates present. Carlisle and Clements (1999) conducted a detailed comparison of the reliability and sensitivity of different benthic macroinvertebrate community metrics as indicators of metal effects and concluded that total abundance is a poor metric for detecting metal effects. In contrast, measures of taxa richness and the presence of metal-sensitive taxa were found to be the most reliable and consistent metrics.

8.3 TOXICOLOGICAL DATA

Several toxicity studies have been conducted in which invertebrates have been exposed to water or sediment from the Coeur d'Alene River basin either in the field or under controlled laboratory conditions. The studies are summarized in Table 8-1 and described in detail below. In addition, a study has been conducted on the mouthpart deformity rates in invertebrates from the assessment area.

A small scale, 16-day *in situ* test with benthic macroinvertebrates was initiated by Rabe and Biggam (1990). Invertebrates collected from the South Fork Coeur d'Alene River upstream of Mullan and from the North Fork Coeur d'Alene River were placed in vials in the South Fork Coeur d'Alene River and Canyon Creek downstream of mining. Invertebrates were also placed in the South Fork Coeur d'Alene River upstream of Mullan and in the North Fork Coeur d'Alene River as reference sites. Twelve individual invertebrates were placed at each location. Mortality varied across locations; however, the authors concluded that because of the small sample size, differences in survival across sites could not be determined.

Table 8-1
Summary of Invertebrate Toxicity Studies Conducted Using Coeur d'Alene Basin Water or Sediment

Study	Year of Study	Media Tested	Location Tested	Reference Location	Test Organism	Summary of Results
Rabe and Biggam (1990)	Not specified	Surface water	South Fork Coeur d'Alene Canyon Creek	South Fork Coeur d'Alene (upstream) North Fork Coeur d'Alene	Invertebrates collected from reference areas	Small sample sizes make results difficult to interpret.
Hornig et al. (1988)	1986	Surface water	South Fork Coeur d'Alene Coeur d'Alene River	South Fork Coeur d'Alene (upstream) North Fork Coeur d'Alene	Waterflea (*Ceriodaphnia dubia*)	100% mortality in water collected from all locations downstream of mining activity. Less than 10% mortality in reference site water.
		Sediment	Coeur d'Alene River Coeur d'Alene Lake	Chatcolet Lake	Waterflea (*Daphnia magna*); amphipod (*Hyallela azteca*)	Hyallela had higher mortality in Coeur d'Alene River sediments than in reference; Daphnia had unusually high reference mortality.
Dames & Moore (1989)	1987-1988	Surface water	South Fork Coeur d'Alene	North Fork Coeur d'Alene	Waterflea (*Ceriodaphnia dubia*)	100% mortality in South Fork Coeur d'Alene water. Low mortality in North Fork Coeur d'Alene water.

In 1986, bioassays were conducted with the waterflea *Ceriodaphnia dubia* at the U.S. EPA Environmental Research Laboratory in Duluth, Minnesota (Hornig et al., 1988). Organisms were exposed to water collected from seven locations on the South Fork Coeur d'Alene River between the mouth and Canyon Creek and the mainstem Coeur d'Alene River near Cataldo. Organisms were also exposed to reference water collected from the North Fork Coeur d'Alene River near Enaville and the South Fork Coeur d'Alene River upstream of Mullan. Exposures of invertebrates to water collected from the South Fork Coeur d'Alene and mainstem Coeur d'Alene rivers downstream of mining activity (i.e., between Cataldo and Canyon Creek) resulted in 100% mortality (Table 8-2). Dilution tests showed that as little as 10% South Fork Coeur d'Alene water mixed with clean water caused an increase in mortality relative to reference water. Mortality was less than 10% in site reference water.

Table 8-2
Results of Site Water Invertebrate Toxicity Tests by Hornig et al. (1988)

Site	River Mile[a]	Ceriodaphnia Survival (%)	Mean Young Produced (#)
North Fork Coeur d'Alene at Enaville (reference)	0.6	95	25.8
South Fork Coeur d'Alene above Mullan (reference)	29.1	90	23.1
Mainstem Coeur d'Alene at Cataldo	6.0	0	0
South Fork Coeur d'Alene at mouth	0.0	0	0
South Fork Coeur d'Alene above Pine Creek	2.4	0	0
South Fork Coeur d'Alene below Smelterville	4.8	0	0
South Fork Coeur d'Alene at Bunker Avenue	6.9	0	0
South Fork Coeur d'Alene above Kellogg	8.3	0	0
South Fork Coeur d'Alene above Big Creek	11.4	0	0
South Fork Coeur d'Alene above Canyon Creek	21.0	0	0

a. Number of miles from the North Fork and South Fork Coeur d'Alene confluence.

Source: Hornig et al., 1988.

Hornig et al. (1988) also conducted sediment toxicity tests with the macroinvertebrates *Daphnia magna* and *Hyalella azteca* in 1986. Organisms were exposed to sediment collected from five locations on the mainstem Coeur d'Alene River and Coeur d'Alene Lake and from a single location designated by the study authors as a reference location (Chatcolet Lake). Table 8-3 presents the metal concentrations and organism survival rates for sediment from each location.

Table 8-3
Results of Site Sediment Invertebrate Toxicity Tests by Hornig et al. (1988)

Site	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Mean Survival[a]	
				Daphnia	Hyallela
Chatcolet Lake (reference)	0.6	10	77	33%	88%
Coeur d'Alene River near Rose Lake	7.2	3,870	7,300	73%	65%
Coeur d'Alene River near Blue Lake	8.3	3,992	4,220	27%	37%
Coeur d'Alene Lake near Coeur d'Alene River delta	8.0	4,158	3,680	63%	80%
Coeur d'Alene Lake near Conkling Point	9.9	367	1,310	70%	93%
Coeur d'Alene Lake near Rockford Bay	7.7	2,136	3,620	87%	77%

a. Mean of three replicates of 10 organisms (Daphnia) or 20 organisms (Hyallela).

Source: Hornig et al., 1988.

Although statistical tests were not conducted, the data in Table 8-3 indicate that Hyallela exposed to sediment from the Coeur d'Alene River near Blue Lake had lower mean survival (37%) than those exposed to reference sediment (88%). Low survival was observed in the Daphnia exposed to the reference sediment (33%), making comparisons with Coeur d'Alene River results difficult.

Dames & Moore (1989) exposed the waterflea *Ceriodaphnia dubia* to water collected from four sites on the South Fork Coeur d'Alene River and one site on the North Fork Coeur d'Alene River (used as a reference site). Water was collected on three different dates in 1987 and 1988, representing low flow conditions, transient high flow, and late spring runoff. Results are expressed as LC50s, which are the percentages of site water that were calculated to cause mortality to 50% of the exposed organisms. Table 8-4 shows that from 0.1% to 6.1% of South Fork Coeur d'Alene River water diluted with clean water resulted in mortality to 50% of the exposed organisms. In contrast, limited mortality was observed for invertebrates exposed to water from the North Fork Coeur d'Alene River. Metal concentrations measured in the South Fork Coeur d'Alene River water to which invertebrates were exposed were many times higher than concentrations in North Fork Coeur d'Alene River water (Table 8-4). For example, dissolved zinc ranged from 1,230 to 3,000 µg/L in South Fork Coeur d'Alene River water compared with 9.4 to 30 µg/L in North Fork Coeur d'Alene River water. Therefore, the higher mortality of invertebrates exposed to South Fork Coeur d'Alene River water is associated with elevated metal concentrations.

Table 8-4
Results of Site Water Invertebrate Toxicity Tests by Dames & Moore (1989)

Site	Date	Hardness (mg/L)	Dissolved Metal Concentration: Cadmium (µg/L)	Lead (µg/L)	Zinc (µg/L)	LC50[a] (as % of site water)
North Fork Coeur d'Alene near Enaville (reference)	Sept. 1987	18	<2	31[b]	9.4	>100.0
	Dec. 1987	17.4	<4	<5	<20	>100.0
	June 1988	17.1	<4	<5	30	>100.0
South Fork Coeur d'Alene near Elizabeth Park (RM 9)	Sept. 1987	84	12	21	1,800	2.0
	Dec. 1987	80	6	13	2,190	6.1
	June 1988	67	10	<5	1,230	5.1
South Fork Coeur d'Alene near Bunker Creek (RM 6.8)	Sept. 1987	104	10	<19	2,200	0.1
	Dec. 1987	88.7	7	25	2,760	1.9
	June 1988	74.4	10	<5	1,490	3.7
South Fork Coeur d'Alene near Government Creek (RM 5)	Sept. 1987	168	11	<19	2,400	0.1
	Dec. 1987	141	7	<25	3,000	1.9
	June 1988	78.5	13	9	1,710	1.7
South Fork Coeur d'Alene near Pine Creek (RM 2.2)	Sept. 1987	120	8	<19	2,100	3.9
	Dec. 1987	121	6	18	2,780	5.6
	June 1988	73.8	9	<5	1,480	1.9

a. Represents the percentage of the site water that, when mixed with clean water, causes lethality to 50% of the test organisms.
b. Potential residual lead contamination on ICP torch (Dames & Moore, 1989; p. 18).

