



Selenium in the Kootenai River Basin, Montana and Idaho, United States, and British Columbia, Canada

Introduction

Selenium entering the 90-mile long transboundary Koocanusa Reservoir (also called Lake Koocanusa) in southeastern British Columbia, Canada, and northwestern Montana, United States, has been measured at concentrations above State and Federal water-quality and aquatic life standards (Montana Department of Environmental Quality [MTDEQ], 2020b). The reservoir is within the international Kootenai (or “Kootenay” in Canada) drainage basin (fig. 1), which contains critical habitat for native fish species and is impounded by Libby Dam (fig. 2A) 16 miles upstream

from Libby, Montana. A complete hydrological description of the drainage basin, reservoir, and tributaries is in Lotic Environmental (2018). Since 1984, selenium concentrations have ranged from below detection to greater than 8 micrograms per liter ($\mu\text{g/L}$) in the Elk River, measured 2.2 miles above its discharge into Koocanusa Reservoir at a British Columbia environmental monitoring station (site 0200016; British Columbia Ministry of Forests Lands Natural Resource Operations and Rural Development [BCFLNR], 2022; fig. 3). Selenium is a required micro-nutrient, but elevated concentrations in water bioaccumulate in egg-laying fish and birds, causing various sublethal effects and death. One possible source of selenium in the Kootenai River Basin is the excavation of bedrock in the Elk River Valley (not shown) to access coal seams for metallurgical steelmaking and coal production (fig. 2B). Five open-pit coal mines (only the southernmost mine is shown) are operating in this region of southeastern British Columbia (fig. 1) that produce about 21 million tons of metallurgical coal annually (Teck Coal, 2020).

Site-specific selenium standards were established for the reservoir in 2020 following collaborative work by the U.S. Geological Survey (USGS), MTDEQ, the British Columbia Ministry of Environment and Climate Change Strategy, the

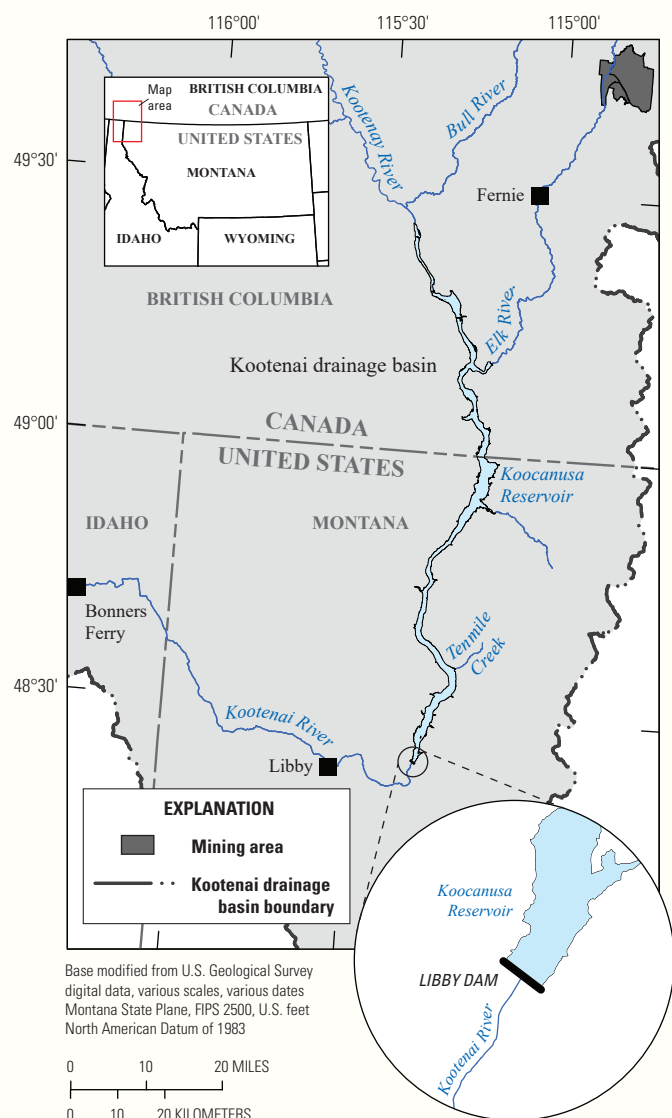


Figure 1. Map of study area.



