UPPER COLUMBIA RIVER

Acute Water Exposures of Two Early Life-Stages of White Sturgeon (*Acipenser transmontanus*) to Copper and Lead

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1 PURPOSE AND OBJECTIVES

The purpose of this study was to evaluate the acute toxicity to early life-stages (ELS) of white sturgeon (*Acipenser transmontanus*) of water-borne copper and lead at two different life-stages. Specifically, this study was designed to provide data needed to answer the following questions:

1. What concentrations of copper and lead are acutely toxic to ELS (i.e., 8 and 40 days post hatch [dph]) of white sturgeon as determined using standard 96-hour (hr) toxicity tests?
2. Are ambient water quality criteria (AWQC) for copper and lead protective of ELS of white sturgeon?

2 METHODS

2.1 TEST SPECIES AND SOURCE

Fertilized white sturgeon eggs were obtained from the Kootenay Trout Hatchery (KTH) located in Fort Steele, British Columbia on July 14, 2009. Hatchery staff collected eggs from two female and six male adult white sturgeon captured in the Columbia River (CR) near Waneta, Canada (Ek 2009, pers. comm.). Fertilization of the eggs was harmonized in the hatchery by injecting the sturgeon with a gonadotropin analog on two subsequent days. Embryos were transported in oxygenated bags and received at the testing facilities within 6 hours of fertilization. Embryos were acclimated to test waters for 1-hour before being incubated in McDonald-type hatching jars (Aquatic Ecosystems, Apopka, FL) with a low flow velocity for 72 hrs until neurulation occurred. After 72 hrs, flow conditions were increased to gently agitate the embryos and prevent the development of fungus. Egg hatching jars were inspected daily, and infertile, damaged or fungus infected eggs were removed. Hatching began and ended on July 20 and 25, respectively; approximately 6 to 11 days post-fertilization.

After hatch, fry were transferred into large insulated holding tanks (i.e., Laboratory Water Experiment = 378 liters [L]; River Water Experiment = 205 L) and cultured under the same conditions until initiation of the study. At approximately 8 to 10 dph (just before swim up), live artemia (*Artemia salina*), ground bloodworms (Hagen, San Francisco Bay Brand), and a semi-moist diet consisting of 1 part Ewos micropellet trout chow #0, 0.03 parts cyclopeze from Argent Chemicals, and 0.03 parts krill obtained from Screttings were introduced into the culture tank to familiarize fry with food. Food was supplied *ad libitum* and feeding took place 3 to 4 times per day. Uneaten food and other debris were removed daily.

2.2 TEST MATERIALS

Stock solutions were prepared using copper (II) sulfate pentahydrate (Chemical Abstracts Service number 7758-99-8; purity 99.995 percent) and lead (II) nitrate (Chemical Abstracts Service number 7790-78-5; purity 99.999 percent. Chemicals were obtained from Sigma-Aldrich (Oakville, ON, Canada). All chemicals were directly dissolved in test waters and allowed to equilibrate for approximately 72 hrs prior to testing.

Nominal concentrations in micrograms per liter (μg/L) tested were

Copper @ 8 dph = (0, 1, 3, 9, 27, 54, 108, and 216) μg/L

Copper @ 40 dph = (0, 1.3, 4, 12, 24, 48, 96, and 192) μg/L

Lead @ 8 dph = (0, 1, 3, 9, 27, 81, 243, and 486) μg/L

Lead @ 40 dph = (0, 31, 61, 122, 244, 488, 976, and 1,952) μg/L

2.3 EXPOSURE METHODS

Acute 96-hr toxicity tests were conducted at the Aquatic Toxicology Research Facility, University of Saskatchewan (U of S), Saskatoon, Saskatchewan; and adjacent to the CR at a location upstream of the Teck Metals Ltd. Trail smelter facility (the facility) along the east bank of the CR (49°07′01.32″ N; 117°43′27.25″ W) at river mile (RM) 758.

