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Background and Comparison of Water-Quality, Streambed-Sediment, and Biological Characteristics of Streams in the Viburnum Trend and the Exploration Study Areas, Southern Missouri, 1995 and 2001

Water-Resources Investigations Report 03–4285

U.S. Department of the Interior
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CONTENTS

FIGURES

TABLES

VERTICAL DATUM

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Elevation, as used in this report, refers to distance above or below NGVD 29. NGVD 29 can be converted to the North American Vertical Datum of 1988 (NAVD 88) by using the National Geodetic Survey conversion utility available at URL http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html.

Background and Comparison of Water-Quality, Streambed-Sediment, and Biological Characteristics of Streams in the Viburnum Trend and the Exploration Study Areas, Southern Missouri, 1995 and 2001

By Suzanne R. Femmer

Abstract

Missouri has a long history of lead mining in the Park Hills and Viburnum Trend areas. Lead ore production has been a significant economic presence since the settlement of Missouri in the 1700's. As lead sources are depleted in active mining areas, new areas are being explored for economical ore bodies. The exploration area south of Winona, a possible extension of the Viburnum Trend lead-producing area, lies in an area of intense interest because of its scenic beauty and sensitive environment.

Water-quality, streambed-sediment, fish tissue, instream and riparian habitat, and invertebrate-community samples were collected from three sites in the Viburnum Trend for the National Water-Quality Assessment (NAWQA) program Black River synoptic study in 1995 and from four sites in the exploration study area in 2001. The samples, which were collected using NAWQA protocols, were analyzed and compared to establish background conditions and similarities between sites.

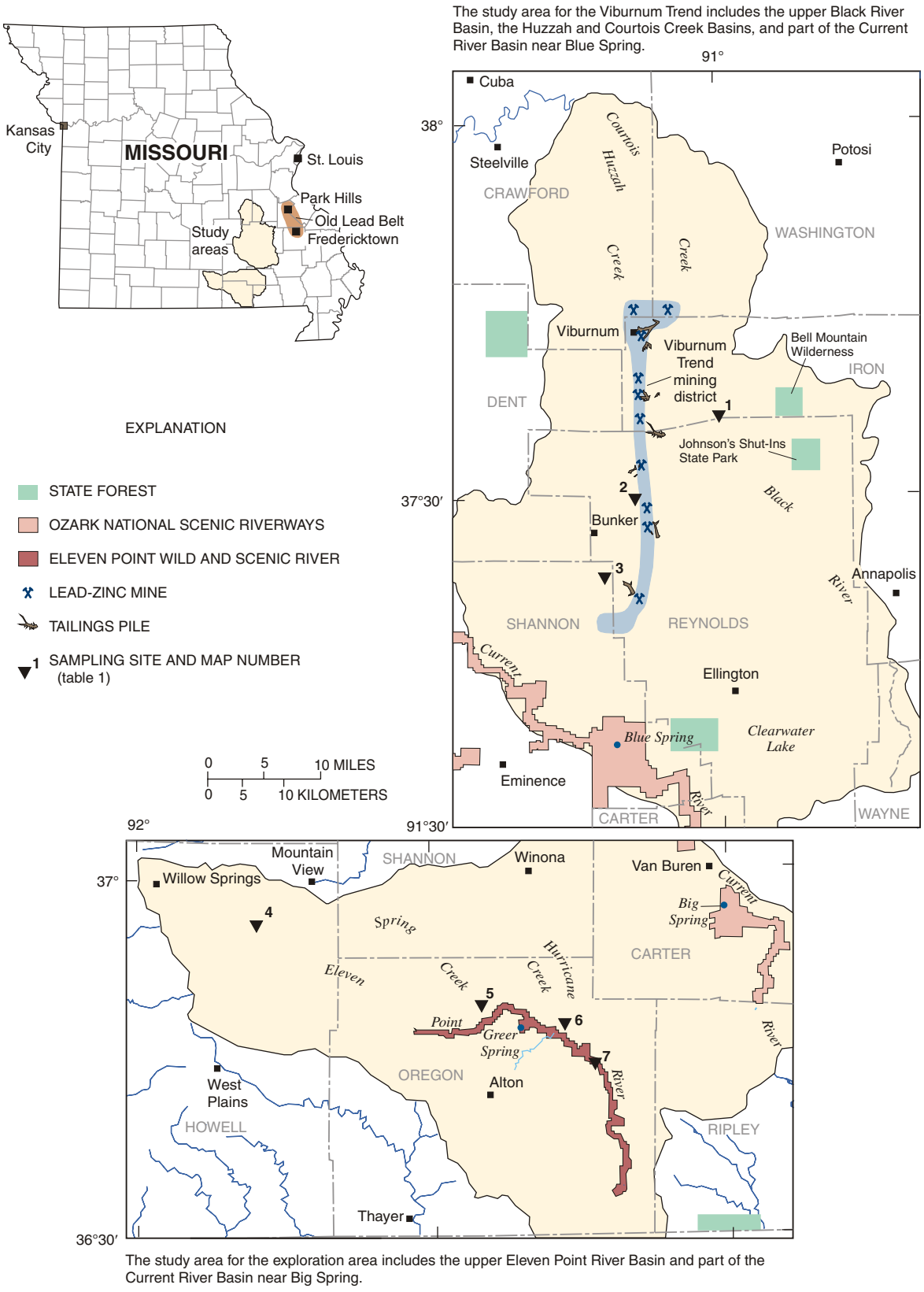
Bacteria, lead, and zinc concentrations were substantially different between the study areas. Habitat characteristics, such as streambed substrate size and embeddedness were similar. The Eleven Point River at Turner's Mill is substantially larger in size than the other six surveyed sites. Trace element concentrations in fish tissue samples collected in the two study areas are similar. Samples from both areas had elevated mercury levels. Invertebrate community data indicated similarity among the Viburnum Trend study area sites, but these sites had little in common with the exploration study area sites. The invertebrate community structure in the exploration study area were not similar.

Introduction

Lead mining has been a part of Missouri history from the time French prospectors discovered and mined lead from the Mine La Motte area near Fredericktown (fig. 1) in the 1700's. During the 1860's, lead mining activities moved north to the Bonne Terre—Flat River (Park Hills) area (Old Lead Belt; fig. 1), and mining continued in that area through the early 1950's. By 1907, Missouri had become the leader in lead ore production in the United States, a title the State still holds (St. Louis Post-Dispatch, June 2, 2002). The Old Lead Belt produced lead ore steadily (peaking during World War II) until the 1950's when the ore mineral content reached about 2 percent lead, and was no longer economical to extract. Attention then shifted to the area of the 1955 discovery of lead-zinc deposits around Viburnum (fig. 1). This new source of economical ore, the Viburnum Trend, was producing lead by the mid-1960's. Eight underground mines were in operation between 1960 and 1973 (Warner and others, 1974). During 2000, there were nine active mines in the Viburnum Trend producing lead ore and its associated minerals, zinc and copper.

Although lead-zinc exploration has continued in southern Missouri since the 1960's, exploration for new lead deposits began in earnest during the late 1970's and early 1980's because of declining economical ore reserves in the Viburnum Trend. The area south of Winona and north of the Eleven Point River (fig. 1) is an area of intense interest to mining companies because it is considered to be a possible extension of the Viburnum Trend. More than 300 boreholes have been drilled in the general area between Winona, Big Spring, and Greer Spring since the recent exploration began.

