U.S. Department of the Interior
U.S. Geological Survey

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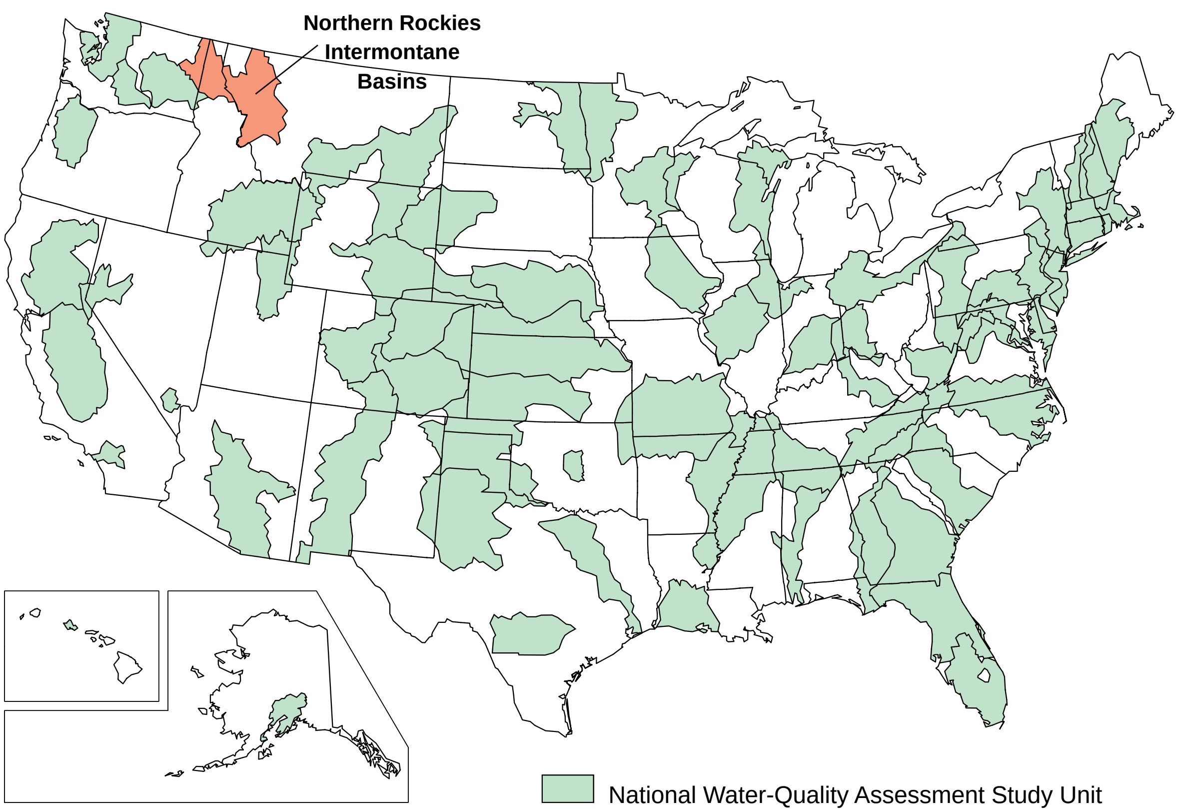
Water-Resources Investigations Report 98–4254



National Water-Quality Assessment Program

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U.S. Department of the Interior
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Summary of Information on Synthetic Organic Compounds and Trace Elements in Tissue of Aquatic Biota, Clark Fork-Pend Oreille and Spokane River Basins, Montana, Idaho, and Washington, 1974–96

By Terry R. Maret *and* DeAnn M. Dutton

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National Water-Quality Assessment Program

Boise, Idaho
1999

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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or
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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resources agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequence of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND OTHER ABBREVIATED UNITS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04381	million cubic meters per second
square mile (mi^2)	0.2590	square kilometer
ton	0.9072	metric ton

To convert °C (degrees Celsius) to °F (degrees Fahrenheit), use the following equation:

$$^{\circ}F = (1.8\ ^{\circ}C) + 32$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Other abbreviated units:

g	gram
kg	kilogram
µg/g	microgram per gram
µg/kg	microgram per kilogram

Summary of Information on Synthetic Organic Compounds and Trace Elements in Tissue of Aquatic Biota, Clark Fork-Pend Oreille and Spokane River Basins, Montana, Idaho, and Washington, 1974–96

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Abstract

As part of the Northern Rockies Intermontane Basins study of the National Water-Quality Assessment Program, data collected between 1974 and 1996 were compiled to describe contaminants in tissue of riverine species. Tissue-contaminant data from 11 monitoring programs and studies representing 28 sites in the study area were summarized. Tissue-contaminant data for most streams generally were lacking. Many studies have focused on and around mining-affected areas on the Clark Fork and Coeur d'Alene Rivers and their major tributaries.

DDT and PCBs and their metabolites and congeners were the synthetic organic contaminants most commonly detected in fish tissue. Fish collected from the Spokane River in Washington contained elevated concentrations of PCB arochlors, some of which exceeded guidelines for the protection of human health and predatory wildlife. Tissue samples of fish from the Flathead River watershed contained higher-than-expected concentrations of PCBs, which might have resulted from atmospheric transport.

Trace element concentrations in fish and macroinvertebrates collected in and around mining areas were elevated compared with background concentrations. Some cadmium, copper, lead, and mercury concentrations in fish tissue were elevated compared with results from other studies, and some exceeded guidelines. Macroinvertebrates from the Coeur d'Alene River contained higher concentrations of cadmium, lead, and zinc than did macroinvertebrates from other river systems in mining-affected areas. A few sportfish fillet samples, most from the Spokane River in Washington, were collected to assess human health risk. Concentrations of PCBs in these fillets exceeded screening values for the protection of human health.

At present, there is no coordinated, long-term fish tissue monitoring program for rivers in the study area, even though contaminants are present in fish at levels considered a threat to human health. Development of a coordinated, centralized national data base for contaminants in fish tissue is needed. The National Water-Quality Assessment Program can provide a framework for other agencies to evaluate tissue contaminants in the Northern Rockies Intermontane Basins study area. As of 1996, there are no fish consumption advisories or fishing restrictions as a result of elevated contaminants on any rivers within the study area.

INTRODUCTION

The U.S. Geological Survey (USGS) fully implemented the National Water-Quality Assessment

(NAWQA) Program in 1991. The long-term goals of the NAWQA Program are to describe the status of and trends in the quality of a representative part of the Nation's surface- and ground-water resources and to provide a technically sound, scientific understanding of the primary natural and human factors affecting the quality of these resources (Hirsch and others, 1988; Leahy and others, 1990). These goals are accomplished by collecting biological, physical, and chemical data at sites that represent major natural and human factors (for example, ecoregion, land use, stream size, hydrology, and geology) that are thought to control water quality in a river basin. The NAWQA Program will provide an improved scientific basis for evaluating effectiveness of water-quality management programs in large hydrologic basins. Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and the costs associated with decisions involving land and water conservation and management.

The Northern Rockies Intermontane Basins (NROK) study area in eastern Washington, northern Idaho, and western Montana (fig. 1) is 1 of 59 areas, or study units, selected for assessment under the full-scale implementation of the NAWQA Program. Collectively, these study units cover about one-half of the land area of the United States and include about 70 percent of the Nation's water use and population served by public water supplies. The NROK study area has been selected to include several important montane river systems that represent a mixture of forested, agricultural, urban, and developing areas, and contains major sole-source aquifers such as the Spokane Valley/Rathdrum Prairie and Missoula Valley aquifers. Historical and current mining practices in the study area are believed to affect the quality of the streams and aquifers. Study activities by the USGS in the NROK area began in late 1996.

The biological component of the NAWQA Program consists of ecological surveys that characterize the fish, macroinvertebrate, and algal communities and associated riparian and instream habitats. Tissue studies to assess the occurrence and distribution of environmental contaminants also are an important component (Gurtz, 1994).

As part of the initial phase of the NAWQA Program, data were compiled to describe the current (1996) and historical aquatic biological conditions of surface water in the NROK study area. Assessment of contaminants in biota provides information about the occurrence and distribution of contaminants in aquatic systems. Contaminants can be more concentrated in tissue than in surrounding water or sediment (U.S. Environmental Protection Agency, 1992). Biomagnification of selected contaminants such as mercury and organochlorine compounds may result in tissue concentrations that are high enough to affect human or ecological health. According to the Natural Resource Defense Council (NRDC), fish tissue contaminants are a serious national health concern that has not been adequately addressed by current pollution abatement and monitoring programs (Natural Resource Defense Council, Inc., accessed April 1998, online).

The focus of this retrospective report is to provide data summaries describing contaminants analyzed in aquatic biota from streams in the study area. The information presented represents the compilation of aquatic biological contaminant data available from Federal, State, academic, and private sources. The information will be useful to resource managers in describing the occurrence and distribution of contaminants of concern in streams of the study area. Ultimately, this information will provide a scientific basis for designing a cost-effective surface-water monitoring network to describe the occurrence and distribution of contaminants that can affect the quality of water resources in the NROK study area.

Rationale for Evaluating Tissue Contaminants

Fish and aquatic macroinvertebrates are indicators of biologically available contaminants because environmental contaminants can accumulate in their bodies at higher concentrations than in surrounding water. The bioaccumulation of contaminants in tissue provides an indication of the presence of environmental pollutants. Contaminants also can accumulate by biomagnification in the food chain as a result of predation. This process has been most notable in contaminated fish eaten by predatory wildlife. Data on synthetic organic compounds and trace elements in tissue can be used to evaluate national and regional long-term trends in water quality. Information on contaminant concentrations in fish and other aquatic biota also can be used as an indicator of potential risk to human health and wildlife. Concentrations of contaminants in the tissue of fish and macroinvertebrates provide a time-averaged assessment and a better understanding of the complexities of the fate, distribution, and effects of various contaminants (Crawford and Luoma, 1993). Contaminants also can influence the species richness and composition of aquatic biota. Consequently, analyzing for contaminants in tissue can help assess the biological integrity of streams.

Purpose and Scope

This retrospective report summarizes information on contaminants in tissue of aquatic biota in the NROK study area. Specifically, the purposes of this report are to:

- Summarize and evaluate the information that has been collected on synthetic organic compounds and trace elements in tissue of aquatic biota from streams in the study area;
- Compare tissue concentrations among reported studies and with guidelines established for the protection of human health and wildlife; and
- Provide a bibliography of aquatic tissue-contaminant studies for streams in the study area.

This summary of tissue-contaminant studies will be useful for characterizing contaminants of concern in two large montane river basins of the West, the Clark Fork-Pend Oreille and Spokane. Most contaminant studies in this region have been limited to relatively small-scale, site-specific assessments. This report is intended to identify future monitoring needs for assessment of land-use effects on surface-water quality and associated aquatic biota. Fish and aquatic macroinvertebrates are the only groups summarized because they have been the primary focus of past tissue monitoring and biological assessment programs by Federal, State, academic, and private agencies and institutions.

Sources and Limitations of Tissue-Contaminant Data

Tissue-contaminant data for the study area were available from two general sources—the U.S. Environmental Protection Agency (USEPA) data base Storage and Retrieval System (STORET), and reports produced by various other agencies and institutions. Because of inconsistencies and errors in some STORET data, the data base was queried primarily to identify sources of tissue-contaminant reports and the collecting agency. This was accomplished by creating an electronic data base for the study area by using hydrologic unit codes and producing a statistical data summary. Remark code inconsistencies in the STORET data base, such as reported concentrations less than the detection limit and changes in detection limits, prevented accurate determination of the actual number of detections. Also, no remark code or comments were used to differentiate between analyses based on composite or individual fish tissue samples. The data set provided only a qualitative description of constituent concentrations. Tissue data summarized by the USEPA National Sediment Inventory were reviewed for the study area but were found to be redundant with STORET data.

All data tabulated or summarized in this report were taken directly from reports or electronic data files supplied by the organization responsible for collecting the data. In a few cases, data from USGS sources and unpublished agency reports and consultant reports were used. Data on trace element concentrations in tissue of macroinvertebrates in the Clark Fork Basin, Mont., were obtained from USGS computer files (Dodge and others, 1997).

In this report, synthetic (manufactured) organic compound and trace element concentrations in fish tissue are expressed in parts per million (μg/g), wet weight. Some fish tissue concentrations reported as dry weight were converted to wet weight by multiplying the dry-weight concentration by a factor of 0.25, which is based on 1 minus the percentage of moisture content (fish tissue assumed to be 75-percent moisture on the basis of findings in a report by Lowe and others, 1985). Trace element concentrations in macroinvertebrate tissue are expressed as μg/g, dry weight.

Tissue-contaminant data collected by Federal, State, academic, and private organizations were used to

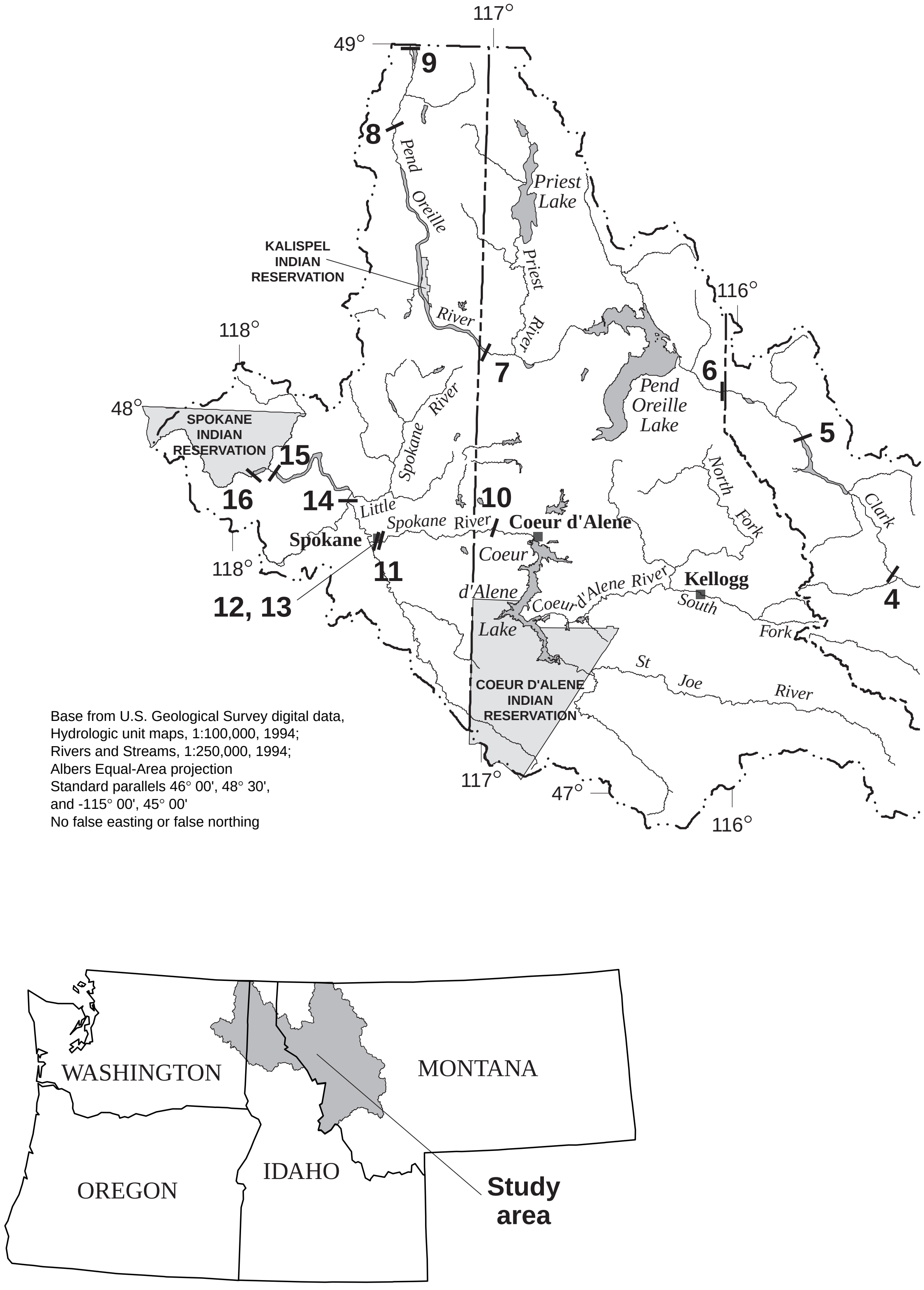
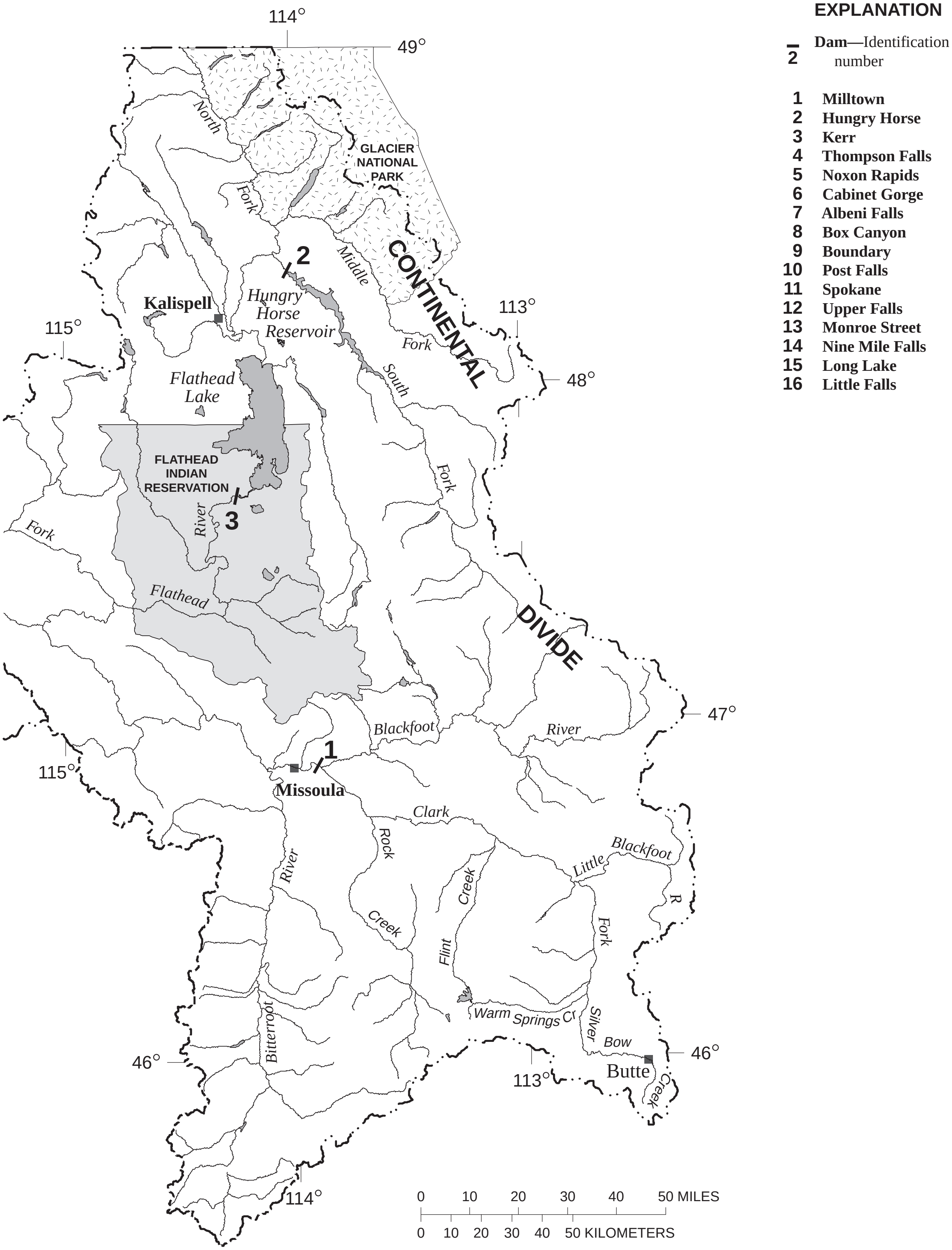


Figure 1. Location of Northern Rockies Intermontane Basins study area, major dams, Indian reservations,



and Glacier National Park, Montana, Idaho, and Washington.

assess the status and trends of contaminants in the study area. Most of the information reviewed in this report is from studies and reports by the U.S. Fish and Wildlife Service (USFWS); USEPA; USGS; Idaho Division of Environmental Quality (formerly Idaho Department of Health and Welfare, Division of Environmental Quality) (IDEQ); Washington State Department of Ecology (WDOE); and University of Montana (U of M). Spatial data coverages used to help characterize the study area were obtained from the Interior Columbia Basin Ecosystem Management Project (ICBEMP) World Wide Web site (U.S. Forest Service and Bureau of Land Management, accessed March 1998, online).

