

# The Copper, Zinc and Lead Content of Trout Livers as an Aid in the Search for Favourable Areas to Prospect

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## ABSTRACT

Ninety-six rainbow and cut-throat trout livers were collected from forty-seven widely separated localities in British Columbia. The livers from thirty localities contained 60 or less ppm copper (wet weight), and those from forty-four localities had 50 or less ppm zinc.

All of the livers with more than 50 ppm zinc came from fish living in water known to be associated with economic zinc mineralization.

Of the seventeen localities where the fish livers showed more than 60 ppm copper, four are known to contain significant mineralization (Stellako River (2), Buttle Lake, Okanagan Lake), and at least seven, on the basis of their background geology, merit further "serious investigation". These seven are Tlowils, Camp and Elsie lakes on Vancouver Island; Mud, Hyas and Rhoda lakes north of Kamloops; and Sleeping Water lake in the South Okanagan. The other six anomalous copper localities, equally divided between the Cariboo and the southeast Kootenay districts, suggest possibilities, but the authors lack the detailed geological data necessary for any assessment of their potentialities.

Disease and/or pollution may cause the copper content of human livers to be higher than normal. We do not know if fish livers may be similarly affected. However, neither disease nor pollution are known to occur in those lakes meriting "serious investigation".

## INTRODUCTION

ONE HUNDRED AND NINE SAMPLES of trout livers were analyzed for copper, zinc and lead. The trout were collected from forty-five lakes and one river in British Columbia. The majority of the fish were rainbow trout (*Salmo gairdnerii*), but a few were cut-throat (*Salmo clarkii*). Molybdenum analyses were also attempted, but, because of the inadequate amounts of many of the samples, definitive analyses were not possible in many cases.

For purposes of comparison, nine trout (probably *Salmo trutta*) from the Swincombe and Dart rivers in West Devonshire, England, were also analyzed. The area drained by these two rivers is well mineralized and is the subject of controversy at present. It is feared by some people that, if reservoirs are established on these rivers, they may be subjected to mineral pollution. On the other hand, both rivers provide fishermen with sport — a fact that poses two questions. Are trout able to adapt to concentrations of heavy metals usually considered lethal? Alternatively, is the natural run-off sufficient adequately to dilute the heavy metals being leached from the earth's crust in this area?

Analyses were made on the livers of several other species of fish, but, for the sake of brevity, the resulting data are not reported in this paper. It is sad to have to report that, although the program was started in 1966, three years were lost when, owing to a regrettable mishap, nearly all the samples collected in 1966 and 1967 were destroyed.

## PURPOSE OF THE INVESTIGATION

The Department of Geology of the University of British Columbia has, for many years, been exploring the possibilities of employing various geochemical techniques in searching for metal-rich areas. The metal contents of lake, river and ground waters suggest an obvious method of approach. However, the difficulty of obtaining satisfactory representative samples does present practical problems, particularly in a country where surface run-offs are extremely variable. It is well known that phytoplankton and zooplankton can concentrate heavy metals to a remarkable degree (Marsden, 1964). Trout feed voraciously on these organisms. Heavy metals may accumulate in fish and animal tissue, especially in livers (Hannerz, 1968). Thus, it seemed logical to explore the possibilities of using trout livers in mineral exploration.

The Fish and Wildlife Branch of the Province of British Columbia wished to determine the normal levels of heavy-metal concentration in various fish living in lake and river waters in British Columbia. This knowledge was essential in order that any future environmental contamination might be considered in correct perspective.

By pooling the resources of the two groups mentioned above, it has been possible to achieve results of sufficient value to justify an expanded program in the coming year.

Because this paper is intended primarily for exploration geochemists, only modest references will be made in it to the important effects that heavy metals may have on various aquatic organisms, on fish and even on man himself.

## METHODS

Most liver samples were taken by the Fish and Wildlife Branch from lake survey areas in the summer of 1969. Some samples were collected by other Branch personnel and by various geologists and personal friends of the authors.