Land use is known to affect aquatic communities in many ways. Changes in vegetation and the disturbance of soils create the potential for altered runoff, sediment yield, and biological, chemical, and physical stream characteristics. There generally is a sequence of action from land use change to the alteration of the physical and chemical habitat to changes in stream biota. Land use disturbances, such as mining, often cause changes in streambed material and channel morphology (Graf and others, 1995) and changes in the chemical makeup of the water and sediment. Bioassessments of stream communities provide an overall index of stream health. Analyses suggest that without bioassessments there is a risk of not identifying land use effects to our streams (Rankin, 1995).



The study area for the exploration area includes the upper Eleven Point River Basin and part of the Current River Basin near Big Spring.

Figure 1. Study areas, stream-water quality, streambed-sediment, and biological sampling sites for investigation of background characteristics.

There are concerns as to the biological effects of mining and its associated release of trace metals in the Viburnum Trend study area and potential release in the exploration study area, thereby affecting stream biota. Surveys that define the biological, chemical, and physical quality of these areas are scarce. The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program conducted an environmental assessment during 1995 of the Black River Basin, located in the Viburnum Trend study area. The goal of this synoptic survey was to quantify and qualify the biological, chemical, and physical effects of lead-zinc mining in the basin. Water chemistry, streambed sediment, fish tissue contaminants, instream and riparian habitat, and algal and invertebrate communities (fig. 2) were surveyed in this effort. The sites sampled were strategically located upstream and downstream from active mining areas in an effort to identify the effects of mining in this area.

There are concerns that if lead-zinc mining occurs in the exploration study area, the unique beauty and sensitive environment of the area could be compromised. One concern is that mine dewatering could lower water levels and thereby decrease or eliminate ground-water discharge from some springs. Also, there is concern about the degradation of spring and stream water quality and biotic integrity as a result of lead and other metals being introduced into the environment from mining-related activities.

Purpose and Scope

The purpose of this report is to document the background water-quality, streambed-sediment, and biological characteristics at sites in the Viburnum Trend study area upstream from mining activities and the exploration study area and compare the data for similarities. Data from three sites sampled during the 1995 Black River synoptic study (Viburnum Trend study area) and four sites in the exploration study area sampled in 2001 are used.

For the Black River synoptic survey, water-quality samples were analyzed for major ions, nutrients (because reagents containing organic liquids, nitrogen, and phosphorous compounds are used in milling operations of lead and zinc ore), bacteria, and trace elements. Fish tissue and fine-streambed sediment were collected for trace-element analysis and measurements of instream and riparian habitat were made. To assess the biological integrity of the system, qualitative and semi-quantitative algae and invertebrate samples were collected to assess the community structure.

The methods for the Black River synoptic study were duplicated at four sites in the exploration area study in 2001 to establish background conditions and to compare the two areas of concern. Water-quality samples were analyzed for major ions, nutrients, bacteria, and trace elements. Fish tissue and fine-streambed sediment were collected and analyzed for trace elements. Physical measurements of instream and riparian habitat were made. Invertebrate samples were collected to assess community structure.

Figure 2. Aquatic invertebrates, such as the Hellgrammite, were surveyed as part of the biological investigation.

Description of Study Areas

The Viburnum Trend study area is located in an upland area with rugged relief and numerous springs and streams. This area is characterized by deep, narrow valleys and steep-sided ridges. The ridges generally are covered by oak-hickory forests and the valleys usually support pastures or hay fields. The Black River and its tributaries flow through the southeastern part of the Viburnum Trend study area and drain into Clearwater Lake (fig. 1). Much of this area lies in the Mark Twain National Forest, managed by the U.S. Department of Agriculture, Forest Service (FS), and several State Forest areas. Recreational areas such as Johnson's Shut-Ins State Park and Bell Mountain Wilderness attract many visitors.

The exploration study area is in an area of intense interest because of its scenic beauty, recreational potential, and geohydraulic properties. The area consists of rugged, forested highlands that contain numerous springs and support a fragile and diverse ecosystem. Two federally designated scenic riverways that host more than 2 million visitors annually are in the area; the Ozark National Scenic Riverways (ONSR), managed by the National Park Service (NPS), and Eleven Point Wild and Scenic River (EPWSR), managed by the FS (fig. 1). Dye-trace studies have shown that the exploration study area is within the recharge area of two large springs, Big Spring and Greer Spring (fig. 3; Imes and Kleeschulte, 1995). Big Spring, located 20 miles east of the exploration area, is one of the largest single orifice springs in the Nation, has an annual mean discharge of 447 ft^3/s (cubic feet per second) or 289 million gallons per day (Mgal/d) and Greer Spring, about 3 miles south of the exploration area, has an annual mean discharge of 344 ft^3/s (Hauck and Nagel, 2001) or 222 Mgal/d.

Both the exploration study area and the Viburnum Trend study area are located in the Salem Plateau (Fenneman, 1938) with forest to forest-pasture land use (Adamski and others, 1994). Both areas are in a soil region of alfisol and ultisols of the Ozark Highlands dolomites (Adamski and others, 1994). Both the Viburnum Trend study area and the exploration study

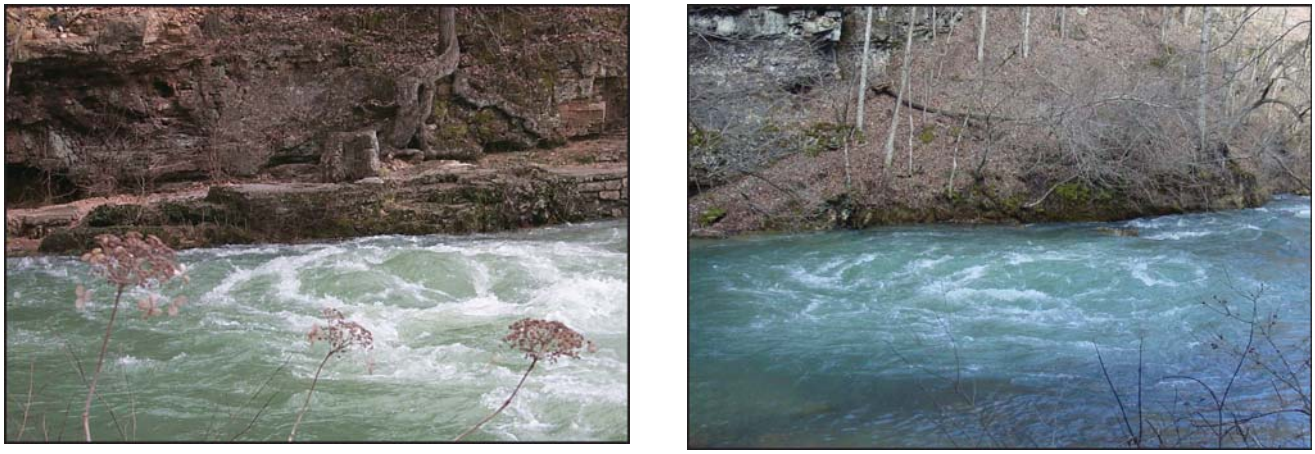


Figure 3. Big Spring (left) and Greer Spring (right), two large springs with recharge areas in the exploration area (photographs courtesy of Brian S. Fredrick, U.S. Geological Survey, 2002).

area contain areas of well-developed karst terrane. Karst is a geologic feature that forms with the dissolution of carbonate or other soluble rock by precipitation and ground water and is characterized by the presence of springs, caves, sinkholes, and underground conduits. Ground- and surface-water exchange is common in karst areas, contributing to the fact that land-use activities have the potential to affect ground-water quality. Streams in karst areas can lose water to the subsurface through underground conduits that cause the ground-water levels to decline below the stream level. The underground flow of water from one surface-water basin to another is common in karst terrane. Data collected by the USGS indicates that ground water travels from the Eleven Point River Basin to Big Spring in the Current River Basin (Kleeschulte, 2000).

