Analysis of Selenium Tissue Concentrations in Multiple Fish Species of the Oldman River

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Prepared for Crowsnest Headwaters, Crowsnest, Alberta

August, 2026

Summary

Thirty-eight fish, from five species and representative of the fish assemblage of the Oldman River downstream of the Oldman dam, were analyzed for selenium concentrations in muscle tissue. Of the sportfish species (rainbow trout, brown trout, and mountain whitefish), 33 per cent of the fish exceeded Alberta's threshold for the protection of aquatic life. This also has implications for people who consume these fish. Compared with fish in Alberta waterbodies not impacted by coal mining, the mean selenium species concentrations for Oldman River fish suggests a broader selenium problem for the Oldman ecosystem, both upstream and downstream of the Oldman dam.

Introduction

Selenium is an element of concern, based on its toxicity to aquatic life, to wildlife , and to human consumers of fish at elevated levels. Studies of selenium concentrations in fish flesh have been undertaken in Crowsnest Lake and in Crowsnest River tributaries of Blairmore and Gold creeks. These show troubling indications of selenium contamination of fish. This reconnaissance level study assessed selenium concentrations in fish tissue of species found in the Oldman River, downstream of the Oldman Reservoir and a reach through the Piikani Nation. The data form a partial benchmark of selenium concentrations in fish lower in the watershed and an indication of the need for a greater scope of study to evaluate the issue.

Methods

The Oldman Reservoir impounds water which is subsequently diverted at a structure 38 km downstream, into the main canal of the Lethbridge Northern Irrigation District (Figure 1). When irrigation diversions end in the fall, flows drop and fish are trapped at various structures in the canal. Freshwater Conservation Canada undertakes an annual fish rescue operation at these structures to return fish to the river.

The location to collect fish samples was on the Lethbridge Northern Main Canal (49°44'45.3"N 113°34'38.1"W). The collection was made on October 18, 2025.

A number of fish of five species were sacrificed to allow removal of tissue samples for selenium analysis. Clove oil was used to euthanize the fish collected. The collection and sacrifice of fish was done under a Fish Research License (FRL 25-2610) issued by Alberta Environment and Protected Areas and followed the Provincial Standard for the Ethical Use of Fish in Alberta (GOA 2013).

Sampling included a range of sizes per species, and generally these were representative of the size classes observed during the rescue operation.

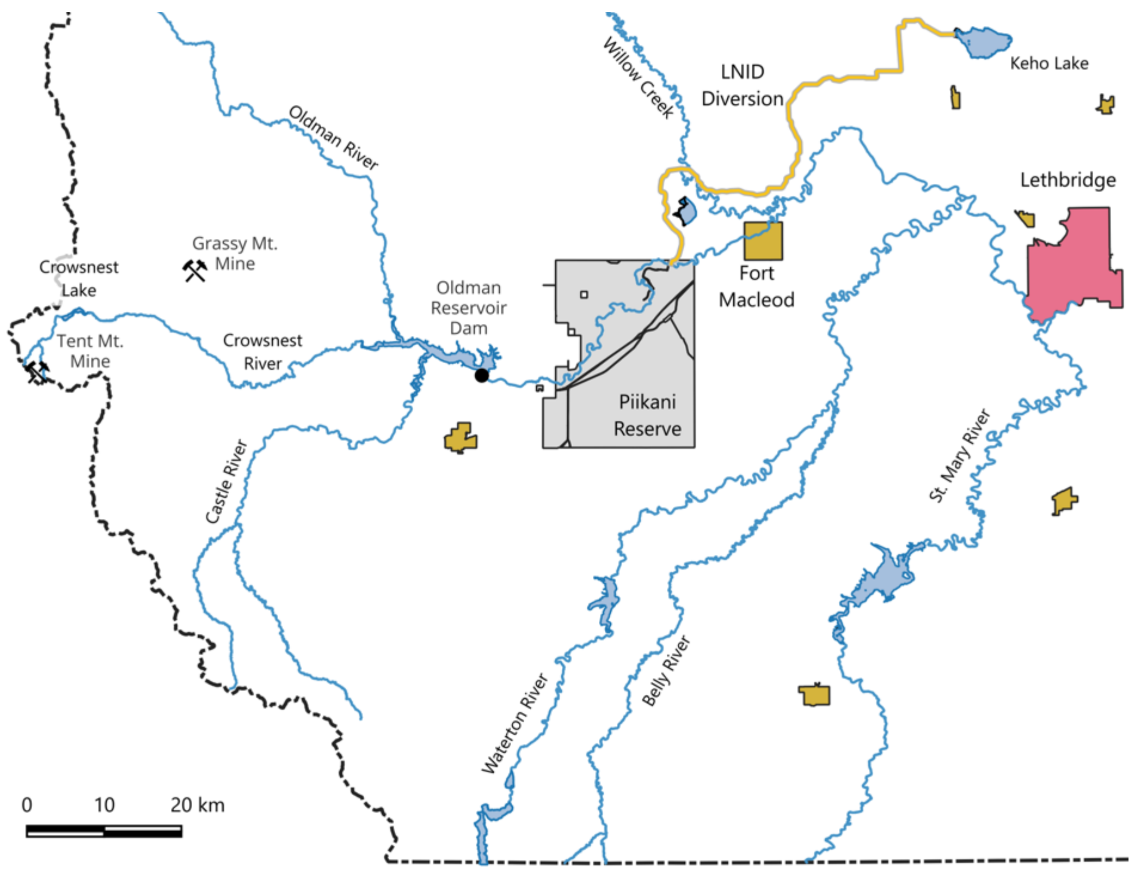
Fish were processed within a few hours of being caught. All fish were measured (fork length in mm) and sex determined (where possible). Muscle tissue of a 2x2 cm minimum size was taken from behind the dorsal fin and the skin removed. Ovaries of female fish were taken and bagged separately. Tissue samples were bagged individually in small Ziplock bags. An identifying paper label with the sample ID number was placed into each bag with the tissue. Tissue samples were frozen within an hour of removal and kept frozen until laboratory analysis at Mount Royal University, Calgary.

