Bull. Environ. Contam. Toxicol. (1986) 36:186–191

Environmental Contamination and Toxicology

Survival of *Salmo gairdneri* (Rainbow Trout) in the Zinc Polluted Molonglo River Near Captains Flat, New South Wales, Australia

G. A. Graham, G. Byron, and R. H. Norris*

Water Research Centre, Canberra College of Advanced Education, PO Box 1, Belconnen ACT 2616, Australia

Gold, lead, zinc and copper were mined continuously at Captains Flat between 1938 and 1962. The Molonglo River was polluted from a number of sources at the mine site. Acid mine water pumped from the lower levels of the mine was a major source, and a slimes dump collapse occurred in 1943 when approximately 30,000 m^3 of fine tailings slipped into the town's water supply reservoir. An equivalent volume of water carrying large amounts of finely divided tailings which included high concentrations of base metals was displaced into the Molonglo River. This water caused extensive flooding downstream on a plain between site 3 and 4 (Fig. 1) onto which large volumes of the tailings were deposited (Weatherley **et al.** 1967).

The mine was finally abandoned in 1962, but it was not until 1974 that a programme was instituted to stabilize and rehabilitate the mine workings and waste deposits (Anon, 1974). These works involved the reshaping of tailings dumps and their capping with impervious material to prevent surface run off and erosion. Settling dams were removed and small streams in the area were rerouted away from the dumps and other areas containing toxic materials. Some effort was also made to prevent water entering the old underground mine workings.Field experiments showed that the water quality of the river was unsuitable for the survival of **Salmo gairdneri** both before and after the closure of the mine (Weatherley **et al** 1967). In order to determine whether the remedial works had effectively improved water quality of the Molonglo River the study reported here was designed to repeat that portion of the work published by Weatherley **et al.** (1967) which examined the survival of rainbow trout held in cages in the Molonglo River.

MATERIALS AND METHODS

At each of four sites (Fig. 1) 10 hatchery bred rainbow trout fingerlings were held in closed cages. Site 1 was located

* All correspondence to R.H. Norris

upstream of the abandoned mine workings at Captains Flat, while the remaining 3 sites were located downstream. Stations 2, 3 and 4 were in similar locations to sites 2, 5 and 6 used by Weatherley **et al.** (1967). The cages (0.06 m^3) were welded stainless steel frames covered with plastic mesh (2mm opening). They were secured in the main channel of the river where continuous water flow could be assured. The fish were inspected on 5 occasions over 12 days. Dead fish were removed, placed in labelled bags and frozen within 2 hours of collection at -20°C until analysed for trace metals. Where all ten fish had died prior to the completion of the study the cages were restocked with another ten fingerlings.

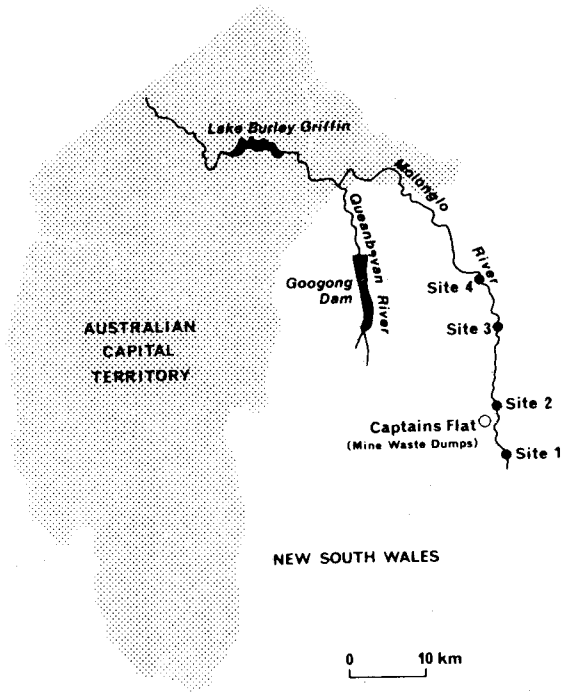

Figure 1. Captain's Flat and Molonglo River study area and site location.

Fish were also held in two large aquaria as laboratory controls. Domestic supply tapwater was used in each aquarium. At the completion of the field experiment, ten fish from the aquaria were killed and stored with those fish taken from the cages in the river.