Methods of Study

Documented USGS protocols and methods were used for this study. Biological sampling sites selected in the exploration study area were as physically similar as possible to the selected sites in the Viburnum Trend study area. Accepted statistical methods were employed for the analysis of the data for this report.

Site Selection

To compare background characteristics of both study areas, three sites from the NAWQA Black River synoptic study were selected to represent non-mining conditions in the Viburnum Trend study area. The sites are the Middle Fork Black River near Redmondville (map number 1), West Fork Black River near Greeley (map number 2), and Big Creek near Rat, Missouri (map number 3) (fig. 1). The Middle Fork Black River and the West Fork Black River sites are located upstream from mining operations and the Big Creek site is located in a nearby basin where there are no mining activities. The three sites from the Black River synoptic study are located in the headwaters upstream from Clearwater Lake. Background characteristics from these sites were compared to four sites from the exploration study area.

The sites sampled in the exploration study area are located in the basin of the Eleven Point River. Unlike the Viburnum Trend study area, the exploration study area has few perennial streams; most of the tributaries in the area are intermittent streams that lose water to ground-water sources. The Eleven Point River is the largest stream in the exploration study area (fig. 1). Four sites were selected in 2001 for evaluation of pre-mining conditions, two sites on the main stem of the Eleven Point River and two sites on perennial reaches of tributaries to the Eleven Point River; Eleven Point River near Round Hollow (map number 4), the Eleven Point River near Turner's Mill (map number 7) (fig. 4), Spring Creek near Eleven Point River (map number 5), and Hurricane Creek at the Ozark Trail (map number 6) (fig. 5).

Sampling Methods

Sampling methods were duplicated as much as possible between the two study areas. The sampling occurred during August 2001 and September 1995 to take advantage of stable, low-flow conditions. The sampling methods used were from established protocols developed for the NAWQA program for all streambed material, fish tissue, and biological sampling.

Field parameters, such as dissolved oxygen, pH, specific conductance, and water temperature were recorded. *Escherichia coli* (*E. coli*), fecal coliform, and fecal streptococci were sampled. Protocols used for field parameters are detailed in Wilde and Radtke (1998).

Water-quality samples were collected using procedures detailed in Shelton (1994). A water sample was collected from 3 to 10 locations in a stream cross section. Because all of the

Figure 4. The Eleven Point River at Turner's Mill sampling site, looking downstream, 2001.

Figure 5. Hurricane Creek at the Ozark Trail sampling site, looking downstream, 2001.

streams were wadable at the time of sampling, a DH-81 sampler was used to collect the water for processing. After field processing, the samples were shipped to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, for analysis of physical parameters, major ions, nutrients, and trace elements.

Streambed sediment was collected for trace-element analyses at all four exploration study area sites and two sites in the Viburnum Trend study area. Methods used for collecting and processing streambed-sediment samples are documented in Shelton and Capel (1994). Fine sediments in depositional areas were targeted to optimize detection of trace elements. Streambed sediment was collected and composited from a minimum of 10 locations at each sampling site. Teflon sampling scoops were used to collect the sediment, which was then composited in a glass bowl for processing. After mixing well, the sediment was processed through a 63-µm (micron) mesh nylon cloth and the less than 63-µm portion was sent to the NWQL for analysis of trace elements.

Biological tissue was collected at two sites, one in the Viburnum Trend study area and the other in the exploration study area, and analyzed for trace elements. Livers were collected and composited from eight smallmouth bass (*Micropterus dolomieu*) at the West Fork Black River near Greeley (map number 1) and from seven shadow bass (*Ambloplites ariommus*) at the Eleven Point River at Turner's Mill (map number 7). Protocols described in Crawford and Luoma (1993) were used for both sample collections.

A modification of the NAWQA protocol was used for habitat sampling at all sites. Instream and riparian conditions were measured and recorded. Reference points were established and a sampling reach was selected at each site. Geomorphologic features were noted and three transects were selected for measurement. Channel width, water depth, velocity, streambed substrate, substrate embeddedness, canopy angle, and bank woody vegetation were measured and recorded. Procedures for collecting these data are given in Meador and others (1993).

A semi-quantitative invertebrate sample was collected at each site from the most diverse habitat available, which in these study areas are the riffles. All of the sampled riffles were wadable. A minimum of five invertebrate samples from at least two separate riffles were collected and composited at each site. A modified Slack sampler was used to sample an area of 0.25 m^2 (square meter) at five locations at each site. A 425-µm mesh net was used for the Viburnum Trend study area, and a 500-µm mesh net was used for the exploration study area collection because of changes in NAWQA protocol. Details of the invertebrate sampling protocols can be found in Cuffney and others (1993) and Moulton and others (2002). After the samples were composited, they were preserved and shipped to NWQL for processing and analysis. NWQL uses a 300 fixed-count method to identify and enumerate the invertebrate samples (Moulton and others, 2002).

Statistical Methods

Several statistical methods were used to describe and compare invertebrate community data. Analytical methods using population and species assemblages at the community level such as enumerations, taxa richness, and diversity were used (Johnson and others, 1993; Resh and Jackson, 1993).

Pearson's correlation coefficient statistical method (Helsel and Hirsch, 1992) was used to measure the amount of correlation and similarity between the sampling sites and the study areas. The Pearson correlation coefficient method calculates the coefficient (r) of the x-y pairs of relative abundance of all taxa collected at each site.

A Hierarchial dendrogram cluster analysis method (SPSS, Inc., 2000) was used to group sites with similar community structure. This method links two of the closest (most similar) communities as a cluster and continues in a step-wise manner joining communities until all are combined. These clusters are then displayed as a dendogram. For this report, the data were analyzed using a Euclidean distance matrix (SPSS, Inc., 2000). A normalized Euclidean distance (root-mean-squared differences) is computed for all the variables (taxa in this case) to determine the distance between the clusters.

Background Characteristics and Statistical Comparisons

The singular nature of the water-quality, streambed sediment, and biological data limits the interpretation that can be applied for background determination and comparisons. There are only seven samples, one at each site, for analysis. Although this is a small dataset, the data provide an indicator of characteristics at these sites.

Water Quality

Water-quality physical parameters were measured and water samples collected at the seven sites (table 1). Dissolved oxygen, pH, specific conductance, water temperature, and bacteria samples were collected and analyzed on site. Major ions, nutrient, and trace element samples were analyzed at the NWQL. Dissolved oxygen concentrations ranged from 4.2 to 12.9 mg/L (milligrams per liter) with a median value of 8.9 mg/L. The pH of the sampled streams ranged from 7.3 to 8.2, with a median concentration of 7.8 standard units. Specific conductance ranged from 109 to 423 µS/cm (microsiemens per centimeter at 25 degrees Celsius) with a median value of 361 µS/cm. Water temperature ranged from 17.3 to 26.9 °C (degrees Celsius) with a median value of 21.0 °C. There were slight differences in physical parameters between the two study areas.

