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Acute Toxicity of Zinc to Juvenile and Subadult Rainbow Trout, *Salmo gairdneri*

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Published data indicate that toxicity of zinc to fishes increases from the embryo stage to a maximum just after the transition to an exogenous food source, then decreases through the juvenile and adult stages (see Weatherley et al. 1980 and Spear 1980 for reviews). This relationship was derived from studies of cyprinids, small percids, and the young stages of salmonids. There is, however, a paucity of data on the acute toxicity of zinc to the mid-juvenile and early adult stages of the salmonids.

We present the results of two bioassays of juvenile and subadult rainbow trout which suggest that zinc is equally toxic to these two life stages.

MATERIALS AND METHODS

Two bioassays were conducted using flow-through conditions: one in 1981 with juvenile trout of 15.7 (± 1.25) cm fork length (25-70 g), the other in 1984 using trout of 25.8 (± 1.0) cm fork length (160-290 g). All trout were obtained from Franklin Trout Farm, Mt. Albert Ontario. The experimental procedures employed in both bioassays followed the guidelines of ASTM (1980). The laboratory facility consisted of a 6000-L recirculation system with UV sterilization and charcoal filtration. Laboratory water which originated from the Toronto municipal supply was maintained at 12.0 °C and illuminated with fluorescent lights with a daily photoperiod of 16:8, light:dark.

Fish were acclimated to laboratory water for a minimum of 2 wk before being randomly distributed to the 300-L treatment and control tanks. Ten fish were

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exposed to each test concentration for 96 h at a loading density of not less than 1.0 L of dilution water/g of fish (wet weight) every 24 h, and at an instantaneous density of less than 9 g/L. Ninety nine percent replacement of test water occurred every 18 h. Fish were fed pelleted food once daily and starved for 36 h before the start of each bioassay.

The continuous supply of gravity-fed dilution water to the aerated treatment and control tanks was regulated by Gilmont flow meters. Concentrated zinc sulphate ($ZnSO_4.7H_2O$, analytical grade) was delivered to the dilution water before it entered a treatment tank via a multiple channel Buchler peristaltic pump. Water leaving the control tanks returned to the main recirculation system, whereas that of the treatment tanks ran to waste; water lost from the system was replaced with tap water.

The flow of dilution water and toxicant was checked daily to ensure that each tank received a constant volume of dilution water and that the zinc concentrations in the treatment tanks did not vary. Zinc concentrations in the control and treatment tanks were determined twice daily with the dithiazone colorimetric test for total zinc (APHA 1976). Our zinc analyses were verified by an outside laboratory. Dissolved oxygen and pH measurements were made daily.

Mortalities during both bioassays were monitered using the following observation schedule: 1, 15, 30 min; 1, 2, 4, 6, 8 and 12 h, then 3 times daily until the end of the 96-h period. Fish were considered dead when no gill ventilation was apparent and no response to gentle prodding occurred, at which time they were removed from the tank.

The large volumes of dilution water required in both bioassays because of the size of test fish (25-290 g) meant that only two of a maximum of six test concentrations could be run at one time. Each pair of test concentrations had its own control group. The chemical composition of the dilution waters (Table 1), determined by an outside laboratory, remained constant during both bioassays.

RESULTS AND DISCUSSION

The 96-h median lethal concentrations of zinc to the juveniles and subadults (Table 2) were 26.0 and 24.0 mg/L (Litchfield and Wilcoxon 1949). The slopes of the dose-effect curves and the potency of zinc in both bioassays did not differ significantly ($\alpha = 0.05$) (Litchfield and Wilcoxon 1949).

Table 1. Chemical composition of the dilution waters of both bioassays.

Parameter	Juvenile	Subadult
temp °C	12.7 ± 1.0	12.1 ± 1.0
O_2 (% sat)	>80.0	>80.0
pH	7.3	7.1
hardness (mg/L $CaCO_3$)	137.0	143.4
alkalinity (mg/L $CaCO_3$)	-	74.8
Ca (mg/L)	42.0	42.0
Mg "	8.0	9.5
Zn "	0.05	0.024
Fe "	0.01	0.01
Cu "	0.005	0.003
total organic carbon (mg/L)	-	2.5
total suspended solids (mg/L)	-	<0.5

- data not available

The LC50s of this study suggest that juvenile and subadult rainbow trout are equally tolerant of zinc. Other studies of the toxicity of metals to different life stages have found similar results. Anderson and Spear (1980) found the 96-h LC50s of copper to juvenile and adult rainbow trout were 0.19 and 0.21 mg/L, respectively. Body size did not affect

Table 2. Zinc concentrations (mean ± S.D.), percent mortalities, LC50s (mg/L) and slope functions of both bioassays.

	Juvenile		Subadult	
	Zn conc. (mg/L)	%mort.	Zn conc. (mg/L)	%mort.
control	0.050	0	0.024	0
control	0.050	0	0.023	0
control	0.051	0	0.024	0
test	0.38 ± 0.014	0	0.50 ± 0.050	0
"	0.85 ± 0.046	20	1.00 ± 0.005	10
"	1.29 ± 0.075	10	1.50 ± 0.080	20
"	1.95 ± 0.040	30	2.40 ± 0.410	60
"	2.90 ± 0.095	60	3.3 ± 0.120	60
"			5.2 ± 0.360	100
LC50 (mg/L)	2.6 *(1.72-3.92)		2.4 *(1.77-3.24)	
Slope function	2.41		1.86	

* 95% confidence limit

resistance to copper and zinc in Atlantic salmon *Salmo salar* (Sprague 1964). Median survival time of rainbow trout fingerlings to copper sulphate decreased as body size increased (Harrison 1975).

Chapman (1978) found young juvenile steelhead *Salmo gairdneri* and chinook salmon *Oncorhynchus tshawytscha* were less tolerant to zinc than developing embryos but also showed the smolt stage to be slightly more tolerant than all of the younger stages. Unfortunately his study did not include the adult form. In a study with 14.0 cm and 7.0 cm rainbow trout (Goettl *et al*. 1976, cited by Taylor and Demayo 1980), the larger fish were more tolerant to zinc than the smaller form in both hard and soft water. Goettl's data contrast with those presented here, but direct comparison is difficult due to the absence of large fish (25.0 cm) in his study.

The equation, LC50 (96-h) = aW^b, describes the relationship between zinc tolerance and body weight (W) in cyprinids and young salmonids (Spear 1980). The b exponent ranges between 0.1 and 0.4. indicating an increase in tolerance with body size. The insignificant difference ($\alpha = 0.05$) between the LC50s of the two sizes of rainbow trout here suggests that 0.31 for b, derived for fingerling and young juvenile rainbow trout (Holcombe and Andrew 1978, cited by Spear 1980), is too high for the older stages of this species. Indeed, Anderson and Spear (1980) derived a b exponent of zero in their study of the toxicity of copper to juvenile and adult rainbow trout.

It is possible that the influence of body weight on zinc tolerance in rainbow trout decreases after the mid-juvenile or adult stage is reached. This would disqualify the body weight-zinc tolerance relationship derived for the younger stages as a tool for the prediction of acute toxicity to the adults. Further study of the acute toxicity of zinc to the older stages of the salmonids is required. The toxicity and the mechanisms of toxicity of heavy metals, such as zinc, to all life stages in fishes must be clearly understood before relationships between tolerance and body or organ size can be formulated with confidence.

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