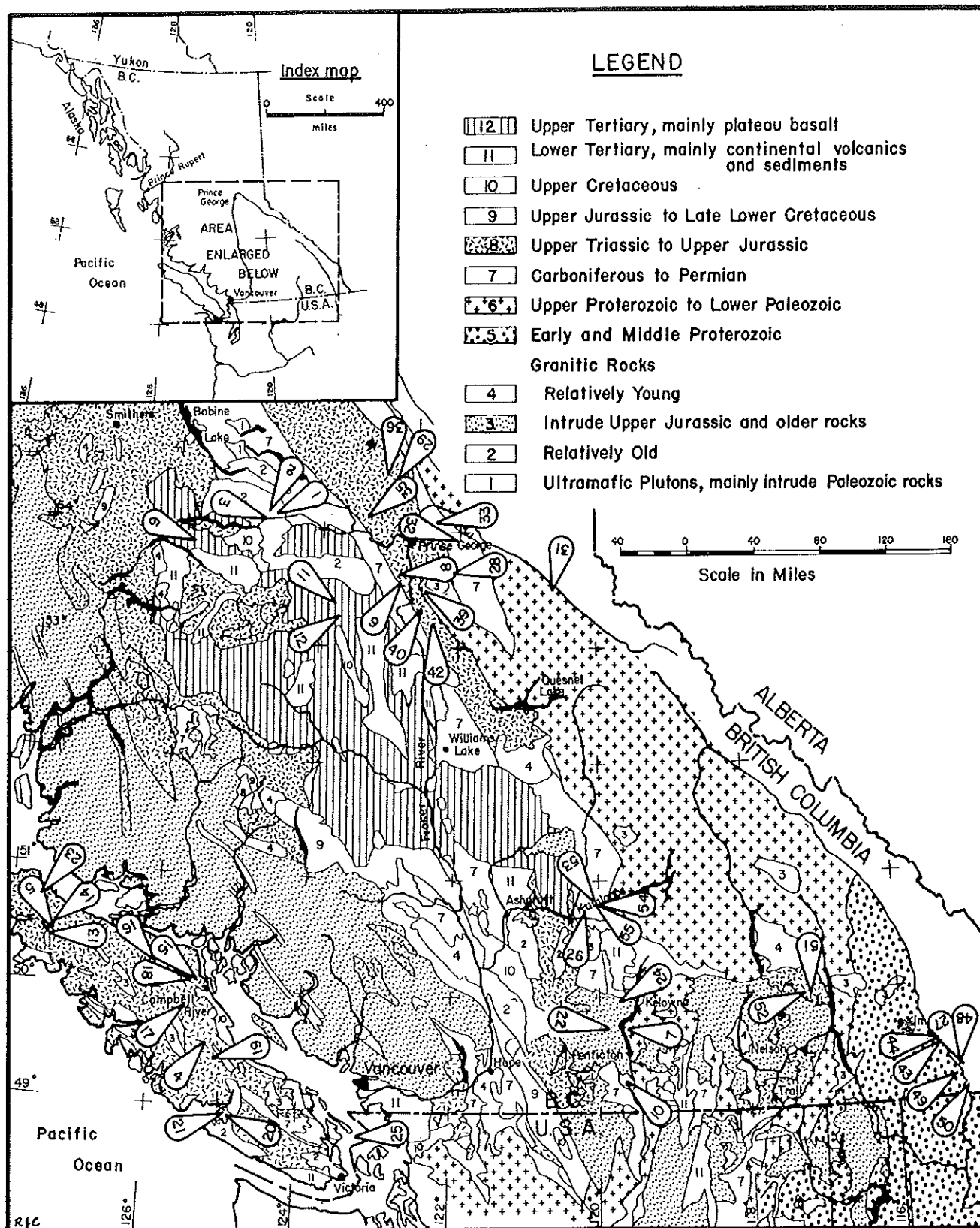


FIGURE 1 — Generalized Map Showing Sample Locations.

Modified from map (Fig. 10-1) accompanying a paper by W. H. White in "Tectonic History and Mineral Deposits of the Western Cordillera", CIM Special Volume No. 8, Montreal, 1966.

Samples of liver were taken from rainbow trout, cut-throat trout, mountain whitefish, Dolly Varden char, brook trout, Kokanee salmon, burbot, squawfish and suckers. However, in order to make this paper as brief as possible, only the results obtained from rainbow and cut-throat trout will be considered. Further results will be reported in a later paper.

Table I and Figure 1 list the localities where the different samples originated, together with other relevant data. Figure 1 makes use of a map adapted from Fig. 10-1 accompanying a paper by W. H. White in "Tectonic History and Mineral Deposits of the Western Cordillera", published by The Canadian Institute of Mining and Metallurgy, Montreal, 1966, as Special Volume No. 8.

Entire livers were excised from fish within an hour of being taken, usually by gill net, and either placed in plastic vials and quick-frozen or dusted with paraformaldehyde powder and then placed in plastic vials and frozen. The liver remained frozen until analysis.

During our early experiments, we found that it was possible to use paraformaldehyde without freezing to preserve the livers, but, if practical, it is prudent to freeze.

In some instances, individual fish livers appeared to be too small for analysis, and this necessitated the combining of several livers. Unfortunately, no record was kept indicating which samples were so treated and consequently comparisons between individual fish are not possible.