Major ions analyzed are dissolved calcium, magnesium, potassium, sodium, chloride, silica, and sulfate. Big Creek near Rat has some of the smallest concentrations of dissolved ions of

Table 1. Water-quality data from sites sampled in the Viburnum Trend and the exploration study areas, 1995 and 2001.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; SiO^2, silica oxide; SO^4, sulfate; N, nitrogen; P, phosphorus; col/100 mL, colonies per 100 millileters of sample; µg/L, micrograms per liter; <, less than; --, no data; E, estimated]

Map number (fig. 1)	Station name	Date	Time	Dissolved oxygen (mg/L)	pH, (standard units)	Specific conductance (µS/cm)	Water temperature (°C)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)
1	West Fork Black River near Greeley	09/12/1995	0845	8.9	8.1	343	17.3	37.0	22.0	0.80
2	Middle Fork Black River near Redmondville	09/14/1995	0915	9.6	8.2	319	17.7	35.0	20.0	1.30
3	Big Creek near Rat	09/11/1995	1115	4.2	7.6	109	21.0	11.0	5.6	1.30
4	Eleven Point River near Round Hollow	08/27/2001	1500	12.9	8.1	373	26.9	41.2	23.8	.52
5	Spring Creek near Eleven Point River	08/28/2001	1200	4.6	7.3	382	24.2	49.3	29.4	.41
6	Hurricane Creek at the Ozark Trail	08/29/2001	1515	7.1	7.5	423	22.8	48.4	28.5	.42
7	Eleven Point River at Turner's Mill	08/30/2001	1345	10.3	7.8	361	18.6	42.0	25.0	.22

Map number (fig. 1)	Station name	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO^2)	Sulfate, dissolved (mg/L as SO^4)	Solids, residue at 180 °C, dissolved (mg/L)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)
1	West Fork Black River near Greeley	1.5	1.8	8.0	2.0	178	<0.020	<0.05	<0.010	<0.010
2	Middle Fork Black River near Redmondville	1.3	1.4	9.3	2.7	167	.020	.06	<.010	<.010
3	Big Creek near Rat	1.4	1.5	.1	2.7	61	.050	.25	<.010	<.010
4	Eleven Point River near Round Hollow	2.2	2.3	9.0	2.3	196	<.040	--	E.005	<.020
5	Spring Creek near Eleven Point River	2.1	2.7	8.7	3.0	241	<.040	--	--	<.020
6	Hurricane Creek at the Ozark Trail	1.8	2.1	8.6	3.0	186	<.040	<.05	<.006	<.020
7	Eleven Point River at Turner's Mill	2.0	2.7	10.8	2.2	205	<.040	<.05	<.006	<.020

Table 1. Water-quality data from sites sampled in the Viburnum Trend and the exploration study areas, 1995 and 2001.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; SiO^2, silica oxide; SO^4, sulfate; N, nitrogen; P, phosphorus; col/100 mL, colonies per 100 millileters of sample; µg/L, micrograms per liter; <, less than; --, no data; E, estimated]

Map number (fig. 1)	Station name	*Escherichia coli* bacteria (col/100 mL)	Fecal coliform bacteria (col/100 mL)	Fecal streptococci bacteria (col/100 mL)	Aluminum, dissolved (µg/L)	Antimony, dissolved (µg/L)	Barium, dissolved (µg/L)	Cadmium, dissolved (µg/L)	Chromium, dissolved (µg/L)	Cobalt, dissolved (µg/L)
1	West Fork Black River near Greeley	37	54	61	5	<1.00	40.0	<1.00	2.0	<1.00
2	Middle Fork Black River near Redmondville	44	34	50	4	<1.00	43.0	<1.00	1.0	<1.00
3	Big Creek near Rat	120	86	37	12	<1.00	40.0	<1.00	<1.0	<1.00
4	Eleven Point River near Round Hollow	38	43	39	6	.44	83.4	<.04	<.8	.07
5	Spring Creek near Eleven Point River	2	5	43	6	.41	85.3	<.04	<.8	.11
6	Hurricane Creek at the Ozark Trail	55	55	200	8	.43	95.9	<.04	<.8	.12
7	Eleven Point River at Turner's Mill	20	33	29	11	1.15	188.0	E.02	<.8	.13

Map number (fig. 1)	Station name	Copper, dissolved (µg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)	Manganese, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Zinc, dissolved (µg/L)
1	West Fork Black River near Greeley	<1.0	<3	<1.00	2.0	<1.0	13
2	Middle Fork Black River near Redmondville	<1.0	<3	<1.00	2.0	<1.0	7
3	Big Creek near Rat	<1.0	10	<1.00	12.0	<1.0	8
4	Eleven Point River near Round Hollow	.5	--	<.08	3.8	1.3	14
5	Spring Creek near Eleven Point River	.4	20	E.04	18.0	.4	39
6	Hurricane Creek at the Ozark Trail	.3	20	E.05	22.7	.4	42
7	Eleven Point River at Turner's Mill	.3	60	.10	29.6	1.2	6

all the sites. Calcium concentrations for all sites ranged from 11.0 to 49.3 mg/L with a median value of 41.2 mg/L. Magnesium concentrations ranged from 5.6 to 29.4 mg/L with a median concentration of 23.8 mg/L. Potassium concentrations ranged from 0.22 to 1.30 mg/L with a median concentration of 0.52 mg/L. Sodium concentrations ranged from 1.3 to 2.2 mg/L with a median concentration of 1.8 mg/L. Chloride concentrations ranged from 1.4 to 2.7 mg/L with a median concentration of 2.1 mg/L. Silica concentrations ranged from 0.1 to 10.8 mg/L with a median concentration of 8.7 mg/L. Sulfate concentrations ranged from 2.0 to 3.0 mg/L with a median concentration of 2.7 mg/L. There were slight differences in major ion concentrations between the two study areas. Generally, the dissolved ion concentrations were larger at the exploration study area sites than in the Viburnum Trend study area, with the exception of potassium.

Water samples were analyzed for dissolved ammonia, nitrite plus nitrate, nitrite, and orthophosphorus (table 1). The analyses indicated that most nutrient concentrations were below laboratory detection levels and that concentrations are not substantially different between the two study areas. Minimum reporting levels (MRL) for the nutrient species differ between analyses for the two sampling efforts for some of the parameters. The MRL for ammonia was 0.02 mg/L during the 1995 sampling effort and was 0.04 mg/L during the 2001 sampling effort. The Middle Fork Black River near Redmondville (map number 2) and Big Creek near Rat (map number 3) had ammonia concentrations at or slightly above MRL (0.02 and 0.05 mg/L, respectively); the other five sites had concentrations below the MRL. All the sites had concentrations below the MRL for nitrite plus nitrate, with the exception of the Middle Fork Black River near Redmondville (map number 2) and Big Creek near Rat (map number 3), which had concentrations of 0.06 and 0.25 mg/L, respectively. All concentrations of nitrite and orthophosphorus were below the MRL. These concentrations indicate that nutrients are not at a level of concern at these sites.