Exposures were initiated at 8 to 10 dph and were conducted under static renewal conditions in decontaminated 0.5 L polypropylene containers per American Society for Testing and Materials (ASTM) guidelines for testing ELS of fish (ASTM 2009 – E1241-05 and ASTM 2007 – E729-96). Exposures initiated at 40 dph were also conducted under static renewal conditions, in larger 4 L decontaminated polypropylene containers. Per ASTM guidelines, 50 percent of the test solution was replaced every 12 hrs for each life-stage tested. All exposures were conducted under an illumination cycle of 16 light to 8 dark hours; and a target temperature of 16 ± 1 degrees Celsius (°C). Mortality and routine observations were recorded at time (t) = [0, 24, 48, 72, and 96] hrs. At the conclusion of the test, sturgeon larvae were euthanized using tricaine methanesulfonate (MS222), measured, weighed, and stored in 10 percent buffered formalin.

2.3.1 U of S Toxicity Testing

Test solutions were prepared in reverse osmosis (RO) water adjusted to a water hardness of approximately 60 milligrams as calcium carbonate per liter (mg/L $CaCO_3$), and a dissolved organic carbon (DOC) concentration of approximately 1.5 to 2.5 mg/L by adding laboratory (i.e., dechlorinated City of Saskatoon water) in a 1:1 ratio. Water quality parameters measured at the beginning and end of the study included temperature, dissolved oxygen (DO), pH, conductivity, hardness, ammonia, nitrate, nitrite, total chlorine, DOC, total organic carbon (TOC) and dissolved metal concentrations.

2.3.2 Columbia River Toxicity Testing

Test solutions were prepared by mixing stock solutions directly with CR water and allowed to equilibrate for a minimum of 48 hrs. Water quality parameters measured at the beginning and end of the study included hardness, ammonia, nitrate, nitrite, DOC, TOC, dissolved metal concentrations. Temperature, DO, pH, and conductivity were measured daily.

2.4 WATER CHEMISTRY AND WATER QUALITY

Routine water quality parameters (i.e., temperature, pH, DO, and conductivity) were recorded daily with symphony electrodes (VWR, Cat #11388-328). Hardness, alkalinity, ammonia, nitrate, nitrite, and total chlorine were recorded at the initiation and termination of the study using LaMotte colorimetric and titrator test kits. In addition, composite water samples were collected from all replicate exposure chambers of a treatment group at the beginning and end of the test, and analyzed for dissolved metals. Samples were collected using acid-cleaned high density polyethylene (HDPE) bottles[1], filtered through a 0.45 micrometer (μm) polycarbonate filter with Nalgene® filter holders and receivers; acidified with ultrapure nitric acid to a pH <2 standard units (s.u.), and maintained at approximately 4°C for shipment to the analytical laboratory (Columbia Analytical Services).

A summary of the samples collected, blanks, analytical methods and associated method detection limits are provided in Tables 1 and 2.

2.5 DATA ANALYSIS AND STATISTICS

Data are summarized as the mean ±1 standard deviation (SD). Fish mortality was analyzed by comparing the proportion of dead fish in each of the three or four exposure chambers of a given metal concentration to that of the controls. Data were tested for normality using the Shapiro-Wilk test or probability plots. All data were normally distributed or approximated a normal distribution, and analysis of variance (ANOVA) and Bonferroni *post hoc* tests were used to detect significant differences between treatment and control groups. Concentrations at which 50 percent mortality occurred (LC50) were calculated using a two-parameter logistic model, as appropriate. All statistical analyses were conducted using either SPSS (SPSS Inc., Chicago, IL, USA), R (R Development Core Team 2009), or Microsoft Excel. Statistical significance was accepted when $p < 0.05$.

[1] Samples to be tested for dissolved mercury were collected in fluoropolymer bottles.

Table 1. Analytical Methods and Associated Method Detection Limits

Parameter	Method	Laboratory	Unit	LOD
Copper	EPA 6020	CAS	mg/L	0.02
Lead	EPA 6020	CAS	mg/L	0.005
Temperature	VWR Symphony 14002-860	U of S	˚C	0
pH	VWR Symphony 14002-860	U of S	s.u.	0
DO	VWR Symphony 11388-374	U of S	mg/L	2
Conductivity	VWR Symphony 11388-372	U of S	µS/cm	1
Ammonia-Nitrogen	LaMotte Kit 3304	U of S	mg/L	0.05
Nitrate	LaMotte Kit 3319	U of S	mg/L	0.25
Nitrite	LaMotte Kit 7674	U of S	mg/L	0.02
Total Chlorine	LaMotte Kit 6905	U of S	mg/L	0.2
Hardness	SM 2340C	CAS	mg/L	0.8
Alkalinity	SM 2320B	CAS	mg/L	1.0
TOC	SM 5310C	CAS	mg/L	0.07
DOC	SM 5310C	CAS	mg/L	0.07