RM — river mile from the confluence of the South and North Fork Coeur d'Alene rivers.

Thornberg (1995) and Martinez (1998) both found a significantly higher incidence of mouthpart deformities in chironomid larvae from sites in the South Fork Coeur d'Alene River at Smelterville and in the mainstem Coeur d'Alene River than at sites upstream of mining related contamination. Rates of mouthpart deformity were positively correlated with metals concentrations in sediment at the collection sites, but were not related to metal concentrations in the chironomids (Martinez, 1998). In subsequent laboratory experiments, Martinez (2000) observed significantly greater rates of mouthpart deformities in populations exposed to lead or zinc than in the control population, and the incidence of mouthpart deformities increased with exposure duration. No clear dose response relationship between exposure concentration and deformity rate was observed, however. Martinez (2000) also found that the increase in the rate of mouthpart deformities induced by lead exposure persisted in the progeny of the exposed population, which suggests that lead exposure is mutagenic.

8.4 BENTHIC MACROINVERTEBRATE COMMUNITY DATA

This section presents and discusses data on the benthic macroinvertebrate community structure of the South Fork Coeur d'Alene and Coeur d'Alene rivers, their tributaries, and Coeur d'Alene Lake, focusing on two measures of metal effects on benthic communities: total taxa richness (i.e., the total number of benthic invertebrate taxa present) and mayfly species richness (i.e., the number of mayfly species present). These community measures are highlighted because they are proven, reliable indicators of metal effects on benthic communities (see Section 8.2.2). Exposure to metals causes a loss of metal-sensitive taxa from the community, resulting in a decrease in total taxa richness and a decrease in the number of mayfly taxa, which are among the metal-sensitive taxa.

8.4.1 Historical Data

The historical benthic macroinvertebrate community studies that have been conducted in the Coeur d'Alene River basin are summarized in Table 8-5. In general, these studies show that no or very few invertebrates were present in the South Fork Coeur d'Alene and Coeur d'Alene rivers until the early 1970s, soon after construction of tailings ponds reduced direct discharge of tailings to the system. The invertebrate community continued to improve slightly through the early 1980s following the reductions in metal loadings, but the community remained severely affected. Only a few metal-tolerant species were able to survive, and metal-sensitive taxa (such as mayflies) were largely absent. Surveys in the South Fork Coeur d'Alene and Coeur d'Alene rivers through the early 1990s have continued to show a community characteristic of an aquatic ecosystem impacted by metals, with metal-sensitive taxa largely absent.

South Fork Coeur d'Alene and Coeur d'Alene Rivers

Ellis (1940) was the first to report on the condition of benthic macroinvertebrates in the Coeur d'Alene River basin. In a 1932 survey of biological resources, he observed that the mainstem Coeur d'Alene River between the mouth and the confluence of the North Fork and South Fork Coeur d'Alene rivers, and the South Fork Coeur d'Alene River from its confluence with the North Fork to a point upstream of Wallace, were essentially devoid of aquatic biota, including benthic macroinvertebrates (Ellis, 1940). Benthic organisms were found only in the immediate areas where clean tributaries entered the contaminated rivers. Upstream of Wallace, benthic invertebrate communities included abundant caddisfly larvae (Trichoptera), stonefly larvae (Plecoptera), and mayfly nymphs (Ephemeroptera) and appeared unaffected by mining related disturbances (Ellis, 1940). Ellis attributed the absence of aquatic biota in the South Fork and mainstem Coeur d'Alene rivers to the turbidity and adverse effects on habitat caused by tailings and to acute zinc toxicity.

Table 8-5
Summary of Historical Invertebrate Community Studies

Study	Sampling Dates	Assessment Area Sampled	Reference Area Sampled[a]	Summary of Results
Ellis (1940)	1932	South Fork Coeur d'Alene River Mainstem Coeur d'Alene River Coeur d'Alene Lake Various tributaries	South Fork Coeur d'Alene River upstream of Mullan St. Joseph River	Areas downstream of mining "practically devoid of bottom fauna." Healthy, diverse communities at reference sites.
Wilson (1952) and Olson (1963)	Early 1950s and 1960s	South Fork Coeur d'Alene River Mainstem Coeur d'Alene River	None specified	"Virtually no benthic invertebrates."
Savage and Rabe (1973)	1968-1971	South Fork Coeur d'Alene River (three sites) Mainstem Coeur d'Alene River (one site)	North Fork Coeur d'Alene River South Fork Coeur d'Alene River upstream of Mullan	Reduced taxa richness and density at all assessment area sites.
Stokes and Ralston (1972)	1969-1970	South Fork Coeur d'Alene River (four sites) Mainstem Coeur d'Alene River (one site)	North Fork Coeur d'Alene River South Fork Coeur d'Alene River upstream of Mullan	Reduced taxa richness and density at all assessment area sites.
Funk et al. (1975)	1973	South Fork Coeur d'Alene River (one site) Mainstem Coeur d'Alene River (two sites)	North Fork Coeur d'Alene River	Reduced taxa richness and density at all assessment area sites.
Hornig et al. (1988)	1986	South Fork Coeur d'Alene River (five sites) Mainstem Coeur d'Alene River (one site)	North Fork Coeur d'Alene River South Fork Coeur d'Alene River upstream of Mullan	Reduced taxa richness at most South Fork Coeur d'Alene River sites.
Dames & Moore (1989)	1987	South Fork Coeur d'Alene River (four sites)	North Fork Coeur d'Alene River	Reduced taxa richness at all assessment area sites.

Table 8-5 (cont.)
Summary of Historical Invertebrate Community Studies

Study	Sampling Dates	Assessment Area Sampled	Reference Area Sampled[a]	Summary of Results
Hoiland (1992); Hoiland et al. (1994)	1987-1989, 1991	South Fork Coeur d'Alene River (three sites; two sites, 1991 only) Mainstem Coeur d'Alene River (one site) Ninemile Creek (three sites, 1991 only) Canyon Creek (three sites, 1991 only)	North Fork Coeur d'Alene River South Fork Coeur d'Alene River upstream of Mullan Canyon Creek upstream of Burke (1991 only)	Reduced taxa richness at all assessment area sites.
Clark (1992)	1992	South Fork Coeur d'Alene River (four sites) Mainstem Coeur d'Alene River (two sites)	South Fork Coeur d'Alene River upstream of Canyon Creek	Reduced taxa richness at South Fork Coeur d'Alene River sites.
U.S. Bureau of Mines (1995)	1993	Moon Creek (2 sites)	Moon Creek upstream of mine (one site)	Reduced taxa richness at both assessment area sites.
McNary et al. (1995)	1993 or 1994	Pine Creek basin (15 sites)	East Fork Pine Creek and Highland Creek upstream of mining activity	Reduced taxa richness at some assessment area sites.
Winner (1972)	1971-1972	Coeur d'Alene Lake	Lake Chatcolet and Round Lake	Difference in communities between assessment area and reference sites.
Skille et al. (1983)	1981-1982	Mainstem Coeur d'Alene River (two sites) Coeur d'Alene Lake (one site downgradient of Coeur d'Alene River mouth)	St. Joe River Coeur d'Alene Lake (four sites upgradient of Coeur d'Alene River mouth)	Reduced total abundance and biomass.
Ruud (1996)	1995	Coeur d'Alene Lake	Priest Lake Lake Chatcolet	Differences in communities between assessment area and reference sites.

a. As designated by study authors.

Tailings settling ponds in the basin installed in 1968 reduced tailings loads to the system (Savage and Rabe, 1973). Mink et al. (1971, as cited in Savage and Rabe, 1973) reported a significant reduction in suspended solids after the installation of settling ponds, but little change in metals concentrations in surface water. In late 1968, a single metals-tolerant taxon, midge fly larvae (Chironomids), had established in the South Fork Coeur d'Alene River (Savage, 1970). By late 1970 and in 1973, additional metals-tolerant taxa, including the mayfly *Baetis tricaudatus* and other stonefly, caddisfly, and beetle species, were found in the South Fork Coeur d'Alene River downstream of Wallace and on the mainstem Coeur d'Alene River near Cataldo (Figure 8-2) (Stokes and Ralston, 1972; Savage and Rabe, 1973; Funk et al., 1975). Nevertheless, the total number of taxa in the impacted areas of the South Fork Coeur d'Alene and mainstem Coeur d'Alene rivers remained low. For example, Savage and Rabe (1973) reported finding 25 to 32 invertebrate taxa in the North Fork Coeur d'Alene River and 19 taxa in the South Fork Coeur d'Alene River upstream of Mullan, compared with 2 to 4 invertebrate taxa at South Fork Coeur d'Alene and mainstem Coeur d'Alene river locations downstream of Canyon Creek (Figure 8-2). Water chemistry samples collected during the same time confirm the high metals exposure in the South Fork Coeur d'Alene River downstream of Mullan and in the mainstem Coeur d'Alene River compared with upstream and reference areas (Mink et al., 1971, as cited in Savage and Rabe, 1973).