Three types of bacteria, *E. coli*, fecal coliform, and fecal streptococci, were analyzed at each site (fig. 6). These bacteria are indicative of the presence of fecal material from warm-blooded animals, including humans. *E. coli* bacteria ranged from 2 to 120 col/100 mL (colonies per 100 mL) of sample. Big Creek at Rat (map number 3) had the largest *E. coli* concentration and Spring Creek near Eleven Point River (map number 5) had the smallest *E. coli* concentration. Fecal coliform bacteria ranged from 5 to 86 col/100 mL of sample. Big Creek at Rat (map number 3) had the largest fecal coliform concentration and Spring Creek near Eleven Point River (map number 5) had the smallest concentration of fecal coliform bacteria. Concentrations of fecal streptococci bacteria ranged from 29 to 200 col/100 mL of sample. Hurricane Creek at the Ozark Trail (map number 6) had the largest concentration and the Eleven Point River at Turner's Mill (map number 7) had the smallest concentration of fecal streptococci bacteria. Overall, the Viburnum Trend study area sites had larger concentrations of bacteria than the sites in the exploration study area; however, most concentrations are below the maximum recommended levels for

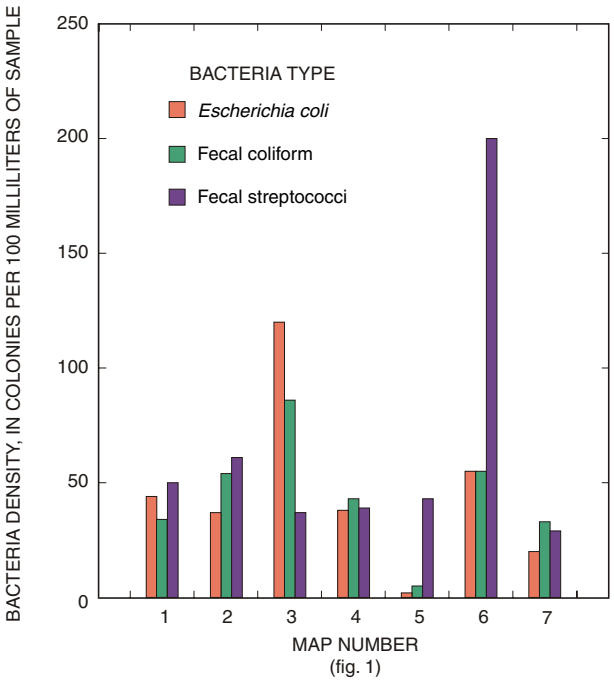


Figure 6. Bacteria density at the sampled sites, 1995 and 2001.

whole-body contact waters (100 col/100 mL sample, *E. coli*; 200 col/100 mL, fecal coliform) (Missouri Department of Natural Resources, 2000; U.S. Environmental Protection Agency, 1986).

Dissolved trace-element samples were collected at each site for analysis (table 1). Although there were differences in the MRLs between the two sampling efforts, the analyses indicate low concentrations of trace elements in background conditions. Generally, the samples from the exploration study area were analyzed with lower detection limits than the Viburnum Trend study area samples. All samples had above MRL concentrations for aluminum, barium, manganese, and zinc. Dissolved lead concentrations were all less than 1.0 µg/L (microgram per liter). Although many samples were above the MRL, the concentrations were low and not at levels of concern for human and wildlife protection (Missouri Department of Natural Resources, 2000). Concentrations of trace elements were not substantially different between the study areas.

Streambed Sediment

Streambed-sediment samples were collected at six sites, two in the Viburnum Trend study area and four in the exploration study area, and analyzed for trace elements. Fine sediments found in depositional zones of each sampling reach were targeted to increase the probability of detecting trace elements. In general, inorganic carbon, cobalt, lead, strontium, and zinc were detected in slightly larger concentrations at the Viburnum Trend study area sites than in the samples of the exploration study area (table 2). Sulfur, organic plus inorganic carbon, organic carbon, cadmium, chromium, manganese, and selenium

Table 2. Streambed-sediment data from sites sampled in the Viburnum Trend and the exploration study areas, 1995 and 2001.

[<, less than; µm, microns; µg/g, micrograms per gram]

Map number (fig. 1)	Station name	Date	Time	Calcium, <63 µm (µg/g)	Magnesium, <63 µm, (µg/g)	Potassium, <63 µm (µg/g)	Sodium, <63 µm (µg/g)	Sulfur, <63 µm (µg/g)	Phosphorus, <63 µm (µg/g)	Carbon, inorganic, <63 µm (percent)	Carbon, organic plus inorganic, <63 µm (percent)
1	West Fork Black River near Greeley	09/12/1995	1130	1.4	0.40	0.88	0.26	0.07	0.06	0.37	4.1
2	Middle Fork Black River near Redmondville	09/14/1995	0915	4.9	.83	2.10	.19	.11	.07	1.60	6.0
4	Eleven Point River near Round Hollow	08/27/2001	1500	3.2	.32	.96	.19	.07	.07	1.00	4.7
5	Spring Creek near Eleven Point River	08/28/2001	1200	1.0	.42	.88	.16	.19	.09	.10	10.0
6	Hurricane Creek at the Ozark Trail	08/29/2001	1515	1.3	.38	.78	.14	.20	.10	.22	9.4
7	Eleven Point River at Turner's Mill	08/30/2001	1345	4.2	.42	.85	.16	.13	.10	1.20	7.1

Map number (fig. 1)	Station name	Carbon, organic, <63 µm (percent)	Aluminum, <63 µm (percent)	Antimony, <63 µm (µg/g)	Arsenic, <63 µm (µg/g)	Barium, <63 µm (µg/g)	Beryllium, <63 µm (µg/g)	Bismuth, <63 µm (µg/g)	Cadmium, <63 µm (µg/g)	Cerium, <63 µm (µg/g)	Chromium, <63 µm (µg/g)
1	West Fork Black River near Greeley	3.7	3.8	0.6	4.9	340	1.0	<10	0.5	61	32
2	Middle Fork Black River near Redmondville	4.4	4.7	.6	6.9	350	2.0	<10	.8	61	43
4	Eleven Point River near Round Hollow	3.7	3.3	.4	5.4	360	1.2	<1	.5	59	43
5	Spring Creek near Eleven Point River	10.0	4.3	.5	5.8	330	1.8	<1	.9	55	47
6	Hurricane Creek at the Ozark Trail	9.1	3.8	.5	7.5	320	1.6	<1	.8	60	42
7	Eleven Point River at Turner's Mill	6.0	3.5	.4	6.0	320	1.7	<1	1.1	52	43

Map number (fig. 1)	Station name	Cobalt, <63 µm (µg/g)	Copper, <63 µm (µg/g)	Europium, <63 µm (µg/g)	Gallium, <63 µm (µg/g)	Gold, <63 µm (µg/g)	Holmium, <63 µm (µg/g)	Iron, <63 µm (percent)	Lanthanum, <63 µm (µg/g)	Lead, <63 µm (µg/g)	Lithium, <63 µm (µg/g)
1	West Fork Black River near Greeley	16	17	<2	7	<8	<4	1.6	30	33	20
2	Middle Fork Black River near Redmondville	15	26	<2	9	<8	<4	2.1	32	80	20
4	Eleven Point River near Round Hollow	9	17	<1	8	<1	<1	1.5	32	26	22
5	Spring Creek near Eleven Point River	7	30	1	10	<1	<1	1.7	35	29	28
6	Hurricane Creek at the Ozark Trail	10	22	1	9	<1	<1	1.9	34	28	26
7	Eleven Point River at Turner's Mill	8	16	1	8	<1	<1	1.5	34	24	22

