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Bioaccumulation of Lead in Atlantic Salmon *(Salmo salar)*

S. Ray
Department of Environment, Fisheries & Marine Service, Resource Branch
Bedford Institute of Oceanography
Dartmouth, N.S., B2Y 4A2, Canada

INTRODUCTION

Lead is one of the most toxic elements known and the concentration is steadily increasing in the aquatic environment due to activities of man. However, meagre data are available on the chronic toxic effects of lead to fish. A level not exceeding 0.03 mg/ℓ at any time or place has been considered safe to aquatic life (WATER QUALITY CRITERIA, 1972). DAVIES and EVERHART (1973) have shown that low concentrations of lead in water caused black tails and spinal curvature of rainbow trout (*Salmo gairdneri*). HOLCOMBE *et al.*(1976) also observed similar effects on long term exposure of brook trout (*Salvelinus fontinalis*). MATC value for lead in soft water at the eyed egg stage has been found to be between 4.1 and 7.6 μg/ℓ for rainbow trout and direct neurological damage to fish on chronic exposure to lead has been observed (DAVIES *et al.*1976). The red blood cell enzyme δ-aminolevulinic acid dehydratase activity of rainbow trout was shown to be significantly inhibited by a lead concentration of only 13 μg/ℓ after a 4-week exposure (HODSON, 1976). Brook trout exposed to once a day slug dose of 25 mg/ℓ lead suffered reduced growth (DORFMAN and WHITWORTH, 1969). Methylation of lead in the environment has been documented (WONG *et al.*1975).

Northeast New Brunswick is known for its fishery resources, especially Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*). The salmon fishery industry in the Miramichi River system (Fig. 1) is by far the largest in New Brunswick. However, in recent years a marked decrease in salmon stocks have been recorded due to mining and other industrial activities (ELSON, 1974).

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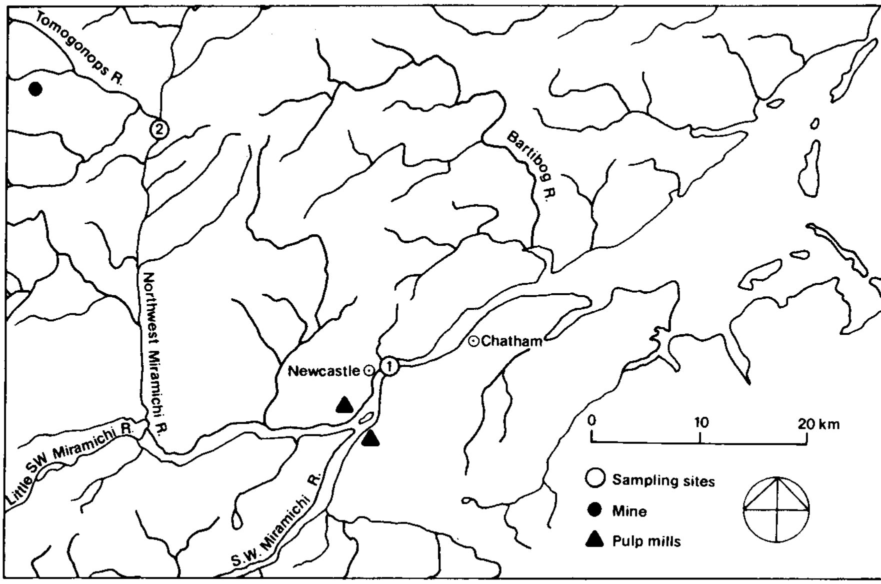

FIG. 1. Map of Study Area.

The northwestern part of the Miramichi River system is also highly metallogenic with copper, zinc, and pyrite ore bodies with several active mines. A number of trace elements including lead is associated with them. One of the biggest mining operations in the area discharges its effluents in Tomogonops River, a tributary of the Northwest Miramichi River. Salmon parr was sighted in the area for the first time in 1973 after a lapse of several years after the effluent treatment plant came into operation.

It is desirable to have a broad understanding of lead level in the most important commercial and sport fish of the area in this highly metallogenic region. Information gathered from these studies can provide a basis for early detection of possible future environmental damage and subsequent recommendation for remedial action. Environmental influence of trace metals in fish has been discussed by a number of workers (ABDULLAH *et al.*1976; FALK *et al.* 1973; PAGENKOPF and NEUMAN, 1974; LUCAS *et al.*1970) and the trace metal level has been related to high background level. However, interpretation of published data with respect to the precise dependence of the metal level in the fish is often complicated by the use of whole fish in analysis. The distribution of metal levels in different organs, which may have different response to environmental influence, should give much more meaningful results.

