Characterizing the Aquatic Health in the Boulder River Watershed, Montana

By Aïda M. Farag, Daniel F. Woodward, Don Skaar, and William G. Brumbaugh.

ABSTRACT

The Boulder River and some of its tributaries receive direct effluent from abandoned mine adits and runoff from old tailings piles located in the basin. This biological assessment identified a pathway of metals exposure in the Boulder River Watershed as measured by concentrations of metals in biofilm (abiotic and biotic material on rock surfaces), invertebrates, and fish collected from the Boulder River and a select number of its tributaries. These data along with data from fishery population surveys are being used to assess the ecological health of the Boulder River and its tributaries. Preliminary data suggest that concentrations of arsenic, copper, cadmium, lead, and zinc are elevated to varying degrees in biological tissues collected from the Boulder River and its tributaries. Tissue damage in fish livers, as measured by an increase of products of lipid peroxidation, along with reductions in fish sizes and populations in lower Cataract Creek were also noted. Thus, exposure to metals may have resulted in a deterioration of fish health and a quantitative loss in fish populations in Cataract Creek. We also documented 100% mortality of fish placed in live containers in the upper sections of the Basin Creek and Cataract Creek and lower High Ore Creek.

INTRODUCTION

The Boulder River Watershed, located in southwest Montana, encompasses lands managed by the Bureau of Land Management and the U.S. Forest Service. Managers from these agencies plan to remediate the effects of past mining activities in the watershed. As part of the Abandoned Mine Lands Initiative, personnel from the U.S. Geological Survey are assisting managers in their attempts to characterize the effects of mining activities in this watershed.

The Boulder River and some of its tributaries receive direct effluent from abandoned mine adits and runoff from old tailings piles. There are three tributaries of concern in this watershed (Figure 1): Basin Creek, Cataract Creek, and High Ore Creek. Wastes from the Bullion Mine are discharged into Jack Creek, which flows into Basin Creek. Basin Creek then flows into the Boulder River below Sullivan Gulch. Uncle Sam Gulch and Morning Glory Mine provide inputs into Cataract Creek which flows into the Boulder River downstream of Basin Creek. The Comet Mine is located along High Ore Creek which flows into the Boulder River upstream of Galena Gulch.

Interest in the effects of mining on aquatic life in the Boulder River began in 1976. Nelson (1976) studied three sections of the Boulder River: below Red Rock Creek, below Cataract Creek, and below High Ore Creek. Reductions in the survival of fish eggs during an egg bioassay and reductions in fish population estimates were noted below Cataract Creek and High Ore Creek. Although metals were not analyzed in sediments, water, or biological tissues, Nelson attributed this population reduction to mining activities in the Boulder River Watershed.

It was not until 1990 that another investigation of the Boulder River was initiated. Gless (1990) designated Basin Creek a “stream of concern,” Cataract Creek as “degraded” and High Ore Creek as “extremely degraded.” These classifications were based on elevated concentrations of arsenic (As) observed in the water column and the reduced presence of aquatic life in some creek sections. Gless (1990) observed metals stains and dead vegetation as high as five feet above the stream banks of Cataract Creek.

One goal of the present biological assessment was to identify the biological pathway of metals in the Boulder River Watershed. The concentrations of metals in aquatic biota present in the Boulder River and its tributaries have not been previously documented. Pathways were determined from measured concentrations of metals in biofilm (abiotic and biotic material on rock surfaces), invertebrates, and fish collected from the Boulder River and a select number of its tributaries.

A second goal of this study was to determine the current health status (quality) and population status (quantity) of aquatic life in the Boulder River Watershed. Metal exposures can affect the quantity and quality of the aquatic biota present and deteriorate the overall ecological health of a river system (Farag et al. 1995). No assessments of individual fish health had been previously performed in the Boulder River. Measures of physiological function and tissue residues were used along with fishery population surveys to assess the ecological health of the Boulder River and its tributaries.

Measurements of lipid peroxidation and metallothineins were used to assess the physiological status of fish exposed to metals. Lipid peroxidation results in damage to polyunsaturated fatty acids located in the cell membrane. This damage can decrease fluidity, increase leakiness, and inactivate membrane-bound enzymes. An ultimate result may be cell death and tissue damage (Halliwell and Gutterirdge, 1985; Wills, 1985). These measurements have been associated with reduced growth in laboratory experiments (Woodward et al. 1995). Additionally, metallothioneins are proteins that are induced following metal exposures. While induction of these proteins is often associated with acclimation of fish to metals, the metabolic costs of metallothionein induction have been associated with reduced growth in laboratory experiments (Dixon and Sprague 1981, Roch and McCarter 1984, Marr 1995).

Lipid peroxidation and metallothinein data can then be related to the specific tissue dose of metals accumulated in fish (Farag et al. 1995). Therefore, data that define the physiological status of fish can provide managers with an explanation of the cause-effect relationship between metals present and reductions in fish health and fish populations.