Analyses for copper, zinc, lead and molybdenum were made by the Department of Geology, University of British Columbia, using procedures developed by R. E. Delavault and K. Fletcher.

## ANALYTICAL PROCEDURE

The samples of liver were washed with distilled water to

remove the coating of paraformaldehyde, allowed to dry, and then sliced into cubes less than 3 mm in thickness. Up to 2 grams were placed in a glazed porcelain crucible, dried at 110°C for seven hours, weighed again to determine the dry weight and then ashed overnight, with a cover on the crucible, in an electric muffle furnace at 500°C.

To the ashes, after transference to a beaker, one milliliter of 6N HCl was added and the whole was evaporated to dryness. The residue was taken up with 10 milliliters of 1.5N HCl, warming gently to dissolve any residue, and the resulting solution was made up to 20 milliliters with 1.5N HCl.

Metals were determined by the usual geochemical techniques: lead by dithizone colorimetry (Warren and Delavault, 1960), and copper and zinc by atomic absorption. The copper contents were checked by biquinoline colorimetry (Warren and Delavault, 1959) and zinc by dithizone titration (Warren and Delavault, 1949, pp. 537-540).

The over-all precision of the analyses given in this paper is no better than plus or minus 25 per cent at 95 per cent

TABLE I—Fish Collections for Liver Analysis

| Lake or Stream    | Regional*<br>Location | Number<br>on<br>Fig. 1 | Species<br>Sampled | Number<br>of<br>Samples | Year<br>of<br>Collection | Geologi-<br>cal Back-<br>ground <sup>†</sup> | Collected<br>by |
|-------------------|-----------------------|------------------------|--------------------|-------------------------|--------------------------|--|-----------------|
| Alice L.          | 1                     | 14                     | Cut-throat         | 3                       | 1969                     | 8  | F and W**       |
| Bear L.           | 5                     | 52                     | Rainbow            | 2                       | 1969                     | 8  | F and W         |
| Benson L.         | 1                     | 5                      | Rainbow            | 1                       | 1966                     | 8  | Cominco         |
| Buttle L.         | 1                     | 4                      | Rainbow            | 6                       | 1966                     | 7  | Western Mines   |
| Buttle L.         | 1                     | 4                      | Rainbow            | 5                       | 1969                     | 7  | Western Mines   |
| Camp L.           | 1                     | 17                     | Rainbow            | 2                       | 1969                     | 8  | F and W         |
| Cherry L.         | 5                     | 49                     | Cut-throat         | 2                       | 1969                     | 5  | F and W         |
| Claminchil L.     | 7                     | 35                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Eaglet L.         | 7                     | 33                     | Rainbow            | 1                       | 1969                     | 7  | F and W         |
| Elsie L.          | 1                     | 19                     | Cut-throat         | 2                       | 1969                     | 8  | F and W         |
| Erickson L.       | 7                     | 9                      | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Fish Lake         | 5                     | 51                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Fisher Lake       | 7                     | 29                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Frederick L.      | 1                     | 21                     | Cut-throat         | 2                       | 1969                     | 8  | F and W         |
| Garbuts L.        | 5                     | 44                     | Rainbow            | 2                       | 1969                     | 5  | F and W         |
| Genevieve L.      | 7                     | 42                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Glen L.           | 4                     | 22                     | Rainbow            | 1                       | 1968                     | 3  | Hatfield        |
| Government L.     | 7                     | 39                     | Rainbow            | 1                       | 1969                     | 6  | F and W         |
| Grizzley L.       | 7                     | 28                     | Rainbow            | 1                       | 1969                     | 7  | F and W         |
| Hart Lake         | 5                     | 27(48)                 | Rainbow            | 1                       | 1969                     | 5(?)   | F and W         |
| Hayes L.          | 1                     | 18                     | Rainbow            | 2                       | 1969                     | 8  | F and W         |
| Hyas L.           | 3                     | 54                     | Rainbow            | 5                       | 1969                     | 7  | Mitchell        |
| Kains L.          | 1                     | 23                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Lac La Salle      | 7                     | 31                     | Rainbow            | 1                       | 1969                     | 6  | F and W         |
| Lambly L.         | 4                     | 24                     | Rainbow            | 2                       | 1967                     | 3  | Hatfield        |
| Loon L.           | 5                     | 50                     | Rainbow            | 2                       | 1969                     | 5  | F and W         |
| Lynx L.           | 7                     | 8                      | Rainbow            | 4                       | 1969                     | 8  | F and W         |
| Magic L.          | 1                     | 25                     | Rainbow            | 3                       | 1969                     | 10   | Bayley          |
| Mohun L.          | 1                     | 15                     | Cut-throat         | 2                       | 1969                     | 8  | F and W         |
| Mud L.            | 3                     | 55                     | Rainbow            | 3                       | 1969                     | 7  | Mitchell?       |
| Okanagan L.       | 4                     | 7                      | Rainbow            | 2                       | 1968                     | 3  | Hatfield        |
| Oona L.           | 7                     | 2                      | Rainbow            | 4                       | 1969                     | 2  | F and W         |
| Ormand L.         | 7                     | 1                      | Rainbow            | 4                       | 1969                     | 2  | F and W         |
| Peckham's L.      | 5                     | 43                     | Rainbow            | 2                       | 1969                     | 5  | F and W         |
| Peculiar L.       | 7                     | 36                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |
| Pelican L.        | 7                     | 12                     | Rainbow            | 4                       | 1969                     | 12   | F and W         |
| Pinatan L.        | 3                     | 26                     | Rainbow            | 6                       | 1969                     | 7  | F and W         |
| Purden L.         | 7                     | 32                     | Rainbow            | 1                       | 1969                     | 7  | F and W         |
| Rhoda L.          | 3                     | 53                     | Rainbow            | 1                       | 1969                     | 7  | Mitchell        |
| Sarita L.         | 1                     | 20                     | Cut-throat         | 4                       | 1969                     | 8  | F and W         |
| Sleeping Water L. | 4                     | 10                     | Rainbow            | 1                       | 1967                     | 8  | Hatfield        |
| Stellako River    | 7                     | 3                      | Rainbow            | 2                       | 1967                     | 2  | Endako Mines    |
| Tagai L.          | 7                     | 11                     | Rainbow            | 4                       | 1969                     | 12   | F and W         |
| Takysie L.        | 7                     | 6                      | Rainbow            | 5                       | 1969                     | 12   | F and W         |
| Tlowils L.        | 1                     | 16                     | Rainbow            | 2                       | 1969                     | 8  | F and W         |
| Victoria L.       | 1                     | 13                     | Cut-throat         | 3                       | 1969                     | 8  | F and W         |
| Yardley L.        | 7                     | 40                     | Rainbow            | 1                       | 1969                     | 8  | F and W         |

