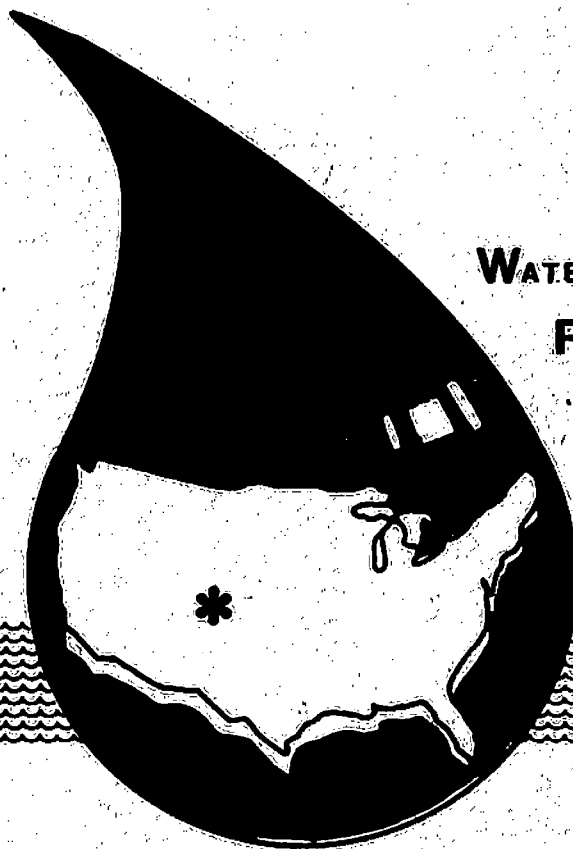


HARRIS

**METAL CONCENTRATIONS IN FISH AT
CURECANTI NATIONAL RECREATION AREA,
GUNNISON, COLORADO**



WATER

RESOURCES

FIELD

SUPPORT

LABORATORY

WRFSL PROJECT REPORT NO.83-3-P



**WATER RESOURCE FIELD SUPPORT LABORATORY
NATIONAL PARK SERVICE
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80523**

This report presents the results of a study conducted by the National Park Service Water Resources Field Support Laboratory. It is intended primarily for use by the particular Park Service area or areas that are addressed in the report but may be of interest to other persons working in water resources management. Requests for copies of this report or other WRFSL documents should be addressed to:

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**METAL CONCENTRATIONS IN FISH AT CURECANTI NATIONAL RECREATION AREA,
GUNNISON, COLORADO**

WRFSL Report No. 83-3-P

Submitted to

**Curecanti National Recreation Area
Gunnison, Colorado 81230**

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December 1983

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	ii
ACKNOWLEDGMENTS	iii
INTRODUCTION	1
SPECIES OF FISH SAMPLED	3
FIELD AND LABORATORY METHODS	4
DATA PRESENTATION	6
Core Data	6
Fish Flesh Concentrations	6
Principal References	6
RESULTS AND DISCUSSION	7
Species Differ in Their Accumulation Patterns	7
Certain Parts of the Fish Accumulate the Chemicals	7
Human Consumption of the Fish	9
CONCLUSIONS	11
REFERENCES	24
APPENDIX A	27
APPENDIX B	30
APPENDIX C	31

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Concentrations of 11 chemical constituents found in five parts of four species of fish	14
2	A general comparison of element concentrations in Curecanti fish flesh	18
3	A guide to information found in literature references	22

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INTRODUCTION

This report summarizes the results of the chemical analyses of fish collected from the Gunnison River, which is the major stream flowing into the Blue Mesa Reservoir in the Curecanti National Recreation Area. Curecanti NRA is located near Gunnison, Colorado and is administered by the National Park Service, U.S. Department of the Interior. One purpose of collecting and analyzing the fish was to provide an index of the environmental status of the Park's aquatic life, for future reference, to detect any degradation that might occur later. A secondary purpose was to compare chemical element concentrations--especially metals--in Gunnison River (Curecanti) fish with those found in fish from other water bodies, as reported in the literature, to see if the levels are high or low at this point, compared to other sites. The third objective was to see if metal levels in the fish flesh appeared to be safe for human consumption.

Fish studies appropriate for comparison with Curecanti NRA data are not as readily available as one might expect. A relatively extensive literature review was carried out by searching the Colorado State University Library and by assistance from the U.S. Department of the Interior Library, Washington, D.C. and the Toxicology Information Response Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The library searches revealed relatively few studies on fish contaminated with metals, other than mercury, cadmium, lead, and zinc. Mercury, according to the searches, has received the most attention in the literature, from case studies of contaminated sea food in Japan in

the 1950s and from other studies, also in the U.S., during the 1970s (16,33). Cadmium, lead and zinc in food also have caused problems, for example, when cadmium contamination caused the Japanese disease called itai-itai (21,23). Industrial pollution or mining impacts can produce metal contamination in fish flesh, but Curecanti NRA at this time has little development upstream. Water quality within Curecanti NRA is threatened by proposed energy, mining and residential development. Deterioration of the existing resources could adversely affect sport fisheries.

As a number of researchers have pointed out, the uptake and accumulation of metals in fish is a complex and often confusing interaction of many factors, including a species' diet and trophic status, age, the extent of pollution of a water body and other factors. With our limited data base, we cannot expect to examine all potential factors, but we are able to highlight some of the more obvious observations from the data and draw some tentative conclusions.

SPECIES OF FISH SAMPLED

Four species of fish were captured, to represent a variety of feeding habits: rainbow trout (Salmo gairdneri), brown trout (Salmo trutta), kokanee salmon (Oncorhynchus nerka) and white sucker (Catostomus commersoni). These four species of fish accumulate their chemical concentrations at somewhat different points in the food chain.

Brown trout and rainbow trout are predators, eating aquatic and terrestrial insects, worms and crustaceans (35). As they grow larger than about 9-12 inches, they consume more fish (34) and take in metal concentrations from higher levels of the food chain. Rainbow trout move around more than most trout, such as the browns, and take in food from a wide range of locations. Brown trout reportedly tolerate warmer waters than most other trout, and prefer pools when in rivers. In addition, brown trout can achieve up to 65 percent of their year's growth during spring insect hatches (34). As a result, springtime chemical concentrations in waters play a major role in the types and amounts of elements they accumulate. Kokanee salmon, like rainbow and brown trout, are game fish. They are a small, inland variety of the sockeye salmon and are predators, seeking out larvae and insects for food. Finally, white suckers are bottom feeders, foraging the river and reservoir bottom eating aquatic plants, insects, worms and small mollusks; in a river they stay at the edge of currents or in pools (35). White suckers may be preyed upon by the three predators above, and, strictly speaking, are lower on the food chain. However, they are bottom feeders, no doubt being exposed to elements picked up by snails and other creatures that they consume.