Temperature (°C), pH and dissolved oxygen (mgl^{-1}) were recorded at each site on each visit. Hydrographic data for the river were obtained from the Commonwealth Government, Department of Housing and Construction at a gauging site between sites 3

Water samples were collected at each site on every visit in 250 ml polyethylene bottles which had been washed with 20% HNO_3 and filled with nanopure water. All water samples were preserved with concentrated HNO_3 (pH < 1). The samples were subsequently stored at a temperature of 4°C prior to analysis. Water samples were analysed for zinc and copper using a Varian Techtron model AA6 atomic absorption spectrophotometer.

The gills were removed from each fish for metal analysis. Since the gills of the fingerlings were very small, some weighing as little as 0.2 g (wet weight), all gills taken from fish at the same site on any visit were combined to provide sufficient sample for analysis. Samples were dried to constant weight in an oven at 60°C and digested in concentrated HNO_3, as described by Norris and Lake (1984).

RESULTS AND DISCUSSION

Throughout the study the levels recorded for temperature, oxygen and pH in the Molonglo River, were all well within the ranges required for the survival of **S. gairdneri** (Table 1).

Concentrations of zinc and copper in the water at sites 2 to 4 were fifty to sixty times higher than at site 1 which was upstream of the mine workings at Captain's Flat (Table 1). Although the data collected were insufficient to be statistically tested, the concentrations of both zinc and copper in the gills of **S. gairdneri** appear to show similar trends to those in the water (Table 1). Fish mortality was greatest at sites 2 and 4 (both were restocked) while only two fish died at the control site 1 (Table 1).

The fish held in the cages in the river during the study had suffered anterior skin abrasions, caused by repeated contact with the cage mesh. This condition may have led to low resistance to stress from trace metals and contributed to the death of a number of the fish. Based on the mortality rate at site 1 during the study, it would seem reasonable to expect mortality from injury alone to approach 20% after 12 days.

The concentration gradients of both copper and zinc in the river water between all sites were generally consistent with the findings of Weatherley **et al.** (1967). The concentrations of zinc at site 4, which appeared to be independent of changes in concentrations at sites 2 and 3 agrees with the suggestion by Weatherley **et al.** (1967) that the tailings deposited on Carwoola plain (between sites 3 and 4, Fig. 1) from past slimes dump collapses may act as a source of re-contamination to the river. All fish had died at site 4 by day 7 of the study (Table 1) suggesting that a surge of water carrying higher cocentrations of metals had occurred. Although higher metal concentrations were not recorded at site 4 (Table 1) there was a sudden increase in discharge from 1.0 m^3s^{-1} to 7.0 m^3s^{-1}

on the fourth and fifth day of the study. **Salmo gairdneri** held in cages may be regarded as effectively summarizing water quality for the preceding periods whereas chemical measurements can only provide information at the point in time of sample collection.

Table 1 Zinc and copper concentrations in the Molonglo River and in the gills of **Salmo gairdneri**, cumulative mortality and the basic water characteristics. Zn in water (mgl^{-1}), Cu in water (ugl^{-1}), Zn and Cu in gills (ugg^{-1} dry weight), temperature (^{o}C), oxygen (mgl^{-1}).

Site no.	Days	Water Zn	Water Cu	gills Zn	gills Cu	Number Mortality	Number Analysed	Temp	Oxygen	pH
1	0	0.03	0.5	-	-	0		11.3	9.55	6.45
	5	0.03	0.5	-	-	0		5.2	11.45	6.03
	7	0.03	0.5	-	-	0		13.0	9.29	6.30
	10	0.02	0.5	-	-	0		10.6	10.25	6.37
	12	0.02	0.5	446.0	9.6	2	10	11.3	9.60	6.58
2	0	1.65	26.0	-	-	0		8.4	10.80	6.35
	5	2.31	26.0	1016.0	24.8	10	10	8.3	10.60	6.17
	7	2.32	29.0	-	-	*		12.1	10.04	6.30
	10	1.70	41.5	640.0	80.8	10	10	9.8	10.10	6.55
	12	1.40	14.5	-	-			10.8	9.59	6.54
3	0	0.91	20.0	-	-	0		10.1	10.30	6.75
	5	1.33	14.0	-	-	0		8.8	10.87	6.55
	7	1.40	18.0	192.0	12.0	6	6	13.0	10.56	6.39
	10	0.76	12.0	600.0	46.7	8	2	9.5	10.90	6.82
	12	0.98	30.0	225.9	36.5	8	2	11.0	9.49	6.82
4	0	1.28	17.0	-	-	0		8.4	10.58	6.60
	5	1.14	8.0	752.0	38.4	7	7	11.7	10.47	6.77
	7	1.06	13.0	328.0	11.2	10*	3	11.8	10.81	7.12
	10	1.04	11.5	220.0	10.4	7	7	9.7	10.54	6.76
	12	0.96	10.0	333.3	10.0	7	3	11.0	9.51	6.85
Control fish				215.2	8.8		10			