Figure 2. A, Libby Dam, Montana, in 2008. Photograph by the U.S. Army Corps of Engineers, Seattle District Public Affairs Office. B, Mining operations in the Elk River Valley, 2021. Photograph by Travis Schmidt, U.S. Geological Survey.

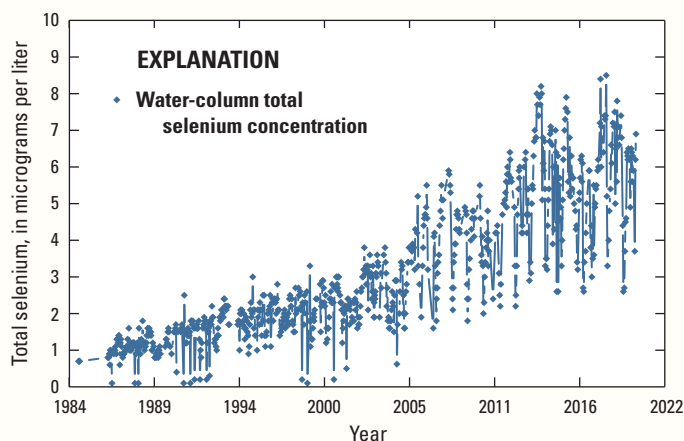


Figure 3. Water-column total selenium concentrations measured at British Columbia site 0200016 on the Elk River from 1984 to 2022. Data from the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (2022).

Lake Koocanusa Monitoring and Research Working Group, and the Selenium Technical Subcommittee (MTDEQ, 2020a). The standards of 0.8 µg/L for dissolved selenium in the water column and 15.1 milligrams per kilogram (mg/kg) dry weight for fish egg (ovary) tissue (in addition to the muscle and whole-body standards) were adopted into Montana State law in 2020 and approved by the U.S. Environmental Protection Agency (EPA) in 2021 (MTDEQ, 2020a; EPA, 2021).

Previous Work in the Kootenai River Basin

Monitoring water quality and fish populations in Koocanusa Reservoir and the Kootenai River has been a collaborative effort since at least 1967, when the U.S. Army Corps of Engineers (USACE), who manage the reservoir, and the USGS began collecting water samples (Easthouse, 2013) to better understand the relation between Libby Dam operations and downstream effects on the Kootenai River. Numerous biological inventories were also conducted before and after dam construction, and the Kootenai Tribe of Idaho (KTOI), among other agencies and local groups, have been trying to restore declining fish populations (for example, the burbot fish population; fig. 4) in the Kootenai

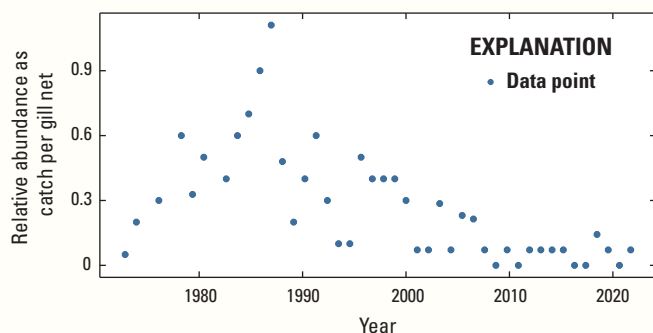


Figure 4. Time series of the relative abundances of burbot (*Lota lota*) in Koocanusa Reservoir, 1980–2020. Data from Dunnigan and others (2021).

River (KTOI, 2022). Monitoring has increased recently because of concerns that discharge from coal mining operations has led to increased selenium concentrations, but more data and analyses are needed to understand the biogeochemical dynamics and ecological effects of selenium in the basin (Presser and Naftz, 2020).