FIELD AND LABORATORY METHODS

A total of 50 fish were collected on October 19 and 20, 1981, including seven rainbow trout, twelve brown trout, fifteen kokanee salmon and sixteen white suckers. The fish were collected by electrofishing between two locations: Twin Bridges, which is near Gunnison, Colorado and Cooper Ranch, which is just upstream of Blue Mesa Reservoir. All collections were made by Curecanti NRA staff with assistance from the Colorado Division of Wildlife.

Following the collections, the fish were transported to a local fish hatchery where they were weighed, individually bagged, properly identified and placed in a freezer. The fish were later transported to Fort Collins, Colorado where the specific parts of the fish to be analyzed were removed, individually bagged and returned to a freezer. The various parts were later freeze dried, using lyophilization procedures, and shipped to the Institute of Ecology of the University of Georgia, Athens for the chemical and data analyses. Mercury was analyzed by cold vapor atomic absorption and all remaining elements were analyzed using an inductively-coupled plasma emission spectrophotometer (ICP). Detection limits and methods are summarized in Appendix B.

Five parts of each fish were analyzed: 1) kidneys, 2) liver, 3) flesh, 4) scales and 5) gut content. Each of these parts was analyzed for twenty elements: mercury, aluminum, boron, calcium, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, sodium, nickel, phosphorus, lead, silicon, zinc, molybdenum, strontium and barium. Of these elements, the following eleven were selected from a toxicity to humans viewpoint and were the focus of this study:

Aluminum	(Al)	Mercury	(Hg)
Cadmium	(Cd)	Molybdenum	(Mo)
Chromium	(Cr)	Nickel	(Ni)
Cobalt	(Co)	Strontium	(Sr)
Copper	(Cu)	Zinc	(Zn)
Lead	(Pb)		

Data on concentrations of the other nine elements also are available and on file at Curecanti NRA or at WRFSL, Fort Collins, Colorado.

DATA PRESENTATION

Core Data

Core data from the Curecanti NRA (Gunnison River) fish analyses are presented in Table 1, which shows the main constituents found in the five fish parts analyzed for each of the four species of fish. The table also shows the mean, standard deviation and median for each group of analyses.

Fish Flesh Concentrations

Table 2 is a comparison of chemical concentrations in Gunnison River (Curecanti NRA) fish flesh to concentrations that have been found in fish flesh in other geographic areas. Columns 1 and 2 of Table 2 show the general range of concentrations of eleven elements found in various kinds of fish flesh, as described in the literature. Some of the references presented fish flesh concentrations in wet weight and some in dry, so for this reason both values are used in Table 2. All measurements are reported in parts per million (ppm). Parts per million are essentially synonymous to micrograms of metal per gram of fish flesh ($\mu\text{g/g}$) or to milligrams of metal per kilogram of fish, (mg/kg). Column 3 presents the element concentrations, in ppm, that were found in the Curecanti NRA fish samples. Column 4 shows the amount of element contained in one pound (0.454 kg) of wet Curecanti NRA fish sample flesh in μg . Finally, Column 5 presents literature values for the average daily human consumption of an element.

Principal References

A numerical guide to references that were used to compile Table 2 may be found in Table 3. The numbers appearing in Table 3 match those of the

Reference section of the report. For example, one of the references used to determine the normal flesh content of mercury in rainbow trout is number 16 which corresponds to number 16 in the reference list, "Environmental Mercury Contamination" by R Hartung and B. D. Dinman.

RESULTS AND DISCUSSION

Species Differ in Their Accumulation Patterns

Studies in the literature (e.g., 27) confirm that species are individualistic in how they accumulate metals. The information in Table 1 shows that the four species from the Gunnison River of Curecanti NRA also vary in the manner in which they accumulate metals. For example, kokanee salmon do not show the relatively high aluminum levels in their gut, as do the other three species, nor do they accumulate as much chromium. Rainbow trout seem to accumulate less lead than the other three species. Reasons for these differences partly are due to the feeding habits of the species and their life habits (areas of rivers where they live, etc.).

Certain Parts of the Fish Accumulate the Chemicals

Many metals tend to accumulate in fish livers and kidneys, rather than in the edible flesh (37,38). As seen in Table 1, cadmium concentrations are very small in fish flesh at Curecanti NRA, but are higher in the livers and kidneys. Cobalt, zinc and especially copper follow the tendency also to accumulate in internal organs, as does molybdenum to some extent.

Mercury, on the other hand, does not accumulate particularly in the kidneys or livers, but is spread more evenly to all body parts. Nickel

likewise does not accumulate in any particular part, according to these data. Other studies in the literature confirm that mercury usually does not vary appreciably among different fish parts (32). White suckers are an exception, however, as they appear to accumulate more mercury in the flesh than the other species.

The digestive tract is where the more abundant metals aluminum and zinc are present in highest concentrations, while these metals are found in relatively low concentrations in other internal organs. It should be noted that Al, Zn and Cu make up part of the molecule of several of the digestive enzymes found in fish digestive tracts, so can be expected to occur naturally. For instance, zinc does not readily accumulate in the kidneys and livers, according to some researchers (38), and likewise ingested copper has been observed to pass through the fish, as revealed in high concentrations in the gut content (36). In the Curecanti NRA (Gunnison River) data, aluminum and zinc concentrations are much higher in the gut content than any other part of the fish (in seven out of eight cases of Al and Zn in Table 1), indicating that these common metals are mostly passing through the fish or in enzyme molecules there. Copper also shows some tendency toward high concentrations in the gut, but not as distinctly as aluminum and zinc.

Strontium, the only alkaline earth among the metals discussed in this paper, is unique in accumulating particularly in the scales. This may be due to strontium's chemical similarity to calcium, which is normally the major component in scales, as also shown in the Blue Mesa data. Nickel and zinc also show some tendency to accumulate in scales. Zinc

is relatively more common in all the fish parts than other metals, since it is a common element (Table 1).

Human Consumption of the Fish

The chemical element concentrations in the Curecanti NRA fish have been reviewed from a human health viewpoint, comparing the amount of an element ingested by eating Curecanti NRA fish to: (i) the average amount of a metal typically taken in by a human in daily food and water, or (ii) the levels of intake established as "safe" by public health agencies. Average daily human consumption data could not be found for all the elements. We also found human health criteria for mercury and cadmium only.