Laboratory protocols involved the use of approximately one gram (wet weight) of fish tissue (muscle) which was weighed into a microwave digestion vessel (CEM Mars 6 acid digestion system). Five mL of nitric acid (Optima grade) was added into each vessel, and these were kept under a fume hood overnight. Five mL of deionized water was added into each vessel the next day, and vessels were loaded on the microwave digestion instrument. Each digested sample was quantitatively transferred into a 50 mL beaker and the solution evaporated to ~1 mL at 200 °C.

Finally, the solution was diluted to 10 mL with 2 per cent nitric acid for analysis and selenium was quantified using an Agilent 7900 ICP-MS. Quality assurance and quality control protocols included duplicate procedural blanks during each run, reanalysis of the calibration standards, and comparison of measured values to certified values of standard reference material 1566b Oyster tissue. All samples were analyzed as wet tissue and were converted to dry weight using species specific moisture values (brown trout: 78 per cent; mountain whitefish and rainbow trout: 80 per cent). All fish tissue selenium concentrations are reported and discussed in dry weight and as µg/g (micrograms/gram or parts per billion).

Ages were assigned to each sportfish according to size, following the age/length relationship found in Fitch (1978). No aging information was available for non-sport species.

Figure 1. Map of the Study Area



Results

Five fish species were collected as part of a fish rescue effort in the LNID main canal—rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), mountain whitefish (*Prosopium williamsoni*), white sucker (*Catostomus commersoni*), and longnose sucker (*Catostomus catostomus*). A total of 38 fish were analysed for selenium levels in tissue and ovaries. (Figure 2, Tables 1, 2).

Of the sportfish species, 33 percent of the fish had selenium tissue concentrations greater than the Alberta threshold for protection of aquatic life of 4.0 µg/g, as well as the guideline for fish consumption—one of the seven brown trout, two of the 14 rainbow trout and all six of the mountain whitefish.