Because of the diversity of data reviewed, it was difficult to consolidate the data for summary or comparison. Data comparability is a major problem in environmental contaminant studies because laboratory and field methods are constantly changing and many different methods are published by USEPA, other Federal and State agencies, and various private organizations. For example, various Federal and State programs collect fish tissue-contaminant data from a variety of species (for example, sportfish or bottom feeders) and tissue types (for example, fillets, whole body, livers, and gills), which makes comparisons between studies or programs difficult. Because of the lack of documentation on quality assurance and methods, the data were screened only for obvious errors and were assessed qualitatively. Data are presented for total number of analyses for the various constituents and the detected concentrations. An overview of the categories of analytes determined for the monitoring programs and studies summarized in this report is provided in table 1.

Because information on specific locations was not always available, such as latitude and longitude or legal description, a few sites were assigned locations (latitude and longitude and river mile) by using location descriptors for the closest USGS streamflow gaging station. River mile was assigned according to USGS gaging station descriptions or Pacific Northwest River Basin Commission (1976) or Columbia Basin Inter-Agency Committee (1964) river mile index.

Traditional approaches to presenting and analyzing data, such as boxplots and descriptive statistics, generally could not be performed in this report because of the paucity of data and inadequate information on methods and quality assurance. However, a few tissue studies provided sufficient information and data that were summarized and assessed in more detail.

Acknowledgments

Jim Hileman, USEPA, Seattle, provided access to STORET data. Art Johnson, WDOE, Olympia, provided numerous agency publications. Don Skarr, Montana Department of Fish, Wildlife, and Parks, Helena, provided information on studies in Montana. Bill Clark, IDEQ, Boise, provided some useful agency reports. Mike Beckwith, Michelle Hornberger, John Lambing, and Paul Woods, USGS, provided contaminant reports and (or) data for the Idaho and Montana parts of the study area. Bernie Bonn, USGS, Portland, provided information on dioxins and furans in tissue. Colleague reviews by Mark Munn, Terry Short, and Lan Tornes, USGS, improved the quality of the manuscript.

ENVIRONMENTAL SETTING

The NROK study area is a 31,500-mi^2 area in western Montana (68 percent), northern Idaho (21 percent), and northeastern Washington (11 percent) (fig. 1). The study area is composed of two major river basins: the Clark Fork-Pend Oreille River Basin, which encompasses about 24,900 mi^2, and the Spokane River Basin, which encompasses about 6,600 mi^2 (Tornes, 1997).

The Clark Fork originates near Butte in southwestern Montana and flows more than 350 mi to Lake Pend Oreille in northern Idaho. The Pend Oreille River flows from the lake northward with an average annual discharge of 28,000 ft^3/s and joins the Columbia River in Canada. The Spokane River originates in northern Idaho as the outflow from Coeur d’Alene Lake, which has two principal tributaries, the Coeur d’Alene and St. Joe Rivers. The Spokane River has an average annual discharge of about 7,000 ft^3/s at Spokane, Wash. (Tornes, 1997).

The study area has numerous natural lakes and reservoirs, including Flathead Lake (the largest natural freshwater lake in the Western United States), Pend Oreille Lake (one of the deepest lakes in the United States), Coeur d’Alene Lake, Hungry Horse Reservoir,

Table 1. Categories of analytes determined for various programs and studies summarized for the Northern Rockies Intermontane Basins in Montana, Idaho, and Washington

[USEPA, U.S. Environmental Protection Agency; USFWS, U.S. Fish and Wildlife Service; IDEQ, Idaho Division of Environmental Quality; WDOE, Washington State Department of Ecology; NBS, National Biological Service; U of M, University of Montana; USGS, U.S. Geological Survey; X, analyte included in the program or study]

Category of analytes	USEPA National Bioaccumulation Study[1]	USEPA water-quality monitoring report[2]	USFWS National Contaminant Biomonitoring Program[3]	USFWS contaminants program[4]	IDEQ fish tissue ambient monitoring program[5]	IDEQ study[6]	WDOE screening survey of PCBs and metals in the Spokane River[7]	WDOE pesticide monitoring program[8]	NBS study[9]	U of M study[10]	USGS study[11]
Synthetic organic compounds											
Polynuclear aromatic hydrocarbons	X										
Organochlorine insecticides	X		X	X	X			X			
Herbicides	X		X		X						
Fungicides	X		X	X	X			X			
Miscellaneous industrial compounds	X		X					X			
Polychlorinated biphenyls	X		X	X	X		X	X			
Chlorinated dioxins and furans	X										
Organophosphates									X		
Trace elements											
Aluminum				X							
Arsenic		X	X	X	X				X		X
Barium				X							
Beryllium				X							
Boron				X							
Cadmium		X	X	X	X	X	X		X	X	X
Chromium				X	X						
Copper		X	X	X	X		X		X	X	
Iron		X	X	X							
Lead		X	X	X	X	X	X		X	X	X
Magnesium				X							
Manganese				X							
Mercury	X	X	X	X	X	X	X			X	X
Molybdenum				X							
Nickel				X							
Selenium			X	X							
Strontium				X							
Vanadium				X							
Zinc		X	X	X	X	X			X	X	

[1] U.S. Environmental Protection Agency (1992).
[2] Hornig and others (1988).
[3] Schmitt and others (1981, 1983, 1985); May and McKinney (1981); Lowe and others (1985); Schmitt and Brumbaugh (1990).
[4] Palawski and others (1991b); J. Malloy, U.S. Fish and Wildlife Service (written commun., 1998).
[5] Nautch and Clark (1998).
[6] M. Hartz, Idaho Department of Health and Welfare, Division of Environmental Quality (written commun., 1994).
[7] A. Johnson, Washington State Department of Ecology (written commun., 1997).
[8] Davis and others (1995).
[9] Farag and others (1995).
[10] Van Meter (1974).
[11] Farag and others (1998).

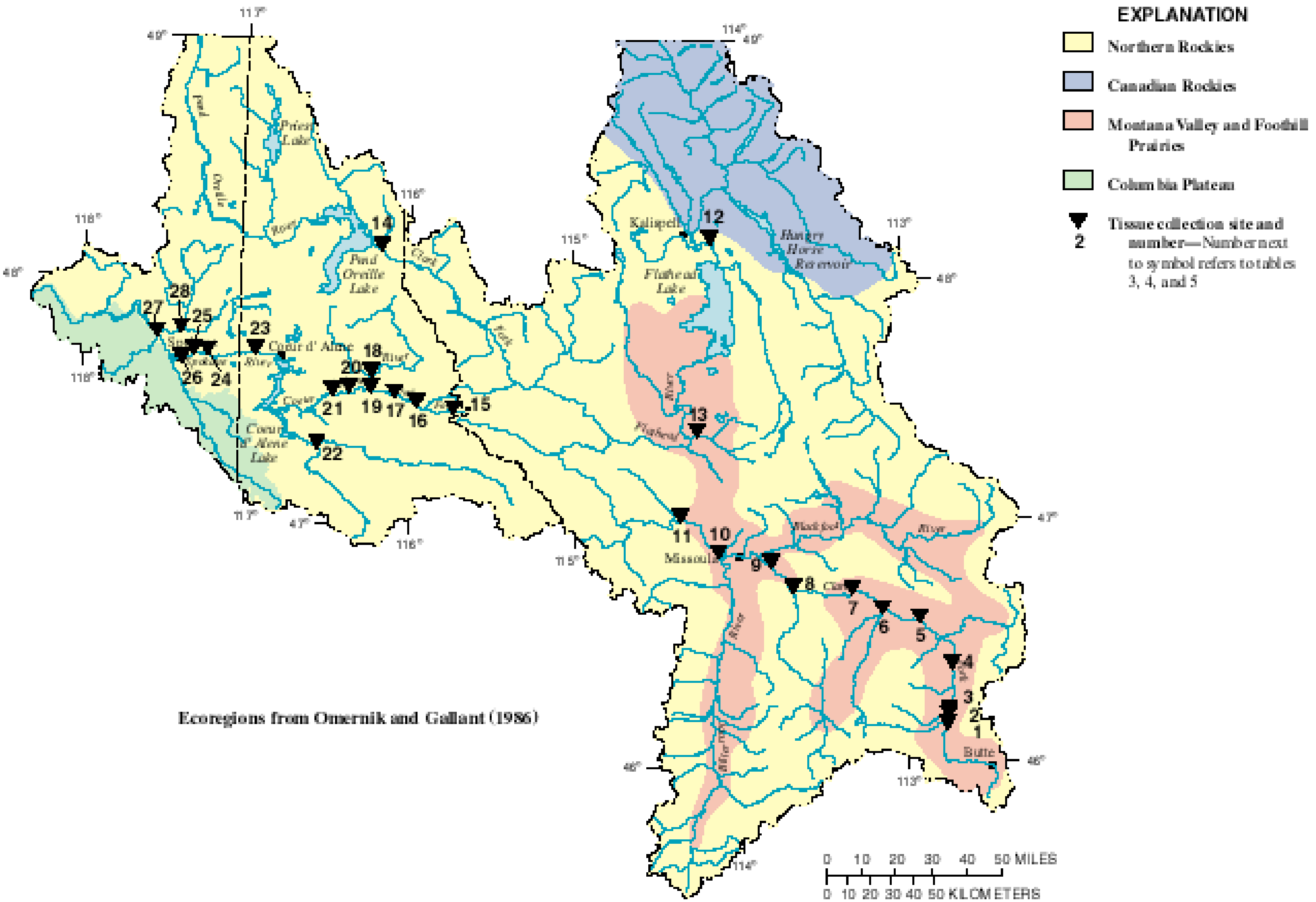


Figure 2. Ecoregions and tissue collection sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington.

and Priest Lake. Sixteen dams on the Clark Fork and the Flathead and Spokane Rivers regulate flows primarily for hydroelectric-power generation and flood control (fig. 1). These main-stem barriers impede fish passage and change the natural hydrologic patterns (Johnson and Schmidt, 1988).

The study area includes four ecoregions (fig. 2): Northern Rockies (72 percent of the land area); Montana Valley and Foothill Prairies (16 percent); Canadian Rockies (9 percent); and Columbia Plateau (3 percent) (A. Woods, U.S. Environmental Protection Agency, written commun., 1998). Ecoregions are areas having similar land use, natural vegetation, soils, and land surface forms, and have been useful for organizing water-resource information on the basis of regional patterns of ecosystem quality (Omernik and Gallant, 1986). The Northern Rockies and Canadian Rockies ecoregions characterize the high-elevation, mountainous parts of the study area. These ecoregions consist primarily of coniferous forests, and the predominant land uses are timber, mining, and recreation. The Montana Valley and Foothill Prairies and the Columbia Plateau ecoregions represent low elevations characterized by flatlands and rolling hills vegetated with grasses and, in drier areas, sagebrush. Land use in these low-elevation ecoregions is primarily dryland agriculture, irrigated cropland, and grazing.

The population of the study area in 1990 was about 725,000: 350,000 in Washington, 255,000 in Montana, and 120,000 in Idaho (Tornes, 1997). Land ownership is about 56 percent public, 37 percent private, and 7 percent tribal. Tribal lands are Coeur d'Alene, Flathead, Kalispel, and Spokane Indian Reservations (fig. 1).

The hydrogeology of the study area has been described extensively in reports for the USGS Regional Aquifer-System Analysis Program (Kendy and Tresch, 1996). The study area has a complex geologic history of sedimentation, compressional deformation, igneous activity, and, most recently, extensional block faulting. Aquifers in deposits of Tertiary and Quaternary ages provide water for public-supply, domestic, stock, irrigation, commercial, and industrial uses. Most households rely on wells or springs for domestic supply (Clark and Kendy, 1992). The largest uses of ground water are for irrigation and public supply, although most water for irrigation is obtained from surface-water sources. The average water use in the study area in 1990 was about 1,600 Mgal/d. About 80 percent was from surface-water sources (Tornes, 1997).

The topography ranges from high-elevation, mountainous areas to large, flat valleys. Land-surface elevation ranges from more than 10,000 ft above sea level in the mountainous areas of western Montana to less than 1,500 ft along the Spokane River.

The climate is characterized by cold winters and mild summers. Annual precipitation varies widely and ranges from almost 100 in. near the Continental Divide in northwestern Montana to less than 15 in. in many of the intermontane basins of western Montana. Most valleys receive about 10 to 30 in. of precipitation per year, mostly in winter and spring. Large snowpacks in the mountains release water as snowmelt. Snowmelt runoff from April to July represents the main source of surface water and ground water in the study area (Kendy and Tresch, 1996).

Upland forest and low-elevation rangeland streams typically have coarse-grained substrates (gravel and cobble), high gradients (greater than 1.0 percent), well-defined riffle-pool habitats, and sparse macrophyte growth. Large rivers and streams at low elevations typically have finer grained substrates and lower gradients. Most streams in the study area support coldwater aquatic biota whose optimal growing temperature is generally below 20 °C. Both Idaho and Montana have specific coldwater aquatic biota use designated for most streams listed in their respective Water Quality Standards (Idaho Department of Health and Welfare, Division of Environmental Quality, 1997; Montana Department of Health and Environmental Sciences, 1994).