\* Regional location numbers correspond to Fisheries Management regions in B.C.

1. Vancouver Island 3. Kamloops 4. Okanagan 5. Kootenay 7. Northern

<sup>†</sup> Refers to Geological Legend on Figure 1.

\*\* Fish and Wildlife

confidence limits. Checks between colorimetry and atomic absorption results were satisfactory.

## RESULTS

Results are given in tabular form in Table II, which shows the copper, zinc and lead contents of the livers in ppm, wet weight, and gives the dry weights and ash weights of the livers as percentages of their wet weights. In order to simplify the table, copper, zinc and lead determinations, in terms of dry and ash weights, are not shown. These can, however, be calculated from the data given.

## DISCUSSION OF RESULTS

It must be explained that the analytical work was done entirely without the analyst knowing anything about the relationships between the various samples. Thus, even after making due allowances for any analytical weakness, the following observations appear valid.

There is probably some significance in the low copper concentrations in the fish caught in Frederick, Victoria, Mohun and Cherry lakes.

Positive copper anomalies are evident in the trout livers taken from Buttle lake (1969), Camp and Elsie lakes on Vancouver Island, Hyas, Mud and Rhoda lakes north of Kamloops, Sleeping Water lake in the South Okanagan and Peckham's lake in the Kootenay region.

It may be argued that the Buttle Lake rainbow trout have picked up their copper from ore tailings being deposited in the lake since 1966, a fact which may also explain the higher than normal lead content in these fish. However, the zinc concentrations in the above fish are not correspondingly high, and this may be considered unexpected in view of the fact that zinc is not only more abundant in these tailings but it is also more soluble than lead. Further to complicate matters, Camp and Elsie lakes both show trout livers with copper contents comparable to the Buttle Lake (1969) fish, and there are no mines operating on these lakes.

Many of the trout taken from Hyas, Mud and Rhoda lakes show anomalously high copper, lead and dry weight in their livers, and as yet no explanation for these facts has been forthcoming. No pollution is known or suspected. Possibly prospectors may find an explanation. Magic lake does have an answer for its slightly higher than normal copper content. In order to cope with an infestation of snails, the shores of the lake had been treated with copper sulphate. However, the details of the treatment are not known to us. The distinctly high copper content in the trout livers of Peckham's lake in the Kootenays likewise remains unexplained. An examination of outcrops in Sleeping Water lake has not provided any explanation for the high values obtained there.

It may be a coincidence, but Elsie, Camp and Tlowils lakes — the latter having one high-copper sample — all line up parallel to the lineaments so clearly depicted on White's map, to which reference has already been made.