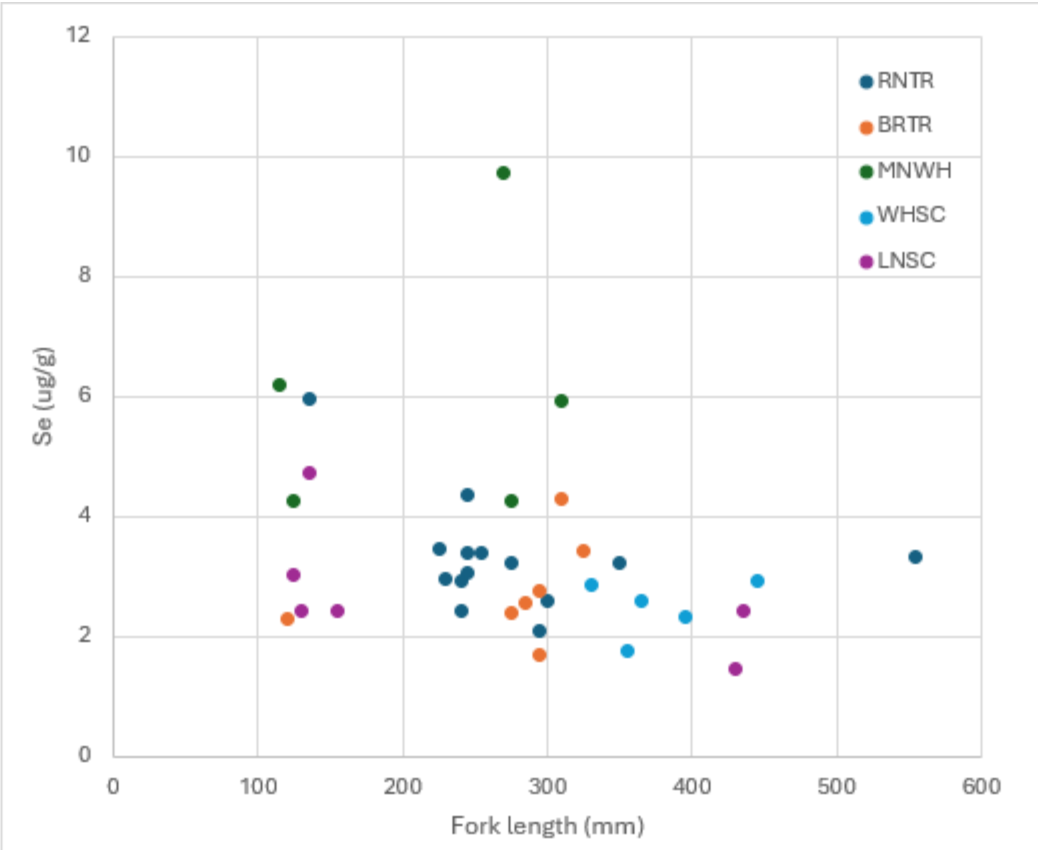
Selenium concentrations in rainbow trout tissue ranged from 2.076 to 5.964 µg/g, with a mean of 3.306. In brown trout the range was 1.696 to 4.285 µg/g, with a mean of 2.774. For mountain whitefish the range was 4.238 to 9.727 µg/g, with a mean of 6.020.

Of the non-sport species, only one fish (a longnose sucker) had selenium concentrations in tissue greater than the aquatic health guideline. For white sucker the range in selenium concentrations was 1.744 to 2.931 µg/g, with a mean of 2.483. For longnose sucker the range was 1.436 to 4.710 µg/g, with a mean of 2.740.

Only three females were collected, one rainbow trout, one white sucker, and one longnose sucker. Ovaries were collected and analyzed separately. For the egg selenium results, the one rainbow trout (555 mm in size) sample of eggs measured was 15.8 µg/g. Yet that trout did not display high selenium tissue levels. The other two species (both sucker species) had egg selenium concentrations of 6.7 µg/g. For ovary concentrations BC has set a guideline of 11 µg/g, Environment and Climate Change Canada has set a guideline of 14.7 µg/g, and the US Environmental Protection Agency has set a criterion of 15.1 µg/g.

No fish collected had any external abnormalities. The sample sizes were too small to draw connections between selenium concentrations and species (with the possible exception of mountain whitefish) as well as with fish size, age, and sex.

Figure 2. Range of selenium results for Oldman River fish



RNTR- rainbow trout, BRTR-brown trout, MNWH- Rocky mountain whitefish, WHSC- white sucker, LNSC- longnose sucker.

Table 1. Selenium concentrations in eggs

Species[1]	Fork length (mm)	Selenium (µg/g)	Selenium threshold exceeded[2]
RNTR	555	15.76	Y
WHSC	445	6.761	N
LNSC	435	6.782	N

[1]RNTR- rainbow trout, WHSC-white sucker, LNSC-longnose sucker. [2]BC- 11 µg/g: ECCC-14.7 µg/g: US EPA- 15.1 µg/g

Table 2. Summary of Oldman River species, size, age, sex, and selenium concentrations in fish tissue.