The quality of surface and ground water in both the Clark Fork-Pend Oreille and Spokane River Basins is affected by mining activities. About 1,600 active and abandoned hard-rock mines of various sizes are located in the study area (fig. 3). Many mines are still operating, and several new mines are proposed (Steve Box, U.S. Geological Survey, Mineral Resources Data System data base, oral commun., 1998). Historically, metal extraction and processing were relatively inefficient, yielding large volumes of metal-rich tailings that were deposited in nearby streams. These tailings continue to provide a source of trace elements to streams, lakes, and reservoirs as streams meander through and erode

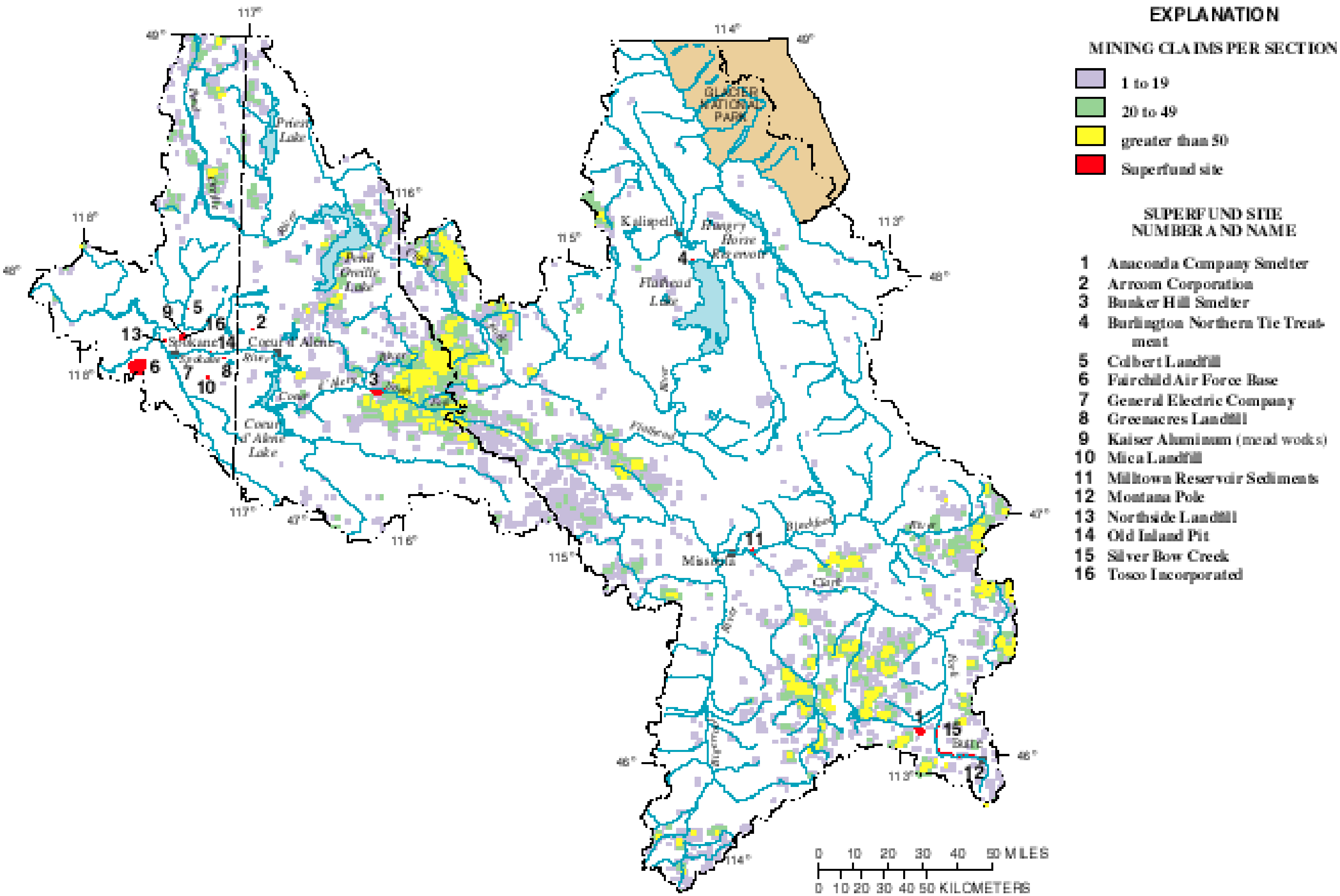


Figure 3. Locations of Superfund sites and mining claims in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington.

tailings deposits and transport them downstream. Andrews (1987) estimated that 100 million tons of tailings have been supplied to the headwaters of the Clark Fork during the period of mining from 1880 to 1982. Metal enrichment remains evident in the Clark Fork sediments and biota for more than 150 mi, from Butte to near Missoula, Mont. (Moore and Luoma, 1990). Similarly, tailings discharged directly to the South Fork Coeur d'Alene River have been transported and deposited along the river channel and flood plain into Coeur d'Alene Lake and out of the lake into the Spokane River. Horowitz and others (1995c) estimated that 85 percent of the Coeur d'Alene Lake bed is enriched with trace elements. Mine tailings in the study area typically contain elevated levels of the trace elements arsenic, cadmium, copper, lead, mercury, and zinc. The WDOE (1996) Water Quality Status Report has placed the Spokane River on its 303(d) list submitted to USEPA as not supporting one or more of its designated uses. Some of the contaminants listed were cadmium, mercury, and zinc. The USEPA (1997b) National Sediment Inventory identified the Coeur d'Alene River and Lake as "areas of probable concern for sediment contamination," the most severe contamination category in their assessment.

Sixteen Superfund sites are located in the study area (fig. 3). Superfund investigations and remediations are active along the upper 150-mi reach of the Clark Fork and in a 21-mi^2 area near Kellogg, Idaho, along the South Fork Coeur d'Alene River. Currently, four Superfund sites (fig. 3; sites 1, 3, 11, and 15) related to mining activities are operational. The Anaconda Company Smelter and Bunker Hill Smelter are the two largest Superfund sites in the Nation (Doppelt and others, 1993). The Department of the Interior currently is conducting Natural Resource Damage Assessments in and around these Superfund complexes.

According to USEPA, 30 major facilities in the study area are permitted under the National Pollution Discharge Elimination System (NPDES) to discharge effluent to streams (J. Hileman, 1998, unpubl. data on diskette, on file at U.S. Environmental Protection Agency, Seattle, Wash.). Of these, 7 are industrial, 14 are wastewater treatment, and 9 are mining facilities (fig. 4 and table 2). Major NPDES permitted facilities are ranked using a rating system based on volume of effluent discharged, streamflow characteristics of the receiving water, potential public health risk, and chemical content of the effluent. A facility that is permitted to discharge 1 Mgal/d or process wastewater for 10,000 people per day or more is considered a major facility in the permit system.

Elevated trace element concentrations in the Clark Fork in Montana have caused fish kills and suppression of fish production (Phillips and Lipton, 1995). Juvenile trout have shown reduced growth and survival as a result of ingesting macroinvertebrates from the Clark Fork, where trace element concentrations are elevated (Farag and others, 1994; Woodward and others, 1994). Adult trout also have shown avoidance response to elevated trace element concentrations similar to ambient concentrations in the Clark Fork (Woodward and others, 1995).

Some aquatic biota populations in the study area could be so altered (some species are absent) in streams affected by mining that it might be difficult to sample comparable tissues from mining-affected versus reference streams. Changes in the diversity of bottom-dwelling organisms in Coeur d'Alene Lake and River have been attributed to the toxic effects of trace elements from mining areas upstream (Winner, 1972; Hornig and others, 1988; Ruud, 1996). Ellis (1940) reported the lower Coeur d'Alene River and southern end of the lake as almost "totally devoid of aquatic life" from mining-related pollution in the South Fork Coeur d'Alene River valley. Macroinvertebrate communities also have been affected by habitat degradation such as channelization and loss of streamside cover resulting from mining and ore processing along the South Fork Coeur d'Alene River (Hoiland and Rabe, 1992). Additional biological monitoring by Hoiland and others (1994) on the South Fork Coeur d'Alene River indicated improvements as a result of mine wastewater treatment and mine closures. However, biotic integrity of affected sites continues to lag behind that of reference sites, probably as a result of poor physical habitat structure and metals leaching from mine tailings. Moore and others (1991) found depauperate benthic communities, reduced fish populations, and elevated trace elements in fish livers coincident with sediment contaminated with trace elements in the Blackfoot River in Montana. Trace element concentrations in fish and macroinvertebrates in and around mining areas are

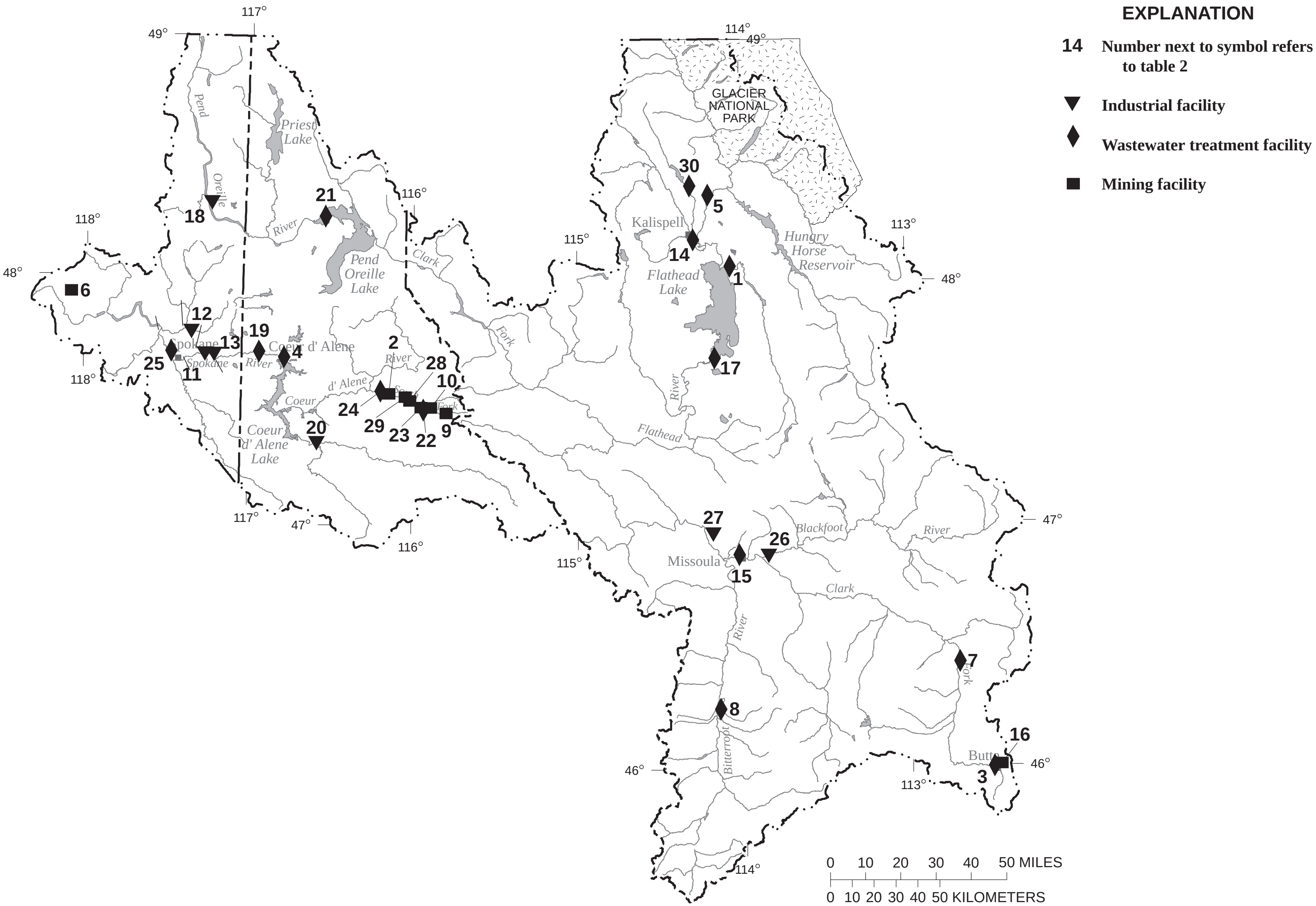


Figure 4. Locations of major industrial, wastewater treatment, and mining facilities in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington.

Table 2. Major industrial, wastewater treatment, and mining facilities in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington

[Data from U.S. Environmental Protection Agency Permit Compliance System, J. Hileman, 1998, unpubl. data on diskette on file at U.S. Environmental Protection Agency, Seattle, Wash.; No., number; Mont., Montana; Wash., Washington; W, wastewater treatment; I, industrial; M, mining]

Map No. (fig. 4)	Facility name	Receiving water	Facility type
1	City of Big Fork, Mont.	Flathead Lake	W
2	Bunker Hill Mining Company, Idaho	South Fork Coeur d'Alene River	M
3	City of Butte-Silver Bow, Mont.	Silver Bow Creek	W
4	City of Coeur d'Alene, Idaho	Spokane River	W
5	City of Columbia Falls, Mont.	Flathead River	W
6	Dawn Mining Company, Wash.	Blue Creek	M
7	City of Deer Lodge, Mont.	Clark Fork	W
8	City of Hamilton, Mont.	Bitterroot River	W
9	Hecla Mining Company, Idaho	South Fork Coeur d'Alene River	M
10	Hecla Mining Company, Idaho	Canyon Creek	M
11	Inland Empire Paper Company, Wash.	Spokane River	I
12	Kaiser Aluminum and Chemical, Wash.	Deadman Creek	I
13	Kaiser Aluminum and Chemical, Wash.	Spokane River	I
14	City of Kalispell, Mont.	Ashley Creek	W
15	City of Missoula, Mont.	Clark Fork	W
16	Montana Resources, Mont.	Silver Bow Creek	M
17	City of Polson, Mont.	Flathead River	W
18	Ponderay Newsprint Company, Wash.	Pend Oreille River	I
19	City of Post Falls, Idaho	Spokane River	W
20	Potlatch Corporation, Idaho	St. Joe River	I
21	City of Sandpoint, Idaho	Pend Oreille River	W
22	Silver Valley Resources Corporation, Idaho	Daly Creek	M
23	Silver Valley Resources Corporation, Idaho	Lake Creek	M
24	South Fork Coeur d'Alene Sewer, Idaho	South Fork Coeur d'Alene River	W
25	City of Spokane, Wash.	Spokane River	W
26	Stimson Lumber Company, Mont.	Blackfoot River	I
27	Stone Container Corporation, Mont.	Clark Fork	I
28	Sunshine Precious Metals Incorporated, Idaho	South Fork Coeur d'Alene River	M
29	Sunshine Precious Metals Incorporated, Idaho	Big Creek	M
30	City of Whitefish, Mont.	Whitefish River	W

elevated compared with background concentrations (Farag and others, 1995 and 1998).

STATUS AND TRENDS OF CONTAMINANTS IN TISSUE

The STORET data base contained 65 sites in the study area for which tissue-contaminant information was available. About half of these sites were represented by samples collected from lakes and reservoirs. Eleven monitoring programs and studies (table 1) representing 28 different sites were summarized to best represent tissue-contaminant data for streams of the study area (fig. 2; tables 3 and 4, back of report; table 5).

Tissue-contaminant data generally are lacking for most streams. Data have been collected primarily from large rivers for national monitoring programs or site-specific studies on fish tissue or aquatic macroinvertebrates. Most of the studies between 1974 and 1996 were conducted in and around mining areas on the Clark Fork and the Coeur d’Alene River and their major tributaries (fig. 2; sites 1 through 11 and sites 15 through 21, respectively). More recently (1993–96), intensive contaminant sampling was conducted on the Spokane and Little Spokane Rivers near the city of Spokane, Wash., to evaluate polychlorinated biphenyl (PCB) and trace element contamination (fig. 2; sites 23 through 28). Few tissue-contaminant data have been collected to define background or expected reference concentrations for aquatic biota in the four predominant land-use settings in the study area.

A small amount of information on tissue contaminants in the study area has been collected for two

Table 5. Aquatic macroinvertebrates collected and analyzed for selected trace elements, and period of data collection at selected long-term U.S. Geological Survey sampling sites in the upper Clark Fork Basin, Montana, 1986–96

[No., number; USGS, U.S. Geological Survey; data from Dodge and others (1997); river mile, distance upstream from Columbia River]

Site No. (fig. 2)	USGS gaging station No.	Gaging station name	Latitude Longitude	River mile	Period of data collection	Aquatic macroinvertebrates	No. of composite samples
1	12323750	Silver Bow Creek	46°10'50"	484.5	1992–96	*Arctopsyche grandis*	1
		at Warm Springs	112°46'46"			*Hydropsyche cockerelli*	14
					1992–95	*Hydropsyche occidentalis*	3
					1995	*Hydropsyche* spp.	2
3	12323800	Clark Fork	46°12'30"	482.7	1987, 1991–96	*Hydropsyche cockerelli*	11
		near Galen	112°45'59"			*Hydropsyche morosa* group	5
						Hydropsyche occidentalis	16
						Hydropsyche tana	1
						Hydropsyche spp.	4
4	12324200	Clark Fork	46°23'52"	461.2	1986–87, 1990–96	*Arctopsyche grandis*	1
		near Deer Lodge	112°44'31"			*Hydropsyche cockerelli*	16
						Hydropsyche occidentalis	19
						Hydropsyche spp.	3
5	12324680	Clark Fork	46°35'26"	436.9	1992–96	*Arctopsyche grandis*	10
		at Goldcreek	112°55'40"			*Claassenia sabulosa*	10
						Hydropsyche cockerelli	9
						Hydropsyche morosa group	4
						Hydropsyche occidentalis	8
6	12331500	Flint Creek	46°37'44"	417.6	1986, 1992–96	*Arctopsyche grandis*	27
		near Drummond	113°09'02"			*Hydropsyche cockerelli*	6
						Hydropsyche occidentalis	5
						Hydropsyche tana	2
7	12331800	Clark Fork	46°42'44"	403.9	1986, 1991–96	*Hydropsyche cockerelli*	11
		near Drummond	113°19'48"			*Hydropsyche morosa* group	6
						Hydropsyche occidentalis	9
						Hydropsyche spp.	1
8	12334510	Rock Creek	46°43'21"	381.8	1987, 1991–96	*Arctopsyche grandis*	25
		near Clinton	113°40'56"			*Claassenia sabulosa*	13
						Hydropsyche cockerelli	3
						Hydropsyche occidentalis	4
						Hydropsyche spp.	1
9	12334550	Clark Fork	46°49'34"	370.2	1986, 1991–96	*Arctopsyche grandis*	20
		at Turah Bridge	113°48'48"			*Claassenia sabulosa*	17
		near Bonner				*Hydropsyche cockerelli*	15
						Hydropsyche morosa group	1
						Hydropsyche occidentalis	10
10	12353000	Clark Fork	46°52'09"	349.5	1986, 1990–96	*Hydropsyche cockerelli*	21
		below Missoula	114°07'33"			*Hydropsyche occidentalis*	8
						Hydropsyche spp.	1

national programs. Since 1967, the USFWS has assessed concentrations of contaminants in whole-fish samples as part of the National Contaminant Biomonitoring Program (NCBP) (Schmitt and others, 1990). The Flathead River at Creston, Mont. (site 12), is the only site in the study area with any long-term information on fish tissue contaminants. Tissue-contaminant data have been collected from this site four times, once each in 1976, 1978, 1980, and 1984. In 1997, this site was resampled for the Biomonitoring of Environmental Status and Trends (BEST) program conducted by the USGS, Biological Resources Division (formerly the National Biological Service), to assess trends in tissue contaminants and biomarkers (T. Bartish, U.S. Geological Survey, written commun., 1997), but these data were not available for inclusion in this report. Selected contaminants in whole-body tissue samples of fish from four sites in the study area were analyzed on a one-time basis in 1987 as part of the USEPA National Bioaccumulation Study (USEPA, 1992).

The IDEQ collected fish tissue-contaminant data as part of a statewide monitoring effort in 1989, and three of the sites were in the Coeur d'Alene River Basin (Nautch and Clark, 1998). In addition, IDEQ used fish tissues to assess contaminants in the vicinity of the Bunker Hill Superfund site and around mine-tailing deposits on the South Fork Coeur d'Alene River in 1993 (M. Hartz, Idaho Department of Health and Welfare, Division of Environmental Quality, written commun., 1994). Currently, the USGS conducts a statewide surface-water quality monitoring program, in cooperation with IDEQ, to collect chemical, physical, and biological data at 53 river sites. As part of this monitoring program, tissues of whole fish from four sites in the NROK study area, the South and North Fork Coeur d'Alene, St. Joe, and Priest Rivers, are analyzed for trace elements and synthetic organic compounds.