Another unexpected result was that none of the Okanagan fish provided measurable amounts of lead. Because lead arsenate was once extensively used to protect apple trees from pests, and because two of us (Warren and Delavault) had found anomalously high lead contents in many Okanagan soils, more lead was expected.

## FURTHER WORK NECESSARY

Since embarking on this program, much has been learned which can be put to use in further studies. Trout are voracious feeders when provided with a suitable oppor-

tunity, such as when there are 'blooms' of zooplankton. They can, if necessary, survive for considerable periods with what might be termed a 'sparse' diet. Obviously, it would be important to know whether or not the trout involved had recently fed lustily. The sex and spawning condition of fish may well influence the metal content of their livers. The age and size of the fish may also be of importance.

We propose to try and evaluate these and other factors in our future studies. However, we put forward as working hypotheses the following assumptions.

On the basis of local knowledge and a subjective examination of histograms prepared from the data in Table II, we propose as a preliminary working hypothesis that more than 80 ppm copper, more than 40 ppm zinc and more than 1.2 ppm lead be considered exceptional. It follows, therefore, that it should be worthwhile to attempt to discover the cause of any higher analyses.

It is also obvious that a 'grab' sample may be misleading. It might be wise to consider only a 'channel' sample, such as might be provided by a minimum of five samples.

## An Illustrative Example

Noel Belam, formerly a United Kingdom Trade Commissioner in Vancouver, kindly sent us nine samples from an area in West Devonshire. Table III gives the results obtained from these livers.

The exceptional character of this general area with respect to copper, lead and zinc has already been demonstrated in studies of soil and vegetables (Warren and Delavault, 1967). However, the above results provide an excellent illustration of how trout livers may be used to recognize anomalous areas, and they also point out that it is not wise to rely on any individual sample.

## BIOLOGICAL SIGNIFICANCE OF COPPER, ZINC AND LEAD

This aspect of our work will be discussed at greater length in a paper to be presented to a less specialized audience. However, the following remarks may be of general interest.

In fresh-water environments, heavy metals may occur naturally and as man-induced pollutants. In natural surface waters, copper may occur in concentrations of up to 0.05 mg/l (Calif. State Water Quality Control Board, 1963), zinc in concentrations of up to 0.2 ppm (Wurtz, 1962) — although it can be as high as 7 ppm in mining areas (Calif. State W.Q.C.B., 1963) — and lead in concentrations of up to 0.08 mg/l (Calif. State W.Q.C.B., 1963). In British Columbia, the concentrations of these metals are probably lower than the above because of abundant run-off.

The above heavy metals normally occur in combined form and, because of their indestructibility, can constitute serious pollution problems.

Metals play an integral part in our society. Consequently, it is to be expected that many of man's activities cause pollution, but it is well to remember what Tully (1966) has stated: "It is recognized that some degree of alteration of the environments is a necessary consequence of man's activities. Such alterations are not considered pollution until they reach 'the limit of tolerance'."

In 1966, the Canadian Council of Resource Ministers held a conference on "Pollution and Our Environment". At this Conference, one paper was presented in which various standards were presented for the copper, zinc and lead content of water (Canadian Council of Resource Ministers, 1966, Paper C.22-1, p. 5). (See Table IV.)