The maximum concentration of mercury in fish flesh has been set at 0.5 ppm wet weight and daily intake of mercury should not exceed 30 μg for adults. Daily intake of cadmium should be limited to 70 μg from all sources.

The values presented in Table 2 confirm that the concentrations of chemical elements found in Curecanti NRA (Gunnison River) fish flesh are:

- (i) similar to or in most cases lower than concentrations found in fish flesh in studies in other areas, aluminum being an exception, as discussed below;
- (ii) well below allowable public health limits as set for mercury and cadmium for the three game fish; mercury levels are marginal for white suckers, as discussed below;

- (iii) such that consumption of one pound (0.454 kg) of Curecanti fish flesh causes no concern as compared to average human chemical consumption levels.

The average intake of aluminum, based on the consumption of one pound (0.454 kg) of Curecanti NRA brown trout flesh, is 503.68 μg , far above the average human daily consumption of 10-100 μg given in the literature. However, no evidence has yet been found to show that aluminum in concentrations usually coming from water supplies, cooking utensils, or baking powders is harmful to human beings (25); therefore, aluminum in public food or water supplies is normally not considered a health hazard (25). McKee and Wolf also point out that aluminum is common in fruits and vegetables, for example, with one pound (0.454 kg) of peaches containing as much as 1,678 μg of aluminum, or about three times as much as a pound (0.454 kg) of the Gunnison River brown trout in our data. There is, therefore, no reason to believe that the Gunnison River brown trout aluminum concentrations--although somewhat higher than might be expected--present any hazard. Aluminum levels in the other three fish species are much lower than in brown trout.

The average intake of mercury based on the consumption of one pound of white sucker flesh is 65.2 μg , which exceeds the recommended maximum safe level of intake for humans of 30 μg . This maximum level is based on a continuous daily intake, rather than a single event intake. More importantly, the mean mercury flesh content level in white suckers is 0.46 ppm dry weight or approximately 0.15 ppm fresh or wet weight, which is well below the common mercury limit of 0.5 ppm wet weight (32). The

white sucker is not a game fish, hence consumption by most fishermen is not a concern. Mean flesh concentrations of the other three (game) species are much lower and not a health safety concern, according to our data.

Zinc concentrations are high in the flesh compared to all other metals (Table 1); however, zinc concentrations are still not at levels to present a health risk (Table 2).

CONCLUSIONS

In summary, the concentrations of chemicals found in the fish from the Gunnison River in Curecanti NRA generally fall into the ranges that have been found in other studies. No Curecanti NRA fish concentrations appear to be high enough to cause concern about human health. The amount of chemical elements in one pound (0.454 kg) of Gunnison River, Curecanti fish flesh, compared to the typical daily intake of elements by humans, indicates that consumption of Gunnison River fish would not result in an excessive intake of mercury, cadmium or other metals of concern from a viewpoint of toxicity to humans. Conversely, these fish should be of added Al, Co, Cu, Mn and Zn value for the levels of these elements useful in human nutrition.

Finally, this report provides some basic background or reference information for future studies on the environmental status of the water resource and toxic metal concentrations in fish found in the Blue Mesa Reservoir of Curecanti National Recreation Area. It will be important to have some follow-up monitoring of the metal levels in fish. It also would therefore be advisable, in our view, to sample at least some of

the game fish about every five years, to continue to build a better baseline of data. If, however, large scale mining, energy, residential or major industrial development should occur upstream, more intensive fish sampling would then be advisable. Curecanti NRA also is attempting to carry out routine water chemistry monitoring along the reservoir and river at this time, which is important. Any future fish analyses should include comparisons of the water chemistry with fish tissue chemistry. The relationship is important because water samples are much cheaper and easier to analyze than fish tissue; water can therefore provide an early warning index that fish could be running a risk of metal contamination.

Table 1. Concentration of 11 chemical constituents found in the five parts of four species of fish. $\bar{X}$ = mean; S = standard deviation; m = median; n = number of observation for each batch. All values parts per million (dry weight).

1 Element	2 Parts of Fish	3 Rainbow Trout n = 7		4 Brown Trout n = 12		5 Kokanee Salmon n = 15		6 White Sucker n = 16	
		$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
		m		m		m		m	
Al	Kidney	0.73 <0.25	1.92	3.49 <0.25	6.46	1.34 <0.25	4.61	1.87 <0.25	4.31
	Liver	3.31 <0.25	6.89	3.43 <0.25	6.79	0.32 <0.25	0.80	1.29 <0.25	3.20
	Flesh	0.92 <0.25	1.73	3.52 <0.25	4.39	1.34 <0.25	4.63	<0.25 <0.25	<0.25
	Scale	0.73 <0.25	1.93	1.82 <0.25	4.91	0.32 <0.25	0.69	0.83 <0.25	1.10
	Gut	18.52 16.62	12.41	39.66 38.31	15.54	1.74 <0.25	2.87	19.81 18.95	6.50
Cd	Kidney	1.61 1.81	0.94	1.51 1.60	0.57	1.07 1.00	0.49	0.95 0.84	0.92
	Liver	0.83 0.86	0.46	1.32 1.22	0.47	0.24 <0.01	0.32	0.12 <0.01	0.32
	Flesh	<0.01 <0.01	<0.01	<0.01 <0.01	<0.01	<0.01 <0.01	<0.01	<0.02 <0.01	0.07
	Scale	0.05 <0.01	0.13	0.08 <0.01	0.18	0.02 <0.01	0.09	<0.01 <0.01	<0.01
	Gut	0.96 0.58	1.15	1.33 1.75	0.59	0.39 0.49	0.36	0.41 0.22	0.47
Cr	Kidney	0.81 <0.1	1.39	2.65 2.81	1.37	<0.1 <0.1	<0.1	0.17 <0.1	0.70
	Liver	0.42 <0.1	0.88	1.39 1.62	1.04	<0.1 <0.1	<0.1	0.19 <0.1	0.78
	Flesh	<0.01 <0.01	<0.1	0.10 <0.1	0.24	<0.1 <0.1	<0.1	0.11 <0.1	0.46
	Scale	0.64 0.51	0.56	0.70 0.63	0.76	0.05 <0.1	0.19	0.06 <0.1	0.25
	Gut	0.56 0.50	0.63	1.54 1.52	0.57	<0.1 <0.1	<0.1	0.03 <0.1	0.10

Table 1. continued.