Notes:
CAS – Columbia Analytical Services
DO – dissolved oxygen
DOC – dissolved organic carbon
LOD – limit of detection
TOC – total organic carbon
U of S – University of Saskatchewan

Table 2. Water Quality Measurements in Blanks and Control Test Solutions

Sample Type	Parameter	Method	Unit	Range
Field Blank	DOC	SM 5310C	mg/L	0.32 - 1.5
Field Blank	TOC	SM 5310C	mg/L	0.14 - 0.41
Field Blank	Copper	SM 5310C	mg/L	<0.02 - 0.2
Field Blank	Lead	SM 5310C	mg/L	0.026 - 0.323
Method Blank	DOC	SM 5310C	mg/L	n/a
Method Blank	TOC	SM 5310C	mg/L	<0.07 - 0.37
Method Blank	Copper	SM 5310C	mg/L	<0.02 - 0.03
Method Blank	Lead	SM 5310C	mg/L	<0.005 - 0.01
CR Lab Water (Background; 8 dph)	Copper	EPA 6020	µg/L	0.71 - 1.1
CR UFS Water (Background 8 dph)	Copper	EPA 6020	µg/L	0.63 - 0.79
CR Lab Water (Background; 8 dph)	Lead	EPA 6020	µg/L	0.09 - 0.19
CR UFS Water (Background; 8 dph)	Lead	EPA 6020	µg/L	0.15 - 0.40
CR Lab Water (Background; 40 dph)	Copper	EPA 6020	µg/L	0.37 - 0.39
CR UFS Water (Background 40 dph)	Copper	EPA 6020	µg/L	1.0 - 1.2
CR Lab Water (Background; 40 dph)	Lead	EPA 6020	µg/L	0.044 - 0.12
CR UFS Water (Background; 40 dph)	Lead	EPA 6020	µg/L	0.084 - 0.53

Notes:
CR – Columbia River
DO – dissolved oxygen
DOC – dissolved organic carbon
dph – days post hatch
n/a – not applicable because method blanks were performed on deionized lab water at CAS
RO – reverse osmosis
TOC – total organic carbon
UFS – upstream field site

3 RESULTS AND DISCUSSION

3.1 EXPOSURE VERIFICATION

A summary of nominal and measured metal concentrations is presented in Table 3. As indicated by the data, average measured concentrations were generally in good agreement with target concentrations, with a slight underestimation of the targeted exposure for both metals. Concentrations within exposure chambers remained consistent throughout the exposure period.

Low yet statistically significant concentrations of lead were observed in the blanks. As a result, there is a degree of uncertainty associated with a limited number of lead concentrations recorded. However, lead concentrations in the blanks were always very low (in the sub-microgram range). As no biological effects were observed at lead concentrations less than 243 µg/L, the impact that this level of lead contamination would have on estimates of toxicity thresholds is negligible.

Table 3. Nominal and Measured (Mean ± Standard Deviation) Exposure Concentrations for Copper and Lead during the 96-hr Acute Exposure Experiments with White Sturgeon

Dissolved Metal	Treatment No.	Nominal (µg/L)	Measured	
			U of S Laboratory (µg/L)	River (µg/L)
8 Days Post Hatch				
Copper	0	0	0.93 (±0.30)	0.73 (±0.09)
	1	1	1.5 (±0.16)	1.4 (±0.01)
	2	3	3.0 (±0.16)	2.9 (±0.23)
	3	9	7.5 (±0.05)	6.4 (±0.24)
	4	27	21[a]	22 (±2.0)
	5	54	39 (±2.2)	46 (±1.4)
	6	108	81 (±14)	93 (±3.9)
	7	216	135[a]	180 (±11)
Lead	0	0	0.14 (±0.07)	0.22 (±0.16)
	1	1	0.75 (±0.01)	0.43 (±0.17)
	2	3	2.3 (±0.04)	1.4 (±0.43)
	3	9	6.4 (±0.69)	6.1 (±1.9)
	4	27	19[a]	17 (±0.91)
	5	81	65 (±3.2)	60 (±2.3)
	6	243	210 (±21)	191 (±8.4)
	7	486	414 (±23)	410 (±49)
40 Days Post Hatch				
Copper	0	0	0.38 (±0.01)	1.1 (±0.08)
	1	1.3	1.6 (±0.08)	2 (±0.18)
	2	4	3.8 (±0.16)	4.2 (±0.23)
	3	12	11 (±0.35)	10 (±0.07)
	4	24	21 (±1.2)	20 (±0.42)
	5	48	42 (±1.7)	42 (±0.49)
	6	96	85 (±2.1)	83 (±0.71)
	7	192	171 (±2.1)	Not Tested
Lead	0	0	0.081 (±0.05)	0.31 (±0.32)
	1	31	21 (±0.21)	20 (±3.9)
	2	61	46 (±2.7)	37 (±16)
	3	122	97 (±4.0)	95 (±5.3)
	4	244	208 (±4.9)	185 (±17)
	5	488	396 (±11)	325 (±117)
	6	976	809 (±78)	799 (±39)
	7	1,952	1,610[a]	1,685 (±35)