Direct discharges of metals to the lower South Fork Coeur d'Alene River declined in the 1970s (Hornig et al., 1988). Between the 1970s and 1986, taxa richness increased in the South Fork Coeur d'Alene River downstream of Wallace and in the mainstem near Cataldo (Hornig et al., 1988). Although chironomid species remained dominant, increases in the numbers of species and relative abundance of other invertebrates were reported. Despite the improvement, metal-sensitive taxa remained absent from the South Fork Coeur d'Alene and mainstem Coeur d'Alene rivers, and the community was dominated by metal-tolerant midge fly larvae (Hornig et al., 1988). In 1981-1982, Skille et al. (1983) found almost complete absence of benthic invertebrates in the lower six miles of the mainstem Coeur d'Alene River. Mean invertebrate density in the Coeur d'Alene River ranged from 0 to 56 organisms/m^2, compared to averages of 397 to 1,600 organisms/m^2 in the lower St. Joe River (taxa richness was not reported).

Dames & Moore (1989) conducted benthic macroinvertebrate community surveys at two different flow periods in 1987-1988 in the South Fork Coeur d'Alene and North Fork Coeur d'Alene rivers. All sites sampled had similar substrate composition (dominated by cobble and gravel), riffle and thalweg depths, stream velocity, and stream width. Taxa richness results (Figure 8-3) show that fewer taxa were found in the South Fork Coeur d'Alene River sites (average of 10 to 16) than in the North Fork Coeur d'Alene River site (average of 27). The lowest number of taxa were measured in the South Fork near Bunker Creek (Figure 8-3).

Water quality data collection and site water toxicity tests conducted by Dames & Moore (1989) from the same locations during the same period (described in detail in Section 8.3) confirm that water at these sites had highly elevated metal concentrations and was toxic to invertebrates.

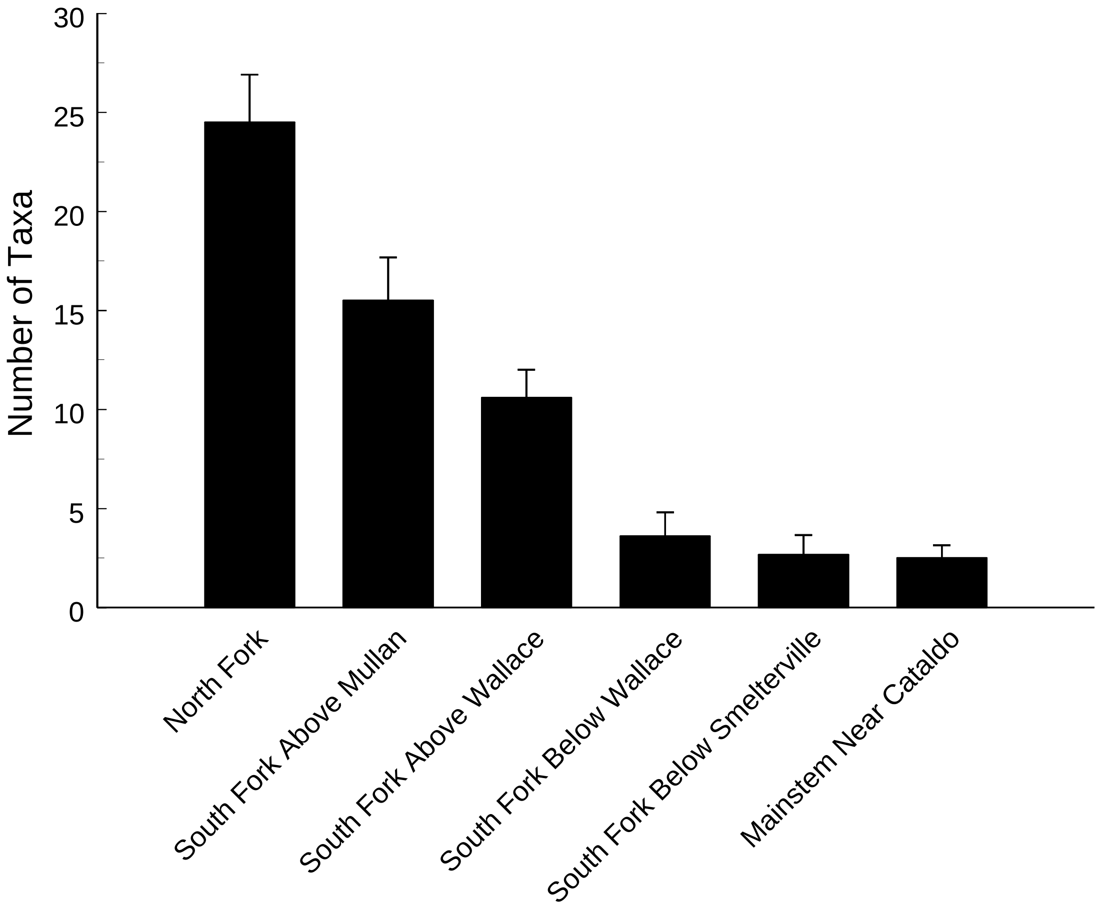

Figure 8-2. Invertebrate taxa richness (categorized to species level) in North Fork Coeur d'Alene, South Fork Coeur d'Alene, and Coeur d'Alene rivers in 1968-1970. Bars are means, vertical lines are means plus one standard error.
Source: Data from Savage and Rabe (1973) and Stokes and Ralston (1972).

Hoiland (1992), Clark (1992, as cited in Hartz, 1993), and Hoiland et al. (1994) report on invertebrate community studies conducted in the late 1980s and early 1990s (through 1992). Their results are similar to the studies conducted in the mid-1980s, with taxa richness reduced in the South Fork Coeur d'Alene and mainstem Coeur d'Alene rivers compared to the North Fork Coeur d'Alene River. Metal-sensitive species were absent or reduced in areas downstream of mining activity. Measurements of dissolved metals in surface water again confirmed the presence of higher metal concentrations at the South Fork Coeur d'Alene and mainstem Coeur d'Alene river sites compared to reference areas (Hoiland and Rabe, 1992). These studies confirm that no or little improvement occurred in the invertebrate communities from the mid-1980s through the early 1990s.

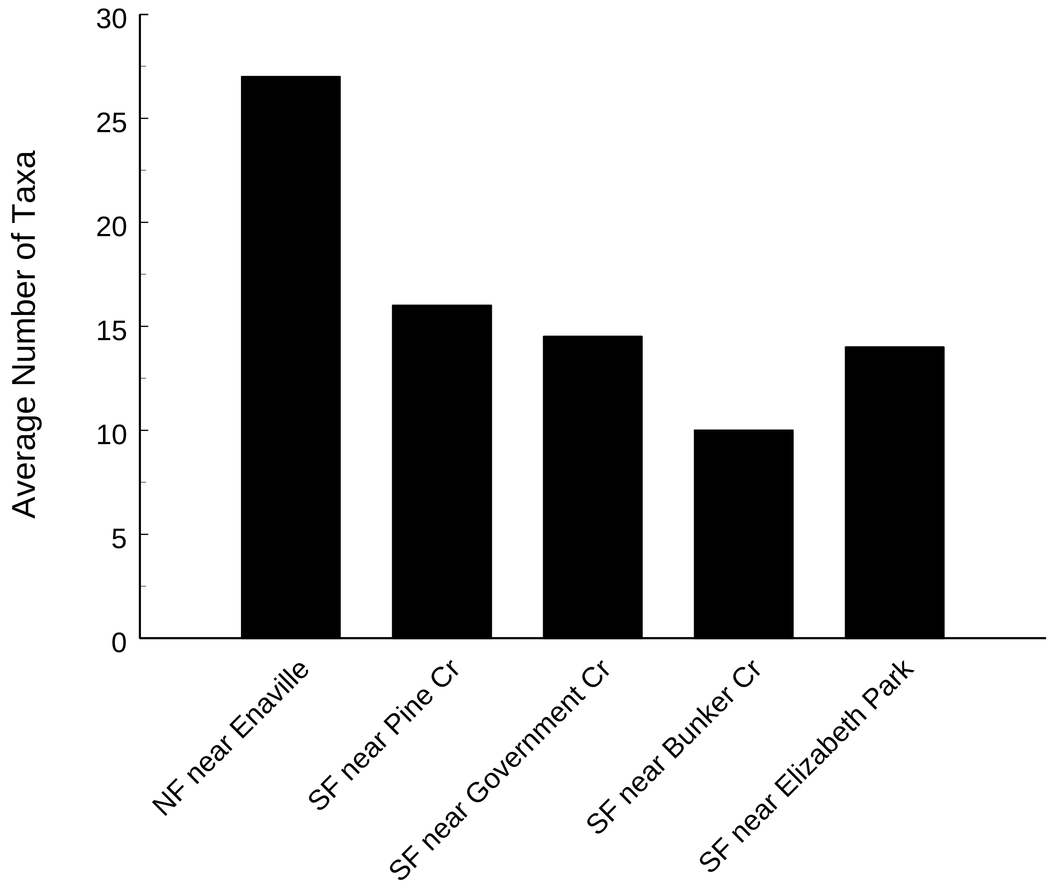

Figure 8-3. Invertebrate taxa richness (categorized to species level) in the South Fork Coeur d'Alene River and North Fork Coeur d'Alene River in 1987.
Source: Data from Dames & Moore, 1989.