1 Element	2 Parts of Fish	3 Rainbow Trout n = 7		4 Brown Trout n = 12		5 Kokanee Salmon n = 15		6 White Sucker n = 16	
		$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
		m		m		m		m	
Co	Kidney	1.57 1.95	0.78	1.61 1.54	0.65	1.31 1.34	0.25	0.81 0.46	0.88
	Liver	1.44 1.49	0.74	1.42 1.43	0.34	0.84 0.75	0.61	0.50 0.38	0.66
	Flesh	<0.01 <0.01	<0.01	0.03 <0.01	0.10	<0.01 <0.01	<0.01	0.05 <0.01	0.22
	Scale	0.10 <0.01	0.25	0.05 <0.01	0.13	0.12 <0.01	0.25	<0.01 <0.01	<0.01
	Gut	1.68 1.42	0.89	2.95 2.83	0.87	0.72 0.70	0.53	1.74 1.90	0.62
Cu	Kidney	2.34 2.57	1.31	2.65 2.56	1.88	2.66 2.54	0.60	1.20 0.82	1.38
	Liver	13.81 14.83	5.29	21.49 20.73	5.17	9.60 8.73	3.87	3.68 3.36	1.53
	Flesh	0.91 0.71	1.12	0.48 0.60	0.51	1.43 1.46	0.83	0.65 0.59	0.68
	Scale	1.53 1.72	0.57	1.47 1.57	0.85	1.86 1.76	1.13	1.14 1.21	0.72
	Gut	3.81 3.42	1.34	3.84 3.76	0.96	3.28 2.68	1.45	3.71 3.51	0.78
Pb	Kidney	<0.75 <0.75	<0.75	2.20 <0.75	4.58	0.14 <0.75	0.53	1.04 <0.75	2.41
	Liver	<0.75 <0.75	<0.75	0.18 <0.75	0.62	0.15 <0.75	0.41	0.25 <0.75	0.99
	Flesh	<0.75 <0.75	<0.75	<0.75 <0.75	<0.75	0.07 <0.75	0.26	0.11 <0.75	0.44
	Scale	<0.75 <0.75	<0.75	0.36 <0.75	1.24	0.22 <0.75	0.57	<0.75 <0.75	<0.75
	Gut	<0.75 <0.75	<0.75	2.15 2.15	1.32	0.38 <0.75	0.72	0.46 <0.75	0.73

Table 1. continued.

1 Element	2 Parts of Fish	3 Rainbow Trout n = 7			4 Brown Trout n = 12			5 Kokanee Salmon n = 15			6 White Sucker n = 16		
		$\bar{X}$	S		$\bar{X}$	S		$\bar{X}$	S		$\bar{X}$	S	
		m			m			m			m		
Hg	Kidney	0.12	0.19	<0.001	0.13	0.19	0.08	0.46	0.15	0.49	0.10	0.11	0.06
	Liver	0.12	0.20	<0.001	0.19	0.41	0.07	0.33	0.15	0.30	0.09	0.09	0.05
	Flesh	0.09	0.13	<0.001	0.18	0.35	0.08	0.23	0.08	0.23	0.46	0.31	0.26
	Scale	0.01	0.02	<0.001	0.02	0.05	0.01	0.07	0.03	0.06	0.09	0.09	0.06
	Gut	0.01	0.02	<0.001	0.04	0.03	0.04	0.28	0.06	0.29	0.09	0.10	0.07
Mo	Kidney	0.96	0.08	<0.1	2.24	2.36	1.51	0.35	0.63	<0.1	0.47	1.36	<0.1
	Liver	1.27	0.45	0.63	2.01	1.74	0.73	0.31	0.61	<0.1	0.29	0.85	<0.1
	Flesh	0.81	0.43	0.66	1.00	0.75	0.71	0.03	0.13	<0.1	0.16	0.44	<0.1
	Scale	0.73	0.13	<0.1	0.76	0.99	0.24	0.24	0.51	<0.1	0.39	0.53	<0.1
	Gut	1.16	0.49	1.59	1.37	0.94	0.69	0.60	0.86	<0.1	0.44	0.70	<0.1
Ni	Kidney	1.08	2.05	<0.1	3.60	2.68	3.61	0.15	0.39	<0.1	0.95	2.76	<0.1
	Liver	0.51	1.01	<0.1	1.68	1.62	1.97	0.22	0.86	<0.1	0.38	1.22	<0.1
	Flesh	<0.1	<0.1	<0.1	0.27	0.51	<0.1	0.19	0.64	<0.1	0.18	0.70	<0.1
	Scale	3.17	1.93	3.41	1.57	1.25	1.24	1.78	2.95	<0.1	0.51	0.81	<0.1
	Gut	0.55	0.80	<0.1	1.55	1.10	1.51	2.93	5.68	<0.1	0.05	0.20	<0.1

Table 1. continued.

1 Element	2 Parts of Fish	3 Rainbow Trout n = 7		4 Brown Trout n = 12		5 Kokanee Salmon n = 15		6 White Sucker n = 16	
		$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
		m		m		m		m	
Sr	Kidney	0.27 <1.0	0.49	1.06 0.87	0.79	0.30 <1.0	0.35	0.23 <1.0	0.69
	Liver	0.10 <1.0	0.28	0.35 0.41	0.37	0.03 <1.0	0.13	0.54 <1.0	0.78
	Flesh	0.58 0.62	0.33	0.50 0.51	0.15	0.42 <1.0	0.65	0.43 3.04	0.55
	Scale	4.00 3.93	0.74	3.63 3.85	0.73	2.20 2.64	0.82	6.20 4.27	1.74
	Gut	2.43 1.75	1.46	3.41 3.38	0.91	1.11 1.08	0.31	3.38 1.04	0.85
Zn	Kidney	12.35 10.10	6.60	14.20 12.06	10.12	12.09 11.47	4.54	14.23 11.80	10.80
	Liver	11.64 11.47	2.03	11.50 11.30	1.80	12.35 11.79	3.64	10.01 9.88	2.31
	Flesh	5.72 4.82	2.36	6.23 5.00	3.60	3.31 3.48	2.87	6.00 5.85	1.20
	Scale	12.24 12.38	2.42	11.58 11.30	2.54	10.07 11.88	5.79	14.02 13.80	2.85
	Gut	20.36 20.31	4.49	20.24 19.50	3.68	69.41 70.85	15.63	11.44 11.34	1.82

Al = aluminum

Cd = cadmium

Cr = chromium

Co = cobalt

Cu = copper

Pb = lead

Hg = mercury

Mo = molybdenum

Ni = nickel

Sr = strontium

Zn = zinc

Note: < indicates that the value is less than the analytical detection limit for the element.