Notes:

[a] Only one measurement value available

U of S – University of Saskatchewan

3.2 ROUTINE WATER QUALITY

Water quality measures recorded throughout the duration of the study are presented within Table 4. In short, averages (± SD) for key water quality parameters were as follows:

- Water temperature
  - U of S = 15.4°C (± 0.5)
  - Streamside = 16.7°C (± 0.8)
- DO
  - U of S = 90 percent (± 8.1)
  - Streamside = 100 percent (± 13.7)
- pH
  - U of S = 7.5 s.u. (± 0.23)
  - Streamside = 7.7 s.u. (± 0.32)
- Conductivity
  - U of S = 187 microSiemens per centimeter ([µS/cm]; ± 26)
  - Streamside = 127µS/cm (± 7.1)
- Hardness
  - U of S = 55 mg/L as $CaCO_3$ (± 2.7)
  - Streamside = 58 mg/L as $CaCO_3$ (± 1.7)
- Total ammonia nitrogen = <0.025 mg as N/L
- DOC
  - U of S = 2.3 mg/L (± 0.45)
  - Streamside = 2.6 mg/L (± 0.42).

Table 4. Summary of Mean ± Standard Deviation of Water Quality Parameters

Parameter	Analysis	Copper Lab	Lead Lab	Copper River [a]	Lead River
8 Days Post Hatch					
Temperature (˚C)[b]	U of S	15.4 (±0.35)	15.8 (±0.61)	16.0 (±0.43)	16.7 (±0.45)
pH (s.u.)	U of S	7.7 (±0.13)	7.6 (±0.20)	7.7 (±0.23)	7.7 (±0.28)
DO (%)	U of S	85 (±7.2)	83 (±8.2)	101 (±17)	98 (±15)
Conductivity (µS/cm)	U of S	183 (±5.7)	181 (±30)	127 (±7.6)	126 (±8.6)
Ammonia Nitrogen (ppm)	U of S	<0.025*	<0.025*	<0.025*	0.031 (±0.048)*
Nitrate (ppm)	U of S	<0.25*	<0.25*	<0.25*	<0.25*
Nitrite (ppm)	U of S	<0.02*	<0.02*	<0.02*	<0.02*
Hardness (ppm)	CAS	54 (±1.8)	56 (±0.75)	56 (±0.83)	57 (±0.82)
Alkalinity (ppm)	CAS	38 (±1.0)	33 (±2.2)	52 (±0.58)	53 (±0.61)
Total Chlorine (ppm)	U of S	<0.1*	<0.1*	<0.1*	<0.1*
TOC (mg/L)	CAS	2.1 (±0.25)	2.1 (±0.30)	1.8 (±0.16)	2.4 (±0.22)
DOC (mg/L)	CAS	1.9 (±0.21)	2.1 (±0.19)	2.5 (±0.27)	2.3 (±0.18)
40 Days Post Hatch					
Temperature (˚C)[b]	U of S	15.0 (±0.11)	15.0 (±0.15)	16.3 (±0.25)	16.3 (±0.21)
pH (s.u.)	U of S	7.4 (±0.23)	7.4 (±0.23)	7.8 (±0.24)	7.9 (±0.26)
DO (%)	U of S	96 (±3.4)	94 (±2.6)	103 (±6.6)	99 (±8.0)
Conductivity (µS/cm)	U of S	195 (±5.6)	188 (±39)	130 (±2.5)	130 (±2.3)
Ammonia Nitrogen (ppm)	U of S	0.026 (±0.058)*	<0.025*	<0.025*	<0.025*
Nitrate (ppm)	U of S	<0.25*	<0.25*	<0.25*	<0.25*
Nitrite (ppm)	U of S	<0.02*	<0.02*	<0.02*	<0.02*
Hardness (ppm)	CAS	53 (±1.0)	52 (±1.2)	60 (±0.45)	59 (±0.27)
Alkalinity (ppm)	CAS	31 (±1.2)	30 (±2.1)	52 (±3.0)	54 (±1.2)
Total Chlorine (ppm)	U of S	<0.1*	<0.1*	<0.1*	0.1
TOC (mg/L)	CAS	2.1 (±0.25)	1.9 (±0.14)	1.9 (±0.12)	1.8 (±0.14)
DOC (mg/L)	CAS	2.3 (±0.27)	2.6 (±0.14)	2.7 (±0.47)	2.8 (±0.57)