The USEPA conducted chemical and biological monitoring along the South Fork Coeur d'Alene River from 1972 to 1986 (Hornig and others, 1988). A major component of this monitoring was the collection and analysis of fish tissue and sediment from Coeur d'Alene River, lateral lakes, and Coeur d'Alene Lake.

A study by the U of M (Van Meter, 1974) evaluated trace element concentrations in a variety of species and tissue types from more than 40 sites along the Clark Fork and in numerous tributaries. Comparisons of concentrations were made among species and various tissue types, such as liver and muscle, to illustrate differences in trace element concentrations.

The WDOE collected fish tissue-contaminant data as part of a State pesticide monitoring program (Davis and others, 1995). This program included one site in the study area on the lower Spokane River. Other investigations by WDOE in 1993–94 and 1996 have targeted PCBs and trace element contaminants in fish tissue and bed sediment near the city of Spokane (Washington State Department of Ecology, 1995; A. Johnson, Washington State Department of Ecology, written commun., 1997).

One of the best long-term (1985 to present) tissue-contaminant data sets for the study area has been collected by the USGS for the Clark Fork and major tributaries in Montana (reported through 1995 in Hornberger and others, 1997). The focus of this study was the hydrologic characteristics, spatial distributions, and temporal trends of trace elements in surface water, bed sediment, and biota during Superfund remediation efforts in the upper Clark Fork Basin. This ongoing sampling program has included data collection from at least 14 sites associated with active USGS gaging stations. This report summarizes tissue-contaminant data for nine of these sites.

Other studies by the USGS, Biological Resources Division, on the Clark Fork and Coeur d'Alene Rivers (Farag and others, 1995 and 1998b) have utilized a variety of ecological indicators to assess mining effects, including water and sediment chemistry, characteristics of biofilm (the layer of abiotic and biotic material on rock surfaces), and tissue contaminants in macroinvertebrates and fish.

According to the 1996 National Listing of Fish Consumption Advisories maintained by the USEPA, there are no fish consumption advisories or fishing restrictions as a result of contaminants on any rivers within the study area (U.S. Environmental Protection Agency, accessed March 1998, online). That same year, fish consumption advisories were imposed on 5 percent of the river miles in the United States. The four major contaminants causing most of these listings were mercury, PCBs, chlordane, and DDT.

Several Montana lakes and reservoirs in the study area are under fish consumption advisories as a result of elevated concentrations of PCBs and (or) mercury in fish tissue. These advisories were the result of a 1992–93 study by the Montana Department of Fish, Wildlife, and Parks and Montana Department of Health and Environmental Sciences on 20 Montana lakes and reservoirs (Phillips and Bahls, 1994). Most notably, fillets of lake trout (*Salvelinus namaycush*) from Flathead Lake contained high concentrations of PCBs and mercury that ranged from 0.08 to 0.94 µg/g and 0.29 to

1.15 µg/g, wet weight, respectively. The concentrations of some of these contaminants in tissue exceeded various guidelines for edible fish tissue (fillet or muscle) (table 6). Most of the water flowing through Flathead Lake originates from Glacier National Park and, owing to the fact that few wastewater treatment and no industrial point-source discharges are located in this part of the study area (fig. 4), atmospheric nonpoint sources of these contaminants are probable. Atmospheric deposition has been identified as the dominant means by which mercury enters surface water and soils in the northern hemisphere (Watras and others, 1995). The Montana Department of Environmental Quality (1996) identified atmospheric deposition as a probable source of pollutants impairing the designated uses of Flathead Lake in their 303(d) water-quality limited listing.

Investigators who studied trace elements in the lower Clark Fork reservoirs determined that more information is needed on the potential bioaccumulation of trace elements in biota, particularly mercury in fish tissue (J. Moore, University of Montana, written commun., 1997).

Table 6. Guidelines for synthetic organic compounds and trace elements in whole and edible fish (fillet and muscle tissue)

[Concentrations are reported in micrograms of constituent per gram, wet weight; —, no data]

	Environmental criteria		Human health criteria		
Contaminant name	NAS/NAE[1] recommended guideline for freshwater whole fish	NYSDEC[2] criteria for whole fish	FDA[3] action level for edible fish	USEPA[4] screening criteria for edible fish	International[5] legal limit for edible fish
Synthetic organic compounds					
Aldrin	0.1	—	0.3	—	—
Total chlordane	0.1	0.5	0.3	0.08	0.3
p,p'DDD	—	0.2	—	—	5.0
p,p'DDE	—	0.2	—	—	5.0
p,p'DDT	—	0.2	—	—	5.0
Total DDT	1.0	—	5.0	0.3	5.0
Dieldrin	0.1	0.12	0.3	—	0.3
Endosulfan	0.1	—	—	60.0	—
Endrin	0.1	0.025	0.3	3.0	0.3
Heptachlor	0.1	0.2	0.3	—	—
Heptachlor epoxide	0.1	0.2	0.3	0.01	0.3
Hexachlorobenzene	—	0.33	—	0.07	—
Lindane	—	—	—	0.08	—
Mirex	—	0.33	—	2.0	0.1
Total PCBs	0.5	0.11	2.0	0.01	2.0
2,3,7,8 TCDD (dioxin)	—	3.0×10^{-6}	2.5×10^{-5}	7.0×10^{-7}	—
Toxaphene	0.1	—	5.0	0.1	0.1
Trace elements					
Arsenic	—	—	—	3.0	1.5
Cadmium	—	—	—	10.0	0.3
Chromium	—	—	—	—	1.0
Copper	—	—	—	—	20.0
Lead	—	—	—	—	2.0
Mercury	0.5	—	1.0	0.6	0.5
Selenium	—	—	—	50.0	2.0
Zinc	—	—	—	—	45.0

[1] National Academy of Sciences/National Academy of Engineering recommended maximum tissue concentration for protection of fish and wildlife (NAS/NAE, 1973).

[2] New York State Department of Environmental Control criteria for protection of piscivorous wildlife (Newell and others, 1987).

[3] Food and Drug Administration legal limit for removing fish from marketplace (from Nowell and Resek, 1994; U.S. Environmental Protection Agency, vol. II, 1992).

[4] U.S. Environmental Protection Agency screening criteria for protection of human health. Based on 1×10^{-5} risk factor for an average-sized adult (70 kg) and a consumption rate of 6.5 grams of fish per day (USEPA, 1995).

[5] International legal limit for removing fish from marketplace for protection of human health (Nauen, 1983).

Types of Tissue

Salmonids (trout) and catostomids (suckers) have been the predominant taxa of fish collected for tissue analysis (tables 3 and 4, back of report). Common and scientific fish names used by the variety of studies summarized in this report were standardized using a report by Robins and others (1991). At least 13 fish species have been collected for analysis of tissue contaminants: brown trout (*Salmo trutta*), bridgelip sucker (*Catostomus columbianus*), brook trout (*Salvelinus fontinalis*), cutthroat trout (*Oncorhynchus clarki*), largescale sucker (*Catostomus macrocheilus*), longnose dace (*Rhinichthys cataractae*), longnose sucker (*Catostomus catostomus*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), rainbow trout (*Oncorhynchus mykiss*), redside shiner (*Richardsonius balteatus*), yellow perch (*Perca flavescens*), and sculpins (*Cottus* sp.).

Macroinvertebrates most frequently collected for tissue analysis have been trichopterans (caddisflies) and plecopterans (stoneflies) (table 5). The WDOE has analyzed crayfish (*Orconectes* sp.) from the Spokane River for PCBs (Washington State Department of Ecology, 1995). Concentrations of PCBs in tissue of crayfish generally were not detectable, unlike concentrations in tissue samples of fish from the same sites on the Spokane River collected during the same period. Because the lifespan of some crayfish can be less than 2 years (Pennak, 1989), they might not be exposed to contaminants as long as more long-lived fish.

Tissue-Contaminant Guidelines and Other Studies

Many comparisons can be made to evaluate whether contaminant concentrations in tissue are elevated for a specific water body. Tissue-contaminant concentrations can be compared with various international, national, Federal, and State guidelines (table 6) to determine whether they pose an environmental hazard to humans and (or) wildlife. For this report, the term “guidelines” refers to any criteria, action level, screening value, or standard concentrations useful in assessing contaminant concentrations in whole or edible fish tissue. The guidelines used for comparison generally do not address the combined effects (additive, synergistic, or antagonistic) or the sublethal effects, such as reproductive or behavioral problems, in organisms. Therefore, caution is advised when comparing tissue types. The National Park Service maintains an environmental contaminants encyclopedia on the World Wide Web (Irwin and others, accessed April 1998, online), where specific toxicity study results for humans and wildlife are summarized.

The National Academy of Sciences and National Academy of Engineering (NAS/NAE) (1973) and the New York State Department of Environmental Conservation (NYSDEC) guidelines (Newell and others, 1987) for the protection of predatory wildlife have been used to compare organochlorine concentrations in whole-body fish tissue. Because the NYSDEC data are the most current and technically based, these guidelines were used to evaluate data in this report. These NYSDEC guidelines were derived using an explicitly stated risk assessment procedure, and results were extrapolated from toxicity tests on laboratory animals or wildlife.

The U.S. Food and Drug Administration (FDA) action level (Nowell and Resek, 1994) and international legal limit (Nauen, 1983) for fish are specific to edible parts of fish and shellfish for the protection of human health. Contaminant concentrations that exceed either of these guidelines in edible fish would be banned from public sale.

The USEPA screening values also are used to evaluate contaminant concentrations in edible fish. These values are being used in many States to assess the health risk to humans eating fish from recreational water bodies (U.S. Environmental Protection Agency, 1995). Screening values, which are values that predict the increased number of cancer cases caused by a particular contaminant, can vary depending on the risk level chosen. In addition, exposure assumptions, such as body weight and fish tissue consumption rates, can change the screening value used. For this report, the USEPA (1995) recommended risk level for the general adult population was used.

Summary statistics for large-scale national and State tissue monitoring programs also can provide useful data against which to compare study area tissue-contaminant concentrations. Results from the USFWS 1980–81 and 1984 NCBP; USGS 1992–94 NAWQA Program; and the State of California’s 1978–95 TSMP are summarized in table 7. The 85th percentile of a particular tissue-contaminant concentration has been used for various programs to help identify concentrations that are elevated.

When comparing synthetic organic compound tissue concentrations with national study results, care must be taken to select the appropriate time period(s). Because concentrations of many of these synthetic organic contaminants have declined in the environment as a result of discontinued use and (or) degradation, earlier studies can be expected to report higher values than more recent studies. This is illustrated in table 7, where whole-fish contaminant concentrations from the 1980–81 and 1984 NCBP are compared with the 1992–94 NAWQA data. In most cases, tissue concentrations of the synthetic organic compounds analyzed during the more recent NAWQA Program are lower than concentrations reported during the NCBP.

Total DDT, as used in this report, refers to the sum of o,p' and p,p' forms of DDD, DDE, and DDT; total chlordane refers to the sum of cis- and trans-chlordane, cis- and trans-nonachlor (major constituents of technical chlordane), and several metabolic by-products of chlordane, including oxychlordane, heptachlor, and heptachlor epoxide; and total PCBs refers to a total analysis or sum of the PCB arochlors (isomers).

Synthetic Organic Compounds

Synthetic organic compounds are prevalent as components of plastics, personal care products, and pesticides. Many chlorinated pesticides and PCB congeners are probable carcinogens, and the use of many of them in the United States has been restricted or suspended by the USEPA (1990b). The use of organochlorine compounds in the United States began in the 1940's and peaked during the late 1950's and early 1960's (Larson and others, 1997). Synthetic organic compounds may enter the aquatic environment from atmospheric sources, industrial and municipal effluent, and agricultural runoff. Organochlorine compounds are hydrophobic and, therefore, tend to sorb to suspended particles and are deposited along the stream bottom, whereas hydrophilic organic compounds dissolve in water. Contaminants can be taken up directly by bottom-dwelling organisms through incidental ingestion of bottom sediment. Bottom-feeding species, such as suckers, are particularly vulnerable to the bioaccumulation of these compounds from bottom sediments. For example, even though their use has been discontinued since the 1970's and 1980's, organochlorine compounds such as DDT and PCBs and their metabolites are expected to be detected in tissue of aquatic biota for many years because of their persistence in the environment and their continued use in other countries (U.S. Environmental Protection Agency, 1992).

Organochlorine compounds are highly lipophilic (lipid soluble), so concentrations in whole-body fish samples often are higher than in fish fillet samples because lipid content of muscle tissue typically is low (Schmitt and others, 1981). Differences in percent lipid of various fish species also can influence organochlorine concentrations, in which case lipid normalization among species can be useful for improving comparability of data (Hebert and Keenleyside, 1995).

Studies also have linked the presence of organochlorine compounds to deleterious effects on endocrine-system development and reproductive viability of fish and wildlife (Fry and Toone, 1981; Colborn and others, 1993; Goodbred and others, 1997). Most organochlorine pesticides have been replaced by more acutely toxic but ephemeral organophosphate, carbamate, and synthetic pyrethroid pesticides.

Total DDT and total PCBs and their metabolites and congeners were the most common synthetic organic contaminants detected in fish tissue samples in the NROK study area (table 3, back of report). Similarly, the USEPA (1992) reported that, of 388 sites sampled throughout the Nation between 1986 and 1989, total DDT and total PCBs were detected at 98 and 90 percent of the sites, respectively. Maret and Ott (1997) found total DDT and total PCBs in more than 80 and 55 percent of the whole-fish samples, respectively, collected during 1992–94 in the upper Snake River Basin in Idaho and Wyoming. Munn and Gruber (1997) reported total DDT in 94 percent of whole-fish samples collected in Columbia Plateau streams of eastern Washington.

Many concentrations of synthetic organic compounds listed in table 3 exceeded guidelines for the protection of predatory wildlife. Most notable are the numerous detections of PCBs in tissue of fish from the Spokane River. Concentrations in all 52 tissue samples

Table 7. Synthetic organic compounds and trace elements detected in tissue of fish collected for the U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program (NCBP), 1980–81 and 1984; U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program, 1992–94; and State of California Toxics Substances Monitoring Program (TSMP), 1978–95

[NCBP concentrations represent 1980–81 and 1984 nationwide geometric mean baseline for synthetic organic compounds and trace elements, respectively; NAWQA tissue concentrations represent the median for synthetic organic compounds for whole fish, and trace elements primarily for fish livers (93 percent of samples) and whole fish; trace element values in parentheses are 85th percentiles; California TSMP concentrations represent an elevated data level (EDL) or 85th percentile for various freshwater fish samples of liver, fillet, and whole body; whole-body composites are reported in micrograms of constituent per gram, wet weight; N, number of samples; <, less than; —, no data]

Contaminant name	NCBP[1] 1980–81 Whole body N=109	NCBP[1] 1984 Whole body N=112	NAWQA[2] 1992–94 Whole body N = 213		TSMP[3], 1978–95 EDL–85					
	Mean	Mean	Median	85th percentile	Liver	N	Fillet	N	Whole body	N
Synthetic organic compounds										
Aldrin	—	—	< 0.005	<0.005	—	—	<0.005	803	<0.005	202
alpha BHC	<0.100	<0.010	<0.005	<0.005	—	—	<0.002	806	<0.002	202
gamma BHC	<0.010	<0.010	<0.005	<0.005	—	—	<0.002	806	<0.003	202
cis-Chlordane	0.030	0.030	<0.005	0.011	—	—	0.012	808	0.031	202
trans-Chlordane	0.020	0.020	<0.005	0.006	—	—	0.007	808	0.020	202
p,p'DDD	0.070	0.060	<0.005	0.022	—	—	0.078	808	0.254	202
p,p'DDE	0.200	0.190	0.027	0.140	—	—	0.540	809	1.570	202
p,p'DDT	0.050	0.030	<0.005	0.015	—	—	0.023	808	0.124	202
Total DDT	0.290	0.260	0.031	0.175	—	—	0.668	809	2.393	202
Dacthal	<0.010	<0.010	<0.005	<0.005	—	—	0.012	809	0.097	202
Dieldrin	0.040	0.040	<0.005	0.013	—	—	0.009	790	0.046	201
Endrin	<0.010	<0.010	<0.005	<0.005	—	—	<0.015	806	<0.015	202
Hexachlorobenzene	<0.010	<0.010	<0.005	<0.005	—	—	<0.002	806	0.004	202
Heptachlor epoxide	0.010	0.010	<0.005	<0.005	—	—	<0.005	803	<0.005	202
Methoxychlor	<0.010	<0.010	<0.005	<0.005	—	—	<0.015	801	<0.015	202
Mirex	<0.010	<0.010	<0.005	<0.005	—	—	—	—	—	—
cis-Nonachlor	0.020	0.020	<0.005	0.006	—	—	<0.005	699	0.017	202
trans-Nonachlor	0.040	0.030	<0.005	0.017	—	—	0.017	779	0.044	202
Oxychlordane	0.010	0.010	<0.005	<0.005	—	—	<0.005	807	0.009	202
PCA	<0.01	0.07	<0.005	<0.005	—	—	—	—	—	—
PCB 1248	0.11	0.06	—	—	—	—	<0.005	839	<0.005	203
PCB 1254	0.24	0.21	—	—	—	—	<0.005	839	0.012	203
PCB 1260	0.25	0.15	—	—	—	—	0.054	839	0.077	203
Total PCBs	0.53	0.39	<0.050	0.356	—	—	0.120	839	0.220	203
Toxaphene	0.28	0.14	<0.200	<0.200	—	—	0.187	821	0.921	202

Contaminant name	Whole body N=109	Whole body N=112	Liver or whole body N = 167							
	Mean	Mean	Median	85th percentile	Liver	N	Fillet	N	Whole body	N
Trace elements										
Arsenic	0.14 (0.22)	0.14 (0.27)	0.08	0.15	0.21	555	0.14	133	0.41	170
Cadmium	0.03 (0.06)	0.03 (0.05)	0.18	0.88	0.36	569	<0.01	112	0.12	167
Copper	0.68 (0.90)	0.65 (1.00)	10.4	27.25	[4]12.00	501	0.69	26	3.30	170
Lead	0.17 (0.25)	0.11 (0.22)	<0.02	0.08	0.10	619	<0.10	26	0.20	167
Mercury	0.11 (0.18)	0.10 (0.17)	0.05	0.10	—	—	0.80	1,248	0.11	174
Selenium	0.47 (0.71)	0.42 (0.73)	1.03	1.78	3.32	112	1.00	566	1.40	194
Zinc	23.82 (40.09)	21.7 (34.20)	26.25	118.5	28.00	621	21.40	26	42.00	167

[1] Data from Schmitt and Brumbaugh (1990) and Schmitt and others (1990).