Table 2. A general comparison of element concentrations in Curecanti fish flesh to concentrations that have been found in fish in other studies, amount of element contained in one pound (0.454 kg) of fresh Curecanti fish flesh, and typical daily element consumption by humans as reported in the literature; RT = Rainbow Trout, BT = Brown Trout, KS = Kokanee Salmon, WS = White Sucker, $\bar{X}$ = mean, S = standard deviation, m = median.

Element	1 Concentrations of Elements for Fish Flesh Literature Examples ^{1/}		3 Element Concentra- tions, ppm, dry Weight for the Curecanti Fish Samples		4 Amount of Element (ug) Contained in 1 lb (0.454 kg) of Wet Curecanti Fish Sample Flesh ^{4/}	5 Typical (ug) Daily Consumption by Human (from literature) ^{2/}
	Wet Weight, ppm examples	Dry Weight, ppm examples				
			$\bar{X}$	S m		
Al	see <u>3/</u>	see <u>3/</u>	RT	0.92	1.73	10-100
				<0.25	131.64	
			BT	3.52	4.39	
				<0.25	503.68	
			KS	1.34	4.63	
Cd	0.01 - 0.1	see <u>3/</u>		<0.25	191.74	25-60 (70 per day limit recommended)
				<0.25	<0.25	
			WS	<0.25	<35.77	
			RT	<0.01	<0.01	
				<0.01	<1.43	
			BT	<0.01	<0.01	
				<0.01	<1.43	
			KS	<0.01	<0.01	
				<0.02	<1.43	
			WS	0.02	0.07	
				<0.01	2.86	

Table 2. continued

Element	1 Concentrations of Elements for Fish Flesh Literature Examples ^{1/}		3 Element Concentra- tions, ppm, dry Weight for the Curecanti Fish Samples		4 Amount of Element (ug) Contained in 1 lb (0.454 kg) of Wet Curecanti Fish Sample Flesh ^{4/}	5 Typical (ug) Daily Consumption by Human (from literature) ^{2/}		
	Wet Weight, ppm examples	Dry Weight, ppm examples		$\bar{X}$	S			
				m				
Cr	0.02 - 1.0	0.1 - 2.75	RT	<0.1	<0.1	30-100		
					<0.1			
			BT	0.10	0.24		<14.31	
					<0.1		<14.31	
			KS	<0.1	<0.1		<14.31	
			WS	0.11	0.45			
					<0.1		15.74	
			RT	<0.01	<0.01		5-40	
					<0.01			<1.43
			BT	0.03	0.10			4.29
Co	see <u>3/</u>	0.01 - 1.50	KS	<0.01	<0.01	<1.43		
					<0.01	71.55		
			WS	0.50	0.22			
					<0.01			
			RT	0.91	1.12	1000-3000		
		0.71	130.21					
BT	0.48	0.51	67.68					
Cu	0.2 - 0.3	5.2 - 6.5	KS	1.43	0.83		204.62	
					1.46		93.01	
			WS	0.65	0.68			
					0.59			

Table 2. continued

Element	1 Concentrations of Elements for Fish Flesh Literature Examples ^{1/}		3 Element Concentra- tions, ppm, dry Weight for the Curecanti Fish Samples		4 Amount of Element (ug) Contained in 1 lb (0.454 kg) of Wet Curecanti Fish Sample Flesh ^{4/}	5 Typical (ug) Daily Consumption by Human (from literature) ^{2/}
	Wet Weight, ppm examples	Dry Weight, ppm examples				
			$\bar{X}$	S		
			m			
Pb	0.01 - 0.35	0.4 - 0.55	RT	<0.75	<0.75	200-300
					<0.75	
			BT	<0.75	<0.75	
					<0.75	
			KS	0.07	0.26	
					<0.75	
Hg	0.01 - 0.5 (0.5 considered the "permissible" upper limit) ^{5/}	1.3	WS	0.11	0.44	1-20 (should not exceed about 30 for adults)
					<0.75	
			RT	0.09	0.13	
					0.001	
			BT	0.18	0.35	
					0.078	
Mo	see <u>3/</u>	see <u>3/</u>	KS	0.23	0.08	100-500
					0.23	
			WS	0.46	0.31	
					0.26	
			RT	0.81	0.43	
					0.66	
			BT	1.00	0.75	
					0.70	
			KS	0.03	0.13	
					<0.1	
			WS	0.16	0.44	
					<0.1	

Table 2. continued

Element	1 Concentrations of Elements for Fish Flesh Literature Examples ^{1/}		3 Element Concentra- tions, ppm, dry Weight for the Curecanti Fish Samples		4 Amount of Element (ug) Contained in 1 lb (0.454 kg) of Wet Curecanti Fish Sample Flesh ^{4/}	5 Typical (ug) Daily Consumption by Human (from literature) ^{2/}
	Wet Weight, ppm examples	Dry Weight, ppm examples				
			$\bar{X}$	S		
			m			
Ni	see <u>3/</u>	0.33 - 1.03	RT	<0.1	<0.1	
					<0.1	
			BT	0.27	0.51	
					<0.1	
			KS	0.19	0.64	<u>3/</u>
					<0.1	
			WS	0.17	0.70	
					<0.1	
					24.33	
Sr	see <u>3/</u>	see <u>3/</u>	RT	0.58	0.33	
					0.62	
			BT	0.50	0.15	<u>3/</u>
					0.51	
			KS	0.42	0.65	
					<1.0	
			WS	0.43	0.55	
					2.89	
					61.53	

Table 2. continued

Element	1 Concentrations of Elements for Fish Flesh Literature Examples ^{1/}		3 Element Concentra- tions, ppm, dry Weight for the Curecanti Fish Samples		4 Amount of Element (ug) Contained in 1 lb (0.454 kg) of Wet Curecanti Fish Sample Flesh ^{4/}	5 Typical (ug) Daily Consumption by Human (from literature) ^{2/}
	Wet Weight, ppm examples	Dry Weight, ppm examples	Element Concentra- tions, ppm, dry Weight for the Curecanti Fish Samples			
			$\bar{X}$	S		
			m			
			RT	5.72	2.36	
				4.82		818.48
			BT	6.23	3.60	
				5.00		891.46
Zn	0.2 - 9.0	60 - 73	KS	3.31	2.87	5000-2000
				3.48		473.63
			WS	6.00	1.20	
				5.85		858.55

^{1/}Examples cited are for "normal" concentrations. Concentrations of "uncontaminated" fish may be lower than reported samples. Example variations are due to differences between fish species, differences due to test location, and natural variation among specific individuals.