Our third goal was to determine the survivability of trout in sections of creeks that lack fish. Some reaches in tributaries to the Boulder River are devoid of fish. These sections of fishless stream coincide with extreme concentrations of metals in the water. We also sought to determine if the lack of fish presence is due to the water quality in these tributaries.

EXPERIMENTAL PROCEDURES

Biological Pathway Determinations

Four samples each of biofilm and benthic macroinvertebrates were collected from 12 sites (Figure 1). Reference sites on the upper Boulder River, the Boulder River (near Red Rock Creek), and the Little Boulder River were chosen to estimate the pre-mining conditions of the nine experimental sites. The upper Boulder River and the Little Boulder River sites were used as references for tributary sites. A site on the Boulder River near Red Rock Creek was used as a reference for the mainstem sites. Arsenic, cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) were measured by inductively coupled plasma-mass spectrometry (ICPMS).

Fish Health and Population Assessment

Sample collections for fish health and population assessments were performed simultaneously at five sites (Figure 1). A site on the upper Boulder River was used as a reference for the lower Cataract Creek and the lower Basin Creek sites. A site on the Boulder River near Red Rock Creek was used as a reference for the site on the Boulder River near Galena Gulch.

Necropsy assessments were performed in the field to define any obvious, gross abnormalities of the resident fish collected for fish health measurements. Gill, liver, and whole body concentrations of As, Cd, Cu, Pb, and Zn were measured by ICPMS. Lipid peroxidation and metallothionein were measured on gill and liver tissues according to Dillard and Tappel (1984) and Hogstrand and Haux (1990) respectively. The metallothionein data are not yet available. Multiple pass depletion was used to estimate fish populations in the tributaries of concern and the mark/recapture method was used to estimate populations in the Boulder River. Lengths and weights were recorded and scales were collected to determine the ages of the resident fish.

Survivability of Fish in Tributaries

Live containers of juvenile westslope cutthroat trout were placed at six sites located in the upper reaches of Basin and Cataract creeks and in lower High Ore Creek. A site on the Little Boulder River was designated as the reference site. Fish were acclimated to Little Boulder River water before the initiation of the experiment. Twenty fish, five in each of four containers, were placed at each site (Figure 1). YSI automatic water quality monitors were deployed in Jack Creek, High Ore Creek, and the Little Boulder River to monitor dissolved oxygen, conductivity, pH, and temperature hourly during the 96-hr study. These measurements were also manually recorded daily at each site. Alkalinity and hardness were measured daily on water samples collected from each site.

RESULTS AND INTERPRETATION

Concentrations of all metals were elevated in biota from most of the tributary sites. The concentrations of metals were generally twice as great in biofilm compared to invertebrates. Concentrations of metals in biofilm and invertebrates decreased at sites furthest downstream from mining sites. The greatest concentrations of Cu and Cd were observed in biofilm from Jack Creek (2060 and >60 µg/g respectively). And concentrations of As, Pb, and Zn were greatest in biofilm from lower High Ore Creek (1910, >100, and 1670 respectively). Additionally, metals accumulated in the biota in the mainstem of the Boulder River. This was most notable at Galena Gulch where > 250 µg/g As, Cu, and Pb were observed in biofilm.

The concentrations of metals in gills and livers collected from resident fish were elevated at lower Basin Creek, lower Cataract Creek, and Boulder River at Galena Gulch, downstream from impacted tributaries. The concentrations were the greatest at lower Cataract Creek where gills and livers from this site had as much Cd (> 60 µg/g) as benthic-macroinvertebrates collected from the same site. Products of lipid peroxidation were elevated in livers but not gills of fish collected from lower Cataract Creek. Furthermore, the size range and number of trout per acre were less in lower Cataract Creek than the reference site (2.7 - 12.4 inches compared to 2.8 - 8.3 and 443±75 trout per acre compared to 63±22).

Survival of westslope cutthroat trout was 0% at all experimental sites by 96 h compared to 95% in the little Boulder River. Much of the mortality was observed during the first 72 h. For example, survival was 0% in fish held in Bullion Creek and Uncle Sam within 24 h; in lower High Ore, within 48 h; and in middle Cataract Creek, at 72 h. Measurements performed by the USGS - Water Resources Division (personal communication, David Nimick) suggest that this mortality may have been due to elevated concentrations of metals, especially Zn, in the water column. However, additional investigations of survivability are planned because preliminary laboratory assays with site waters did not confirm the results of the live-container study.

The preliminary data suggest that metals are accumulating in biofilm, invertebrates, and fish in all three tributaries of concern and in the mainstem of the Boulder River. Fish health may be affected in lower Cataract Creek as demonstrated by lipid peroxidation, reduced size, reduced number of fish per acre and increased tissue metal concentrations. It is unlikely that fish would survive in the upper reaches of Basin and Cataract creeks or in lower High Ore Creek, where fish are currently not present, regardless of habitat restrictions in these tributaries. The concentrations of metals in the water, especially Zn, may be responsible for the acute mortalities of fish. However, habitat restrictions would likely affect fish movement in these tributaries, especially in sections of Cataract Creek.