[2] Data are provisional from T. Short and L. Nowell, U.S. Geological Survey (written commun., 1998); trace element concentrations were converted to wet weight assuming 75 percent moisture content.

[3] Rasmussen, accessed March 1998, online.

[4] Value for nonsalmonids; 85th percentile for salmonids is 170.00 µg/g (N = 230).

of fish from the Spokane River in Washington exceeded one or more of the total PCB guidelines for the protection of human health or predatory wildlife (fig. 5). Concentrations in most fillet samples of sportfish collected at Spokane River sites during 1993–96 also exceeded the USEPA screening value for the protection of human health. Samples from this area contained the highest PCB concentrations in the NROK study area. One whole-fish composite (largescale sucker) collected in 1993 from the Spokane River above Upriver Dam (table 3; site 25) contained a total PCB concentration of 2.78 μg/g. In comparison, the 85th percentile for total PCBs in whole fish analyzed for the NAWQA Program during 1992–94 was 0.356 μg/g (table 7). In addition, because the WDOE study included the tissue analyses of only three arochlors (PCB 1248, 1254, and 1260), an analysis of total PCBs similar to that used in the NAWQA Program would have resulted in higher

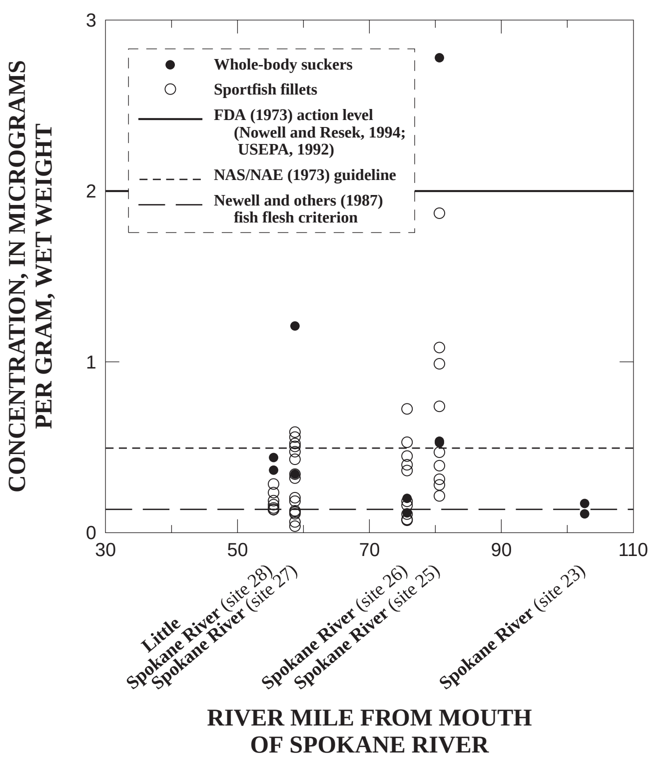


Figure 5. Sum of PCB arochlors in tissue of fish from the Spokane and Little Spokane Rivers near Spokane, Washington. (Site numbers in parentheses refer to locations on figure 2. Guidelines displayed are listed in table 6. Data from Washington State Department of Ecology, 1995, and A. Johnson, Washington State Department of Ecology, written commun., 1997; FDA, Food and Drug Administration; USEPA, U.S. Environmental Protection Agency; NAS/NAE, National Academy of Sciences/National Academy of Engineering)

reported concentrations. On the basis of concentrations of these three arochlors in tissue, the WDOE (1995) identified the PCB sources as primarily industrial and wastewater treatment facilities (fig. 4 and table 2) in and around the city of Spokane, and the Kaiser Aluminum and Old Inland Pit Superfund sites (fig. 3; sites 9 and 14). In addition, the WDOE (1996) identified PCBs as one of the contaminants responsible for impaired uses on the Spokane River in their 305(b) water-quality status report. However, there is currently no State fish consumption advisory for the Spokane River.

Most tissue samples of fish from the Flathead River at Creston, Mont. (fig. 2; site 12), contained detectable concentrations of PCBs (table 3, back of report), and some exceeded guidelines for protection of predatory wildlife. This is an unexpected result, as this watershed represents primarily water originating from Glacier National Park and other mountainous areas with no major industrial and few wastewater treatment facility sources (fig. 4). Tissue of fish from Flathead Lake, just downstream from the Creston site, also contained high PCB concentrations (Phillips and Bahls, 1994). PCBs in the Flathead River watershed are apparently widespread and might be transported from remote sources through the atmosphere. Researchers have determined that PCBs can affect the reproductive success of fish through exposure to contaminated water and sediment (Arcand-Hoy and Benson, 1998). PCBs also can disrupt the development of sexual hormones in rainbow trout (Matta and others, 1998), one of the most common sportfish in the study area.

In 1987, the USEPA collected tissue samples of fish from four sites (table 3; sites 2, 11, 20, and 22) on the Clark Fork and the Coeur d'Alene and St. Joe Rivers and analyzed them for dioxins and furans as part of the National Bioaccumulation Study (U.S. Environmental Protection Agency, 1992). These compounds have been detected in aquatic biota and surface water downstream from paper and pulp mills, wood treatment facilities, industrial areas, and municipal wastewater facilities (U.S. Environmental Protection Agency, 1990a). Dioxins and furans (polychorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans) compose a family of related chemical compounds consisting of 75 dioxins and 135 furan congeners (B. Bonn, U.S. Geological Survey, written commun., 1998). At each of the four sites in the NROK study area, two composite samples (whole-body and fillet) of bottom-feeding fish (suckers) and sportfish (trout) were analyzed for six dioxins and nine furan compounds. Dioxins and furans were detected in tissue of fish at all four sites.

The toxicity of dioxins and furans varies with the congener. The most toxic congener is 2,3,7,8 TCDD. To assess the overall toxicity from these compounds, dioxin and furan concentrations often are converted into units of toxicity equivalents (Schecter and others, 1994). This is done by multiplying the concentration of each 2,3,7,8 congener by its toxicity equivalence factor. This converts the value into an estimated equivalence concentration of 2,3,7,8 TCDD. When the dioxin and furan congeners were converted to toxic equivalents for each of the four sites, no concentrations exceeded guidelines for whole or edible fish. The probable sources of the dioxins and furans detected in tissue of fish from the Clark Fork sites are unclear. However, one possible source of contaminants upstream from sites 2 and 11 is a Superfund site, Montana Pole, a wood treatment facility (fig. 3; site 12). Another possible source of contaminants farther downstream on the Clark Fork is the Stone Container Corporation (fig. 4; site 27), which is permitted to discharge treated waste products directly into the Clark Fork (Department of Environmental Quality, Water Protection Bureau, State of Montana, written commun., 1997).

Trace Elements

Trace elements in the aquatic environment occur naturally from weathering of rocks and mineral soils and from human sources such as the burning of fossil fuels, industrial discharges, automobile emissions, mining, and agricultural pesticides and fertilizers. Unlike their relatively recent exposure to synthetic organochlorine compounds, aquatic organisms have always been exposed to trace elements. As a result, many aquatic organisms have developed mechanisms to control the internal concentrations of certain trace elements or to mitigate their toxicity (Law, 1996). In addition, most trace elements concentrate in the viscera, such as the liver and kidneys, of fish (Johnson and others, 1977). The one notable exception is mercury, which tends to concentrate to higher levels in muscle (Goldstein and others, 1996). The concentrations of trace elements in liver and muscle vary depending upon the chemical properties of the element and the species of fish. Van Meter (1974) found that ratios based on liver-to-muscle trace element concentrations varied for cadmium, copper, lead, and zinc in trout, mountain whitefish, and suckers from the Clark Fork watershed.

Many trace elements are essential to animal and plant nutrition, especially arsenic, copper, selenium, and zinc, but can be toxic in high concentrations (Lowe and others, 1985). There is even some indication that endocrine disruption may result in fish exposed to excessive amounts of cadmium, lead, or mercury (S. Goodbred, U.S. Geological Survey, written commun., 1998). The presence of elevated trace elements in sensitive fish species in the study area, such as bull trout (*Salvelinus confluentus*), which are being considered for listing under the Endangered Species Act (S. Audet, U.S. Fish and Wildlife Service, oral commun., 1998), could become an increasingly important concern.

As with organochlorine compounds, trace element concentrations are generally higher in bed sediments and tissue than in water (Rainbow, 1996). Because of the slow rate of elimination, some of the more toxic trace elements, such as cadmium, lead, and mercury, tend to bioaccumulate or even biomagnify, as in the case of mercury and lead, in aquatic food chains (Eisler, 1987, 1988). As a result, trace element concentrations in tissues of aquatic species generally increase with increasing age, body size, and trophic status (Wiener and Spry, 1996; Park and Curtis, 1997).

FISH

The USEPA has developed screening criteria for the trace elements arsenic, cadmium, mercury, and selenium in edible tissue (table 6). Even though lead is a known health risk to humans when ingested and has been detected in fish tissue, no USEPA criteria currently exist. There is an international ban on selling fish in a public marketplace when lead concentrations exceed 2.0 μg/g, wet weight (Nauen, 1983). Ingestion of lead by fish consumption is a possible human health risk, especially in areas where lead concentrations are elevated and are biologically available to aquatic organisms.

An unusually high lead concentration of 14.62 µg/g was found in whole-body samples of longnose suckers from the Coeur d'Alene River at Rose Lake, Idaho (table 4, back of report; site 21). A quality assurance sample of the same species at this site contained less lead (5.07 µg/g) but still exceeded the guideline of 2.0 µg/g. These concentrations for lead were more than an order of magnitude higher than the NCBP 1984 85th percentile concentration of 0.22 µg/g for whole fish (table 7). The other site where lead exceeded 0.22 µg/g was the Spokane River near Post Falls, Idaho (table 4, site 23), where a concentration of 2.60 µg/g was detected in whole-body largescale suckers.

Cadmium concentrations exceeded the edible fish tissue guideline of 0.30 µg/g at three sites (table 4; sites 5, 7, and 8), and concentrations ranged from 0.40 to 3.90 µg/g. These concentrations are higher than those reported for the 1984 NCBP and State of California TSMP 85th percentile of 0.05 and 0.12 µg/g in whole fish, respectively (table 7). Moore and others (1991) reported that cadmium remained biologically available over long distances from mining sources, whereas copper was biologically available only near localized sources in the Blackfoot River watershed.

Mercury concentrations exceeded the NAS/NAE (1973) and international legal limit guidelines of 0.50 µg/g (table 6) for edible fish tissue at two sites (table 4; sites 6 and 10). Maximum concentrations at these sites were 0.52 and 0.53 µg/g, respectively. Mercury was elevated in the muscle tissue of brown trout from one of the sites, Flint Creek near Drummond, Mont. (fig. 2; site 6). This watershed has a history of mercury contamination from its use in the process of extracting silver from mined ores (Van Meter, 1974).

Zinc concentrations in fish tissue were generally less than the 1984 NCBP mean concentration of 34.20 µg/g and the State of California TSMP 85th percentile concentration of 42.0 µg/g. One exception was a zinc concentration of 65.0 µg/g reported in the whole-body sample of largescale suckers from the Spokane River above Upriver Dam, Wash. (table 4, site 25).

Even though no copper concentrations in fillet or muscle tissue exceeded guidelines, some concentrations in liver tissue were unusually high. Most notably, copper concentrations of 598.40 and 269.70 µg/g were detected in livers of brown trout from the Clark Fork at Warm Springs and at Turah Bridge near Bonner, Mont. (table 4; sites 2 and 9). These concentrations are much higher than the national 85th percentiles for the NAWQA Program and State of California TSMP concentrations of 26.25 and 12.00 µg/g for nonsalmonids, respectively. A more appropriate comparison would be the State of California TSMP, which has a separate category for salmonids (trout). Copper concentrations were higher in salmonid species compared with 85th percentile concentrations of 170 µg/g (table 7, footnote 4). Sediment, tissue, and water samples from both of these Clark Fork sites have exhibited elevated concentrations of trace elements as a result of past and current mining activities in the watershed (Hornberger and others, 1997).

No arsenic or selenium concentrations in fish tissue exceeded guidelines. Detected concentrations were generally less than the 85th percentile reported by other national or State monitoring programs (table 7).

MACROINVERTEBRATES

Macroinvertebrates are useful indicators of trace element bioaccumulation because they are common in most freshwater habitats; easy to collect; relatively immobile; and often associated with benthic habitat and, thus, with sediments where trace elements concentrate (Hare, 1992). Two studies best illustrate the increase of trace elements in tissue as a result of past and current mining practices in the Clark Fork and Coeur d'Alene River watersheds. These studies were conducted by the USGS, Water Resources and Biological Resources Divisions. As shown in figure 3, these areas have a history of mining and active Superfund site cleanups (Anaconda Company Smelter, Bunker Hill Smelter, and Silver Bow Creek; sites 1, 3, and 15).

The relations of cadmium, copper, lead, and zinc concentrations in composite tissue samples of the caddisfly, *Hydropsyche cockerelli*, collected at various river miles along the Clark Fork, are shown in figure 6. The spatial pattern of these trace elements follows a decreasing trend downstream, and concentrations are highest at sites near past mining areas. Trace element concentrations in the upstream reach were lowest directly downstream from treatment ponds designed to reduce trace element mobilization on Silver Bow Creek at Warm Springs (fig. 6; site 1). Concentrations of cadmium, copper, and lead increase within a few miles

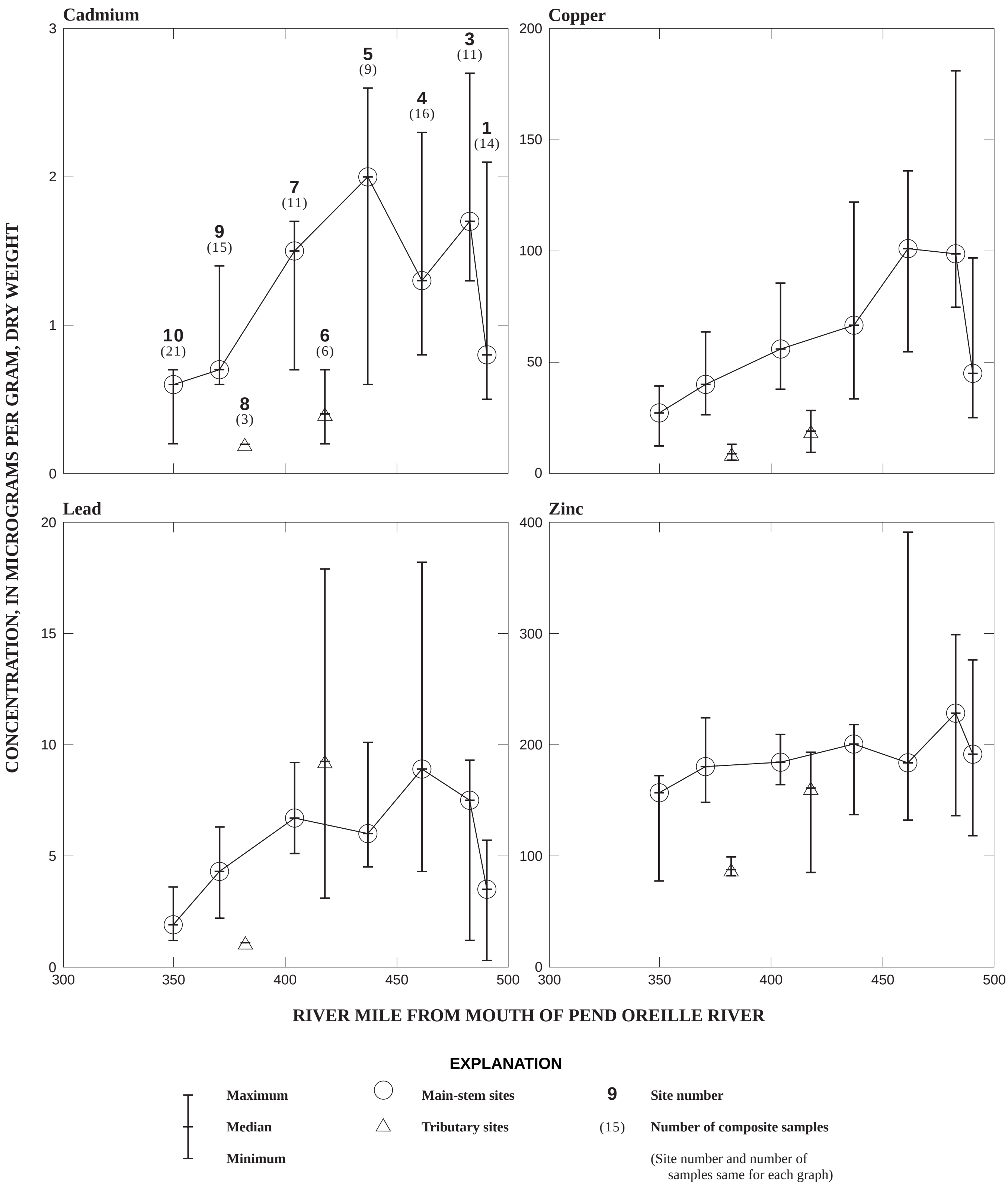


Figure 6. Relations among concentrations of selected trace elements in composite tissue samples of the caddisfly *Hydropsyche cockerelli* from seven main-stem Clark Fork sites and two tributary sites on Flint and Rock Creeks, Montana, 1986–96. (Site locations shown in figure 2; site descriptions and related information shown in table 5; trace element data from Dodge and others, 1997)

downstream from this site at Galen, Mont. (site 3), as local sources apparently become more available. Median zinc concentrations are not much different between sites. However, maximum concentrations are much higher at those sites closest to mining areas. Concentrations of trace elements in tissue samples of caddisflies from the two tributary sites, Flint Creek (site 6) and Rock Creek (site 8), generally were much lower than in samples from the main-stem Clark Fork sites. The one exception was Flint Creek, where median lead concentrations were higher than at many Clark Fork sites. The enrichment of lead in tissue of caddisflies from this site could be a result of past mining activities in the watershed. Van Meter (1974) also reported high concentrations of trace elements in fish tissue as a result of past mining activities in the Flint Creek watershed.