^{2/}Values for typical daily consumption by humans taken from literature listed, by metal, in the Water Quality Criterion column in Table 3.

^{3/}No reference found on this information.

^{4/}Conversions used for column 4 data to obtain weight (ug) of element contained in 1 pound (0.454 kg) fresh (wet) fish was as follows:

$$\frac{\text{ug}}{1 \text{ lb}} = \left(\frac{\text{ug}}{\text{g}} \text{ of Curecanti fish} \right) \left(\frac{453.6 \text{ g}}{1 \text{ lb}} \right) \left(\frac{1 \text{ g dry weight}}{3.17 \text{ g wet weight}} \right),$$

where 453.6 converts g and lb and 3.17 is the dry to wet conversion, taken from literature references. The ug/g Curecanti values were those of Table 2, column 3.

^{5/}References list 0.5 ppm wet weight as the maximum allowable concentration of mercury in fish flesh suitable for human consumption as set by most world wide health organizations.

Table 3. A guide to information found in literature references. Numbers on this table correspond to reference numbers in list of references.

Metal	Type of Fish	Normal and Toxic Flesh Content	Whole Body Concentrations	Kidney Level Concentrations	Liver Level Concentrations	Water Quality Criteria
Al	RT	13	<u>1/</u>			32
	BT	13				24
	WS	13				
	KS	13				
Cd	RT	21,3,38,5,37,13	33			13,26
	BT	3,22,37,13				21,38
	WS	37,13,26,27			24,24	10,1
	KS					30
Cr	RT	33,5	33	5	5	13
	BT	13				10
	WS					
	KS					
Co	RT	33,13	33			13
	BT	13				10
	WS	13				
	KS	13				
Cu	RT	38,2			38,14	13
	BT	22,38,3			38,36,14	10
	WS				24,36,24	1
	KS					
Pb	RT	19,2,37	33,20			13,18
	BT	37				10
	WS					28
	KS					

Table 3. continued.

Metal	Type of Fish	Normal and Toxic Flesh Content	Whole Body Concentrations	Kidney Level Concentrations	Liver Level Concentrations	Water Quality Criteria
Hg	RT	16,21,23,2,3			23	13,21
	BT	21,23,22,3	4			10
	WS	37	16		24	29
	KS	37				
Mo	RT	13				13
	BT	13,11				36
	WS	13				
	KS	13				
Ni	RT	33,5	33	5	5	23
	BT					10
	WS					
	KS					
Sr	RT	1/				
	BT					
	WS					
	KS					
Zn	RT	38,2,33,3			38,14	13,26
	BT	38,3,22			38,14	38,10
	WS	27	26			1
	KS					

1/ No reference found for the blocks left blank in the table.

Wet wt/dry wt conversion - 32

Average daily intake - 13,10,11

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APPENDIX A

Fish catch for tissue sampling from Gunnison River electroshocking between Twin Bridges and Cooper Ranch near Gunnison, Colorado, October 19-20, 1981.

Catch Number	Date	Time	Species	Length (cm)	Weight (gm)
1.	10/19/81	11:00	<u>Salmo gairdneri</u>	21.0	107.0
2.	"	"	"	19.0	70.0
3.	"	"	"	27.2	192.5
4.	"	"	"	30.9	369.0
5.	"	"	"	34.5	412.4
6.	"	"	"	37.8	504.0
7.	"	"	"	39.2	589.7
8.	10/19/81	12:00	<u>Salmo trutta</u>	31.7	291.0
9.	"	"	"	29.4	266.4
10.	"	"	"	28.4	230.0
11.	"	"	"	28.0	200.5
12.	"	"	"	25.3	171.7
13.	"	"	"	23.7	149.8
14.	"	"	"	22.8	124.8
15.	"	"	"	23.4	127.2
16.	"	"	"	22.5	117.2
17.	"	"	"	22.5	102.2
18.	"	"	"	21.9	99.8
19.	"	"	"	19.0	71.0
20.	10/20/81	13:00	<u>Orcorhynchus nerka</u>	42.0	770.0
21.	"	"	"	38.0	516.0

Catch Number	Date	Time	Species	Length (cm)	Weight (gm)
22.	10/20/81	13:00	<u>Orcorhynchus nerka</u>	41.5	653.0
23.	"	"	"	41.0	679.0
24.	"	"	"	38.5	559.0
25.	"	"	"	41.0	707.0
26.	"	"	"	41.5	645.0
27.	"	"	"	43.0	787.5
28.	"	"	"	42.0	669.3
29.	"	"	"	39.0	600.0
30.	"	"	"	42.0	791.0
31.	"	"	"	39.0	585.0
32.	"	"	"	43.0	765.0
33.	"	"	"	33.0	388.6
34.	"	"	"	42.5	748.0
35.	10/20/81	16:00	<u>Catostomus commersoni</u>	36.5	600.0
36.	"	"	"	43.5	450.0
37.	"	"	"	33.2	460.2
38.	"	"	"	32.9	460.2
39.	"	"	"	37.2	573.5
40.	"	"	"	40.0	844.6
41.	"	"	"	31.5	455.0
42.	"	"	"	39.5	726.0
43.	"	"	"	37.0	535.0
44.	"	"	"	35.0	495.0
45.	"	"	"	36.0	466.5

Catch Number	Date	Time	Species	Length (cm)	Weight (gm)
46.	10/20/81	16:00	<u>Catostomus commersoni</u>	30.5	414.5
47.	"	"	"	36.2	565.0
48.	"	"	"	33.8	383.0
49.	"	"	"	34.6	540.0
50.	"	"	"	26.0	170.0

APPENDIX B

Detection limits and methods for the analyses.

Constituent lab no.	Name	Method ^{1/}	Lower Detection Limit ppm	Comment
merc	Hg	cold vapor		
		AA ^{2/}	0.001	
1	Al	ICP	0.25	
2	B	ICP	0.01	
3	Ca	ICP	0.1	
4	Cd	ICP	0.01	
5	Co	ICP	0.01	
6	Cr	ICP	0.1	
7	Cu	ICP	0.01	
8	Fe	ICP	0.1	
9	K	ICP	1.0	
10	Mg	ICP	0.01	
11	Mn	ICP	0.25	
12	Na	ICP	0.01	
13	Ni	ICP	0.01	
14	P	ICP	0.5	
15	Pb	ICP	0.75	
16	Si	ICP	0.1	
17	Zn	ICP	0.01	
18	Mo	ICP	0.1	
19	Sr	ICP	1.0	
20	Ba	ICP	0.1	

^{1/}ICP = inductively-coupled plasma emission spectrograph.