The Kootenai River Basin contains critical habitat for multiple fish species, including white sturgeon (*Acipenser transmontanus*), burbot (*Lota lota*), mountain whitefish (*Prosopium williamsoni*), bull trout (*Salvelinus confluentus*), and genetically pure westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), some of which are threatened or endangered. In a recent study, the USGS, working in cooperation with the EPA, coordinated the collection of fish tissue for selenium analysis as part of the ongoing population surveys performed by State wildlife agencies in Idaho and Montana and the KTOI (Mebane and Schmidt, 2019). In this study, 142 fish representing 13 species were collected in 2018 and 2019 from multiple sites between Libby Dam and Bonners Ferry, Idaho. Ovarian tissues (eggs) were obtained from kokanee salmon (*Oncorhynchus nerka*) and mountain whitefish. Selenium concentrations in most mountain whitefish ovarian tissue samples exceeded the criterion of 15.1 mg/kg dry weight, the level at which fish reproduction may be harmed. In kokanee salmon, eggs were found in two fish from the Kootenai River below Libby Dam, and selenium concentrations ranged from 4.17 to 5.01 mg/kg selenium dry weight (Mebane and Schmidt, 2019).

More recently, selenium analysis of fish tissue samples from the reservoir and collected by Montana, Fish, Wildlife and Parks showed that, relative to samples collected in previous years, 2020 data included higher selenium concentrations, some exceeding 15.1 mg/kg, in samples from peamouth chub (*Mylocheilus caurinus*), redbelt shiner (*Richardsonius balteatus*), and westslope cutthroat trout (Dunnigan and others, 2021).



Figure 5. U.S. Geological Survey personnel sampling for water quality in Koocanusa Reservoir, 2021. Photograph by Ashley M. Bussell, U.S. Geological Survey.

The USACE monitors Koocanusa Reservoir for flow, water quality, and other parameters (USACE, 2022), and the USGS streamgauge at Libby Dam (site 12301933) has recorded discharge, gage height, and other parameters since 1964 (USGS, 2022a). In 2019, the USGS established a water-quality monitoring program in Koocanusa Reservoir to provide water-quality data for United States and Canadian Tribal, State, and Federal regulatory agencies (fig. 5). The objectives of this program are to establish a long-term dataset of selenium concentrations (dissolved and total) and related constituents within the reservoir and to understand the processes controlling selenium occurrence. Water-quality samples and environmental data, such as pH, water temperature, and dissolved-oxygen concentrations, are collected periodically by hand and at high frequency by automated samplers from multiple water column depths. Water samples are collected primarily at the international boundary (USGS site 12300110), the Libby Dam forebay (USGS site 12301919), and in the Kootenai River below Libby Dam (USGS site 12301933) (not shown). All USGS water-quality data are available in the USGS National Water Information System database (USGS, 2022b).

In addition to the USGS, the MTDEQ, the BCFLNR, Teck Coal, and other agencies also collect water-quality and related data. The USACE maintains three monitoring stations on the United States side of Koocanusa Reservoir, and the BCFLNR has long-term stations within the British Columbian tributaries. Additionally, Teck Coal conducts comprehensive physicochemical and biological monitoring at sites upstream and downstream from the Elk River (Teck Coal, 2019). Data collected by the USGS, MTDEQ, and USACE can be found at the National Water Quality Monitoring Council [NWQMC] Water Quality Portal (NWQMC, 2022).

Ongoing and Future Work

To facilitate use of monitoring data for understanding water-quality dynamics and ecosystem health, the USGS is working on a database and sharing platform of environmental data collected from multiple agencies in Koocanusa Reservoir and the Kootenai River. Incorporating datasets from multiple agencies that have different goals is challenging because of field-collection and laboratory-analytical method differences, disparities in sampling frequencies, and spatial and temporal data gaps. These challenges are being addressed by investigating all available quality-assurance data and metadata. Figure 6 shows dissolved selenium concentrations measured in Koocanusa Reservoir by the USGS, USACE, MTDEQ, and Teck Coal using similar water sampling methods at sites clustered around the international border from 2013 to 2021. These data were from the following stations (as referenced in the Water Quality Portal; National Water Quality Monitoring Council, 2022): USGS-12300110, MDEQ_WQ_WQX-K01KOOCL01-01, USACENWS_WQX-LIBBOR-EPI, TECK_AMERICAN-RG_BORDER, and USACENWS_WQX-LIBBOR-HYPO (not shown).