A similar spatial comparison of trace element concentrations in composite tissue samples of macroinvertebrates from the Coeur d'Alene and Spokane Rivers is shown in figure 7. Generally, concentrations downstream from mining sources were higher than at an upstream reference site (South Fork Coeur d'Alene River above Mullan, Idaho, site 15). High concentrations persisted at least 40 mi downstream to the Coeur d'Alene River at Rose Lake, Idaho (site 21). For example, mean zinc concentrations in macroinvertebrate tissue samples from the Coeur d'Alene River at Rose Lake were 10 times higher, about 3,000 versus 300 µg/g, than in samples from site 15 upstream from Mullan. Trace element concentrations in tissue samples from the Spokane River near Post Falls (site 23) were similar to those from reference sites upstream from Mullan. Part of this decline can be attributed to Coeur d'Alene Lake, immediately upstream from the Post Falls site, where river sediments carrying trace elements enter the lake and are deposited.

An important finding from past tissue-contaminant studies is the interbasin differences between specific trace element concentrations in composite tissue samples of macroinvertebrates. Cadmium, lead, and zinc concentrations in macroinvertebrate tissue samples from the Coeur d'Alene River were much higher than those in samples from the Clark Fork, but copper concentrations were similar in both rivers. These differences are clearly visible in figures 6 and 7; cadmium, lead, and zinc concentrations are one to two orders of magnitude higher in macroinvertebrate tissue samples from the Coeur d'Alene River than those in samples from the Clark Fork. Farag and others (1998) concluded that, in general, macroinvertebrates and fine sediments in the Coeur d'Alene River accumulate more lead and zinc but less copper than in other river systems that have a history of mining activities.

IMPLICATIONS FOR MONITORING AND MANAGEMENT

Contaminants that reach surface waters pose a significant environmental and public health problem because they can accumulate in fish. Fish consumption is the principal exposure route for mercury and PCBs in humans (Natural Resources Defense Council, Inc., accessed April 1998, online). At present, there is no coordinated, long-term fish tissue monitoring program for rivers in the study area, even though contaminants are present in fish at levels considered a threat to human health. State programs developing fish consumption advisories vary in quality, and current efforts to manage the problem are limited by funding and resource constraints. Improvements in monitoring and the development of a coordinated, centralized national data base for contaminants in fish tissue are needed. According to the Intergovernmental Task Force on Monitoring Water Quality (1995), tissue contaminants are recommended as a primary indicator of status and trends in surface-water quality. Future design of statewide monitoring programs for the study area should include collection of data on tissue contaminants, particularly as they relate to the risk to human health due to consumption of contaminated fish.

On the basis of a limited set of tissue-contaminant data for the study area, some synthetic organic compounds and trace elements were elevated compared with national study values and guidelines. In particular, the PCB concentrations in whole-fish and fillet samples detected by WDOE in multiple-year studies warrant attention. Concentrations of this contaminant in fish tissue have been reported to exceed guidelines for the protection of human health and predatory wildlife. Additional monitoring could be performed on the Spo-

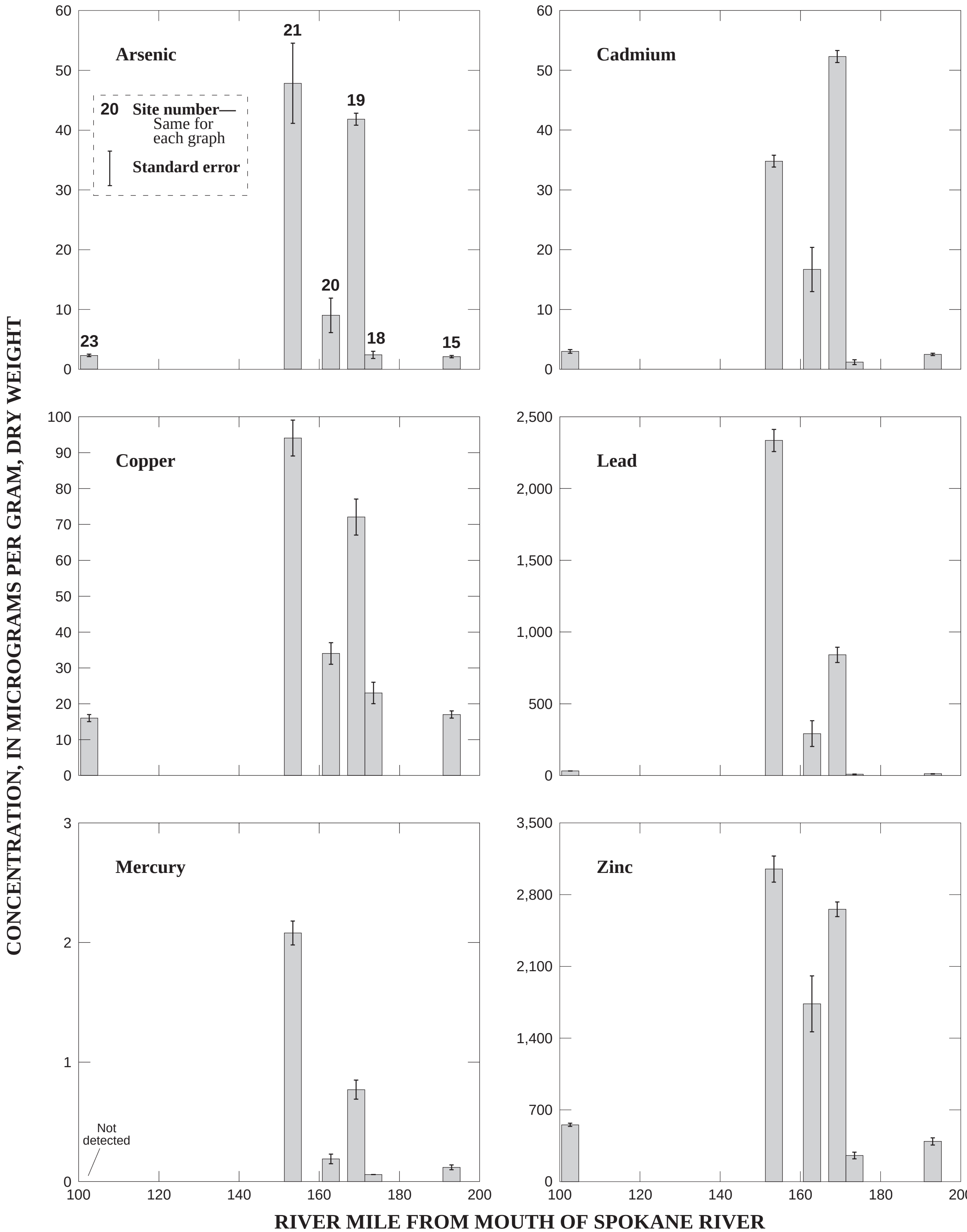


Figure 7. Relations among mean concentrations of selected trace elements in composite tissue samples of macroinvertebrates from the Coeur d'Alene River (sites 15, 18, 19, 20, and 21) and Spokane River (site 23), Idaho. (Site locations shown in figure 2; site descriptions and related information shown in table 4; macroinvertebrates collected from four riffles at each site in 1994; trace element data from Farag and others, 1998)

kane River to determine the spatial extent and temporal trends of PCBs.

Because cadmium, lead, and mercury were some of the most-elevated trace elements in tissue samples collected in the study area and because of their tendency to bioaccumulate to toxic levels, inclusion of these contaminants in tissue monitoring programs for this study area would be appropriate. In addition, the potential exists for endocrine disruption of fish as a result of elevated trace elements, particularly around mining areas. If additional salmonids, such as bull trout, become federally protected under the Endangered Species Act, the potentially chronic effects of trace element contaminants on federally protected fish species would be needed.

Contaminant concentrations of PCBs and mercury in tissue samples from the upper Flathead River near Creston, Mont., and Flathead Lake suggest that the probable sources of contamination are atmospheric transport and deposition. Because most of the water flowing through Flathead Lake originates from Glacier National Park, that water could be carrying contaminants condensed from the atmosphere on the western slopes of the park. Further sampling in this area is needed to determine whether concerns about atmospherically transported compounds are warranted.

Other less traditional forms of monitoring trace elements could provide useful information for assessing the threats to public health and aquatic biota. The use of aquatic bryophytes (mosses) as bioindicators could provide information about the occurrence and bioavailability of trace elements around mining areas. Carter and Porter (1997) found that bryophytes were useful for discriminating stream sites contaminated with arsenic, cadmium, copper, lead, manganese, molybdenum, and zinc, and that they can integrate temporal variations in concentration.

When a tissue monitoring program is designed, it is imperative that the sampling target relevant species and appropriate tissue types. If the interest or concern is to address human health exposure to contaminated fish, then sampling fillets of popular sportfish would be beneficial. In addition, intensive sampling in areas where exposure to contaminants might be highest, such as areas where public use is high, and where contaminants might be concentrated and more biologically available, such as lakes or reservoirs, would provide critically needed information. If the occurrence and trends of tissue contaminants in predatory wildlife are of primary concern, then whole-body samples of bottom-feeding species such as suckers would be most appropriate. Collection of specific tissue types such as liver also can help describe the presence of elevated trace element contaminants. Selection of commonly occurring species with similar habitat and feeding preferences would provide a means for comparison over large areas. Because there are many guidelines on fish tissue-contaminant concentrations, each developed for a specific purpose and location, selection of the most current and appropriate tissue concentration guidelines would be advisable when evaluating results. In addition, data on fish size and (or) age, and examination for external anomalies can be helpful in assessing contaminant effects on populations, age structure, and overall health. Most fish contaminant studies reviewed for this report lacked this information. Of paramount importance for tissue monitoring programs is implementation of quality assurance and quality control measures for both field and laboratory procedures to validate results. Many of the studies reviewed also lacked this information.

Because the study area contains the two largest mining remediation sites in the Nation (on the upper Clark Fork and the Coeur d'Alene River), comparison studies of tissue concentrations in these montane areas would provide a better understanding of the common pathways and potential problems resulting from elevated trace element contaminants in western rivers. Monitoring and documenting the consequences of historical mining activities on human health and aquatic ecosystems and the associated costs of remediation would provide some guidance for evaluating the socioeconomic costs of these land-use practices.

The National Water-Quality Assessment Program can provide a framework for other agencies to evaluate tissue contaminants in the Northern Rockies Intermontane Basins study area in relation to land-use activities. Data are collected in a consistent fashion using standardized protocols, and results are maintained in a national data base. Program results can be used to make spatial data comparisons at the regional or national level. Ultimately, these comparisons can be used to assess the status and trends in water quality in relation to various land-use activities.

SUMMARY

The 31,500-mi^2 Northern Rockies Intermontane Basins study area in eastern Washington, northern Idaho, and western Montana was 1 of 59 areas selected for assessment under the NAWQA Program. The NAWQA Program is designed to provide nationally consistent water-quality information to water managers, policy makers, and the public. Tissue-contaminant studies for the NAWQA Program will assess the occurrence and distribution of environmental contaminants. Information on contaminant concentrations in fish and other aquatic biota also can be used as an indicator of potential risk to human health and wildlife.

Tissue-contaminant data collected by Federal and State agencies and academic and private organizations were used to assess the status and trends of contaminants in the study area. Fish and aquatic macroinvertebrates were the only groups summarized because they have been the primary focus of past tissue monitoring and assessment programs.

The study area encompasses mountainous areas that are primarily coniferous forests where timber, mining, and recreation are the predominant land uses; and lower elevations where dryland agriculture, irrigated cropland, and grazing are the predominant land uses.

Upland forest and low-elevation rangeland streams typically have coarse-grained substrates, high gradients (greater than 1.0 percent), well-defined riffle-pool habitats, and sparse macrophyte growth. Large rivers and streams at low elevations typically have finer grained substrates and lower gradients. Most streams support coldwater aquatic biota whose optimal temperature is generally below 20°C.

The quality of surface and ground water in the Clark Fork-Pend Oreille and Spokane River Basins is adversely affected by mining activities. About 1,600 active and abandoned hard-rock mines of various sizes are located in the study area; many are still operating and several new mines are proposed. There are 16 Superfund sites in the study area, and investigations and remediation activities are ongoing along the Clark Fork in Montana and along the South Fork Coeur d'Alene River near Kellogg, Idaho. Currently, four Superfund sites related to mining activities are operational.

Trace elements in the Clark Fork in Montana have caused fish kills and suppression of fish production. Juvenile trout have shown reduced growth and survival in the Clark Fork, and laboratory studies also have shown adult trout avoidance to trace element concentrations similar to those observed in the Clark Fork. Changes in the species composition of bottom-dwelling organisms in Coeur d'Alene Lake and River also have been attributed to the toxic effects of trace elements from mining areas upstream. Habitat degradation also has affected macroinvertebrate communities along the South Fork Coeur d'Alene River. Trace element concentrations in fish and macroinvertebrates in and around mining areas are elevated compared with background concentrations in the study area.

Eleven monitoring programs and studies comprising 28 sites were evaluated to summarize tissue-contaminant data for streams in the study area. Tissue-contaminant data for most streams in the NROK study area were lacking. Most of the studies conducted during 1974–96 focused on areas affected by mining. Few tissue-contaminant data have been collected to define background or reference concentrations.

There were no fish consumption advisories or fishing restrictions on any rivers within the study area in 1996 as a result of elevated contaminants, but several Montana lakes and reservoirs had fish consumption advisories because of elevated tissue concentrations of PCBs and (or) mercury. Fillets of lake trout from Flathead Lake contained concentrations of PCBs and mercury that exceeded guidelines for edible fish tissue. Because most of the water flowing through Flathead Lake originates in Glacier National Park, atmospheric transport of these contaminants from distant sources is likely.

Salmonids (trout) and catostomids (suckers) have been the predominant fish collected for tissue analysis. At least 13 fish species have been collected in the study area for analysis of contaminants. Macroinvertebrates most frequently collected for tissue analysis have been caddisflies and stoneflies.

DDT and PCBs and their metabolites and congeners were the synthetic organic contaminants most commonly detected in fish tissue. In some instances, especially in the Spokane River, concentrations of the constituents exceeded guidelines. Total PCB concentrations in all 52 tissue samples of fish from the Spokane

River in Washington exceeded guidelines for the protection of human health and predatory wildlife. Fillet samples of sportfish from many Spokane River sites collected during 1993–96 contained concentrations that exceeded the USEPA screening value for the protection of human health.

Most tissue samples of fish from the Flathead River at Creston, Mont., contained detectable concentrations of PCBs, some exceeding guidelines for protection of predatory wildlife. Dioxins and furans were found in tissue of fish from four sites sampled on the Clark Fork in Montana during 1987. When the dioxin and furan congeners detected at each of these sites were converted to toxic equivalents, no concentrations exceeded guidelines for whole or edible fish tissue. These compounds likely originate from wood and paper processing facilities at upstream locations.

A whole-body sample of longnose suckers from the Coeur d'Alene River at Rose Lake, Idaho, contained an unusually high lead concentration of 14.62 μg/g. This concentration for lead was more than an order of magnitude higher than the 1984 NCBP 85th percentile concentration of 0.22 μg/g for whole fish. The other site where lead concentrations exceeded guidelines was the Spokane River near Post Falls, Idaho. A concentration of 2.6 μg/g was detected in a whole-body sample of largescale suckers at this site.

Cadmium concentrations ranging from 0.40 to 3.90 μg/g exceeded the guidelines for edible fish at three sites (sites 5, 7, and 8). Mercury concentrations at sites 6 and 10 ranged from 0.52 to 0.53 μg/g and exceeded the guidelines for edible fish tissue.

Even though no copper concentrations in fillet or muscle tissue exceeded guidelines, some concentrations in liver tissue were unusually high. Copper concentrations of 598.4 and 269.7 μg/g were detected in livers of brown trout from the Clark Fork near Warm Springs and near Bonner, Mont. These are higher than the NAWQA Program national 85th percentile concentration of 27.25 μg/g and the State of California TSMP concentration of 12.00 μg/g for nonsalmonids. Both of these Clark Fork sites have exhibited elevated concentrations of trace elements in sediment, tissue, and water as a result of past and current mining activities in the watershed.

Macroinvertebrate studies by the USGS in the Clark Fork and Coeur d'Alene Rivers reported that concentrations of trace elements in aquatic macroinvertebrates varied along a longitudinal gradient and were highest at sites nearest historical mining areas. In addition, trace element concentrations in macroinvertebrates varied between rivers. Cadmium, lead, and zinc were much higher in samples from the Coeur d'Alene River than in samples from the Clark Fork.

Presently, there is no coordinated, long-term fish tissue monitoring program for rivers in the study area. Fish consumption advisories developed by State programs often vary in scope, and current efforts to manage the problem are limited by funding and resource constraints. In addition, most tissue monitoring programs are difficult to compare because of differences in quality assurance and quality control for field and laboratory procedures. The development of a coordinated and centralized national data base for contaminants in fish tissue is needed. Because guidelines on fish contaminant concentrations vary widely according to species, type of constituent, and location, interpretation of tissue-contaminant data should be approached cautiously.

The study area contains the two largest mining remediation sites in the Nation (on the upper Clark Fork and the Coeur d'Alene River). Accordingly, comparison studies of tissue concentrations in these montane areas should provide a better understanding of the common pathways and potential problems resulting from elevated trace element concentrations in rivers of the Western United States.

The National Water-Quality Assessment Program can provide a framework for other agencies to evaluate tissue contaminants in the Northern Rockies Intermontane Basins study area. Results of the contaminant analyses can be instrumental in developing guidelines for evaluating tissue-contaminant data at the regional and national levels. Ultimately, these comparisons can be used to assess the status and trends in water quality in relation to land-use activities.

SELECTED REFERENCES

The following references are a summary of available information and past studies on contaminants in aquatic biological tissue for the study area. Some other related studies outside the NROK also are included for future reference. Not all the references are cited in the text of this report. However, all the references cited in this report are included in this reference list. Although this list is intended to include all pertinent references, some relevant publications might not be included.

