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Use of Fish Gill and Liver Tissue to Monitor Zinc Pollution

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Many aquatic organisms bioconcentrate heavy metals such as zinc from surrounding waters (Holcombe et al. 1979; Mount 1967; Skidmore 1964). In fish, the gill appears to be the primary organ for zinc accumulation (Lovegrove & Eddy 1982; Skidmore 1972). Damage to the gill tissue in acutely exposed fish interferes with respiration and causes tissue hypoxia (Burton et al. 1972; Skidmore 1970). The liver is also a site of high bioconcentration on exposure to heavy metals (Buckley et al. 1982; Wilson et al. 1981). Gill and liver tissue appear to be the best tissue for analysis if fish are to be used as biomonitors of zinc pollution as suggested by Weatherly et al. (1980).

The Spokane River in eastern Washington is contaminated by zinc due to mining and smeltering operations in northern Idaho (Mink et al. 1971; Ellis 1940). A recent analysis indicated that the zinc concentrations in the Spokane River have decreased by 50% between 1973 and 1978 from a mean annual concentration of 320 µg/ℓ to 160 µg/ℓ (Yake 1979). The present concentration of 103 µg/ℓ (Gibbons et al. 1982) is about twice the current recommended "safe" concentration (U.S. EPA 1980). A discussion of the factors accounting for the survival of wild salmonids in the Spokane River is given in Bailey & Saltes 1982).

The objective of this research was to estimate zinc bioconcentration and determine if the zinc concentrations in gill and liver tissue of these wild salmonids has decreased with the decline in ambient concentrations.

MATERIALS AND METHODS

Fish were collected in 1973 by gill nets and in 1980 and 1981 by electroshocking. All collecting was conducted during the fall in the reach bounded by Post Falls Dam (RKm 164.2) and Upriver Dam (RKm 129.0). The fish were transported to the laboratory on ice and then frozen.

The fish were dissected by methods of Mount (1967). The organ tissues were oven-dried in air (104°C), weighed and then digested with distilled nitric and perchloric acids (Leonard 1971). The

digested samples were filtered through fretted glass filters, brought to a 10, 25 or 50 ml final volume with distilled water and analyzed for zinc by atomic absorption spectrophotometry. Standard zinc solutions and bovine tissue (National Bureau of Standards) were carried through the digestion and analysis to determine metal loss or matrix effects. The tissue of the 1973 fish were also analyzed by neutron activation (Funk et al. 1975).

Liver and muscle tissue were analyzed on 1973 fish. Gill and liver tissue were analyzed on 1980-81 fish. The first gill arch was used for analysis in I and older fish. In 0 fish, the whole gill was analyzed. All concentrations are reported on a dry weight basis (μg Zn per gram dry tissue).

Duncan's modified multiple range test (Duncan 1957) was used to test for differences of zinc concentration among groups of fish. Age classes of fish were based on scale annuli counts on 1980-81 fish and scale analysis (Bailey & Saltes 1982).

RESULTS AND DISCUSSION

Thirteen rainbow trout (Salmo gairdneri) and five brook trout (Salvelinus fontinalis) were collected from the Spokane River in 1973 and analyzed. Although there appeared to be no consistent difference in tissue concentrations between rainbow and brook trout, only the data from the rainbow trout is used in the following comparison. The data for the brook trout, other metals and other organs, are given in Funk et al. (1975). Thirty-one rainbow trout were collected in 1980 and 1981. Gill tissue was analyzed from each of these fish and liver tissue was analyzed from 12 fish.

The mean and range of zinc concentration in gill and liver tissues of the 1980-81 fish was 1000 (382 to 1,634) and 395 (155 to 749) μg/g, respectively. The mean bioconcentration factors were 9708X for gill and 3835X for liver tissue. There was a high correlation ($r = .74$) between the zinc concentration of liver and gill tissue.