Tributaries

Several studies have also been conducted on tributaries to the South Fork Coeur d'Alene and Coeur d'Alene rivers impacted by mining activity. Hoiland (1992) compared benthic invertebrate communities in Canyon and Ninemile creeks downstream of mining activities with the community in Canyon Creek upstream of mining. He found reduced taxa richness, loss of metal-sensitive species, and dominance by metal-tolerant species downstream of mining activities. Zinc concentrations were 20 to 320 µg/L at locations used as reference sites, compared with 1,490 to 5,290 µg/L at locations downstream of mining activity.

Benthic macroinvertebrate populations in Moon Creek upstream and downstream of mining activity were surveyed in 1993 by the U.S. Bureau of Mines (1995). Habitat quality parameters (e.g., embeddedness, diversity, canopy cover, substrate, habitat composition) were similar at all sites. The number of taxa (families) ranged from 17 at the site upstream of the mine to 5 downstream of the mine. Metal concentrations were much higher downstream of the mine (e.g., 477 µg/L Zn) than upstream (2.2 µg/L).

A similar study was conducted by the U.S. Bureau of Mines on the Pine Creek watershed (McNary et al., 1995). This study had similar results, with higher metal concentrations, reduced taxa richness, and loss of metal-sensitive taxa in areas downstream of mining activity compared with upstream.

Coeur d'Alene Lake

Studies of benthic macroinvertebrate communities of Coeur d'Alene Lake include Winner (1972), Skille et al. (1983), and Ruud (1996). Winner (1972) observed strong dominance by chironomids (comprising 51 to 75% of the total number of benthic macroinvertebrates) and oligochaetes (comprising 26 to 49% of the total number of benthic macroinvertebrates) in benthic macroinvertebrate communities of Coeur d'Alene Lake. Species of the subfamily Chironominae (dominated by *Microspectra* spp. and *Chironimus* spp.) comprised the majority (73%) of the Chironomids. Based on one density estimate per site at four sites, Winner (1972) reported no relationship between sediment zinc concentrations and the distribution of chironomids or oligochates. However, the small sample size did not allow statistical analysis of the data.

Skille et al. (1983) sampled benthic macroinvertebrates in Lake Coeur d'Alene to the north (downgradient) and to the south (upgradient) of the mouth of the Coeur d'Alene River. Invertebrate density was greatest at sites upgradient of the Coeur d'Alene River mouth and lowest at the site downgradient of the river mouth.

Horowitz et al. (1995) observed burrow and worm tubes indicative of biological activity in the deeper, pre-mining sediment layers of cores taken from Coeur d'Alene Lake. In sediments deposited after mining began (i.e., sediments with elevated metals concentrations), they observed a complete absence of structures of biological origin. They suggested three potential causes for the elimination of the sediment fauna, all related to increased mining activity in the basin: high turbidity caused by increased concentrations of suspended sediments in the lake, increased sedimentation, and direct metals toxicity. They concluded that the disappearance of at least part of the benthic macroinvertebrate community was related to mine waste disposal.

Ruud (1996) detected significant differences in the dominant taxa of profundal communities (20 m to 40 m depths) and sublittoral communities (5 m to 10 m depths) between Coeur d'Alene Lake and in Priest Lake, Idaho, an oligotrophic lake of similar size, flow, and parent geology. Profundal communities of Priest Lake were dominated by chironominae (*Microspectra* spp. and *Chironomus* spp.) and sphaeriinae, whereas Coeur d'Alene Lake profundal communities were dominated by nematophora, tricladidae, and oligochaetae. Sublittoral communities in Priest Lake were dominated by chironominea and tanypodinae, whereas Coeur d'Alene Lake sublittoral communities were dominated by amphipoda, isopoda, tanypodinae, and oligochaetae. Ruud (1996) reported a positive correlation between zinc concentrations in water and total abundance, total biomass, taxa richness, and mean diversity, as well as between lead concentrations in water and total abundance and total biomass. Ruud did not measure sediment metal concentrations, however, and thus did not explore relationships between sediment concentrations and invertebrate measures.

The available data suggest that benthic macroinvertebrate communities in Coeur d'Alene Lake are significantly different from communities in lakes with no metal enrichment and that deposition of mining related wastes has adversely affected the benthic macroinvertebrate community. Concentrations in lake bed sediments greatly exceed toxicity thresholds (Figure 5-5 and Table 5-4, Chapter 5). The reduced density of invertebrates downgradient of the Coeur d'Alene River mouth relative to densities upgradient and the differences in the Coeur d'Alene Lake community relative to reference areas are consistent with the conclusion that metals in sediments are adversely affecting the invertebrate community.

Summary

In summary, historical studies of benthic macroinvertebrate communities in the Coeur d'Alene River basin show the following:

- Measurements of surface water metal concentrations confirm that the invertebrate communities downstream of mining activity are exposed to greatly elevated concentrations of metals.

- Before the late 1960s, invertebrates were virtually absent from the South Fork Coeur d'Alene and Coeur d'Alene rivers downstream of mining activity, compared with diverse communities upstream. Biological activity in Coeur d'Alene Lake sediment appears to have ceased with the onset of releases of mining-related wastes into the lake.

- The construction of tailings retention ponds in the late 1960s and other reductions in direct mine waste discharges in the 1970s resulted in an improvement in the benthic macroinvertebrate communities in areas downstream of mining activity. However, communities of the South Fork Coeur d'Alene River and its tributaries, the mainstem Coeur d'Alene River, and Coeur d'Alene Lake remained characteristic of metals-impacted systems, with reductions in abundance, taxa richness, and metal-sensitive taxa. Community effects continued in the South Fork Coeur d'Alene River and its tributaries at least through the early 1990s.

8.4.2 Supplemental Trustee Study

In 1996 the Trustees conducted a supplemental invertebrate community survey in the Coeur d'Alene River basin. The objective of the study was to supplement the existing historical data on invertebrate communities with more recent data and with data from tributaries for which historical data are not available.

The 1996 macroinvertebrate sampling was conducted at 25 sites, including 2 sites on the South Fork Coeur d'Alene River upstream of Canyon Creek; 3 sites on the South Fork Coeur d'Alene downstream of Canyon Creek; 15 South Fork, North Fork, and mainstem Coeur d'Alene River tributaries; and 5 sites on the St. Regis River (R2 Resource Consultants, 1997; Woodward et al., 1997). The sampling locations were selected to achieve consistency between sites with respect to habitat type and hydraulic parameters (Woodward et al., 1997). Invertebrate sampling was conducted by placing three artificial habitat substrates at each location from July 10-12, 1996, to August 20-24, 1996. The samplers were then removed, placed in glass jars, and stored in 70% ethanol for preservation. At the laboratory, samples were sorted and identified to the genus level. Habitat and water quality measurements were also made at the invertebrate sampling locations.

For the South Fork Coeur d'Alene River sites downstream of Canyon Creek, two types of reference sites were sampled: (1) sites on the South Fork Coeur d'Alene River upstream of Canyon Creek (two locations), and (2) sites on the St. Regis River (five locations). For the Canyon and Ninemile Creek sites downstream of mining activity, reference sites include one location on Canyon Creek upstream of mining activity, and six locations on other tributaries in the basin that are relatively unaffected by mining.

