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Trace Metal Concentrations in Fish from the South Esk River, Northeastern Tasmania, Australia

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A comprehensive ecological study of the South Esk River (Norris **et al.**, 1980,1981,1982) has provided detailed information on basic water characteristics, concentrations of metals and the relationship of these factors to the distribution and abundance of benthic macroinvertebrates. The numbers of individuals and the variety of species of macroinvertebrates were both much reduced downstream of the source of trace metals from mines entering the South Esk River clearly indicating the low levels of metal contamination. As an adjunct to the study of the South Esk River reported by Norris **et al.** (1980,1981,1982), an investigation was made of the concentrations of zinc, cadmium and copper in South Esk River fish.

The purpose of the work reported here was to assess the value of determining metal concentrations in freshwater fish to indicate metal pollution. Such a practice has been reported as being successful for metals such as mercury and cadmium (Bayly and Lake 1979, Forstner and Wittman 1981). A further aim was to provide information on metal concentrations in fish as few data have been published for Australian rivers (Bayly and Lake 1979).

MATERIALS AND METHODS

The South Esk River in north-eastern Tasmania is polluted by cadmium, zinc, lead and copper (Norris **et al.** 1981) from Storys Creek and Rossarden mines which lie in dissected plateau country between Ben Lomond and the river. Detailed descriptions of the study area and the mining history are provided by Norris **et al.** (1980).

The South Esk River upstream of the entry of trace metals is typical of mountain creeks and rivers which arise on dolerite in Tasmania: clear with a low concentration of total dissolved solids, low conductivity and total ionic concentrations less than 200mg l^{-1} (Tyler and Buckney 1973)

Samples were collected from 10 sites in the South Esk River in January 1976 when the river was at a low flow level (Norris **et al** 1980). Four sites were upstream of the metal inflow to the river (sites 1-3 & 3A) and six were downstream (sites 4-8 and 8A). Site 3A was a backwater which was regularly flooded by the South Esk River. It was chosen as it provided the lentic conditions favoured by some species which were not available in the adjacent section of river.

Samples were collected using an electric fishing apparatus, powered by a Honda 800 W generator and providing a D.C current at 50 pulses sec^{-1} At each site 200 m of stream was exhaustively fished. Immediately after collection the different species of fish were separated, placed in polythene bags and frozen in portable fridges.

All glassware and equipment used for the determination of trace metals were soaked in detergent, rinsed, soaked in 10% HNO_3, and finally rinsed with distilled water. All reagents were analytical grade and pretested for possible contamination by trace metals. Concentrations of cadmium, zinc and copper were determined on a Pye Unicam model SP 1950 atomic absorption spectrophotometer with automatic background correction.

Where possible samples of gills, liver and muscle were obtained. Ten grams of the wet sample was weighed onto glass dishes and then dried at 105°C until constant weight was attained. The samples were then ground in a mortar and 0.25 g, weighed accurately to 0.1 mg, was placed into prepared test tubes, and then digested with 2 ml conc. HNO_3 in a water bath until nitrous oxide fumes were no longer emmitted (normally 2-3 h). The samples were then diluted and analysed as described above.

Details of the methods used for the collection and analysis for heavy metals in water samples from the South Esk River are given in Norris **et al.** (1981).

RESULTS AND DISCUSSION

A total of 178 fish belonging to five species were collected (Table 1). Only five tench were collected from the most heavily contaminated site 4, no fish at all from site 5 and only two trout were collected from site 1, upstream of the effluent inflow (Table 1).

Many of the fish collected were small as adults (**Nannoperca australis**) or as juveniles (most trout were less than one year old), so that insufficient gill and liver tissue was available from these fish for analysis by the method being used (Table 2).

Concentrations for all metals in all species were highest in the liver, intermediate in the gills and lowest in the muscle (Table 2). The short finned eels, **Anguilla australis**, had significant concentrations of all the metals analysed at sites both upstream and downstream of the trace metal inflow to the South Esk River.

Concentrations of zinc, cadmium and copper in the water of the South Esk River clearly indicate elevated levels downstream of site 3.

TABLE 1 Fish species caught and analysed for trace metals from the South Esk River.

species	site																					
	1		2		3A		3		4		5		6		7		8		8A		total	
	*C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
Salmo trutta	2	2	6	5	-	-	6	5	-	-	-	-	8	5	5	5	6	2	18	8	51	32
Anguilla australis	-	-	3	3	7	5	1	1	-	-	-	-	1	1	6	3	5	4	2	2	25	19
Nannoperca australis	-	-	3	3	7	5	1	1	-	-	-	-	-	-	-	-	35	11	18	8	64	30
Tinca tinca	-	-	1	1	3	3	-	-	5	5	-	-	-	-	-	-	-	-	5	4	13	18
Perca fluviatilis	-	-	5	5	2	2	1	1	-	-	-	-	2	2	8	5	1	1	5	2	24	18
total	2	2	20	19	16	14	10	9	5	5	-	-	11	8	19	13	47	18	48	24	178	112

C = number of fish caught
A = number of fish analysed

TABLE 2 Concentrations of zinc, copper and cadmium (ug g^{-1} dry wt.) in fish from the South Esk River.