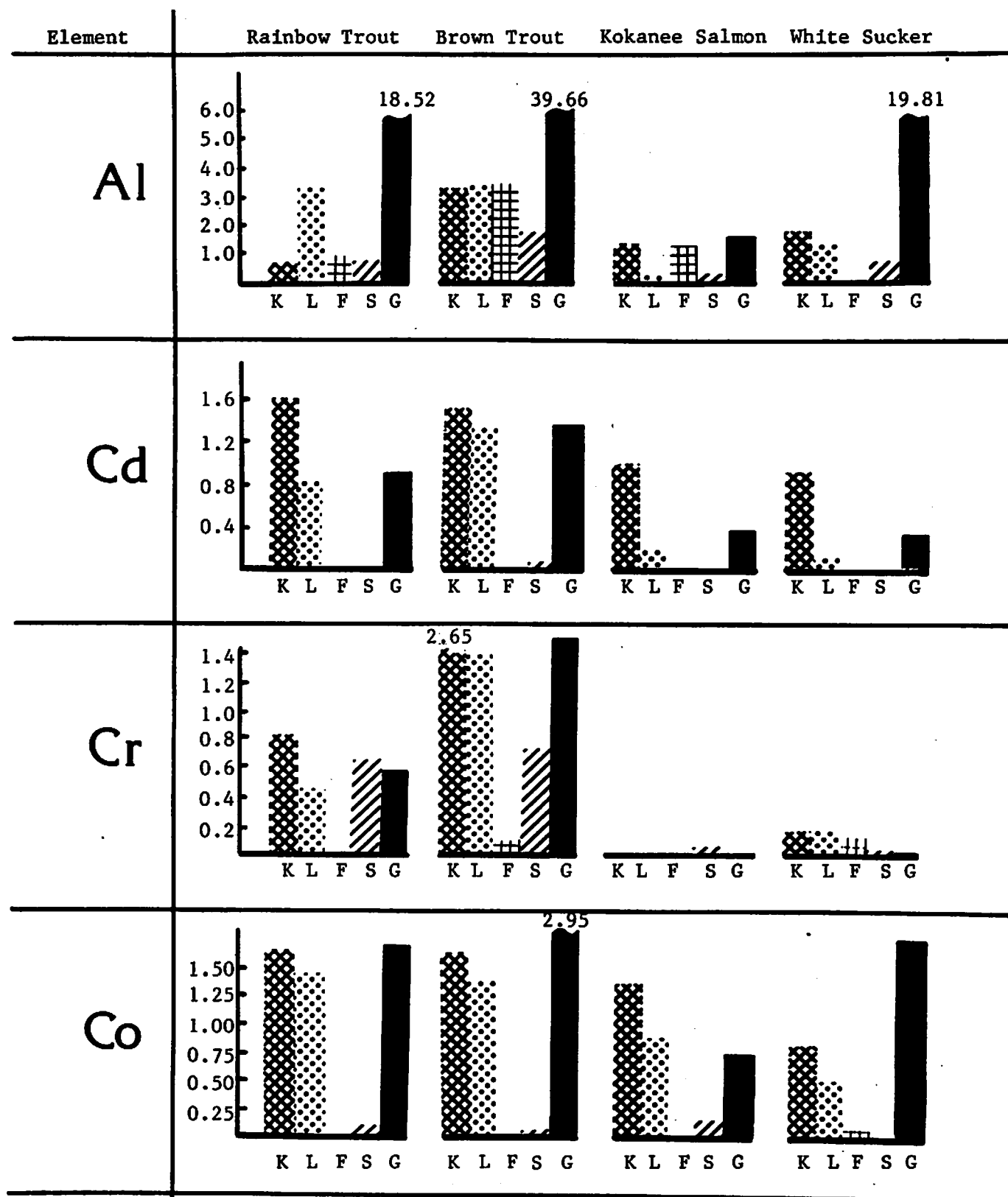
^{2/}AA = Atomic Absorption.

Biological reference tissue was used to establish the detection limits.

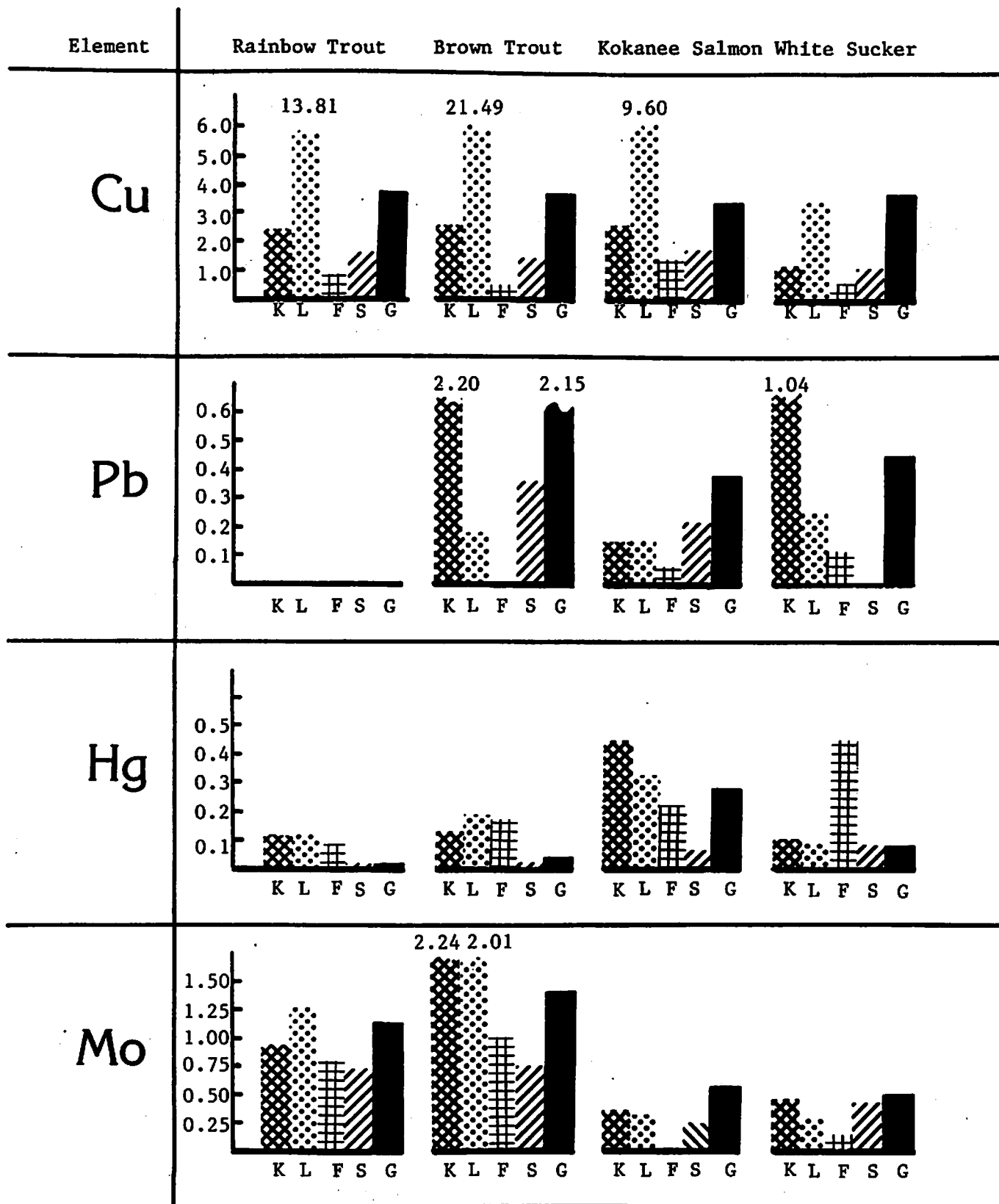
The detection limits for analyses frequently are important to keep in mind. For example, the median ppm levels of many of the metals in the Curecanti fish are essentially identical to the detection limit, particularly where the detection limits were relatively high, such as for lead. From a toxicity viewpoint this does not present a problem, since (i) the detections are adequate to look for levels of concern and (ii) the error in saying that an element is "less than x" is an error on the safe side, i.e., a metal's level could in fact be much lower.