Species[1]	Fork length (mm)	Age	Sex	Selenium (µg/g)	Exceeds threshold[2]
RNTR	135	1	na	5.964	Y
RNTR	225	2	M	3.435	N
RNTR	230	2	M	2.947	N
RNTR	240	2	M	2.910	N
RNTR	240	2	M	2.412	N
RNTR	245	2	M	3.051	N
RNTR	245	2	M	4.356	Y
RNTR	245	2	M	3.392	N
RNTR	255	3	M	3.393	N
RNTR	275	3	M	3.229	N
RNTR	295	3	M	2.076	N
RNTR	300	3	M	2.601	N
RNTR	350	5	M	3.207	N
RNTR	555	8	F	3.308	N
BRTR	120	1	na	2.299	N
BRTR	275	3	M	2.400	N
BRTR	285	3	M	2.567	N
BRTR	295	4	M	2.748	N
BRTR	295	4	M	1.696	N
BRTR	310	4	M	4.285	Y
BRTR	325	4	M	3.426	N
MNWH	115	1	na	5.815	Y
MNWH	125	1	na	6.170	Y
MNWH	270	5	M	4.251	Y
MNWH	275	5	M	9.727	Y
MNWH	310	6	M	4.238	Y
MNWH	325	6	M	5.920	Y
WHSC	330	na	M	2.844	N
WHSC	355	na	M	1.744	N
WHSC	365	na	M	2.594	N
WHSC	395	na	M	2.303	N
WHSC	445	na	F	2.931	N
LNSC	125	na	na	3.028	N
LNSC	130	na	na	2.426	N
LNSC	135	na	na	4.710	Y
LNSC	155	na	na	2.430	N
LNSC	430	na	M	1.436	N
LNSC	435	na	F	2.408	N

[1]RNTR- rainbow trout, BRTR-brown trout, MNWH- Rocky mountain whitefish, WHSC- white sucker, LNSC- longnose sucker. [2]Alberta aquatic health/consumption guideline-4.0 µg/g dry weight

Discussion

This was a reconnaissance level initiative to determine if selenium concentrations in fish tissue in the Oldman River warrant further investigations in this watershed. Fish of five species were collected as part of a fish rescue operation in the LNID main canal in October of 2025 and tissue samples were subsequently analyzed by the Mount Royal University laboratory in Calgary. The sample size of fish is low (38), yet the results provide warning signals of selenium impacts extending further down in the watershed from legacy coal mines.

Ten of the fish (nine sportfish species and one non-game species) showed selenium concentrations greater than the threshold for protection of aquatic life which suggests those consuming fish from the Oldman River downstream of the Oldman dam might be at risk.

Presumably, the fish collected and sampled were resident in the reach of the Oldman River downstream of the Oldman dam and upstream of the LNID main canal diversion structure. Part of the river reach is within the boundaries of the Piikani Nation. Both the Oldman dam and the diversion structure block upstream movement of fish since there are no fish passage facilities at either.

There may be some movement of fish downstream via the spillway at the Oldman dam, when it is operational. However, the spillway is only periodically operated, roughly once every three to five years (Terrence Lazarus, former operations manager, personal communication). Successful fish passage through diversion tunnels at the dam is unlikely since the flow passes through the blades of hydropower turbines, water pressures are high, and decompression would result in mortality. It seems likely that the Oldman dam is a barrier to downstream fish movement and the fish collected were resident in the reach of the river downstream of the dam.

Fish are “lost” to the system at the LNID diversion structure since fish passage back upstream in the canal is blocked by structural impediments and lack of flow when the irrigation season ends and water is no longer diverted. Fish cannot overwinter in the canal.

The species composition of fish collected in the LNID canal was consistent with fish inventories of the Oldman River downstream of the Oldman dam reported by Bryski (2023).

It seems unlikely that there is significant fish movement downstream from the headwaters, past the Oldman dam, that would account for elevated selenium levels in the fish collected. However, waterborne selenium movement would not be impeded by the Oldman reservoir and dam, and upstream sources could be influencing downstream fish populations.

Issues with selenium contamination of fish have been documented in the headwaters of the Oldman watershed, notably in tributaries to the Crowsnest River and in Crowsnest Lake, linked to legacy coal mines.

Hatfield Consultants (2016), as part of an environmental impact assessment of the proposed (and legacy) Grassy Mountain coal mine, provided data on high selenium concentrations in brook trout (*Salvelinus fontinalis*), rainbow trout, and rainbow/cutthroat trout hybrids ranging from 4.5 to 10.4 µg/g from Blairmore and Gold creeks.

Cooke, et al (2026) provided results for selenium in fish tissue from Crowsnest Lake, affected by the legacy Tent Mountain coal mine, that ranged from 6.0 to 22 µg/g for brown trout, 12 to 20 µg/g for lake trout, and 5.0 to 26 µg/g for mountain whitefish. Selenium levels vastly exceeded thresholds.

These high concentrations from Crowsnest Lake fish were contrasted with that of fish from 29 Alberta lake populations, where none of the lakes had active or legacy coal mines within their watersheds. Natural baseline selenium concentrations were low in these lakes, ranging from 0.2 to 2.5 µg/g with means of 0.3 to 1.5. Data on these reference lakes is found in Cooke (ibid)) and represent 840 measurements of selenium in eight species of fish from lakes across Alberta.