MATERIALS AND METHODS

The grilse (one sea year) were caught during the spawning run in July 1974 in the Miramichi River at Millbank below Newcastle. It is not known whether the grilse caught were planted fish. However, the tremendous change in size in the intervening period should have eliminated any direct effect of the hatchery environment. The parr samples were caught 7/10 mile below Tomogonops River mouth in the Miramichi River (on Tomogonops side).

Immediately upon collection of the wild fish, they were weighed, measured and scales removed for age determination. The whole fish were then put in plastic bags with exclusion of air, frozen and transported to the laboratory for storage and individually thawed before dissection. The muscle taken was white muscle, behind operculum and before dorsal and above lateral line. Lead was determined by flameless technique using a Perkin Elmer Model 503 atomic absorption soectrophotometer equipped with a HGA 2100 graphite furnace and a Hewlett Packard Model 7127 recorder.

The precision of the analytical methods was checked against orchard leaves (N.B.S. Standard Reference Material 1571). The calibration curve was drawn using a matrix consisting of copper, zinc, lead, cadmium and iron. Freeze-dried tissue was dry-ashed overnight at 450^{0}C, dissolved in 2 ml of Aristar grade conc. nitric acid (B.D.H. Ltd., Poole, England), diluted with water and heated to boiling. Solutions were filtered (Whatman #42) and made to volume. 25 $\mu\ell$ samples were injected into the graphite furnace with the help of an Eppendorf pipet. All glasswares, filter paper and pipet tips were washed with dil. nitric acid to avoid contamination. Water samples had lead levels of 12 ppb and 64 ppb, at the time of collection of parr and grilse samples,respectively.

RESULTS AND DISCUSSION

The relative standard deviation for the fish samples is large and reflects variations from fish to fish. Similar large variations have been observed by others in related studies (FALK *et al.*1973, PAGENKOPF and NEUMAN, 1974). Lead concentration levels in different organs of the grilse and parr samples are given in Tables I and II, respectively.

The relative lead level in all parr tissues samples are much higher than the grilse (Fig. 2). It has been suggested (ABDULLAH *et al.*1976) that metal uptake by fish is mainly through their diet but the metal concentration in the water will influence the level in the organisms which constitute the bulk of the fish diet. Again, the freshwater fish absorb and pass water through the gill and ultimately through the bloodstream. It is reasonable to suggest that the relative lower metal in grilse is due to either (1) excretion in the ocean environment or (2) extremely rapid growth in size while total metal load remains same. HOLCOMBE *et al.*(1976) observed that exposed brook trout,on being transferred to control water,showed a significantly reduced residue level in gill, kidney and liver tissues. The growth in size from parr to grilse is more

TABLE I

CONCENTRATION OF LEAD IN MIRAMICHI GRILSE (Expressed as μg/g dry wt.)

Fish #	Age	Wt. (Kg)	Total Length (cm)	Muscle	Gill	Liver	Kidney	Spine
1.	3.1+	1.63	57.5	0.032	2.67	6.87	33.79	0.95
2.	3.1+	1.82	58.2	0.030	5.44	3.10	51.15	0.57
3.	3.1+	1.60	55.5	0.044	3.73	6.07	11.39	0.44
4.	3.1+	1.60	55.2	0.058	3.08	5.74	17.34	0.85
5.	2.1+	1.64	54.9	0.048	5.08	1.59	21.86	0.69
6.	3.1+	1.47	53.5	0.037	4.68	10.54	15.19	1.20
7.	2.1+	1.94	56.3	0.082	7.57	5.77	17.77	0.77
8.	3.1+	1.54	56.8	0.031	4.11	11.20	45.94	1.06
9.	3.1+	1.55	56.8	0.172	2.67	--	27.23	0.64
10.	3.1+	1.64	55.8	0.028	1.99	5.12	15.69	1.18

TABLE II

CONCENTRATION OF LEAD IN MIRAMICHI PARR (Expressed as μg/g dry wt.)