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Tables 3 and 4

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96

[Whole-body composite and fillet concentrations are reported in micrograms of constituent per gram,wet weight; collection sites shown in figure 2; Mont., Montana; Wash., Washington; values in bold typeface exceed one or more guidelines listed in table 6 for whole and (or) edible fish (fillet or muscle only) and include all individual isomers or metabolites for DDT, PCBs, and chlordane that, in summation, exceed guidelines; values in parentheses for dioxin and furan congeners are toxicity equivalence factors; river mile, distance upstream from Columbia River; No., number; A, approximate location; WB, whole body; F, fillet; <, less than; —, no data; NA, not available; USEPA, U.S. Environmental Protection Agency; USFWS, U.S. Fish and Wildlife Service; IDEQ, Idaho Division of Environmental Quality; WDOE, Washington State Department of Ecology]

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Synthetic organic compound	No. of detections	Range of detected concentrations
2	Clark Fork	46°11'15"	483.0	1987	largescale sucker	1	Pentachloroanisole	1	0.009
	at Warm Springs, Mont.	112°46'10"A			composite		Biphenyl	1	<0.001
					WB–2		p,p'DDE	1	0.016
	USEPA National						Hexachlorobenzene (HCB)	1	0.001
	Bioaccumulation Study[1]						gamma-HCH (Lindane)	1	0.003
							Tetrachlorobiphenyls	1	**0.018**
							Pentachlorobiphenyls	1	**0.105**
							Hexachlorobiphenyls	1	**0.073**
							Heptachlorobiphenyls	1	**0.006**
							Dioxins and furans		
							2,3,7,8 TCDD (1.0)	1	5.3×10^{-7}
							1,2,3,7,8 PECDD (0.5)	1	7.2×10^{-7}
							1,2,3,4,7,8 HXCDD (0.1)	1	7.5×10^{-8}
							1,2,3,6,7,8 HXCDD (0.1)	1	1.0×10^{-6}
							1,2,3,4,6,7,8 HPCDD (0.01)	1	2.8×10^{-6}
					svc		2,3,7,8 TCDF (0.1)	1	1.7×10^{-6}
							2,3,4,7,8 PECDF (0.5)	1	6.4×10^{-8}
							1,2,3,4,6,7,8 HPCDF (0.01)	1	2.3×10^{-8}
					brown trout	1	Analysis only on dioxins and furans		
					composite		1,2,3,7,8 PECDD (0.5)	1	9.1×10^{-7}
					F–4		2,3,7,8 TCDF (0.1)	1	1.4×10^{-6}
11	Clark Fork	47°01'05"	326.1	1987	largescale sucker	1	Pentachloroanisole	1	<0.001
	near Huson, Mont.	114°21'20"			composite		Biphenyl	1	<0.001
					WB–2		p,p'DDE	1	0.013
	USEPA National						gamma-HCH (Lindane)	1	0.003
	Bioaccumulation Study[1]						Trichlorobiphenyls	1	**0.021**
							Tetrachlorobiphenyls	1	**0.205**
							Pentachlorobiphenyls	1	**0.311**
							Hexachlorobiphenyls	1	**0.197**
							Heptachlorobiphenyls	1	**0.007**
							Dioxins and furans		
							2,3,7,8 TCDF (0.1)	1	2.9×10^{-6}

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Synthetic organic compound	No. of detec-tions	Range of detected concentrations
11	Clark Fork	47°01'05"	326.1	1987	rainbow trout	1	Analysis only on <u>dioxins and furans</u>		
	near Huson, Mont.—	114°21'20"			composite		2,3,7,8 TCDF (0.1)	1	1.7×10^{-6}
	Continued				F–4				
	USEPA National Bioaccumulation Study[1]								
12	Flathead River	48°11'25"	375.3	1976	longnose sucker	2	cis-Chlordane	2	0.010
	at Creston, Mont.	114°08'15"A			individuals		trans-Chlordane	2	0.010
					WB–2		p,p'DDD	2	0.010
	USFWS National						p,p'DDE	2	0.030–0.040
	Contaminant						p,p'DDT	2	0.010
	Biomonitoring						PCB 1254	1	**0.200**
	Program[2]						Toxaphene	1	**0.160**
							alpha-HCH	2	0.010
							Dieldrin	1	0.010
							trans-Nonachlor	2	0.010
					northern pikeminnow	1	cis-Chlordane	1	0.010
					individual		trans-Chlordane	1	0.010
					WB–1		p,p'DDD	1	**0.010**
							p,p'DDE	1	**0.250**
							PCB 1254	1	**0.500**
							PCB 1260	1	**0.200**
							alpha-BHC	1	0.010
							Dieldrin	1	0.010
							Endrin	1	0.010
							Hexachlorobenzene (HCB)	1	0.010
							cis-Nonachlor	1	0.010
							trans-Nonachlor	1	0.010
				1978	longnose sucker	1	p,p'DDE	1	0.010
					individual		PCB 1254	1	0.100
					WB–1				
					northern pikeminnow	1	cis-Chlordane	1	0.010
					individual		p,p'DDD	1	0.020
					WB–1		p,p'DDE	1	0.170
							PCB 1248	1	0.100
							PCB 1254	1	**0.440**
							PCB 1260	1	**0.100**
							cis-Nonachlor	1	0.010
							trans-Nonachlor	1	0.020

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Synthetic organic compound	No. of detections	Range of detected concentrations
12	Flathead River at Creston, Mont.—Continued	48°11'25" 114°08'15"A	375.3	1980	largescale sucker individuals WB–2	2	p,p'DDD	2	0.010
							p,p'DDE	2	0.030
							PCB 1254	2	0.100
	USFWS National Contaminant Biomonitoring Program[2]				northern pikeminnow individual WB–1	1	p,p'DDD	1	0.020
							p,p'DDE	1	0.050
							PCB 1254	1	**0.300**
							PCB 1260	1	**0.100**
							cis-Nonachlor	1	0.010
							trans-Nonachlor	1	0.010
				1984	largescale sucker individuals WB–2	2	p,p'DDD	2	0.010
							p,p'DDE	2	<0.010–0.020
							p,p'DDT	2	0.010
							PCB 1254	1	0.100
					mountain whitefish individual WB–1	1	p,p'DDE	1	0.030
							p,p'DDT	1	0.010
							PCB 1260	1	0.100
							alpha-HCH	1	0.020
13	Mission Creek at National Bison Range Refuge, Mont.	47°22'11" 114°14'58"	273.1	1988	mountain whitefish composite F–6	1		0	—
	USFWS contaminants program[3]				northern pikeminnow composite WB–2	1		0	—
14	Clark Fork at Clark Fork, Idaho	48°08'17" 116°10'45"	139.0	1989	bridgelip sucker composite WB–NA	1		0	—
	IDEQ fish tissue ambient monitoring program[4]				northern pikeminnow composite WB–NA	1		0	—
					mountain whitefish composite WB–NA	1		0	—

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Synthetic organic compound	No. of detec-tions	Range of detected concentrations
20	Coeur d' Alene River near Cataldo, Idaho	47°33'07" 116°22'06"A	162.9	1987	sucker composite WB–2	1	Biphenyl	1	<0.001
							gamma-HCH (Lindane)	1	0.001
							p,p'DDE	1	0.007
							Tetrachlorobiphenyls	1	**0.011**
	USEPA National Bioaccumulation Study[1]						Pentachlorobiphenyls	1	**0.061**
							Hexachlorobiphenyls	1	**0.265**
							Heptachlorobiphenyls	1	**0.187**
							Octachlorobiphenyls	1	**0.040**
							Dioxins and furans		
							1,2,3,4,6,7,8 HPCDD (0.01)	1	8.6×10^{-7}
							2,3,7,8 TCDF (0.1)	1	7.5×10^{-7}
					brook trout composite F–6	1	Biphenyl	1	<0.001
							p,p'DDE	1	0.002
							Hexachlorobiphenyls	1	0.001
							Dioxins and furans		
							No analysis performed		
21	Coeur d'Alene River at Rose Lake, Idaho	47°32'15" 116°28'13"	153.4	1989	longnose sucker composite WB–NA	1	p,p'DDE	1	0.076
	IDEQ fish tissue ambient monitoring program[4]				northern pikeminnow composite WB–NA	1		0	—
					mountain whitefish composite WB–NA	1		0	—
22	St. Joe River at St. Maries, Idaho	47°19'04" 116°33'38"	146.3	1987	bottom-feeding fish composite WB–4	1	Biphenyl	1	0.001
							p,p'DDE	1	0.033
							1,2,4 Trichlorobenzene	1	<0.001
	USEPA National Bioaccumulation Study[1]						Pentachlorobiphenyls	1	0.020
							Hexachlorobiphenyls	1	0.021
							Heptachlorobiphenyls	1	0.015
							Dioxins and furans		
							1,2,3,4,6,7,8 HPCDD (0.01)	1	2.2×10^{-6}
							2,3,7,8 TCDF (0.1)	1	8.6×10^{-7}
							1,2,3,4,6,7,8 HPCDF (0.01)	1	2.3×10^{-7}

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Synthetic organic compound	No. of detections	Range of detected concentrations
23	Spokane River near Post Falls, Idaho	47°42'00" 117°56'42"	102.6	1989	longnose sucker composite WB–NA	1		0	—
	IDEQ fish tissue ambient monitoring program[4]				yellow perch composite WB–NA	1		0	—
	WDOE screening survey of PCBs and metals in the Spokane River[5]			1993	largescale sucker individual WB–1	1	PCB 1254 PCB 1260	1 1	0.055 0.041
				1994	largescale sucker composite WB–5	1	PCB 1254 PCB 1260	1 1	**0.081** **0.071**
24	Spokane River near Myrtle Point, Wash.	47°41'36" 117°14'08"	84.0	1993	largescale suckers composite WB–5	1	p,p'DDE PCB 1248 PCB 1254 PCB 1260	1 1 1 1	0.039 **0.130** **0.950** **0.150**
	WDOE pesticide monitoring program[6]				rainbow trout composite F–5	1	p,p'DDE trans-Nonachlor PCB 1248 PCB 1254 PCB 1260	1 1 1 1 1	0.018 0.001 **0.150** **0.430** **0.140**
25	Spokane River above Spokane Dame (also known as Upriver Dam), Wash.	47°41'53" 117°19'10"	80.6	1993	largescale sucker composite WB–5	1	PCB 1248 PCB 1254 PCB 1260	1 1 1	**0.800** **1.800** **0.180**
	WDOE screening survey of PCBs and metals in the Spokane River[5]				rainbow trout composite F–5	2	PCB 1248 PCB 1254 PCB 1260	2 2 1	**0.400** **0.550–0.610** **0.740**
				1994	largescale sucker composite WB–5	1	PCB 1248 PCB 1254 PCB 1260	1 1 1	**0.230** **0.230** **0.071**
					rainbow trout composite F–8	4	PCB 1248 PCB 1254 PCB 1260	4 4 4	**0.133–0.240** **0.110–0.390** <**0.040–0.110**

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	collection year	Sample sample type, and No. of fish	Species, No. of samples	Synthetic organic compound	No. of detec-tions	Range of detected concentrations
25	Spokane River above	47°41'53"	80.6	1996	largescale sucker	1	PCB 1248	1	**0.140**
	Spokane Dame (also known	117°19'10"			composite		PCB 1254	1	**0.260**
	as Upriver Dam), Wash.—				WB–5		PCB 1260	1	**0.130**
	Continued								
	WDOE screening survey				rainbow trout	3	PCB 1248	3	**0.094–1.020**
	of PCBs and metals				composite		PCB 1254	3	**0.085–0.790**
	in the Spokane River[5]				F–8		PCB 1260	3	**0.036–0.060**
26	Spokane River	47°39'32"	75.7	1994	largescale sucker	1	PCB 1248	1	**0.034**
	above Monroe Street	117°23'35"			composite		PCB 1254	1	**0.096**
	Dam, Wash.				WB–5		PCB 1260	1	**0.071**
	WDOE screening survey				mountain whitefish	3	PCB 1248	3	**0.099–0.174**
	of PCBs and metals in				composite		PCB 1254	3	**0.261–0.462**
	the Spokane River[5]				F–8		PCB 1260	3	**0.039–0.130**
					rainbow trout	3	PCB 1248	3	**0.027–0.039**
					composite		PCB 1254	3	**0.044–0.071**
					F–7		PCB 1260	3	**0.040–0.088**
				1996	largescale sucker	1	PCB 1248	1	**0.034**
					composite		PCB 1254	1	**0.045**
					WB–5		PCB 1260	1	**0.037**
					mountain whitefish	2	PCB 1248	2	**0.077–0.110**
					composite		PCB 1254	2	**0.220**
					F–5		PCB 1260	2	**0.067–0.068**
					rainbow trout	2	PCB 1248	2	**0.026–0.028**
					composite		PCB 1254	2	**0.026–0.033**
					F–7		PCB 1260	2	**0.017–0.021**
27	Spokane River above	47°45'54"	58.7	1993	largescale sucker	1	PCB 1248	1	**0.400**
	Nine Mile Falls Dam, Wash.	117°33'00"			composite		PCB 1254	1	**0.600**
					WB–5		PCB 1260	1	**0.210**
	WDOE screening survey				mountain whitefish	1	PCB 1248	1	**0.200**
	of PCBs and metals in				composite		PCB 1254	1	**0.280**
	the Spokane River[5]				F–5		PCB 1260	1	**0.042**
					rainbow trout	2	PCB 1248	2	**0.200**
					composite		PCB 1254	2	**0.210–0.240**
					F–4		PCB 1260	2	**0.064–0.065**

Table 3. Synthetic organic compounds detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1976–96—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Synthetic organic compound	No. of detec-tions	Range of detected concentrations
27	Spokane River above	47°45'54"	58.7	1994	rainbow trout	3	PCB 1248	3	**0.044–0.059**
	Nine Mile Falls Dam,	117°33'00"			composite		PCB 1254	3	**0.076–0.410**
	Wash.—Continued				F–6		PCB 1260	3	**0.085–0.170**
	WDOE screening survey				mountain whitefish	3	PCB 1248	3	**0.043–0.091**
	of PCBs and metals in				composite		PCB 1254	3	**0.020–0.035**
	the Spokane River[5]				F–8		PCB 1260	3	**0.033–0.074**
				1996	largescale sucker	1	PCB 1248	1	**0.075**
					composite		PCB 1254	1	**0.170**
					WB–5		PCB 1260	1	**0.100**
					mountain whitefish	3	PCB 1248	3	**0.083–0.110**
					composite		PCB 1254	3	**0.140–0.270**
					F–8		PCB 1260	3	**0.110–0.190**
					rainbow trout	3	PCB 1248	3	**0.015–0.028**
					composite		PCB 1254	3	**0.017–0.060**
					F–5		PCB 1260	3	**0.006–0.040**
28	Little Spokane River	47°47'05"	56.3	1994	cutthroat trout	1	PCB 1248	1	**0.023**
	near confluence with	117°24'12"			individual		PCB 1254	1	**0.055**
	Spokane River, Wash.				F–1		PCB 1260	1	**0.110**
	WDOE screening survey				largescale sucker	1	PCB 1248	1	**0.040**
	of PCBs and metals				composite		PCB 1254	1	**0.140**
	in the Spokane River[5]				WB–5		PCB 1260	1	**0.260**
					mountain whitefish	3	PCB 1248	3	**0.020–0.025**
					individuals		PCB 1254	3	**0.035–0.050**
					F–8		PCB 1260	3	**0.090–0.210**
				1996	largescale sucker	1	PCB 1248	1	**0.046**
					composite		PCB 1254	1	**0.160**
					WB–5		PCB 1260	1	**0.160**
					mountain whitefish	3	PCB 1248	3	**0.009–0.023**
					individuals		PCB 1254	3	**0.029–0.060**
					F–8		PCB 1260	3	**0.081–0.097**

[1] U.S. Environmental Protection Agency (1992).
[2] Schmitt and others (1981, 1983, 1985).
[3] J. Malloy, U.S. Fish and Wildlife Service (written commun., 1998).
[4] Nautch and Clark (1998).
[5] Washington State Department of Ecology (1995); A. Johnson, Washington State Department of Ecology (written commun., 1997).
[6] Davis and others (1995).