The zinc concentration of gill tissue increased significantly between age 0 and age I fish (Fig. 1). Zinc concentrations then declined in succeeding age classes; however, the concentration of zinc in gill and liver tissue of age I and II fish was not significantly different ($P = .05$). Chernoff & Dooley (1979) reviewed the literature on metal concentrations in fish tissue and concluded that the relationship between metal concentration and fish length, weight or age appears to be specific for metal and species of fish.

Although an apparent explanation is not readily evident concerning metal equilibrium in fish tissue, perhaps the difference in ability of different size rainbow trout to regulate zinc content

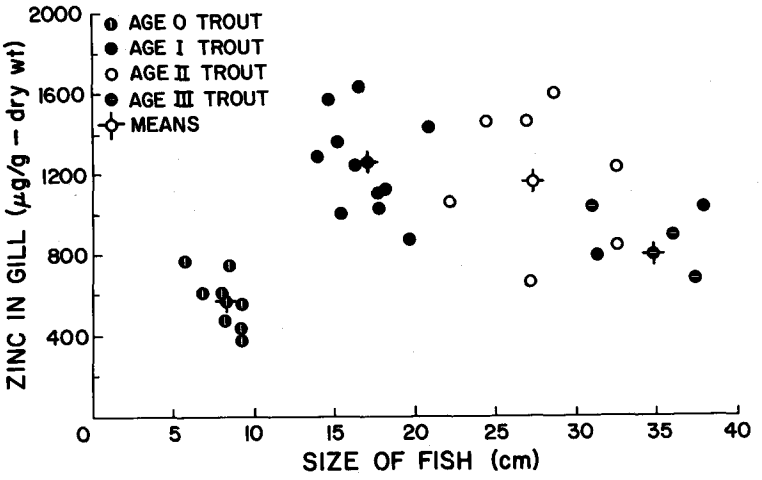

FIG. 1 ZINC CONCENTRATION IN GILL TISSUE OF NATIVE RAINBOW TROUT FROM THE SPOKANE RIVER (1980-81)

in their tissues might contribute to the observed differences in zinc concentrations.

Some of the apparent difference between age 0 and other age fish may also be due to systematic error. The zinc concentration of individual arches within a gill varies significantly (Hughes & Flos 1978). In age 0 fish, we were forced to analyze the whole gill to get sufficient amounts of tissue for analysis. This systematic error may have accounted for 8-14% of the observed difference between age 0 and age I fish.

It was expected that the zinc concentration of liver tissue of Spokane River fish would reflect the lower ambient concentrations. When experimental fish are placed in clean water after exposure to zinc, the loss of zinc in tissue is rapid and significant. Holcombe et al. (1979) observed a zinc loss in gill and liver tissue of 55 and 59%, respectively, when fish were transferred to zinc-free water for 2 weeks. However, our data indicate a significantly ($P = .05$) higher mean zinc concentration in the liver tissue of age I-II, 1981 trout (Table 1). This apparent inverse relationship has also been observed with copper in stone loach (De et al. 1976). There was no significant difference in zinc concentrations between the two groups (1973, 1981) of age III fish, and mean concentrations were remarkably similar.

Apparently there are other unknown factors which account for the discrepancy in tissue concentrations of zinc and zinc exposure for

Table 1. Concentration of zinc (mean and standard error) in the livers of native trout from the study area, 1973 and 1980-81. Concentrations are reported as μg Zn/g dry weight.

Year Collected	Fish Age	
	I, II	III
1973	341 (20) n = 10	243 (10) n = 3
1980-81	484 (56) n = 8	219 (28) n = 4

these Spokane River fish. Chernoff & Dooley (1979) have suggested that the physiological mechanism which regulates uptake and elimination of metals such as zinc is only functional or functions at a higher rate above some threshold concentration of the metal.

The tissue analyses of Spokane River trout do not confirm the measured decrease in zinc loading which has occurred from 1973 to 1980, indicating that the use of fish tissue as an indicator of metal concentration in an aquatic system may not be appropriate for a metal such as zinc which is homeostatically controlled (Giesy & Weiner 1977). Investigators should refrain from using fish as biomonitors of metal pollution (as a routine analysis) until fish response to metal stress can be properly interpreted.

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