* Site Restocked

Levels of zinc lethal to rainbow trout reported in the literature vary greatly. The 96 hour LC50 of zinc to rainbow trout calculated by Lovegrove and Eddy (1982) was 2.00 mgl^{-1}, whereas Skidmore (1964) gives lethal concentrations (100% mortality after 24 hours) of zinc to rainbow trout fingerlings as 0.13 mgl^{-1}. The rapid mortality rates and concentrations of

zinc in the gills of trout and in the water at sites 3 and 4 (Table 1), suggest that the LC50 for the fish held in the river during this study would have been in the vicinity of 0.6 to 0.9 mgl^{-1}.

The effects of copper on rainbow trout juveniles were reported by Grande (1966) to be insignificant after 21 days exposure to concentrations of 40-60 ugl^{-1}. Since the fish used in the study described here were exposed to levels up to approximately 40 ugl for only 12 days (Table 1) it is unlikely that the concentrations of copper were sufficiently high to be lethal , conclusion also reached by Weatherley **et al.** (1967). The known synergistic effects on the toxicity of zinc with other trace metals (Weatherley **et al.** 1967), would suggest that copper contributed to the death of the fish. It is also likely that the long term reproductive success of rainbow trout in the river would be reduced as by the concentrations of copper recorded during this study when compared to the results reported by McKim and Benoit (1971) for **Saluelinus fontinalis.**

The extensive rehabilitation of the abandoned mine workings at Captains Flat have been ineffective. The Molonglo River is still suffering from pollution by heavy metals and that contamination of the river by copper and zinc is at least periodically lethal to rainbow trout as was also found by Weatherley **et al.** (1967) prior to the implementation of the remedial work. Rainbow trout, which have been stocked in the area, will be unlikely to establish resident stocks, or use the Molonglo River for spawning purposes for at least 30 km downstream from Captains Flat.

Acknowledgments. The Canberra College of Advanced Education provided laboratory facilities. Dr A. Georges, of the Water Research Centre of the CCAE and Dr K.R. Norris of the Commonwealth Scientific and Industrial Research Organisation provided useful criticism of the manuscript.

REFERENCES

Anonymous (1974) Mine waste pollution of the Molonglo River. Australian Government Publishing Service, Canberra.

Grande M (1966) Effect of Copper and zinc on salmonid fishes. Third Int Conf Water Pollut Res 1:97-111

Lovegrove SM, Eddy B (1982) Uptake and accumulation of zinc in juvenile rainbow trout, **Salmo gairdneri.** Env Biol Fish 7:285-289.

McKim JM, Benoit DA (1971) Effects of long term exposures to copper on survival, growth and reproduction of brook trout, **Salvelinus fontinalis.** J Fish Res Board Canada 28: 655-662.

Norris RH, Lake PS (1984) Trace metal concentrations in fish from the South Esk River, Northeastern Tasmania, Australia. Bull Environ Contam Toxicol 33:348-354.

Skidmore JF (1964) Toxicity of zinc components to aquatic animals with special reference to fish. Quart Rev Biol 39:227-248.
Weatherley AH, Beevers JR, Lake PS (1967) The ecology of a zinc polluted river. In: Weatherley AH (ed) Australian inland waters and their fauna. Australian National University Press, Canberra, p252-278.

Received April 3, 1985; Accepted April 22, 1985