Benthic community survey results are shown in Figure 8-4 for the South Fork Coeur d'Alene River and reference areas for the South Fork Coeur d'Alene River. Mean total taxa richness at the three South Fork Coeur d'Alene River stations downstream of mining activity was 7.3, 8.7, and 10.0. In contrast, taxa richness at the two South Fork Coeur d'Alene River locations upstream of mining activity was 14.0 and 17.5, indicating a reduction in taxa richness downstream of mining activity. Mean mayfly taxa richness at the three downstream South Fork Coeur d'Alene River stations was 0.7, 1.3, and 1.3, compared with 3.0 and 5.5 at the upstream South Fork Coeur d'Alene River locations. These data indicate that both total taxa richness and mayfly taxa richness were reduced in the South Fork Coeur d'Alene River downstream of mining activity.

Figure 8-5 shows the percent of the sampled invertebrates that are mayflies (order Ephemeroptera) within the South Fork of the Coeur d'Alene River. As discussed previously, most mayflies are relatively sensitive to metal pollution, and decreases in mayflies are indicative of metals effects on the benthic macroinvertebrate community. The figure shows that the percent of mayflies decreases with distance downstream in the South Fork Coeur d'Alene River, from a mean of 30.8% at the most upstream location to 0.4% at the most downstream location (R2 Resource Consultants, 1997). In contrast, the percent of mayflies in the St. Regis River is relatively constant with distance downstream (R2 Resource Consultants, 1997), indicating that

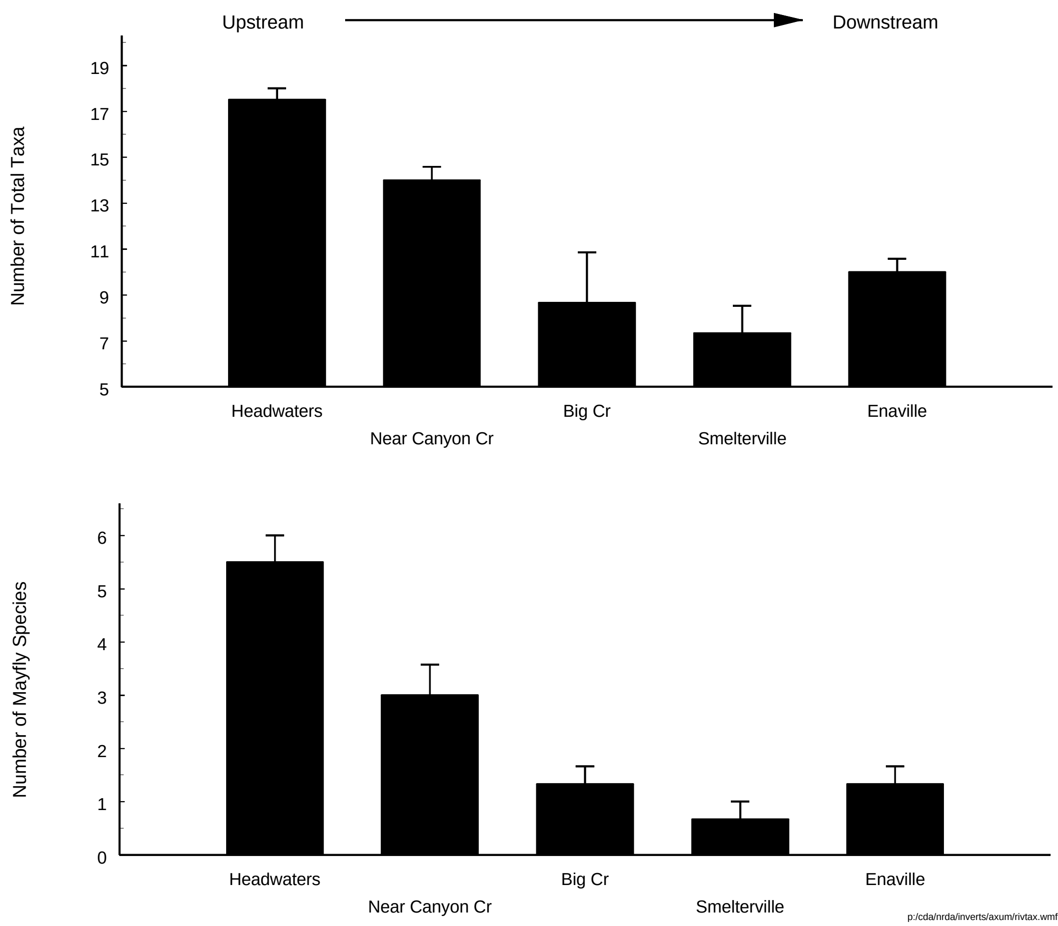

Figure 8-4. Total taxa richness (top panel) and mayfly taxa richness (bottom panel) measured in 1996 in the South Fork Coeur d'Alene River. Bars are means, vertical lines are means plus one standard error.
Source: Data from R2 Resource Consultants (1997) and Woodward et al. (1997).

absent mining impacts, percent of mayflies should also remain relatively constant with distance downstream in the South Fork Coeur d'Alene River. The loss of mayflies in the South Fork Coeur d'Alene River corresponds with an increase in diptera larvae, particularly midges (chironomidae) and blackflies (simuliidae) (R2 Resource Consultants, 1997), many species of which are relatively tolerant of metals (McGuire, 1999). Thus the observed shift in the benthic macroinvertebrate community from metals-sensitive taxa to metals-tolerant taxa from upstream areas to downstream areas is consistent with metals causing the community change.

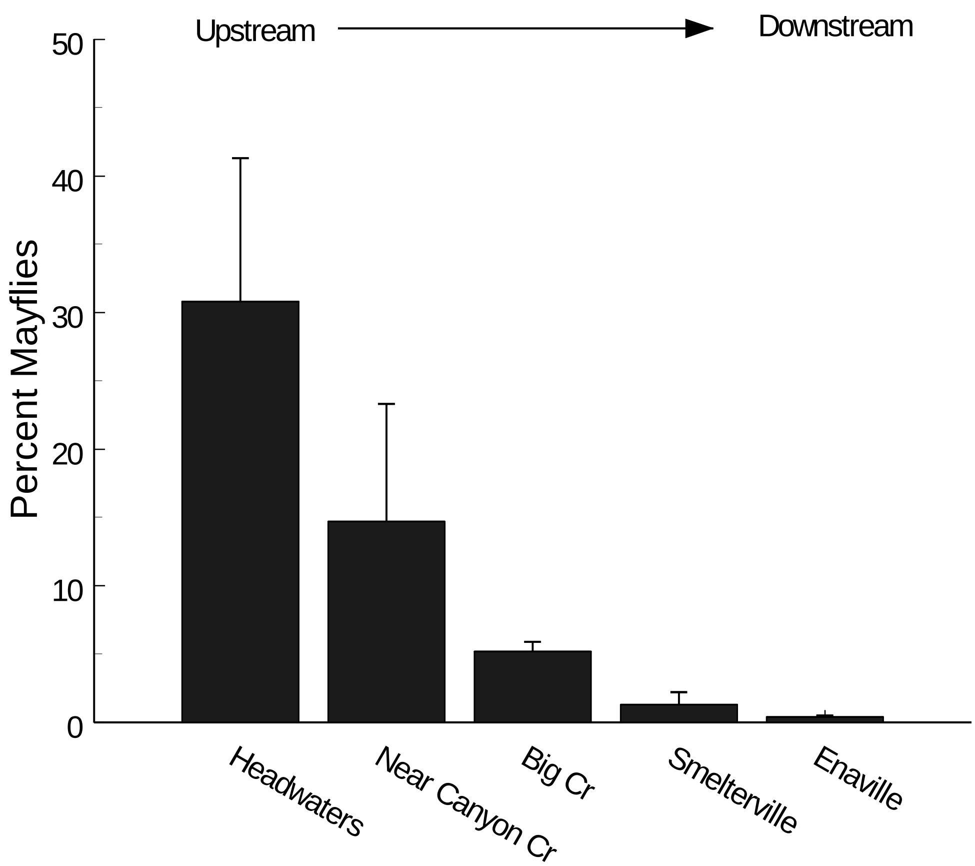

Figure 8-5. Percent mayflies in 1996 in the South Fork Coeur d'Alene River. Bars are means, vertical lines are means plus one standard error.
Source: Data from R2 Resource Consultants (1997) and Woodward et al. (1997).

Figure 8-6 shows the community composition results for Canyon and Ninemile creeks and their reference sites. As in the South Fork Coeur d'Alene River, total taxa richness and mayfly taxa richness are lower in Canyon and Ninemile creeks downstream of mining activity compared with upstream Canyon Creek and with other tributary reference sites. The reduction is greater for mayfly taxa richness, with Canyon and Ninemile creeks downstream sites having 0.33, 1.33, and 1.33 mean mayfly species present, compared with 4.0 at the upstream Canyon Creek site and 3.0 to 4.7 at other reference tributary sites. The communities in Ninemile Creek and downstream Canyon Creek are dominated by metals-tolerant species. Therefore, these data demonstrate that the invertebrate communities in Canyon and Ninemile creeks downstream of mining activity are adversely affected compared with reference areas.