Also, the USGS is conducting a mass balance analysis using USGS loading models and statistical tools to quantify inputs of selenium from the Elk River and other sources to Koocanusa Reservoir, exports (at the outlet of Libby Dam) of selenium from the reservoir, the selenium pool within the reservoir (the reservoir as a control volume), and changes to the pool over time. Mass balances, in general, provide information on sources contributing to water quality, foundations for empirical and mechanistic modeling, and bases for tracking drainage basin and lake or reservoir responses to implementation of control measures. Data for this mass balance analysis are from the USGS (USGS, 2022b), USACE (NWQMC, 2022), and the BCFLNR (BCFLNR, 2022).

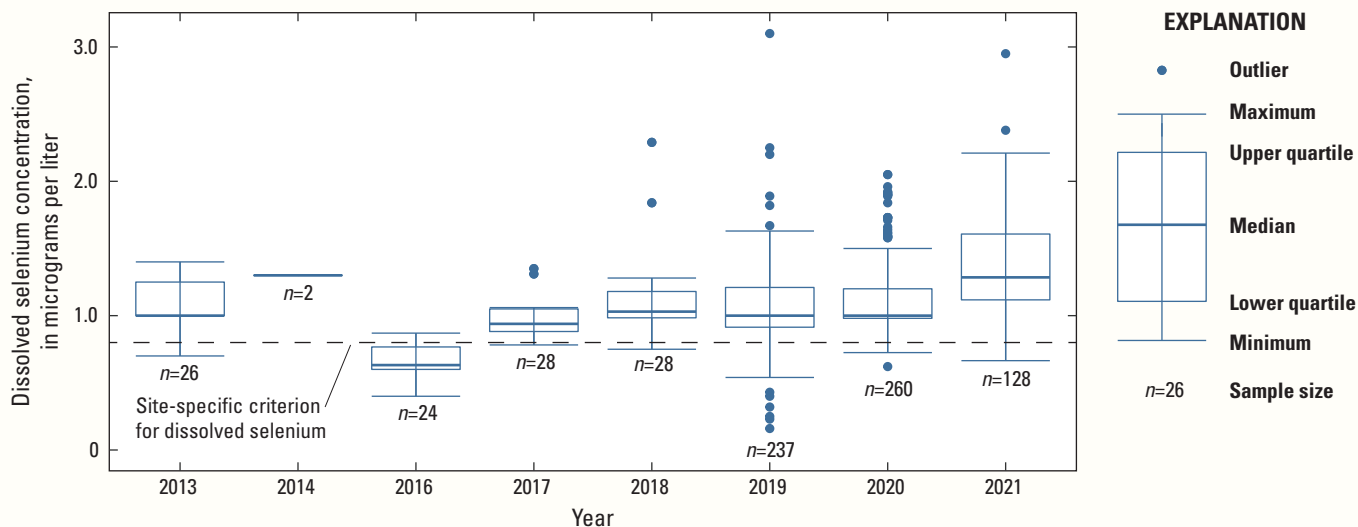


Figure 6. Dissolved selenium concentrations in water samples collected by multiple agencies in Koocanusa Reservoir, 2013–21. Data are from U.S. Geological Survey (2022b), U.S. Army Corps of Engineers and Montana Department of Environmental Quality (National Water Quality Monitoring Council , 2022), and Teck Coal (2019).

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Platform for a high-frequency sampler and associated equipment, 2019. Photograph by Chad Reese, U.S. Geological Survey.

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For more information:

USGS project website: <https://www.usgs.gov/centers/wyoming-montana-water-science-center/science/lake-koocanusa-water-quality>

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Publishing support provided by the
Rolla Publishing Service Center

ISSN 2327-6916 (print)
ISSN 2327-6932 (online)
<https://doi.org/10.3133/fs20223033>