Additional data are being compiled to assist with the final determinations of the effects of metals in the Boulder River Watershed. The pathway of metals through the foodchain will be compared to concentrations of metals measured in the water and sediment. Metallothionein data will be incorporated into the final determination of fish health. Also, habitat assessments performed during 1998 will be used to correct for any habitat variability between sites and finalize the population estimates. Finally, the survivability experiment will be repeated during 1999.

REFERENCES

Dillard, C.J., and A.L. Tappel. 1984. Fluorescent damage products of lipid peoxidation. Methods of Enxymology 105:337-341.

Dixon, D.G., and J.B. Sprague. 1981. Copper bioaccumulation and hepatoprotein synthesis during acclimation to copper by juvenile rainbow trout. Aquatic Toxicology 1:69-81.

Farag, A.M., Stansbury, M.A., Hogstrand, C., MacConnell, E., and Bergman, H.L. 1995. The physiological impairment of free ranging brown trout exposed to metals in the Clark Fork River, Montana. Canadian Journal of Fisheries and Aquatic Sciences 52:2038-2050.

Gless, E.E., 1990. Biological and chemical baseline studies along the Bolder River and its tributaries in Jefferson County, Montana. A report to the Jefferson County Commissioners, January 1990.

Halliwell, B. and Gutteridge, J.M.C.. (Editors). 1985. Free radials in biology and medicine. Clarendon Press, Oxford. pp. 139-170.

Hogstrand, C., and C. haux. 1990. A radioimmunoassay for perch (*Perca fluviatilis*) metallothionein. Toxicology and Applied Pharmacology 103:56-65.

Marr, J.C.A., H.L. Bergman, J. Lipton, and C. Hogstrand. 1995. Differences in relative sensitivity of naive and metals-acclimated brwon and arainbow trout exposed to metals respresentative of the Clark Fork River, Montana. Candadian Journal of fisheries and Aquatic Sciences 52:2016-2030.

Nelson, F.A. 1976. The effects of metals on trout populations in the upper Boulder River, Montana. M.S. Thesis, Monatana State University, Bozeman, Montana, 60 pp.

Roch, M., and J.A. McCarter. 1984. Metallothionein induction, growth, and survival of chinook salmon exposed to zinc, copper, and cadmium. Bulletin of Environmental Contamination and Toxicology 32:478-485.

Wills, E.D. 1985. The role of dietary components in oxidative stress in tissue. In: Oxidative Stress in tissues. Edited by H.Sies, Academic Press, New York

Woodward, D.F., A.M. Farag, W.G. Brumbaugh, C.E. Smith, and H.L. Bergman. 1995. Metals-contaminated benthic invertebrates in the Clark Fork River, Montana: effects on age-0 brown trout and rainbow trout. Canadian Journal of Fisheries and Aquatic Sciences 52:1994-2004.

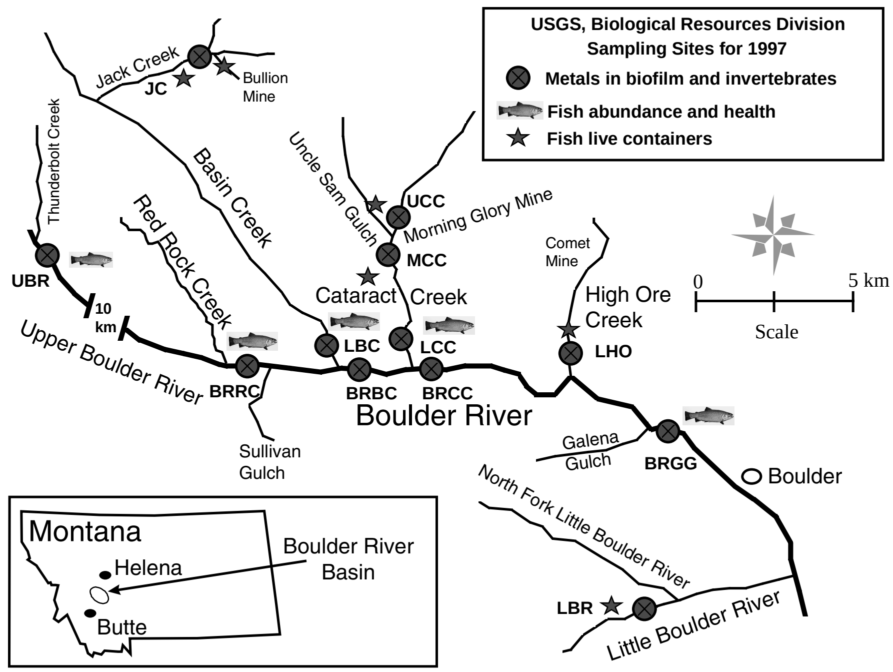

Figure 1. Map of the Boulder River, Montana