Fish #	Age	Wt. (g)	Total Length (cm)	Muscle	Gill	Liver	Kidney	Spine
1.	3	15.5	11.8	1.30	14.45	42.57	73.89	7.90
2.	2	13.6	11.5	1.87	15.56	68.00	61.48	6.13
3.	3	18.4	12.8	2.29	20.65	--	22.55	11.00
4.	2	15.8	11.6	1.80	11.76	58.75	37.95	7.93
5.	3	17.7	12.2	0.79	6.65	16.45	21.19	13.10
6.	2	11.7	10.9	1.23	16.74	132.59	101.89	6.92
7.	3	11.4	10.8	0.78	8.44	18.64	78.38	--
8.	2	12.8	11.1	0.77	11.79	118.53	--	8.42
9.	2	16.3	12.3	1.34	--	23.06	43.21	4.09
10.	2	8.0	9.6	1.45	12.68	31.86	173.47	5.44

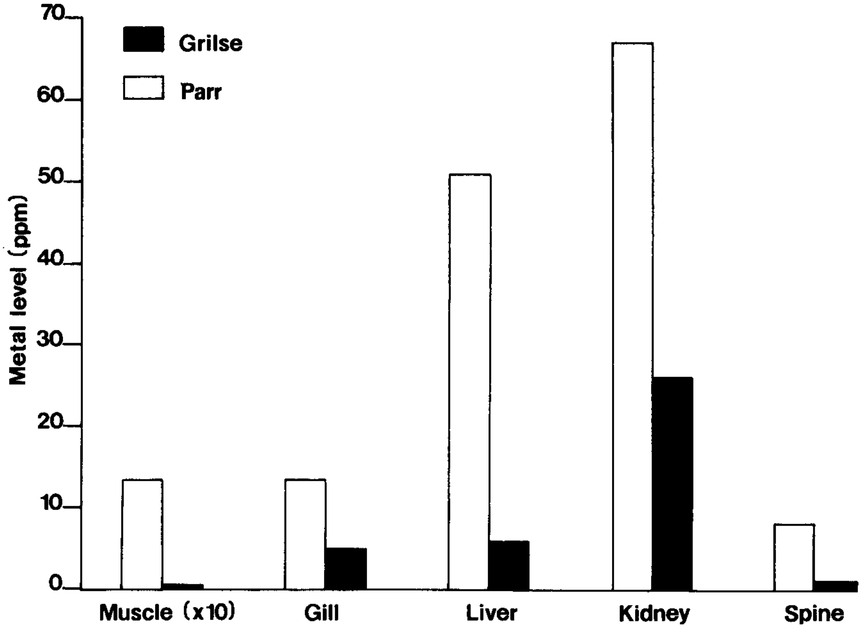

FIG. 2. **Metal distribution in organ tissue**

than 100 times, whereas the metal level in liver and kidney tissues of parr is only ten and three times,respectively,of the grilse; suggesting that the ocean environment plays a major role in excretion of lead.

The trend observed in the present study that the older parr has higher lead level in spine has also been observed by PAGENKOPF and NEUMAN (1974) in trout.

Muscle tissues of both parr and grilse are low in lead level and lower than ever observed by FALK *et al.*(1973) and PAKKALA *et al.* (1972). HOLCOMBE *et al.*(1976) also did not observe any significant accumulation in muscle tissue on chronic exposure to lead.

It is apparent that the liver and kidney tissues selectively accumulate lead. This phenomenon has been observed by others as well (HOLCOMBE *et al.*1976, PAGENKOPF and NEUMAN, 1974). The highest mean value of 4.2 ppm was observed in liver of trout reared in river water containing ca 3 ppb lead (PAGENKOPF and NEUMAN, 1974). The concentration factor is 1400 in comparison 4700 in case of Miramichi salmon parr. HOLCOMBE *et al.*(1976) observed that first and second generation brook trout exposed to 119 μg Pb/liter had 68 and 50 μg Pb/g in liver tissue, and 215 and 179 μg Pb/g of kidney tissues and concluded that these levels might indicate detrimental exposures. The lead levels in liver and kidney tissues of the parr samples are 57 and 68 μg/g,respectively. It is not known at present whether this residual level in the organs would cause any functional damage to the internal organs and have any consequent biological effect on the salmon parr.

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