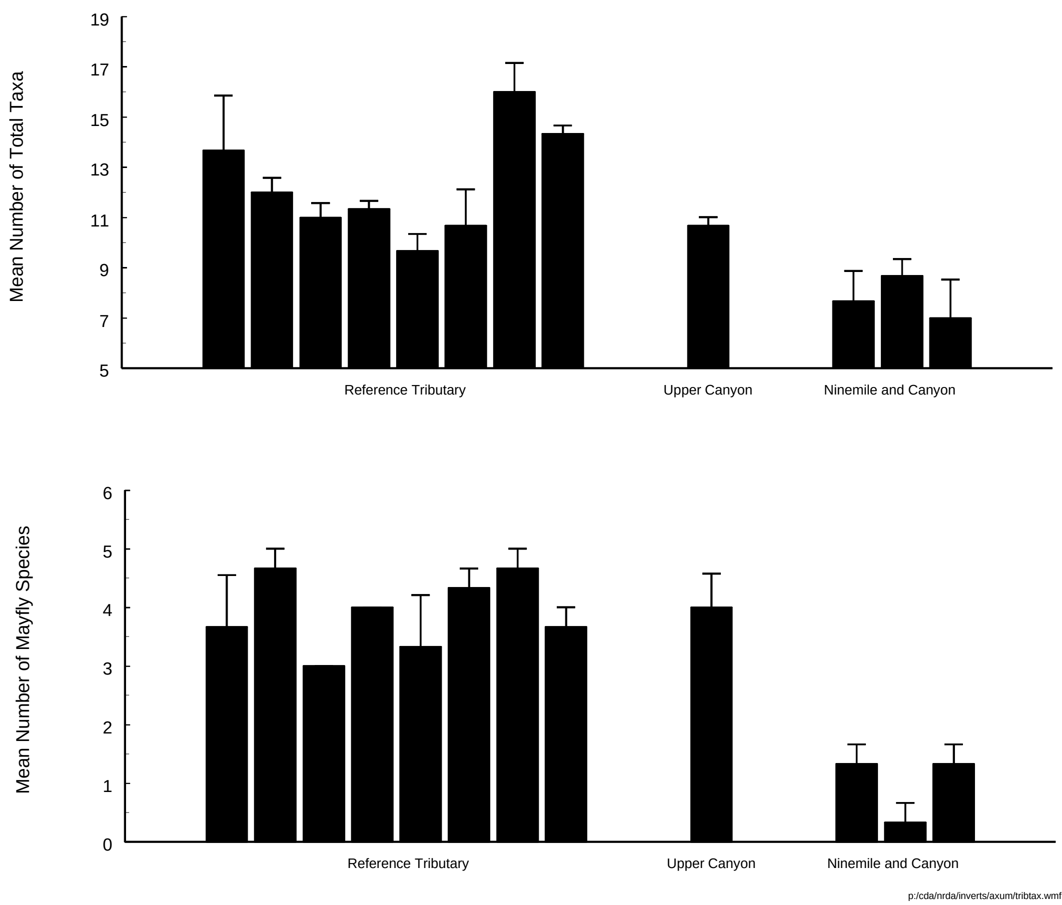

Figure 8-6. Total taxa richness (top panel) and mayfly taxa richness (bottom panel) measured in 1996 in Canyon and Ninemile creeks and in reference areas. Bars are means, vertical lines are means plus one standard error.
Source: Data from R2 Resource Consultants (1997) and Woodward et al. (1997).

Figure 8-7 shows mean total taxa richness and mayfly species richness plotted against dissolved zinc concentrations for all sites sampled. Figure 8-6 shows that at all locations with dissolved zinc greater than approximately 300 µg/L, total taxa richness does not exceed 10. At sites with lower zinc concentrations, taxa richness ranges up to approximately 18. A similar but more pronounced pattern is evident with mayfly taxa richness and dissolved zinc. Mean mayfly taxa richness at all sites with greater than 1,000 µg/L Zn is less than 1.5. Mean mayfly species richness is between 2.0 and 6.5 for sites with zinc concentrations of less than approximately 500 µg/L zinc. These data show that the observed adverse effects on the benthic macroinvertebrate communities are associated with elevated concentrations of hazardous metals.

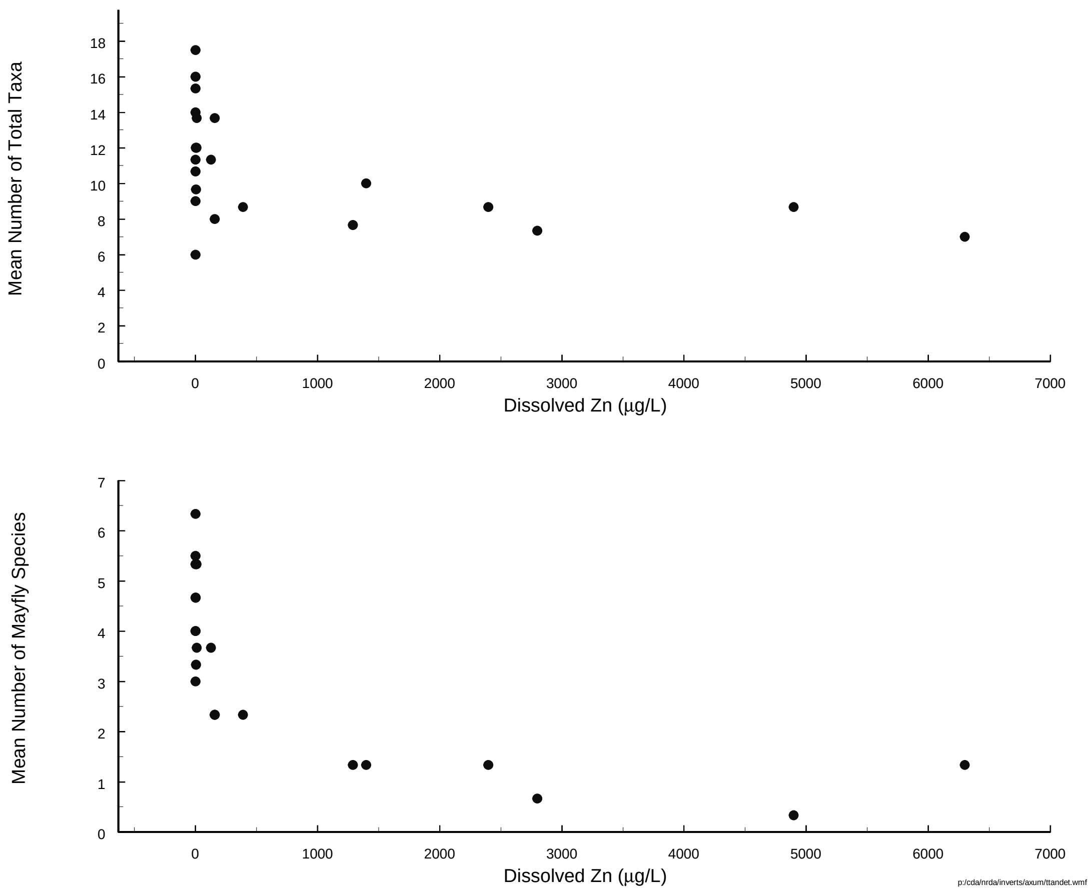

Figure 8-7. Dissolved zinc versus total taxa richness (top panel) and mayfly taxa richness (bottom panel), all 1996 sampling sites combined.
Source: Data from R2 Resource Consultants (1997) and Woodward et al. (1997).

8.4.3 Summary of Community Studies

No or very few invertebrates were present in the South Fork Coeur d'Alene and Coeur d'Alene rivers until the early 1970s, soon after construction of tailings ponds reduced direct discharge of tailings to the system. The invertebrate community of Coeur d'Alene Lake was also historically depauperate. The invertebrate community improved slightly through the early 1980s following the reductions in metal loadings, but the community in the South Fork Coeur d'Alene and Coeur d'Alene rivers remained severely affected. Only a few metal-tolerant species were able to survive, and metal-sensitive species (such as mayflies) were largely absent. Surveys in the South Fork Coeur d'Alene and Coeur d'Alene rivers through the early 1990s have continued to show a community characteristic of an aquatic ecosystem impacted by metals, with metal-sensitive taxa absent or reduced in number.