APPENDIX C

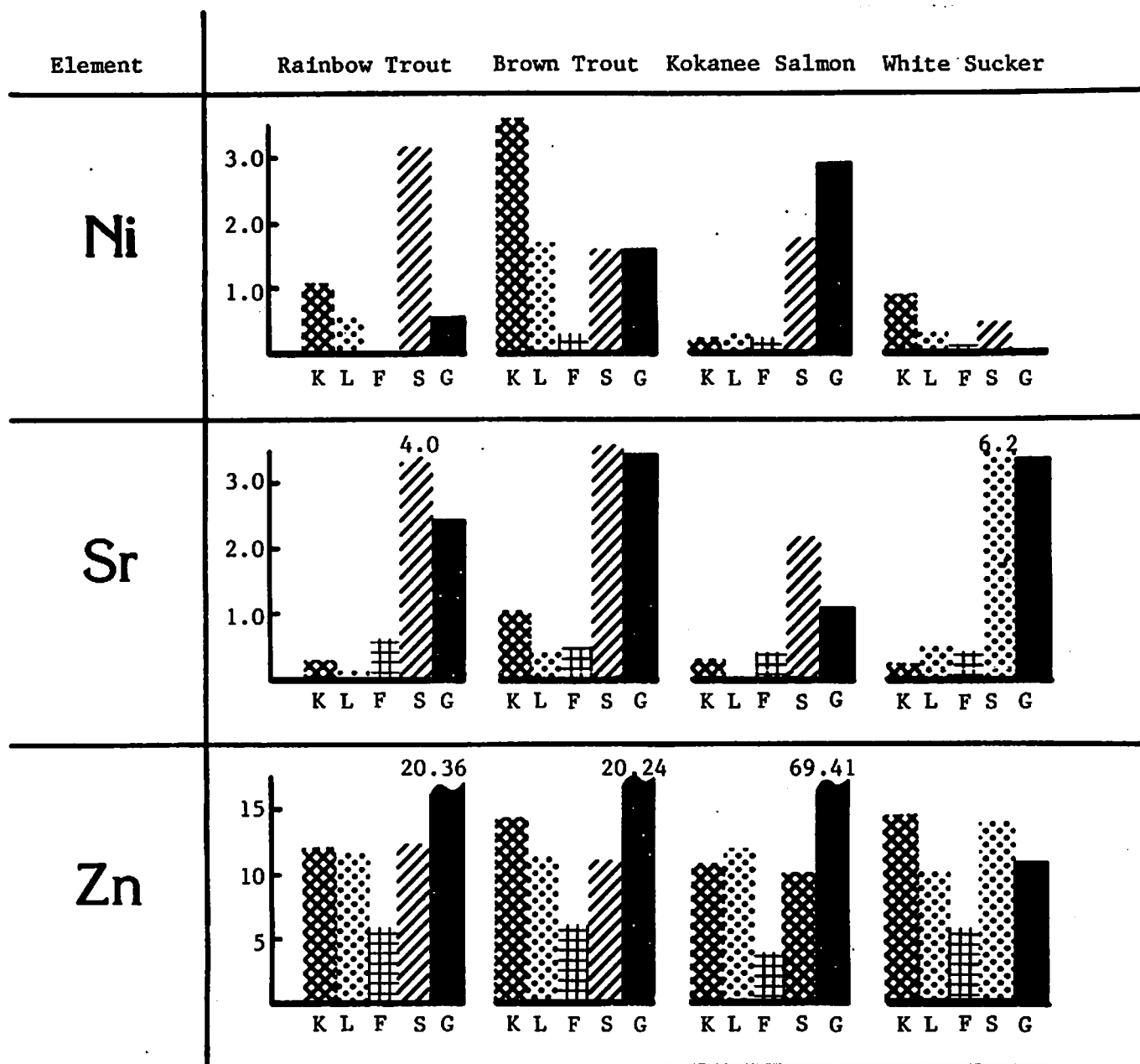
A summary figure of the chemicals found for each species of fish where K = kidneys, L = livers, F = flesh, S = scale and G = gut, as given in detail in Table 1. This figure gives the means from Table 1.



Appendix C, continued



Appendix C, continued



Al = aluminum
 Cd = cadmium
 Cr = chromium
 Co = cobalt
 Cu = copper
 Pb = lead

Hg = mercury
 Mo = molybdenum
 Ni = nickel
 Sr = strontium
 Zn = zinc