There are few other benchmarks available to allow comparison with results from fish in the Oldman River below the Oldman dam. However, if the mean selenium levels in fish from 29 Alberta lakes represent natural background conditions then mean species concentrations ranging from 2.74 to 6.02 for Oldman River fish would be considered high. This suggests a broader selenium problem for this reach of the Oldman headwaters.

Mackay (2006) observed that selenium levels in muscle tissue were noticeably higher in fish collected downstream of two coal mining areas of the upper McLeod River watershed, compared to reference sites unaffected by mining. At a minimum this study of selenium levels in Oldman River fish points out that waterborne selenium has moved from upstream sources downstream to contaminate fish below the Oldman Dam. In addition to the toxicity risks to fish and to population sustainability, human health concerns exist over consuming fish high in selenium.

The results of this reconnaissance study suggest a more systematic and comprehensive examination of selenium is urgently required to connect the dots between legacy coal mines and contamination of fish and aquatic invertebrates for the larger watershed. This should include, at a minimum, fish tissue analysis for selenium over the length of the Crowsnest River, in the Oldman Reservoir, and the Oldman River downstream to Lethbridge. Sampling should also include fish populations in the Castle and upper Oldman rivers to provide biological baselines for comparisons.

Lemly (1993) recommended obtaining measurements of selenium concentrations present in water, food-chain organisms, and fish and wildlife tissues in order to formulate a comprehensive and conclusive assessment of the overall selenium status and health of aquatic ecosystems.

Concentrations of selenium in water higher than 2 µg/l should be considered hazardous to the health and long-term survival of fish and wildlife populations due to the high potential for food-chain bioaccumulation, dietary toxicity, and reproductive effects. This level, currently a guideline, is empirically derived yet is not part of effluent limits in Alberta.

More comprehensive monitoring is required since in some cases, as Lemly (ibid) points out, ultra-trace amounts of dissolved and particulate organic selenium may lead to bioaccumulation and toxicity even when total waterborne concentrations are less than 1 µg/l. This may be the case in Blairmore and Gold creeks. Food-chain organisms such as zooplankton, benthic invertebrates, and certain forage fishes can accumulate up to 30 µg/g dry weight selenium. Aquatic invertebrates should form part of selenium examination because of their role in fish diet and bioaccumulation.

The biological effects threshold for whole body health and reproductive success of freshwater fish is 4 µg/g. Toxicologists point out the most precise way to evaluate potential reproductive impacts to adult fish populations is to measure selenium concentrations in gravid ovaries and eggs. This single measure integrates waterborne and dietary exposure, and allows an evaluation based on the most sensitive biological endpoint.

Although only one rainbow trout female was collected, levels of selenium in eggs were over the US EPA threshold of 15.1 µg/g. This signals issues with reproductive success and reduced or failed recruitment with selenium exposure, even though the parent fish appeared unaffected. In research done by Casey and Siwik (2000) there was a greater concentration of selenium in eggs compared to muscle tissue of the same fish. Pilgrim (2012) found survival of larvae and swim-up success of rainbow trout decreased with increasing egg selenium concentrations.

A more fulsome examination of selenium impacts to these ecosystems is required to assess the current extent, gradients, levels, and sources. Not only is this required for any possible remediation of existing selenium impacts but also for comprehensive environmental impact assessments leading to informed decisions on future land uses, including coal mining. It should be evident this information is required to provide robust notification to anglers, consumers of fish (including those on the Piikani Nation), and other water users from these watersheds.

Acknowledgements

This project was initiated and supported by Crowsnest Headwaters. Jim Lucas, Crowsnest Headwaters, created the map for the study watershed. Freshwater Conservation Canada staff (Elliot Lindsay) and volunteers collected the fish for sampling and FCC staff (Lesley Peterson) arranged the necessary permission for fish sampling. Dr Andrew Hurly, Emeritus professor, University of Lethbridge, assisted with fish collection and tissue preparation. Alexandria Farmer, Department of Biology, Mount Royal University, facilitated laboratory analysis of fish tissue samples. Funding for lab reagents was provided by an NSERC Discovery Grant awarded to Dr Jon Mee, Professor and Chair, Department of Biology (MRU). We thank three anonymous reviewers for their comments.

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Reference for this report:

Fitch, Lorne, and Jon Mee. 2026. Analysis of Selenium Tissue Concentrations in Multiple Fish Species of the Oldman River. Prepared for Crowsnest Headwaters, Crowsnest, Alberta. https://www.crowsnestheadwaters.ca.