The results of a supplemental study by the Trustees in 1996 are consistent with the historical data. The benthic macroinvertebrate communities in the South Fork Coeur d'Alene River, Canyon Creek, Ninemile Creek, and the mainstem Coeur d'Alene River downstream of mining activity are reduced in total taxa richness and mayfly species richness compared with reference areas. Reductions in these community structure measures are consistent with adverse effects from metal toxicity. Dissolved zinc concentrations measured during the supplemental study show that effects on the benthic macroinvertebrate community are associated with elevated concentrations of zinc.

8.5 INJURY DETERMINATION

This section presents the determination of injury for benthic macroinvertebrates in the Coeur d'Alene River basin. The injury definitions for which injuries were tested and the lines of evidence available for evaluation of injuries are discussed, and alternative causes of adverse effects to benthic macroinvertebrates are evaluated. Finally, the regulatory determination of injury is presented.

8.5.1 Injury Definitions

Based on the information presented above, injuries addressed in this determination were:

- death [43 CFR § 11.62 (f)(4)(i)]
- behavioral avoidance [43 CFR § 11.62 (f)(4)(iii)(B)]
- physical deformation [43 CFR § 11.62 (f)(4)(vi)(A)].

Death and behavioral avoidance are manifested as changes in the benthic macroinvertebrate community structure. Studies have shown that the community structure response to metals toxicity can involve both mortality and invertebrate avoidance. Invertebrate avoidance occurs primarily as an increase in invertebrate drift (Brittain and Eikeland, 1988).

8.5.2 Lines of Evidence

Comparison of Toxicity Thresholds with Surface Water and Sediment Data

As discussed in Chapter 7, the U.S. EPA has developed aquatic life criteria (ALC) for the protection of aquatic biota (Stephen et al., 1985). The analysis presented in Chapter 7 demonstrates that ALC exceedences are observed throughout the Coeur d'Alene River basin downstream of mining activity. The frequency of exceedences and the magnitude of the exceedences provide evidence of the likelihood of adverse toxic effects of metals to benthic macroinvertebrates. Although the cadmium, lead, and zinc ALC are based in part on results for invertebrate species, most of the tests used in the ALC development are based on toxicity to fish species (U.S. EPA, 1987). Nevertheless, available data on the toxicity of metals to benthic communities indicate that toxicity tends to occur at concentrations close to the ALC. These studies include controlled laboratory studies, in which transplanted invertebrate communities are exposed to metals (Selby et al., 1985; Clements et al., 1988), and field studies where community-level effects are linked to metals exposure (Leland et al., 1989; Clements et al., 1990). Therefore, the ALC can be used as reasonable estimates of literature-based concentrations above which toxicity can be expected.

EVS (1997) conducted a series of site-specific tests that they concluded may suggest that toxicity to Coeur d'Alene invertebrates begins to occur at metal concentrations well above ALC values. They conducted toxicity tests using invertebrates collected from the South Fork Coeur d'Alene River upstream of Mullan. The invertebrates were exposed to South Fork Coeur d'Alene River water spiked with cadmium, lead, or zinc. However, the thresholds produced from these tests are not appropriate as potential injury thresholds for Coeur d'Alene basin invertebrates for the following reasons:

- The test results are not indicative of toxicity to metal-sensitive invertebrate species. For example, of the five invertebrate species used in the lead toxicity testing, the most sensitive species was the mayfly *Baetis tricaudatus* (EVS, 1997). Although many mayfly species are sensitive to metals, *Baetis tricaudatus* are known to be relatively tolerant of metal toxicity compared to other mayflies. For example, downstream of mining impacts in the Clark Fork River, Montana, *Baetis tricaudatus* are more tolerant of elevated metal concentrations than any other mayfly species (McGuire, 1999). Roline (1988) found *Baetis* both upstream and downstream of mining inputs into the Arkansas River (Colorado) and concluded that they are "quite tolerant of heavy metals pollution." Clements (1994) and Kiffney and Clements (1994) report similar findings for *Baetis tricaudatus* in the Arkansas River. In fact, *Baetis tricaudatus* was one of the first species to recolonize the South Fork Coeur d'Alene River in the early 1970s, when only a few invertebrate species could survive in the river (Stokes and Ralston, 1972; Savage and Rabe, 1973; Funk et al., 1975). Therefore, the tests did not use species representative of metal-sensitive invertebrates.

- The tests used invertebrates collected from the South Fork Coeur d'Alene River in areas downstream of mining activity. Therefore, the organisms used in the tests may have been preselected for metal tolerance.

- Several of the tests did not show a consistent dose-response relationship, making their interpretation difficult.

Nevertheless, metal concentrations in areas of the South Fork Coeur d'Alene and Coeur d'Alene rivers downstream of mining activity still exceed the invertebrate toxicity thresholds from EVS (1997). Figure 8-8 compares dissolved cadmium and zinc concentrations against EVS invertebrate toxicity thresholds. The surface water data plotted in Figure 8-8 are the same data used in Chapter 7 to evaluate potential toxicity to fish. The threshold concentration plotted for cadmium is the concentration observed to cause 40-50% mortality to *Baetis tricaudatus* in site water with added cadmium (EVS, 1997). For zinc, the threshold concentration plotted in Figure 8-8 is the calculated LC50 for the snail *Gyraulus* in site water with added zinc (i.e., the concentration estimated to cause mortality to 50% of the organisms). Figure 8-8 shows that dissolved zinc concentrations in the South Fork Coeur d'Alene downstream of Canyon Creek and in Canyon, Ninemile, and Pine creeks downstream of mining activity exceed the concentration estimated to cause approximately 50% mortality to the test organisms. Dissolved cadmium concentrations in Canyon and Ninemile creeks exceed the EVS thresholds for 40-50% mortality to *Baetis tricaudatus*. Therefore, measured metal concentrations exceed even the EVS thresholds, which most likely are too high to be protective of the invertebrate community.

Although the U.S. EPA has not developed sediment criteria similar to surface water ALC, other agencies have developed sediment toxicity screening thresholds, including the National Oceanic and Atmospheric Administration (NOAA) (Long and Morgan, 1991) and the Ontario Ministry of the Environment (Persaud et al., 1993). These thresholds are based primarily on sediment toxicity to benthic invertebrates observed in the field, and represent concentrations above which toxicity to at least some benthic invertebrates can be expected. Chapter 5 presented a comparison of cadmium, lead, and zinc concentrations in the Coeur d'Alene River and Coeur d'Alene Lake with sediment toxicity thresholds. The comparison shows that hazardous metal concentrations in sediments of the lower Coeur d'Alene River basin are many times greater than sediment toxicity thresholds.

In conclusion, comparison of surface water cadmium, lead, and zinc concentrations with ALC and site-specific threshold concentrations developed for relatively metal-tolerant invertebrates, and comparison of sediment cadmium, lead, and zinc concentrations with sediment toxicity, demonstrate the likelihood that metals concentrations in the Coeur d'Alene basin are sufficient to cause toxicity to benthic macroinvertebrates.

Site-Specific Toxicity Data

Site-specific invertebrate toxicity data include tests conducted using water collected from areas downstream and upstream of mining activity. These tests have confirmed that water from the South Fork Coeur d'Alene and mainstem Coeur d'Alene rivers downstream of mining activity is toxic to invertebrates in controlled laboratory studies (Hornig et al., 1988; Dames & Moore, 1989). In one of the studies (Dames & Moore, 1989), dilutions of 0.1 to 6.1% South Fork Coeur d'Alene River water with clean water caused lethality to 50% of the test organisms. The test organisms used in the two studies, the waterflea species *Daphnia magna* and *Ceriodaphnia dubia*, are among the more sensitive invertebrate species to cadmium and zinc toxicity, although

