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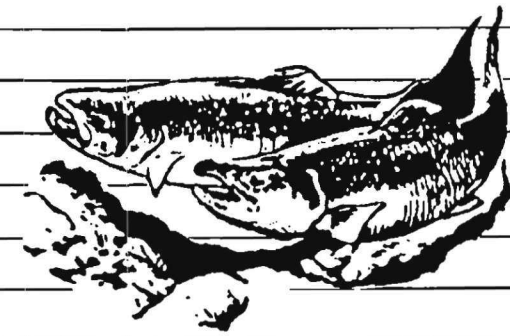

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Irrigation Drainwater May Be Harmful to Endangered Fish in the Green River of Utah

The middle Green River provides critical habitat for several endangered fish species, including bonytail (*Gila elegans*), Colorado squawfish (*Ptychocheilus lucius*), and razorback sucker (*Xyrauchen texanus*). The decline of these species in the upper Colorado River basin has been attributed to the combined effects of habitat alteration or destruction—resulting from the operation of dams, water diversions, and other management practices in the basin—and competition and predation by nonnative fish species.

The discharge of irrigation drainwater into the middle Green River and its tributaries may also be adversely affecting these fish. Recent investigations on wildlife areas in the middle Green River basin, which receive irrigation drainage, found elevated concentrations of boron, selenium, and zinc in water, bottom sediment, and biota.

Irrigation drainwater enters the middle Green River from the Ashley Creek and Stewart Lake outflow. Shallow embayments adjacent to the mouths of these tributaries provide spawning and nursery habitat for Colorado squawfish and razorback sucker. Bonytail may also use these habitats for spawning and staging. Consequently, early life stages of these fish may be exposed simultaneously to several inorganic contaminants carried in irrigation drainwater. We evaluated the toxicity and potential hazard of environmentally relevant mixtures of drainwater contaminants to these fish.

Individual and Mixtures of Inorganics Were Tested

The individual toxicities of copper, selenate, selenite, and zinc to early life stages (larva and juvenile) of bonytail, Colorado squawfish, and razorback sucker were determined in standard 96-h tests. Individual toxicities of boron, vanadium, and uranium were determined in a earlier study at our Laboratory. To evaluate the effects of mixtures of these chemicals, fish were exposed for 96 h to a series of concentrations of these seven inorganic contaminants combined at ratios that simulated those found in water from the Ashley Creek and Stewart Lake outflow. Tests were conducted in a

synthetic test water that simulated the water quality of the middle Green River upstream from the mouth of Ashley Creek and Stewart Lake outflow (hardness = 199 mg/L and alkalinity = 107 mg/L). The measure of acute toxicity was the 96-h LC50 (medium lethal concentration).

The additive index was used to quantify the type of joint toxic action exhibited by the mixtures to each species and life stage. The AI is based on the toxic contribution of each component in the mixture. These contributions are termed "toxic units" (TU), and are expressed as the ratio of the 96-h LC50 of the inorganic tested in the mixture to the 96 h LC50 of the inorganic tested individually. The joint toxicity of a mixture was judged to be additive if the range of AI values overlapped zero, greater than additive (synergistic) if the range of AI values was greater than zero, or less than additive (antagonistic) if the range of AI values was less than zero.

Effect of Inorganic Contaminants on Life Stage Was Species Specific

Colorado squawfish larvae were more sensitive than juveniles to each inorganic contaminant, whereas there were no consistent differences in sensitivities to these inorganics between the two life stages of bonytail and razorback sucker (Table 1). The larvae of all three species exhibited similar sensitivities to each inorganic. Conversely, razorback sucker juveniles were more sensitive to each inorganic than Colorado squawfish juveniles.

Mixtures Were More Toxic Than the Individual Components

Toxic unit values for each inorganic in both mixtures were <1, indicating that the mixtures were more toxic (i.e., had lower 96-h LC50 values) to these fish than the individual components (Tables 2 and 3). Based on the range of AI values, both mixtures produced greater than additive (synergistic) toxic effects in at least one life stage of Colorado squawfish and bonytail. The same two mixtures were additive in toxicity to razorback sucker. Copper was identified as the primary toxic component in each mixture because it contributed 67 to 84% of the summed TU for the Ashley Creek mixture and 52 to 78% of the summed TU for the Stewart Lake mixture. Zinc contributed 16 to 42% of the summed TU in the Stewart Lake mixture. The other components in the mixtures each contributed ≤10% of the summed toxic units. Overall, no one life stage or species was more sensitive to the mixtures than any of the others.