**TABLE II — Concentration of Copper, Zinc and Lead in Rainbow and Cut-throat Trout Livers**  
(in ppm wet weight)

|                                    |     | Cu  | Zn | Pb             | Dry Weight<br>as % of wet<br>weight | Ash Weight<br>as % of wet<br>weight |
|------------------------------------|-----|-----|----|----------------|-------------------------------------|-------------------------------------|
| <b>VANCOUVER ISLAND REGION (1)</b> |     |     |    |                |                                     |                                     |
| Alice lake                         | 1   | 2   | 20 | .3             | 33                                  | 3.5                                 |
|                                    | 2   | 10  | 26 | .3             | 29                                  | 1.6                                 |
|                                    | 3   | 59  | 27 | .5             | 31                                  | 2.3                                 |
| Benson Lake                        | 1   | 28  | 28 | .4             | 37                                  | 2.6                                 |
| Buttle Lake (1966)                 | 1 a | 90  | 52 | 3.0            | 57                                  | 3.4                                 |
|                                    | 2 a | 25  | 60 | .3             | 52                                  | 3.3                                 |
|                                    | 3 a | 59  | 36 | .8             | 30                                  | 2.9                                 |
|                                    | 4 a | 20  | 58 | .8             | 42                                  | 2.3                                 |
|                                    | 5 a | 34  | 25 | <1.3           | 30                                  | 1.7                                 |
|                                    | 6 a | 39  | 50 | <.3            | 37                                  | 1.9                                 |
| Buttle Lake (1969)                 | 1 b | 89  | 50 | 5.3            | 36                                  | 1.9                                 |
|                                    | 2 b | 103 | 78 | 4.4            | 28                                  | 1.8                                 |
|                                    | 3 b | 206 | 39 | 1.1            | 30                                  | 1.9                                 |
|                                    | 4 b | 159 | 43 | 1.8            | 28                                  | 1.5                                 |
|                                    | 5 b | 209 | 42 | 1.2            | 28                                  | 1.6                                 |
| Camp Lake                          | 1   | 128 | 33 | .2             | 29                                  | 1.8                                 |
|                                    | 2   | 144 | 22 | .5             | 29                                  | 1.5                                 |
| Elsie Lake                         | 1   | 129 | 28 | .4             | 28                                  | 1.3                                 |
|                                    | 2   | 130 | 27 | .5             | 29                                  | 1.7                                 |
| Frederick Lake                     | 1   | 4   | 31 | .3             | 29                                  | 1.5                                 |
|                                    | 2   | 6   | 14 | .5             | 29                                  | 2.1                                 |
| Hayes Lake                         | 1   | 51  | 22 | .2             | 30                                  | 1.6                                 |
|                                    | 2   | 77  | 20 | .1             | 31                                  | 3.0                                 |
| Kains Lake                         | 1   | 4   | 25 | .4             | 27                                  | 1.9                                 |
| Magic Lake                         | 1   | 98  | 30 | .3             | 28                                  | 1.4                                 |
|                                    | 2   | 42  | 31 | .4             | 28                                  | 1.6                                 |
|                                    | 3   | 116 | 26 | .6             | 26                                  | 1.6                                 |
| Mohun Lake                         | 1   | 15  | 23 | .2             | 27                                  | 1.4                                 |
|                                    | 2   | 18  | 21 | .2             | 30                                  | 1.4                                 |
| Sarita Lake                        | 1   | 11  | 24 | .5             | 40                                  | 2.5                                 |
|                                    | 2   | 31  | 28 | .8             | 32                                  | 1.8                                 |
|                                    | 3   | 27  | 22 | .3             | 23                                  | 1.3                                 |
|                                    | 4   | 19  | 30 | .4             | 24                                  | 1.7                                 |
| Thowils Lake                       | 1   | 329 | 28 | 1.4            | 30                                  | 1.8                                 |
|                                    | 2   | 22  | 18 | .7             | 29                                  | 1.4                                 |
| Victoria Lake                      | 1   | 4   | 15 | .2             | 28                                  | 1.1                                 |
|                                    | 2   | 6   | 20 | .3             | 29                                  | 3.3                                 |
|                                    | 3   | 4   | 20 | Not obtainable | 27                                  | Not available                       |
| <b>KAMLOOPS REGION (3)</b>         |     |     |    |                |                                     |                                     |
| Hyas Lake                          | 1   | 201 | 36 | .5             | 58                                  | 2.2                                 |
|                                    | 2   | 82  | 53 | 1.6            | 64                                  | 3.1                                 |
|                                    | 3   | 78  | 21 | .6             | 50                                  | 1.8                                 |
|                                    | 4   | 215 | 30 | .5             | 53                                  | 1.8                                 |
|                                    | 5   | 135 | 34 | .3             | 59                                  | 1.6                                 |
| Mud Lake                           | 1   | 289 | 42 | 1.4            | 53                                  | 2.6                                 |
|                                    | 2   | 241 | 37 | 1.0            | 50                                  | 2.4                                 |
|                                    | 3   | 95  | 38 | 1.0            | 56                                  | 2.0                                 |
| Rhoda Lake                         | 1   | 425 | 41 | 2.2            | 53                                  | 2.4                                 |
| Pinatan Lake                       | 1   | 215 | 28 | .9             | 28                                  | 1.4                                 |
|                                    | 2   | 31  | 29 | .8             | 26                                  | 1.5                                 |
|                                    | 3   | 17  | 22 | .8             | 25                                  | 1.5                                 |
|                                    | 4   | 37  | 30 | .6             | 26                                  | 1.6                                 |
|                                    | 5   | 18  | 27 | .3             | 25                                  | 1.7                                 |
|                                    | 6   | 57  | 29 | .4             | 26                                  | 1.5                                 |
| <b>OKANAGAN REGION (4)</b>         |     |     |    |                |                                     |                                     |
| Glen Lake                          | 1   | 47  | 31 | <.3            | 37                                  | 1.9                                 |
| Lambly Lake                        | 1   | 40  | 44 | <.5            | 35                                  | 1.9                                 |
|                                    | 2   | 76  | 29 | <.3            | 35                                  | 1.7                                 |
| Okanagan Lake                      | 1   | 3   | 15 | <.3            | 38                                  | 1.5                                 |
|                                    | 2   | 61  | 27 | <.3            | 35                                  | 1.4                                 |
| Sleeping Water Lake                |     | 138 | 40 | <.3            | 35                                  | 1.9                                 |
| <b>KOOTENAY REGION (5)</b>         |     |     |    |                |                                     |                                     |
| Bear Lake                          | 1   | 40  | 21 | .6             | 27                                  | 1.2                                 |
|                                    | 2   | 33  | 19 | .6             | 28                                  | .9                                  |
| Cherry Lake                        | 1   | 5   | 23 | .5             | 28                                  | 1.6                                 |
|                                    | 2   | 7   | 25 | .6             | 28                                  | 1.5                                 |
| Fish Lake                          | 1   | 50  | 28 | .4             | 27                                  | 1.9                                 |
| Garbuts Lake                       | 1   | 84  | 25 | .6             | 27                                  | 2.3                                 |
|                                    | 2   | 92  | 32 | .3             | 26                                  | 2.1                                 |
| Hart Lake                          | 1   | 16  | 21 | .3             | 27                                  | 1.2                                 |
| Loon Lake                          | 1   | 55  | 26 | .3             | 32                                  | 1.6                                 |
|                                    | 2   | 65  | 24 | .5             | 33                                  | 1.6                                 |
| Peckham's Lake                     | 1   | 136 | 20 | 1.0            | 30                                  | 2.5                                 |
|                                    | 2   | 116 | 25 | .3             | 29                                  | 2.4                                 |