Table 2. Streambed-sediment data from sites sampled in the Viburnum Trend and the exploration study areas, 1995 and 2001.—Continued

[<, less than; μm, microns; μg/g, micrograms per gram]

Map number (fig. 1)	Station name	Manganese, <63 μm (μg/g)	Mercury, <63 μm (μg/g)	Molybdenum, <63 μm (μg/g)	Neodymium, <63 μm (μg/g)	Nickle, <63 μm (μg/g)	Niobium, <63 μm (μg/g)	Scandium, <63 μm (μg/g)	Selenium, <63 μm (μg/g)	Silver, <63 μm (μg/g)	Strontium, <63 μm (μg/g)
1	West Fork Black River near Greeley	610	0.05	<2.0	28	21	12	5	1.0	0.1	51
2	Middle Fork Black River near Redmondville	510	.04	<2.0	28	28	<4	7	.7	.2	65
4	Eleven Point River near Round Hollow	1,700	.04	.6	28	17	11	5	.5	.1	50
5	Spring Creek near Eleven Point River	330	.06	.9	33	25	11	7	2.1	.1	38
6	Hurricane Creek at the Ozark Trail	680	.07	.8	31	21	12	7	2.0	.1	36
7	Eleven Point River at Turner's Mill	920	.05	.7	32	22	7	6	1.4	.1	46

Map number (fig. 1)	Station name	Tantalum, <63 μm (μg/g)	Thorium, <63 μm (μg/g)	Tin, <63 μm (μg/g)	Titanium, <63 μm (percent)	Vanadium, <63 μm (μg/g)	Ytterbium, <63 μm (μg/g)	Yttrium, <63 μm (μg/g)	Zinc, <63 μm (μg/g)	Uranium, <63 μm (μg/g)
1	West Fork Black River near Greeley	<40	10	<10	0.25	53	2	20	150	3.4
2	Middle Fork Black River near Redmondville	<40	7	<10	.23	53	2	21	180	2.6
4	Eleven Point River near Round Hollow	<1	8	2	.29	38	2	15	81	2.5
5	Spring Creek near Eleven Point River	<1	8	2	.25	50	2	21	110	3.5
6	Hurricane Creek at the Ozark Trail	<1	8	2	.27	50	2	18	130	2.8
7	Eleven Point River at Turner's Mill	<1	8	2	.25	40	2	19	97	2.6

were generally detected at slightly larger concentrations at the exploration study area sites than at the Viburnum Trend study area sites. The Middle Fork Black River near Redmondville (map number 2) had the largest concentrations for 45 percent of the parameters analyzed; the Middle Fork Black River had the largest concentrations of inorganic carbon, lead, and zinc. The Spring Creek near Eleven Point River (map number 5) samples had the largest concentrations of organic carbon, chromium, copper, selenium, and uranium. Although many samples were above the MRL, the concentrations were low and not at levels of concern for human and wildlife protection (National Oceanic and Atmospheric Administration, 1990).

Biological Characteristics

Fish-tissue data were collected from one site in the Viburnum Trend study area and from one site in the exploration study area. The small stream sizes in the exploration study area limited the ability to collect enough specimens of the same species for analysis.

Instream and riparian habitat surveys were conducted at all seven sites in the two study areas. Habitat data are a useful tool in analyzing stream biological conditions. For instance, the amount of sunlight that reaches a stream is a major factor in stream productivity and relates to algal, invertebrate, and fish community characteristics.

Invertebrate community data were available from all seven sites selected for this study. Invertebrate community structure can reflect upstream land use and ground-water inflow effects on a stream. Riparian conditions and substrate heterogeneity also affect community structure.

Fish Tissue

Fish tissue samples were collected at the West Fork Black River near Greeley (map number 1) and the Eleven Point River at Turner's Mill (map number 7) for analysis of trace elements (table 3). Fish will bioaccumulate trace elements as a result of long-term exposure to the substances in the water column and the streambed sediment. Low concentrations of contaminants that may not be detected in the water column often can be detected because of bioaccumulation. Smallmouth bass were collected at the West Fork Black River near Greeley and shadow bass were collected at the Eleven Point River at Turner's Mill. Both species belong to the Centrarchidae family. Low levels of copper, iron, manganese, zinc, arsenic, cadmium, cobalt, molybdenum, selenium, mercury, and vanadium were detected in both samples. Boron, chromium, and strontium were detected in the Viburnum Trend study area sample, but not the exploration study area sample. The mercury level at the Viburnum Trend study area site is larger than normally seen in the Ozark region (data on file at the U.S. Geological Survey, Rolla, Missouri). A mercury concentration of 0.3 µg/g (microgram per gram) was one of the highest concentrations detected by the (1992-1995) NAWQA study of fish tissue. The Eleven Point River site had a mercury concentration of 0.16 µg/g. There is no substantial difference in the fish tissue trace-element concentrations between the sites sampled.

Habitat Characteristics

Measurements of the stream channel and riparian corridor quantify stream characteristics for comparison of multiple sites. A subset of the data collected is presented in table 4. These data illustrate that the Eleven Point River at Turner's Mill (map number 7) is substantially larger in size than the other six surveyed sites. If the data from the Eleven Point River at Turner's Mill are omitted from the instream measurements, the exploration study area sites are slightly smaller than the Viburnum Trend study area sites. The average channel width of the Viburnum Trend study area sites is 7.1 m (meters) and the exploration study area is 9.5 m (5.9 m without the Eleven Point River at Turner's Mill). The average channel depth at the measured cross sections is 0.21 m for the Viburnum Trend study area sites and 0.28 m for the exploration study area (0.22 m without the Eleven Point River at Turner's Mill). The average mean velocity for the Viburnum Trend study area sites is 0.19 m/s (meter per second) and the exploration study area is 0.23 m/s (0.12 m/s without the Eleven Point River at Turner's Mill).

The dominant stream channel substrate was cobble at most sites except for the Middle Fork Black River near Redmondville (map number 2), which was an equal mixture of gravel, cobble, and boulder-size substrate, and Big Creek near Rat (map number 3), which had a dominant substrate of boulders. All seven sites had an embeddedness of streambed substrate of less than 50 percent, indicating that the streambed is not armored and may experience streambed disturbances from time to time.

The canopy angle is a measure of how much sunlight can reach the streambed. As the canopy angle increases, so does the exposure of the streambed to sunlight. The mean canopy angles ranged from 22 to 96 degrees; the average mean canopy angle is approximately 60 degrees. The Viburnum Trend study area sites had mean canopy angles that ranged from 61 to 96 degrees and averaged 76 degrees; the sites in the exploration study area had mean canopy angles that ranged from 22 to 81 degrees and averaged 48 degrees. Generally, the Viburnum Trend study area sites had more sunlight available to the streambed than the exploration study area sites.