Mixtures Have a High Hazard Potential

To predict the hazards that chemicals may pose to fish and other aquatic organisms, the biological effect concentrations (BEC) are compared to the expected (or measured) environmental concentrations (EEC). In the early stages of the hazard evaluation process, acute toxicity tests are used to estimate the BEC (i.e., 96-h LC50), and the highest expected waterborne concentration of a chemical is used as the EEC. The magnitude of hazard is expressed as a ratio of the BEC to the EEC, and the ratio is referred to as the margin of uncertainty. Based on acute toxicity values, margins of uncertainty <100 indicate a high potential for hazard to aquatic organisms and a need for additional testing.

The margins of uncertainty we obtained for each species and life stage and both mixtures ranged from 9 to 22 for the Stewart Lake outflow mixture and from 12 to 32 for the Ashley Creek mixture (Table 4). We conclude that mixtures of drainwater contaminants at these locations have a high potential for adversely affecting early life stages of endangered fish and long-term testing is needed.

Because early life stages of Colorado squawfish and razorback sucker use slack water areas adjacent to these outlets and the low margins of uncertainty for mixtures of these inorganics, contaminants associated with irrigation drainwater may adversely affect the early life stages and contribute to the lack of recovery of these species in the Green River basin.

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Table 1. Individual acute toxicity (96-h LC50 in mg/L) of four inorganics to early life stages of three endangered fish in the upper Colorado River basin at 25°C.

Species and life stage	Copper	Zinc	Selenite	Selenate
Colorado squawfish				
Larva	0.363	3.34	12.8	24.6
Juvenile	0.663	8.62	27.9	77.5
Bonytail				
Larva	0.364	5.35	23.3	26.4
Juvenile	0.231	8.01	20.7	43.5
Razorback sucker				
Larva	0.404	4.10	16.8	25.2
Juvenile	0.331	2.92	13.7	13.8

Table 2. Joint toxicity of a mixture of seven inorganic contaminants combined at ratios representative of Ashley Creek to different life stages of three endangered fish in the upper Colorado River basin at 25°C.

Species and life stage	Toxic unit[a]								Additive index and range
	Copper	Zinc	Selenite	Selenate	Boron	Uranium	Vanadium	Total	
Colorado squawfish									
Larva	0.34	0.07	0.01	0.03	0.03	0.01	<0.01	0.49	1.04 0.33 to 2.33
Juvenile	0.48	0.07	0.01	0.02	0.07	0.02	0.02	0.69	0.45 -0.04 to 1.27
Bonytail									
Larva	0.43	0.06	0.01	0.03	0.04	0.01	0.01	0.59	0.69 0.06 to 1.70
Juvenile	0.74	0.04	0.01	0.02	0.04	0.01	0.02	0.88	0.14 -0.41 to 0.75
Razorback sucker									
Larva	0.58	0.11	0.01	0.05	0.06	0.02	0.01	0.84	0.19 -0.25 to 0.79
Juvenile	0.63	0.14	0.01	0.08	0.05	0.02	0.01	0.94	0.06 -0.49 to 0.61

[a]Toxic unit = 96-h LC50 of inorganic contaminant in mixture ÷ 96-h LC50 of inorganic contaminant tested individually.

Table 3. Joint toxicity of a mixture of seven inorganic contaminants combined at ratios representative of Stewart Lake outflow to different life stages of three endangered fish in the upper Colorado River basin at 25°C.

Species and life stage	Toxic unit[a]								Additive index and range
	Copper	Zinc	Selenite	Selenate	Boron	Uranium	Vanadium	Total	
Colorado squawfish									
Larva	0.24	0.18	<0.01	<0.01	0.02	0.01	<0.01	0.45	1.22 0.35 to 2.57
Juvenile	0.29	0.15	<0.01	<0.01	0.04	0.02	<0.01	0.50	1.00 0.37 to 2.03
Bonytail									
Larva	0.30	0.14	<0.01	<0.01	0.02	0.01	<0.01	0.47	1.13 0.47 to 1.94
Juvenile	0.50	0.10	<0.01	<0.01	0.03	0.01	<0.01	0.64	0.56 0.05 to 1.50
Razorback sucker									
Larva	0.55	0.38	<0.01	0.01	0.06	0.02	<0.01	1.02	-0.02 -0.56 to 0.52
Juvenile	0.41	0.33	<0.01	0.01	0.03	0.01	<0.01	0.79	0.27 -0.29 to 0.96

[a]Toxic unit = 96-h LC50 of inorganic contaminant in mixture ÷ 96-h LC50 of inorganic contaminant tested individually.

Table 4. Margins of uncertainty (96-h LC50/EEC[a]) for two environmentally relevant mixtures of seven inorganic contaminants and different life stages of three endangered fish in the upper Colorado River basin at 25°C.

Species and life stage	Ashley Creek	Stewart Lake
Colorado squawfish		
Larva	12	9
Juvenile	32	19
Bonytail		
Larva	16	11
Juvenile	17	12
Razorback sucker		
Larva	23	22
Juvenile	21	14

[a]EEC = Estimated environmental concentration.