There are many lethal and sublethal effects of heavy metals on animals and man described in the literature. Chronic effects appear to occur mostly on organ enzyme systems, probably as a result of the heavy metals' affinity for the protein amino, imino and sulphhydryl groups, which are enzyme reactive sites (Skidmore, 1964; Calif. State W.Q.C.B., 1963). Synergistic effects are probably of great importance. For example, it is known that copper acts

synergistically with zinc or mercury, and this could account for variations in the toxicity of these elements.

In view of the difficulties involved in measuring the heavy-metal content of water accurately and continuously, it would seem to be helpful to determine the normal concentrations of heavy metals in trout in various environments. The liver seems to be an organ admirably suited for these studies.

TABLE II — (Cont.)

|                            |   | Cu  | Zn | Pb   | Dry Weight<br>as % of wet<br>weight | Ash Weight<br>as % of wet<br>weight |
|----------------------------|---|-----|----|------|-------------------------------------|-------------------------------------|
| <b>NORTHERN REGION (7)</b> |   |     |    |      |                                     |                                     |
| Clauminchil Lake           | 1 | 66  | 37 | .3   | 36                                  | 3.7                                 |
| Eaglet Lake                | 1 | 78  | 29 | .5   | 28                                  | 1.3                                 |
| Erickson Lake              | 1 | 12  | 29 | .5   | 33                                  | 2.6                                 |
| Fisher Lake                | 1 | 60  | 54 | 1.3  | 40                                  | 2.3                                 |
| Genevieve Lake             | 1 | 7   | 14 | .6   | 46                                  | .9                                  |
| Government Lake            | 1 | 17  | 21 | .3   | 34                                  | 1.5                                 |
| Grizzley Lake              | 1 | 39  | 31 | .4   | 25                                  | 1.4                                 |
| Lac LaSalle                | 1 | 45  | 23 | .3   | 29                                  | 2.1                                 |
| Lynx Lake                  | 1 | 21  | 36 | .5   | 30                                  | 1.6                                 |
|                            | 2 | 14  | 23 | < .5 | 32                                  | 2.3                                 |
|                            | 3 | 39  | 26 | < .5 | 33                                  | 2.4                                 |
|                            | 4 | 9   | 27 | < .5 | 33                                  | 2.8                                 |
| Oona Lake                  | 1 | 16  | 25 | .8   | Missing                             | 7.9                                 |
|                            | 2 | 35  | 33 | 1.0  | 46                                  | 6.8                                 |
|                            | 3 | 41  | 29 | .9   | 37                                  | 8.2                                 |
|                            | 4 | 68  | 28 | 1.3  | Missing                             | 6.7                                 |
| Ormond Lake                | 1 | 112 | 34 | .6   | Missing                             | 1.3                                 |
|                            | 2 | 7   | 30 | .3   | 35                                  | 2.8                                 |
|                            | 3 | 15  | 26 | .6   | 28                                  | 2.9                                 |
|                            | 4 | 41  | 24 | .6   | 32                                  | 2.1                                 |
| Peculiar Lake              | 1 | 37  | 27 | .5   | 25                                  | 2.7                                 |
| Pelican Lake               | 1 | 87  | 30 | .5   | 35                                  | 1.7                                 |
|                            | 2 | 73  | 27 | .3   | 32                                  | 2.4                                 |
|                            | 3 | 75  | 34 | .5   | 33                                  | 1.8                                 |
|                            | 4 | 35  | 35 | .5   | 32                                  | 1.9                                 |
| Purden Lake                | 1 | 46  | 27 | .5   | 28                                  | 2.0                                 |
| Stellako River             | 1 | 88  | 18 | < .3 | 30                                  | 1.3                                 |
|                            | 2 | 61  | 17 | < .3 | 32                                  | < 1.0                               |
| Tagai Lake                 | 1 | 31  | 31 | .5   | 30                                  | 1.4                                 |
|                            | 2 | 38  | 33 | .6   | 28                                  | 1.4                                 |
|                            | 3 | 63  | 51 | .8   | 33                                  | 1.6                                 |
|                            | 4 | 20  | 46 | .5   | 24                                  | 1.3                                 |
| Takysie Lake               | 1 | 56  | 24 | .4   | 27                                  | 1.7                                 |
|                            | 2 | 40  | 33 | .6   | 29                                  | 2.8                                 |
|                            | 3 | 48  | 31 | .6   | 30                                  | 2.6                                 |
|                            | 4 | 38  | 32 | .5   | 30                                  | 2.6                                 |
|                            | 5 | 47  | 32 | 1.6  | 30                                  | 1.7                                 |
| Yardley Lake               | 1 | 78  | 39 | 1.2  | 30                                  | 1.4                                 |