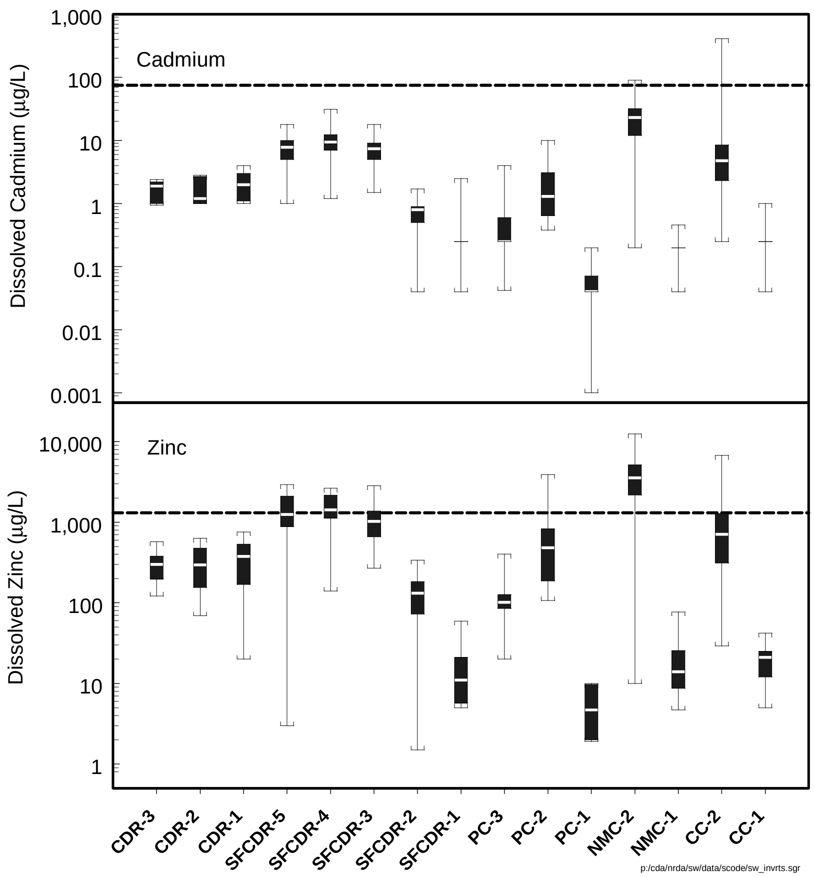

Figure 8-8. Dissolved cadmium and zinc concentrations in the Coeur d'Alene River basin (median value and data maximum) and invertebrate adverse effects concentrations from site-relevant bioassays. Horizontal dashed lines represent concentration observed to cause 40-50% mortality to *Baetis tricaudata* (for Cd) and the calculated LC50 for the snail *Gyraulus* (for Zn). Water chemistry median and maximum values from Chapter 4 (Tables 4-11 and 4-13) are presented. Boxes show the data range, median, and 25th and 75th percentiles of the data.
Source: Data from Ridolfi Engineers Inc. (1999), data presented in Chapter 4, and EVS (1997).

single-species data for invertebrates are limited (U.S. EPA, 1985, 1987). Therefore, these site-specific studies provide direct and compelling evidence that metals are present in the South Fork Coeur d'Alene and Coeur d'Alene rivers at concentrations sufficient to cause toxicity at least to metals-sensitive invertebrates.

Community Data

The results of the benthic macroinvertebrate community studies presented above show that community structures in the South Fork Coeur d'Alene River, the Coeur d'Alene River, Canyon Creek, and Ninemile Creek downstream of mining activity are different from those in areas unimpacted by mining. Specifically, metals-sensitive invertebrates are absent or reduced, and communities are dominated by metals-tolerant species. This shift is indicated by decreases in the total number of invertebrate taxa and the number of mayfly species present in the mining affected areas. Thus, the changes in the benthic macroinvertebrate communities in these areas are consistent with injury resulting from exposure to metals. The benthic invertebrate community of Coeur d'Alene Lake has also been altered compared to reference areas.

8.5.3 Causation Evaluation

In this section, the extent to which the evidence shows that the observed adverse effects on macroinvertebrates resulted from metals exposure, as opposed to other possible causes, is discussed.

Comparison of surface water and sediment metal concentrations in the Coeur d'Alene River basin with ALC and sediment toxicity thresholds demonstrates that Coeur d'Alene River basin concentrations are well above those shown to cause toxicity under laboratory conditions and at other sites. Therefore, a conclusion that metals are the causative factor for the observed effects is consistent with the scientific literature.

The site water toxicity tests demonstrate that site water is indeed toxic to invertebrates. Two independent studies, using water collected from different time periods, both found that water from the South Fork Coeur d'Alene and Coeur d'Alene rivers was highly toxic to invertebrates (Hornig et al., 1988; Dames & Moore, 1989). Metal concentrations measured during the tests were well above the ALC, and well above reference area concentrations. No other possible explanations for the observed toxicity were reported by the study authors. Therefore, these studies provide strong evidence that metals were responsible for the toxicity observed.

The benthic macroinvertebrate community data are consistent with metals as the cause of the adverse effects. The observed pattern of loss of metals-sensitive species and dominance by metals-tolerant species is typical of aquatic systems contaminated by metals. The community results are also consistent across studies, with several independent investigators finding the same conclusions. Similarly, the chironomid mouthpart deformities observed in the Coeur d'Alene River can be caused by exposure to elevated concentrations of lead and zinc in sediment (Thornberg, 1995; Martinez, 2000). The elevated rates of mouthpart deformities in chironomid populations from Smelterville to Harrison are supporting evidence of ongoing invertebrate exposure to metals and adverse effects.

In addition, the temporal trend in the benthic community structure is also consistent with metals as the cause. Soon after direct discharges of metals to the system declined in the 1970s, the benthic macroinvertebrate community improved, although it has remained impacted. Similarly, the disappearance of evidence of biological activity in Coeur d'Alene Lake sediment corresponds to the onset of mining waste accumulation in the sediment.

Another possible causal factor contributing to the observed benthic community alterations is habitat degradation. As part of the Trustee's supplemental study in 1996, stream habitat measurements were taken at locations near where the invertebrate community was sampled (R2 Resource Consultants, 1997). The overall aquatic habitat quality was summarized using U.S. EPA's Rapid Bioassessment Protocol (RBP) scores (Plafkin et al., 1989), in which higher scores mean better overall habitat quality. The overall RBP scores are based on scores for nine variables: bottom substrate and available cover, substrate embeddedness, flow/velocity, channel alteration, bottom scouring and deposition, pool/riffle diversity, bank stability, bank vegetation, and streamside cover. The results of the habitat assessment show that the overall habitat quality in the South Fork Coeur d'Alene River downstream of Canyon Creek (mean RBP score of 74) was lower than in the South Fork Coeur d'Alene River upstream of Canyon Creek and in the St. Regis River (mean RBP score of 108) (R2 Resource Consultants, 1997; Woodward et al., 1997). This decrease in habitat quality most likely would also affect the benthic macroinvertebrate community in the South Fork Coeur d'Alene River downstream of mining activities.

However, mining activities are at least in part the cause for the decrease in invertebrate habitat quality in the downstream areas of the South Fork Coeur d'Alene River. Many of the habitat parameters in the RBP score are dependent on stable riparian vegetation communities. Healthy riparian vegetation decreases bank erosion, minimizes channelization, and provides woody debris cover (Plafkin et al., 1989). These benefits are directly accounted for in many of the RBP parameters, such as streamside cover, bank vegetation, bank stability, channel alteration, bottom substrate and available cover, and substrate embeddedness. The analysis presented in Chapter 9 shows that mining-related hazardous substances have caused a severe reduction in riparian vegetative cover along the South Fork Coeur d'Alene river downstream of Canyon Creek. For example, in field vegetation surveys conducted by the Trustees, bare ground was the dominant cover type at 50% of the South Fork Coeur d'Alene River riparian sites, compared with 0% at the reference sites (Section 9.5.3). This lack of vegetation is a result of phytotoxicity caused by hazardous metals (Section 9.5.5). Therefore, the reduction in habitat quality in the South Fork Coeur d'Alene River downstream of mining activities is associated with the mining-caused loss of riparian vegetation.

Similarly, the increased sediment and tailings-contaminated sediment loads and increased sediment deposition on the Coeur d'Alene River beds and banks, lateral lakes beds, and Coeur d'Alene Lake bed probably historically reduced physical habitat quality as well as chemical habitat quality.

8.5.4 Regulatory Determination

Benthic macroinvertebrate resources have been and are injured in the South Fork Coeur d'Alene River, Canyon Creek, and Ninemile Creek as a result of releases of hazardous substances from mining and mineral processing operations.

Specifically, benthic macroinvertebrate communities downstream of mining activity are altered by exposure to metals. The alteration results from a combination of the following types of injury:

- death [43 CFR § 11.62 (f)(4)(i)], as confirmed by bioassays using site water [43 CFR § 11.62 (f)(4)(i)]
- behavioral avoidance [43 CFR § 11.62 (f)(4)(iii)(B)], as confirmed by alterations in benthic community structure.

Benthic macroinvertebrates are important food sources for many fish species, including trout and sculpin, and serve important roles in the energy and nutrient cycling of aquatic systems. The injury to the benthic macroinvertebrate resources has resulted in a community dominated by metals-tolerant species, with metals-sensitive species absent or greatly reduced.

Historical data show that the benthic macroinvertebrate communities of the lower mainstem Coeur d'Alene River and Coeur d'Alene Lake have been injured. However, recent data were not available to evaluate whether injuries to the macroinvertebrate communities in these areas continue to the present.

In addition, although the data are less conclusive, physical deformation injuries [43 CFR § 11.62 (f)(4)(vi)(A)], specifically, chironomid mouthpart deformities resulting from metals exposure, may be ongoing in the South Fork and mainstem Coeur d'Alene Rivers.

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