A quarter-point survey of woody plants was conducted at the endpoints of three transects at each site. These surveys document the species diversity and density of woody plants in the riparian corridor. A total of 24 woody plants, if present, were surveyed at each site. The number of species recorded in the quarter point surveys ranged from 9 to 13. The Viburnum Trend study area sites averaged 11 species, and the exploration study area averaged 9.5 species. These values indicate that the sites are similar in woody plant species diversity.

The density of woody plant growth was recorded at the endpoints of each transect. Woody plant density can be an indicator of riparian health and stability. The woody plant density

Table 3. Trace element concentrations in fish tissue[1] samples from the Viburnum Trend and the exploration study areas, 1995 and 2001.

[µg/g, microgram per gram; <, less than]

Map number (fig. 1)	Station name	Date	Time	Aluminum (µg/g)	Barium (µg/g)	Boron (µg/g)	Chromium (µg/g)	Copper (µg/g)	Iron (µg/g)	Manganese (µg/g)	Strontium (µg/g)
1	West Fork Black River near Greeley	09/12/1995	1420	<1	<0.01	0.9	0.5	8.9	370	3.8	0.1
7	Eleven Point River near Turner's Mill	08/30/2001	1800	<7	<.30	< 3.9	< 2.6	4.2	300	5.5	< .3

Map number (fig. 1)	Station name	Zinc (µg/g)	Antimony (µg/g)	Arsenic (µg/g)	Beryllium (µg/g)	Cadmium (µg/g)	Cobalt (µg/g)	Lead (µg/g)	Molybdenum (µg/g)	Nickel (µg/g)	Selenium (µg/g)
1	West Fork Black River near Greeley	70	<0.2	0.4	<0.2	1.0	1.2	<0.2	0.9	<0.2	9.6
7	Eleven Point River near Turner's Mill	91	<.1	.9	<.1	.5	1.1	<.1	.9	<.1	10.0

Map number (fig. 1)	Station name	Silver (µg/g)	Uranium (µg/g)	Mercury (µg/g)	Vanadium (µg/g)
1	West Fork Black River near Greeley	<0.2	<0.2	0.30	0.2
7	Eleven Point River near Turner's Mill	<.1	<.1	.16	.4

[1] West Fork Black River, Smallmouth Bass; Eleven Point River at Turner's Mill, Shadow Bass.

Table 4. Habitat characteristics of sites sampled in the Viburnum Trend and the exploration study areas, 1995 and 2001.

[m, meter; m/s, meters per second; m^2, square meters; <, less than]

Map number (fig. 1)	Station name	Channel width (m)	Mean channel depth (m)	Mean velocity (m/s)	Dominant substrate	Substrate embedded-ness (percent)	Mean canopy angle (degrees)	Number of quarter point species	Density of woody plants (individuals per 100 m^2)
1	West Fork Black River near Greeley	7.0	0.27	0.24	cobble	<25	71	13	30.5
2	Middle Fork Black River near Redmondville	9.4	.21	.20	cobble/gravel/ boulder	<50	96	11	19.4
3	Big Creek near Rat	4.8	.14	.13	boulder	<50	61	9	20.2
4	Eleven Point River near Round Hollow	9.1	.36	.07	cobble	<25	42	9	5.0
5	Spring Creek near Eleven Point River	5.3	.20	.04	cobble	<25	46	10	13.1
6	Hurricane Creek at the Ozark Trail	3.3	.11	.26	cobble	<25	22	10	30.7
7	Eleven Point River at Turner's Mill	21.3	.47	.66	cobble	<50	81	9	28.7

ranged from 5.0 individuals per 100 m^2 at the Eleven Point River near Round Hollow (map number 4) to 30.7 individuals per 100 m^2 at Hurricane Creek at the Ozark Trail (map number 6) (table 4). The Eleven Point River near Round Hollow has pastureland use on one bank of the river, contributing to the lower density value. The average woody plant density is 23.3 individuals per 100 m^2 for the Viburnum Trend study area, and 19.4 individuals per 100 m^2 for the exploration study area sites. These values indicated that overall, the sites have similar riparian vegetative densities.

There were slight differences in habitat characteristics between the two study areas. However, the two study areas were similar with respect to the vegetative data.

Invertebrate Community

Invertebrate samples were collected at each site from the riffle habitats present in the sampling area. Riffles often offer the richest habitat for invertebrate communities in the riffle/pool type streams that were sampled for this study. A total of 61 families were identified at the seven sites sampled.

Abundance, or the number of individuals collected at each site ranged from 2,918 individuals at Spring Creek (map number 5) to 9,846 individuals at Middle Fork Black River near Redmondville (map number 2) (table 5). The Viburnum Trend study area sites had more individuals per sample than the exploration study area sites. Species diversity ranged from 24 to 42 genera. There was no substantial difference in species diversity between the two study areas.

The orders Emphemeroptera, Plecoptera, and Trichoptera (EPT) are often used as a biotic measure based on the assumption that most species in these orders are sensitive to contamination. The EPT richness ranged from 51 percent at Spring Creek (map number 5) to 71 percent at the West Fork Black River near Greeley (map number 1) (table 5). There were no substantial differences in EPT richness between the two study areas.

The dominant taxa at six of the seven sites were from the Emphemeroptera order (mayflies). At the Eleven Point River at Turner's Mill (map number 7), the dominant taxa was from the Coleoptera order (riffle beetles).

Similarities between the invertebrate communities of the sites can be determined by using the Pearson correlation analysis (Helsel and Hirsch, 1992) on the invertebrate family data (table 6). The sites with the strongest correlations are the Middle Fork Black River near Redmondville (map number 2), Hurricane Creek at the Ozark Trail (map number 6), and the Eleven Point River at Turner's Mill (map number 7). The invertebrate communities at these sites are similar (73 to 76 percent). The least similar invertebrate communities (21 percent) are Eleven Point River near Round Hollow (map number 4) and Hurricane Creek (map number 6).

Table 5. Abundance and diversity data for invertebrate samples in the Viburnum Trend and the exploration study areas, 1995 and 2001.

[EPT, Emphemeroptera, Plecoptera, and Trichoptera]

Map number (fig. 1)	Station name	Abundance (number of individuals)	Diversity (number of genus identified)	EPT richness (percent)	Dominant taxa
1	West Fork Black River near Greeley	5,188	35	71	Heptogeniidae
2	Middle Fork Black River near Redmondville	9,846	27	58	Isonychia
3	Big Creek near Rat	5,193	42	52	Caenis species
4	Eleven Point River near Round Hollow	3,258	34	64	Caenis species
5	Spring Creek near Eleven Point River	2,918	39	51	Isonychia
6	Hurricane Creek at the Ozark Trail	5,001	24	61	Isonychia
7	Eleven Point River at Turner's Mill	6,234	24	60	Elmidae Optioservus

Table 6. Pearson correlation matrix for invertebrate samples collected from each sampling site.