TABLE III — The Copper, Zinc and Lead Contents of Some West Devon Trout Livers

(in ppm wet weight)

Swincombe and Dart Rivers, Devonshire, England

| Sample | Year | Copper | Zinc | Lead  | Dry Weight<br>as % of wet weight |
|--------|------|--------|------|-------|----------------------------------|
| 1      | 1967 | 34     | 25   | < 1.3 | 30                               |
| 2      | 1967 | 27     | 44*  | < .4  | 41*                              |
| 3      | 1967 | 340*   | 37   | < .3  | 37                               |
| 4      | 1967 | 190*   | 50*  | < .3  | 33                               |
| 1      | 1969 | 62     | 42*  | 2.5*  | 50*                              |
| 2      | 1969 | 6      | 28   | 2.3*  | 45*                              |
| 3      | 1969 | 23     | 69*  | < 1.5 | 44*                              |
| 4(a)   | 1969 | 100*   | 57*  | .4    | 36                               |
| 4(b)   | 1969 | 74     | 52*  | < .3  | 35                               |

\*Exceptional on basis of suggested hypotheses.

**TABLE IV — Abstract from Ideal Quality Water Standards vs Drinking Water Standards**

(maximum amounts in ppm)

|    | IDEAL WATER                    |                          | DRINKING WATER    |             |
|----|--------------------------------|--------------------------|-------------------|-------------|
|    | Recommended Limit<br>Non-Toxic | Tolerance Limit<br>Toxic | Recommended Limit | Toxic Limit |
| Cu | 0.2                            |                          | 1.0               |             |
| Zn | 1.0                            |                          | 5.0               |             |
| Pb |                                | 0.03                     |                   | 0.05        |

## SUMMARY AND CONCLUSIONS

By determining the amounts of heavy metals in trout livers, it may be possible in some cases to determine the presence of anomalous concentrations of heavy metals in an environment.

Much further work is needed, but eventually it should be possible, by this technique, to assess either the degree of pollution or the mineral potentialities of an area, or both.

As in other fields of geochemistry, it is essential to establish local background values before attempting to delineate anomalies. Some of our low values near the west coast of Vancouver Island may be the result of high precipitation. As a preliminary hypothesis, it is suggested that, in British Columbia, copper concentrations of more than 80 ppm, zinc concentrations of more than 40 ppm and lead concentrations of more than 1.2 ppm be considered exceptional and potentially anomalous. Where an anomaly is confirmed by several analyses, the reason for the anomaly should be determined. An anomaly may well be a matter of concern to one or more specialists, including fish biologists, ecologists, epidemiologists, exploration geochemists and prospectors.

## ACKNOWLEDGMENTS

The authors are deeply indebted to their several friends who assisted in collecting fish livers. The analyses were made by Miss Isobel Semple, with help from various members of the Geology Department. Work on the final project was made possible through a research grant by the Lawson Tait Memorial Fund (Canada) and by support from the National Research Council (A-1805 and A-5120). The Donner (Canadian) Foundation purchased the atomic absorption equipment. Several mining companies have also contributed financially to our over-all research program.

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