metal	species	site 1			2			3A			3			4			6			7			8			8A		
		g	l	m	g	l	m	g	l	m	g	l	m	g	l	m	g	l	m	g	l	m	g	l	m	g	l	m
cadmium	**S. trutta**	-	1	-			-						-						21			10			25			2
	A. australis				-	4	-	3	13	1	2	119	-				45	143	3	23	181	4	20	152	4	19	193	1
	N. australis						-			-			-												5			5
	T. tinca				-	-	-	-	1	-				95	116[A]	16										19	63	1
	P. fluviatilis				-[A]	21[A]	-	-	-	-			-				70	550[A]	4			13	8	643	2	17	159	1
zinc	**S. trutta**	256	416	18			112						131						494			365			84	715	349	60
	A. australis				85	247	97	93	251	78	104	268	64				95	233	66	100	284	73	95	287	63	103	405	85
	N. australis						102			110			82												121			97
	T. tinca				93	87	13	78		21				612	517[A]	322										132	167	44
	P. fluviatilis				[A]87	154[A]	38	98		28			93				963	1580[A]	69			227	447	388	34	141	215	37
copper	**S. trutta**	7	198	1			-						2						5			5			4	7	436	5
	A. australis				4	146	5	3	100	3	14	163	9				4	123	3	6	127	6	4	201	3	10	234	4
	N. australis						-			5			-												14			11
	T. tinca				4		-	3	30	2				10	276[A]	9										11	138	4
	P. fluviatilis				-[A]	34[A]	32			1			7				8	45[A]	1			4	5	129	7	6	67	11

g = gill, l = liver, m = muscle, - = below the detection limit, <0.002 ug g^{-1} Cd, <0.005 ug g^{-1} Zn, <0.01 ug g^{-1} Cu, A = one fish analysed.

TABLE 3 Cadmium, zinc and coppper (ug l^{-1}) in the South Esk River water in December 1975

site	metal		
	Cd	Zn	Cu
1	-	20.00	-
2	-	10.00	3.20
3	-	30.00	0.80
4	5.00	140.00	2.40
5	4.20	260.00	4.00
6	2.20	70.00	2.40
7	1.80	50.00	1.00
8	0.40	40.00	4.00

- = not detected
<0.0005 ug l^{-1} Cd
<0.0005 ug l^{-1} Zn
<0.004 ug l^{-1} Cu

All the species collected exhibited discontinuous distributions. Most species were not collected from the heavily contaminated sites, 4 and 5 and lower numbers were collected from sites 6 and 7. In terms of distribution pygmy perch (**Nannoperca australis**) appears to have been the most sensitive to trace metal contamination occurring at uncontaminated upstream sites and at the least contaminated downstream sites (Table 1 and 2). Tench, the least sensitive, were collected from site 4, the most heavily contaminated site (Table 3 and Norris **et al.** 1981). This species normally inhabits still or slow flowing water and it was only collected from three other sites. Comparisons of metal concentrations in fish in relation to distance from the source are made difficult by these discontinuous distributions.

The largest tench (300g) collected from site 4 had both pectoral fins missing and deformed pelvic and tail fins. As no scarring was evident it seems likely that the condition observed in this fish was due to bone deformation caused by trace metals. Malformation of vertebrae in fish due to cadmium has been reported by several authors, e.g. (Bengtsson **et al.** 1975, Muramoto 1981) as well as retardation of fin regeneration (Weis and Weis 1976). It is probable that the five tench found their way to site 4 from the uncontaminated river immediately upstream.

Metal concentrations for each species for each tissue at each site were averaged. This was done as preliminary examination failed to find any consistent correlation between metal concentration and fish size (length and weight). Such a finding is consistent with the studies of Northcote **et al.** (1975), Romeril and Davis (1976), Wiener and Giesy (1979), Vinikour **et al.** (1980) and Wilson **et al.** (1981).

For the three metals in the five species of fish, the liver consistently had the highest concentrations followed by the gills then muscle. This is a result in partial agreement with previous studies, e.g. Muller and Prosi (1978), Wilson **et al.** 1981).

For zinc in the five fish species, only concentrations in the gills and liver of **Perca fluviatilis** appeared to reflect environmental contamination (Tables 2,3), thus illustrating the considerable differences between fish species as regards metal concentrating ability (viz. Giesy and Wiener 1977, Murphy **et al.** 1978).

An indication of copper contamination of the river is given by copper concentrations in the liver of brown trout, short finned eels and tench but not in the gills or muscle (Tables 2,3). In freshwater fish several studies (e.g. Muller and Prosi 1978, Wilson **et al.** 1981) have reported that the liver is an organ of copper accumulation.

Concentrations of cadmium in **Perca fluviatilis**, especially in the liver appeared to most emphatically allow a differentiation between contaminated and uncontaminated sites. Cadmium concentrations in the muscle of trout also show such a differentiation. In contrast, Wilson **et al.** (1981) found that cadmium concentrations in the muscle of trout from a Californian stream did not vary with levels of contamination.

The short finned eel **Anguilla australis** from uncontaminated sites had in some cases relatively high concentrations of cadmium. Eels are catadromous and cadmium levels in them at uncontaminated sites may reflect their migration through contaminated waters. The concentrations of metals in fish species which are migratory are thus of limited value for indicating metal pollution, as suggested by Bayly and Lake (1979).

The results of this study tend to support the observations of Wiener and Giesy (1979), Vinikour **et al.** (1980) and Wilson **et al.** (1981), that waterbody contamination by copper and zinc may not be reflected in concentrations of these metals in fish but that contamination by cadmium may be reflected by cadmium concentrations in resident fish.

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