Map number (fig. 1)	1	2	3	4	5	6	7
1	1.00						
2	.64	1.00					
3	.46	.32	1.00				
4	.56	.36	.60	1.00			
5	.51	.35	.54	.40	1.00		
6	.65	.76	.33	.21	.41	1.00	
7	.65	.73	.39	.34	.38	.58	1.00

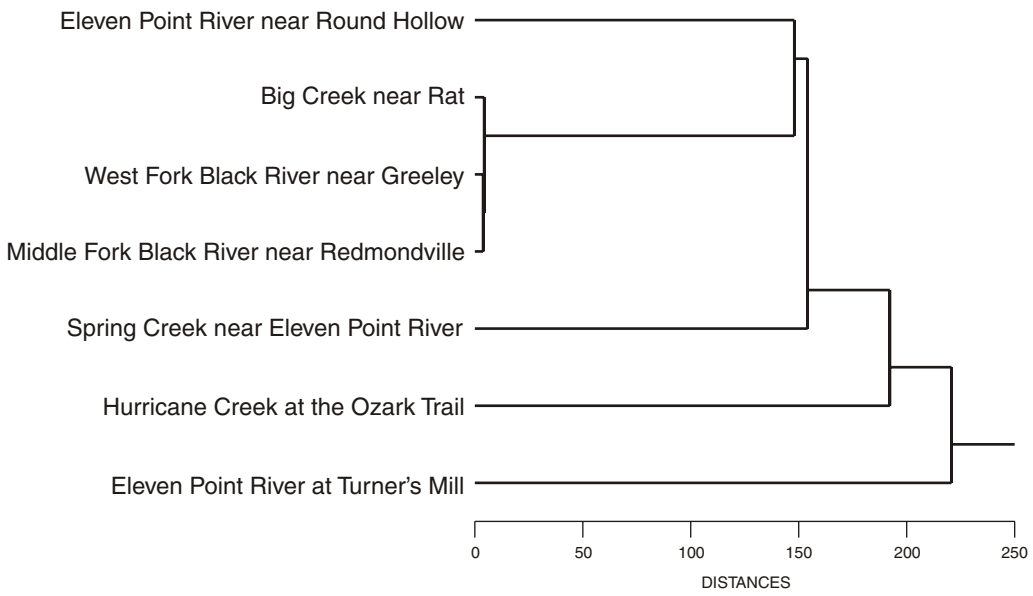


Figure 7. Hierarchal clustering using Euclidean distances and single linkages for invertebrate community data collected in the Viburnum Trend and exploration study areas, 1995 and 2001.

Analyzing the invertebrate data by the hierarchical dendrogram cluster analysis method (SPSS, Inc., 2000) is another method available to determine similarities between community data. Using a Euclidean distance matrix (SPSS, Inc., 2000) with a single linkage method, the community data were separated into groups of decreasing similarity (fig. 7). The shorter linkage distances indicate greater community similarities. The three Viburnum Trend study area sites appear to be the most closely related of the all the sites. Of the exploration study area sites, the Eleven Point River near Round Hollow (map number 4) is the closest in community similarity to the three Viburnum Trend study area sites. The hierarchical dendrogram does not show great similarity among the exploration study area sites, each is fairly unique in comparison with the community structure of the other sites.

SUMMARY

This report describes a study to establish background conditions and to compare background conditions of streams in two areas. The Viburnum Trend study area, is in an active lead-zinc mining district, and the exploration study area, is in an area being explored for economical lead-zinc ore bodies. The Viburnum Trend study area primarily lies in the Black River Basin, an area of rugged relief and numerous springs and streams. Geologic formations of the Black River Basin have been mined for lead and zinc ores since the 1960's. The exploration study area lies south of Winona and is an area of unique scenic beauty and environmental sensitivity. Biological, chemical, and physical data were collected at three Viburnum Trend study area sites in September 1995. As part of a synoptic study for the National Water-Quality Assessment (NAWQA) program, biological, chemical, and physical data were collected at four exploration study area sites in August 2001. The NAWQA protocols were followed at the exploration study area sites to duplicate methods used in the synoptic study to the greatest extent possible to allow data comparison. Although some laboratory reporting limits changed between 1995 and 2001, most of the protocols and procedures had not changed between the two sampling periods.

Water-quality parameters were sampled at each of the seven sites. Generally, the exploration study area sites had larger concentrations of the parameters sampled for than the sites in the Viburnum Trend study area. Dissolved ion concentrations generally were larger at the exploration study area sites than at the Viburnum Trend study area sites, with the exception of potassium. Big Creek near Rat generally had the smallest concentrations of dissolved ions at the seven sites analyzed. Most of the samples had concentrations below minimum reporting levels (MRL) for nutrients. Two Viburnum Trend study area sites, Middle Fork Black River near Redmondville and Big Creek near Rat, had low levels of ammonia and nitrite plus nitrate concentrations above the MRL.

Escherichia coli (*E. coli*), fecal coliform, and fecal streptococci were sampled at each site. The Viburnum Trend study area sites had slightly larger concentrations of *E. coli* and fecal coliform than the sites in the exploration study area. The exploration study area sites had larger concentrations of fecal streptococci than the Viburnum Trend study area sites. Most sites had bacteria levels below levels of concern for whole-body contact.

Dissolved trace-element samples were collected at each site for analysis. Although there were differences in the MRLs between the two sampling efforts, concentrations indicate low-level trace metals in all samples. Fine particle [<63 µm (micron)] streambed-sediment samples were collected at six sites: two in the Viburnum Trend study area and four in the exploration study area. Generally, concentrations of trace elements in stream sediment were detected above the MRL and did not differ greatly between the Viburnum Trend study area sites and the exploration study area sites. Concentrations were slightly larger in the exploration study area samples.

Fish tissue samples were collected at two sites, one from the Black River and one from the Eleven Point River. Small concentrations of metals were present in samples from both sites. Lead was not detected above the MRL, although concentrations of zinc were detected. Mercury was present in both samples, with the largest concentration in the sample from the West Fork Black River near Greeley.

Habitat characteristics were recorded at each site. Instream and riparian features were measured to quantify site characteristics. The Eleven Point River at Turner's Mill was the largest site, in size, sampled for this study. Disregarding the Eleven Point River at Turner's Mill site, the exploration study area sites were slightly smaller than the Viburnum Trend study area sites. The dominant streambed substrate was cobble at most sites with the exception of the Middle Fork Black River near Redmondville, which did not have a dominant substrate, and Big Creek near Rat, which had a dominant substrate of boulders. The streambed substrate was less than 50 percent embedded at all of the sites, indicating that the streambeds experience streambed disturbances from time to time. Canopy angles ranged from 22 to 96 degrees. The Viburnum Trend study area sites had larger canopy angles than the sites in the exploration study area, allowing more sunlight to reach the stream channel. Riparian woody plants recorded from quarter-point measurements ranged from 9 to 13 species. Woody plant densities ranged from 5.0 to 30.7 individuals per 100 m^2 (square meters) with an average density of 23.3 individuals per 100 m^2 at sites in the Viburnum Trend study area and 19.4 individuals per 100 mi^2 at sites in the exploration study area.

Analysis of the invertebrate community data at the family level indicated that the Viburnum Trend study area sites had stronger correlations than the sites in the exploration study area. The Eleven Point River near Round Hollow was the exploration study area site with the most similarities in invertebrate community structure to the Viburnum Trend study area sites.

The background data for the Viburnum Trend study area sites and the exploration study area sites illustrate some similarities in water-quality parameters. Background conditions at sites in the exploration study area are not substantially different from non-mining sites in the Viburnum Trend study area in relation to nutrients, trace elements, streambed sediment and fish tissue. Data for physical parameters, major ions, bacteria, and habitat characteristics indicated slight differences between the two study areas. Invertebrate communities were diverse and demonstrated differences between study areas.

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