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94

[Whole-body composite and fillet concentrations are reported in micrograms of constituent per gram, wet weight; collection sites shown in figure 2; Mont., Montana; Wash., Washington; values in bold typeface exceed one or more guidelines listed in table 6 for whole and (or) edible fish (fillet or muscle only); river mile, distance upstream from Columbia River; No., number; A, approximate location; WB, whole body; F, fillet; L, liver; G, gill; K, kidney; M, muscle; NA, not available; USEPA, U.S. Environmental Protection Agency; NBS, National Biological Service; U of M, University of Montana; USFWS, U.S. Fish and Wildlife Service; IDEQ, Idaho Division of Environmental Quality; USGS, U.S. Geological Survey; WDOE, Washington State Department of Ecology]

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detections	Range of detected concentrations
2	Clark Fork at Warm Springs, Mont.	46°11'15" 112°46'10"A	483.0	1987	largescale sucker composite WB–2	1	Mercury	1	0.10
	USEPA National Bioaccumulation Study[1]				brown trout composite F–4	1	Mercury	1	0.08
	NBS study[2] (assumed 75 percent moisture content for conversion from dry to wet weight; concentrations reported in reference are means for all individual fish analyzed)			1992	brown trout individual WB–10	10	Copper	NA	[3]1.60
					brown trout individual L–10	10	Copper	NA	[3]598.40
					brown trout individual G–10	10	Copper	NA	[3]3.33
					brown trout individual K–10	10	Copper	NA	[3]9.60
4	Clark Fork near Deer Lodge, Mont.	46°23'52" 112°44'31"A	461.2	1974	mountain whitefish individual M	5	Mercury	NA	0.08–0.30
	U of M[4]				mountain whitefish individual L	5	Cadmium Copper Lead Zinc	NA NA NA NA	1.80 12.00 0.11 21.00
					brown trout individual M	2	Cadmium Copper Lead Mercury Zinc	NA NA NA NA NA	0.01 2.80 0.05 0.28–0.46 3.90
					brown trout individual L	2	Cadmium Copper Lead Zinc	NA NA NA NA	1.20 9.30 0.06 37.00

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec-tions	Range of detected concen-trations
4	Clark Fork near Deer Lodge, Mont.—Continued	46°23'52" 112°44'31"A	461.2	1974	largescale sucker individual	1	Cadmium	NA	0.41
							Copper	NA	4.50
	U of M[4]				L		Lead	NA	0.27
							Zinc	NA	35.00
5	Clark Fork at Goldcreek, Mont.	46°35'26" 112°55'40"A	436.9	1974	largescale sucker individual	1	Cadmium	NA	**3.90**
							Copper	NA	0.75
					M		Lead	NA	0.65
							Mercury	NA	0.02
							Zinc	NA	12.00
	U of M[4]				largescale sucker individual	1	Cadmium	NA	0.77
							Copper	NA	3.10
					L		Lead	NA	0.12
							Zinc	NA	30.00
					mountain whitefish individual M	2	Mercury	NA	0.06–0.15
					mountain whitefish individual	2	Cadmium	NA	0.37–1.30
							Copper	NA	0.95–1.40
					L		Lead	NA	0.13–0.16
							Zinc	NA	27.00–29.00
					sculpin species individual	3	Cadmium	NA	0.35–0.52
							Copper	NA	0.94–11.00
					L		Lead	NA	0.22–0.28
							Zinc	NA	0.29–0.31
					brown trout individual	2	Cadmium	NA	0.08
							Lead	NA	0.04
					M		Mercury	NA	0.10
							Zinc	NA	4.20
					brown trout individual	2	Cadmium	NA	0.36–1.60
							Copper	NA	16.00–17.00
					L		Lead	NA	0.02–0.05
							Zinc	NA	27.00–35.00
6	Flint Creek near Drummond, Mont.	46°37'44" 113°09'02"A	417.6	1974	brown trout individual	3	Cadmium	NA	0.09
							Copper	NA	7.70
					M		Lead	NA	0.39
							Mercury	NA	0.38–**0.53**
							Zinc	NA	7.10
	U of M[4]				brown trout individual	3	Cadmium	NA	0.45
							Copper	NA	28.00
					L		Lead	NA	0.78
							Zinc	NA	31.00

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec- tions	Range of detected concen- trations
6	Flint Creek near Drummond, Mont.—Continued	46°37'44" 113°09'02"A	417.6	1974	mountain whitefish individual M	4	Mercury	NA	0.21–0.40
	U of M[4]				mountain whitefish individual L	4	Cadmium Copper Lead Mercury Zinc	NA NA NA NA NA	0.31 38.00 0.77 0.24 27.00
					sculpin species individual M	1	Mercury	NA	0.28
7	Clark Fork near Drummond, Mont.	46°42'44" 113°19'48"A	403.9	1974	brown trout individual M	3	Mercury	NA	0.08–0.17
	U of M[4]				brown trout individual L	3	Cadmium Copper Lead Zinc	NA	0.35–0.63 51.00–64.00 0.71–1.70 47.00–90.00
					largescale sucker individual M	2	Cadmium Copper Lead Mercury Zinc	NA NA NA NA NA	0.06 0.10 0.06 0.11–0.13 5.70
					largescale sucker individual L	2	Cadmium Copper Lead Zinc	NA NA NA NA	0.33–3.10 0.37–0.96 0.15–0.63 21.00
					redside shiner individual M	2	Mercury	NA	0.16–0.29
					redside shiner individual L	2	Cadmium Copper Lead Zinc	NA NA NA NA	0.23–0.34 0.90–1.30 0.21–0.26 20.00–28.00
					longnose dace individual M	1	Mercury	NA	0.16

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec-tions	Range of detected concen-trations
7	Clark Fork near Drummond, Mont.—Continued	46°42'44" 113°19'48"A	403.9	1974	mountain whitefish individual M	2	Cadmium	NA	**0.66**
							Copper	NA	1.60
							Lead	NA	2.00
	U of M[4]						Mercury	NA	0.17–0.21
							Zinc	NA	26.00
					mountain whitefish individual L	2	Cadmium	NA	0.34–1.30
							Copper	NA	0.96–14.00
							Lead	NA	0.14–0.56
							Zinc	NA	19.00–22.00
8	Rock Creek near Clinton, Mont.	46°43'21" 113°40'56"A	381.8	1974	brown trout individuals M	3	Cadmium	NA	0.11–**0.40**
							Copper	NA	1.00–1.10
							Lead	NA	0.68–0.88
							Mercury	NA	0.11–0.25
							Zinc	NA	4.90–5.40
	U of M[4]				brown trout individuals L	3	Cadmium	NA	1.80
							Copper	NA	28.00
							Lead	NA	5.60
9	Clark Fork at Turah Bridge near Bonner, Mont.	46°49'34" 113°48'48"	370.2	1992	brown trout individual WB–9	9	Copper	NA	[3]1.08
	NBS study[2] (assumed 75 percent moisture content for conversion from dry to wet weight; concentrations reported in reference are means for all individual fish analyzed)				brown trout individual L–9	9	Copper	NA	[3]269.70
					brown trout individual G–9	9	Copper	NA	[3]1.65
					brown trout individual K–9	9	Copper	NA	[3]2.30
10	Clark Fork below Missoula, Mont. (includes three sites downstream from Missoula, Mont.)	46°52'09" 114°07'33"A	349.5	1974	mountain whitefish individuals M	8	Cadmium	NA	0.02–0.15
							Copper	NA	0.49
							Lead	NA	0.03–0.49
							Mercury	NA	0.06–0.21
							Zinc	NA	3.00–5.00
	U of M[4]				mountain whitefish individuals L	8	Cadmium	NA	0.03–0.39
							Copper	NA	0.32–1.50
							Lead	NA	0.03–0.32
							Zinc	NA	19.00–29.00

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec-tions	Range of detected concen-trations
10	Clark Fork below Missoula, Mont.—Continued (includes three sites downstream from Missoula, Mont.)	46°52'09" 114°07'33"A	349.5	1974	redside shiner individuals L	4	Cadmium	NA	0.15–0.52
							Copper	NA	0.67–3.10
							Lead	NA	0.11–1.10
							Zinc	NA	17.00–24.00
	U of M[4]				redside shiner individuals M	4	Mercury	NA	0.05–0.17
					largescale sucker individuals L	4	Cadmium	NA	0.16–0.35
							Copper	NA	0.26–0.40
							Lead	NA	0.04–0.53
							Zinc	NA	31.00–36.00
					largescale sucker individuals M	4	Mercury	NA	0.08–0.34
					northern pikeminnow individuals M	2	Mercury	NA	0.17–**0.52**
					northern pikeminnow individuals L	2	Cadmium	NA	0.38–0.68
							Copper	NA	1.80–7.10
							Lead	NA	0.18–0.40
							Zinc	NA	20.00–21.00
					rainbow trout individuals M	1	Cadmium	NA	0.13
							Copper	NA	0.15
							Lead	NA	0.07
							Mercury	NA	0.07
							Zinc	NA	4.30
					rainbow trout individuals L	1	Cadmium	NA	0.24
							Copper	NA	22.00
							Lead	NA	0.13
							Zinc	NA	22.00
11	Clark Fork near Huson, Mont.	47°01'05" 114°21'20"	326.1	1987	largescale sucker composite WB–2	1	Mercury	1	0.14
	USEPA National Bioaccumulation Study[1]				rainbow trout composite F–4	1	Mercury	1	0.08

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec-tions	Range of detected concen-trations
12	Flathead River at Creston, Mont.	48°11'25" 114°08'15"A	375.3	1978	longnose sucker individual WB–1	1	Arsenic	1	0.09
							Cadmium	1	0.02
							Copper	1	1.60
							Lead	1	0.10
							Mercury	1	0.09
							Selenium	1	0.26
							Zinc	1	29.40
	USFWS National Contaminant Biomonitoring Program[5]				northern pikeminnow individual WB–1	1	Arsenic	1	0.05
							Cadmium	1	0.01
							Copper	1	0.50
							Lead	1	0.10
							Mercury	1	0.17
							Selenium	1	0.21
							Zinc	1	27.80
				1980	largescale sucker individuals WB–2	2	Arsenic	2	0.05–0.08
							Cadmium	2	0.01–0.02
							Copper	2	0.90–1.00
							Lead	2	0.10
							Mercury	2	0.09–0.11
							Selenium	2	0.17–0.23
							Zinc	2	16.60–20.00
					northern pikeminnow individual WB–1	1	Arsenic	1	0.05
							Cadmium	1	0.01
							Copper	1	0.50
							Lead	1	0.10
							Mercury	1	0.22
							Selenium	1	0.22
							Zinc	1	14.90
				1984	largescale sucker individuals WB–2	2	Arsenic	2	0.06–0.09
							Cadmium	2	0.02
							Copper	2	0.82–0.91
							Lead	2	0.05–0.08
							Mercury	2	0.14–0.21
							Selenium	2	0.18
							Zinc	2	19.39–20.81
					mountain whitefish individual WB–1	1	Arsenic	1	0.09
							Cadmium	1	0.01
							Copper	1	0.48
							Lead	1	0.07
							Mercury	1	0.05
							Selenium	1	0.32
							Zinc	1	21.91

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detections	Range of detected concentrations
13	Mission Creek at National Bison Range Refuge, Mont.	47°22'11" 114°14'58"	273.1	1988	mountain whitefish individuals F–5	5	Arsenic	5	0.06–0.10
							Mercury	5	0.03–0.10
							Selenium	5	0.16–0.38
							Zinc	5	5.55–14.00
	USFWS contaminants program[6] (assumed 75 percent moisture content for conversion from dry to wet weight)				largescale sucker individuals F–4	4	Arsenic	4	0.05–0.08
							Mercury	4	0.08–0.19
							Zinc	4	7.08–10.95
					mountain whitefish individual WB–1	1	Arsenic	1	0.07
							Mercury	1	0.04
							Selenium	1	0.48
							Zinc	1	15.88
					rainbow trout individual WB–1	1	Arsenic	1	0.05
							Mercury	1	0.03
							Selenium	1	0.20
							Zinc	1	29.00
					northern pikeminnow individual WB–1	1	Arsenic	1	0.04
							Copper	1	16.98
							Mercury	1	0.08
							Selenium	1	0.25
							Zinc	1	24.40
14	Clark Fork at Clark Fork, Idaho	48°08'17" 116°10'45"	139.0	1989	bridgelip sucker composite WB–NA	1	Cadmium	1	0.12
							Copper	1	1.05
							Lead	1	0.18
							Mercury	1	0.13
	IDEQ fish tissue ambient monitoring program[7]				northern pikeminnow composite WB–NA	1	Copper	1	1.19
							Mercury	1	0.46
					mountain whitefish composite WB–NA	1	Cadmium	1	0.05
							Copper	1	0.77
							Lead	1	0.22
							Mercury	1	0.10
15	South Fork Coeur d'Alene River above Mullan, Idaho	47°28'00" 115°44'00"	193.0	1986	rainbow trout composite F–NA	1	Arsenic	1	0.48
							Cadmium	1	0.01
							Copper	1	0.52
							Mercury	1	0.01
							Zinc	1	4.30
	USEPA water-quality monitoring report[8]				trout species composite F–NA	1	Arsenic	1	0.08
							Cadmium	1	0.06
							Copper	1	0.82
							Mercury	1	0.01
							Zinc	1	6.30

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detections	Range of detected concentrations
16	South Fork Coeur d'Alene River at Silverton, Idaho	47°29'30"	182.2	1993	rainbow/cutthroat	1	Cadmium	1	0.45
	IDEQ study[9]	115°57'30"			hybrid		Lead	1	0.48
					composite		Mercury	1	0.04
					F–3		Zinc	1	34.70
17	South Fork Coeur d'Alene River at Elizabeth Park, Idaho	47°31'53"	176.9	1993	brook trout	1	Cadmium	1	0.13
	IDEQ study[9]	116°05'30"			composite		Lead	1	0.78
					F–3		Mercury	1	0.04
							Zinc	1	13.80
18	North Fork Coeur d'Alene River near Enaville, Idaho	47°37'00"	173.4	1994	brook trout	4	Cadmium	4	0.78
		116°14'00"A			individual		Copper	4	1.65
					K–4		Lead	4	0.05
							Zinc	4	33.00
	USGS study[10]				brook trout	4	Cadmium	4	0.12
	(assumed 75 percent moisture content for conversion				individual		Copper	4	1.48
	from dry to wet weight; concentrations reported in				G–4		Lead	4	0.40
	reference are means for all individual fish analyzed)						Zinc	4	30.75
19	South Fork Coeur d'Alene River near Pinehurst, Idaho	47°33'06"	169.2	1993	mountain whitefish	1	Cadmium	1	0.30
	IDEQ study[9]	116°14'13"			and brook trout		Lead	1	0.15
					F–3		Mercury	1	0.03
							Zinc	1	24.00
	USGS study[10]			1994	brook trout	6	Cadmium	6	58.40
	(assumed 75 percent moisture content for conversion				individual		Copper	6	19.28
	from dry to wet weight; concentrations reported in				K–6		Lead	6	31.92
	reference are means for all individual fish analyzed)						Zinc	6	124.75
					brook trout	6	Cadmium	6	31.85
					individual		Copper	6	7.65
					G–6		Lead	6	6.20
							Zinc	6	148.50
20	Coeur d'Alene River near Cataldo, Idaho	47°33'07"	162.9	1987	sucker	1	Mercury	1	0.21
		116°22'06"			composite				
					WB–2				
	USEPA National Bioaccumulation Study[1]				brook trout	1	Mercury	1	0.08
					composite				
					F–6				
	USGS study[10]			1994	cutthroat trout	4	Cadmium	4	38.80
	(assumed 75 percent moisture content for conversion				individual		Copper	4	33.35
	from dry to wet weight; concentrations reported in				K–4		Lead	4	24.10
	reference are means for all individual fish analyzed)						Zinc	4	74.00

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec-tions	Range of detected concen-trations
20	Coeur d'Alene River near Cataldo, Idaho—Continued	47°33'07" 116°22'06"	162.9	1994	cutthroat trout individual G–4	4	Cadmium	4	11.70
							Copper	4	4.10
							Lead	4	19.70
							Zinc	4	201.50
	USGS study[10] (assumed 75 percent moisture content for conversion from dry to wet weight; concentrations reported in reference are means for all individual fish analyzed)				rainbow trout individual K–4	6	Cadmium	6	29.88
							Copper	6	26.02
							Lead	6	25.68
							Zinc	6	110.00
					rainbow trout individual G–4	6	Cadmium	6	27.18
							Copper	6	3.820
							Lead	6	4.60
							Zinc	6	308.25
21	Coeur d'Alene River at Rose Lake, Idaho	47°32'15" 116°28'13"	153.4	1989	longnose sucker composite WB–NA	1	Cadmium	1	0.57
							Copper	1	1.22
							Lead	1	14.62
	IDEQ fish tissue ambient monitoring program[7]				northern pikeminnow composite WB–NA	1	Cadmium	1	0.48
							Copper	1	0.48
							Lead	1	1.68
							Mercury	1	0.10
					mountain whitefish composite WB–NA	1	Cadmium	1	0.10
							Copper	1	0.72
							Lead	1	0.31
22	St. Joe River at St. Maries, Idaho USEPA National Bioaccumulation Study[1]	47°19'04" 116°33'38"	146.3	1987	bottom–feeding fish composite WB–4	1	Mercury	1	0.16
23	Spokane River near Post Falls, Idaho	47°42'11" 116°56'42"	102.6	1989	longnose sucker composite WB–NA	1	Cadmium	1	0.32
							Copper	1	1.18
							Lead	1	1.20
							Mercury	1	0.06
	IDEQ fish tissue ambient monitoring program[7]				yellow perch composite WB–NA	1	Cadmium	1	0.18
							Copper	1	0.68
							Lead	1	1.14
							Mercury	1	0.11
	WDOE screening survey of PCBs and metals in the Spokane River[11]			1993	largescale sucker individual WB–1	1	Cadmium	1	0.21
							Copper	1	0.90
							Lead	1	2.60
							Mercury	1	0.05
							Zinc	1	38.00

Table 4. Trace elements detected in tissue of fish from selected sites in the Northern Rockies Intermontane Basins study area in Montana, Idaho, and Washington, 1974–94—Continued

Site No. (fig. 2)	Site name, collecting agency, and program	Latitude Longitude	River mile	Sample collection year	Species, sample type, and No. of fish	No. of samples	Trace element	No. of detec-tions	Range of detected concen-trations
25	Spokane River above Upriver Dam, Wash.	47°41'53" 117°19'10"	80.6	1993	largescale sucker composite WB–5	1	Cadmium	1	0.25
							Copper	1	1.00
							Lead	1	1.80
							Mercury	1	0.02
							Zinc	1	65.00
	WDOE screening survey of PCBs and metals in the Spokane River[11]				rainbow trout composite F–5	2	Cadmium	2	0.03–0.04
							Lead	2	0.05–0.75
							Mercury	2	0.03–0.03
							Zinc	2	24.00–27.00
27	Spokane River above Nine Mile Dam Falls, Wash.	47°45'54" 117°33'00"	58.7	1993	largescale sucker composite WB–5	1	Cadmium	1	0.20
							Copper	1	4.20
							Lead	1	2.00
							Mercury	1	0.38
							Zinc	1	34.00
	WDOE screening survey of PCBs and metals in the Spokane River[11]				mountain whitefish composite F–5	1	Cadmium	1	0.01
							Lead	1	0.05
							Mercury	1	0.02
							Zinc	1	13.00
					rainbow trout composite F–4	2	Cadmium	2	0.01
							Lead	2	0.05–0.06
							Mercury	2	0.03–0.04
							Zinc	2	11.00–12.00

[1] U.S. Environmental Protection Agency (1992).
[2] Farag and others (1995).
[3] Mean value; no range available (Farag and others, 1995).
[4] Van Meter (1974).
[5] May and McKinney (1981); Lowe and others (1985); and Schmitt and Brumbaugh (1990).
[6] Palawski and others (1991b).
[7] Nautch and Clark (1998).
[8] Hornig and others (1988).
[9] M. Hartz, Idaho Department of Health and Welfare, Division of Environmental Quality (written commun., 1994).
[10] Farag and others (1998).
[11] A. Johnson, Washington State Department of Ecology (written commun., 1997).