Notes:

[a] Measurement conducted in river water prior to dilution of stock solutions to avoid contamination of equipment (exception [b])

[b] Measured in randomly selected test chamber

Analysis – refers to laboratory by which analyses were conducted

* Limit of detection, all or majority of values below this value

CAS – Columbia Analytical Services

DO – dissolved oxygen

DOC – dissolved organic carbon

TOC – total organic carbon

U of S – University of Saskatchewan

3.3 MORTALITY

Average control mortalities were between 0 and 6.7 percent. This resulted from mortality of one fish in the 8 dph laboratory lead exposure, two fish in the 40 dph laboratory copper exposure, and one fish in the 40 dph laboratory lead exposure.

For each metal tested, with the exception of the 8 dph streamside lead exposure treatment, concentration-dependent and statistically significant increases in mortality were observed at the highest concentrations (Table 5). In general, white sturgeon were more sensitive to exposure with copper than with lead. Copper concentrations at which 50 percent of the test populations died were between 9.9 and 29 µg/L. In contrast, lead concentrations required to elicit 50 percent mortality was between 180 and >410 µg/L.

Table 5. Mean ± Standard Deviation Percent Mortality and Lethal Concentrations for Early Life-stages of White Sturgeon after 96 hours of Exposure to Copper and Lead

	Copper (% Mortality)		Lead (% Mortality)	
Treatment [a]	Laboratory	River	Laboratory	River
8 Days Post Hatch				
0	0 (±0)	0 (± 0)	1.6 (± 3.1)	0 (± 0)
1	1.7 (± 3.3)	0 (± 0)	0 (± 0)	0 (± 0)
2	0 (± 0)	10 (± 12)	0 (± 0)	0 (± 0)
3	9.7 (± 8.1)	4.8 (± 5.8)	0 (± 0)	2.3 (± 4.5)
4	60 (± 14) ***	26 (± 14) *	1.7 (± 3.3)	2.3 (± 4.5)
5	92 (± 10) ***	86 (± 13) ***	0 (± 0)	4.5 (± 5.2)
6	100 (± 0) ***	100 (± 0) ***	82 (± 11) ***	0 (± 0)
7	100 (± 0) ***	100 (± 0) ***	100 (± 0) ***	2.3 (± 4.5)
LC50 (µg/L)	18	29	180	>410
40 Days Post Hatch				
0	6.7 (± 12)	0 (± 0)	6.7 (± 12)	0 (± 0)
1	6.7 (± 12)	10 (± 0)	6.7 (± 12)	0 (± 0)
2	0 (± 0)	3.3 (± 5.8)	0 (± 0)	6.7 (± 12)
3	60 (± 27)**	20 (± 20) ***	3.3 (± 5.8)	10 (± 17)
4	79 (± 20) ***	57 (± 21) ***	13 (± 15)	3.3 (± 5.8)
5	97 (± 5.8) ***	87 (± 5.8) ***	47 (± 5.8) **	3.3 (± 5.8)
6	100 (± 0) ***	100 (± 0) ***	77 (± 15) ***	10 (± 10)
7	100 (± 0) ***	Not Tested	63 (± 15) ***	67 (± 25) ***
LC50 (µg/L)	9.9	18	518	1410

Notes:

[a] Refer to Table 3 for a summary of the treatment numbers listed herein.

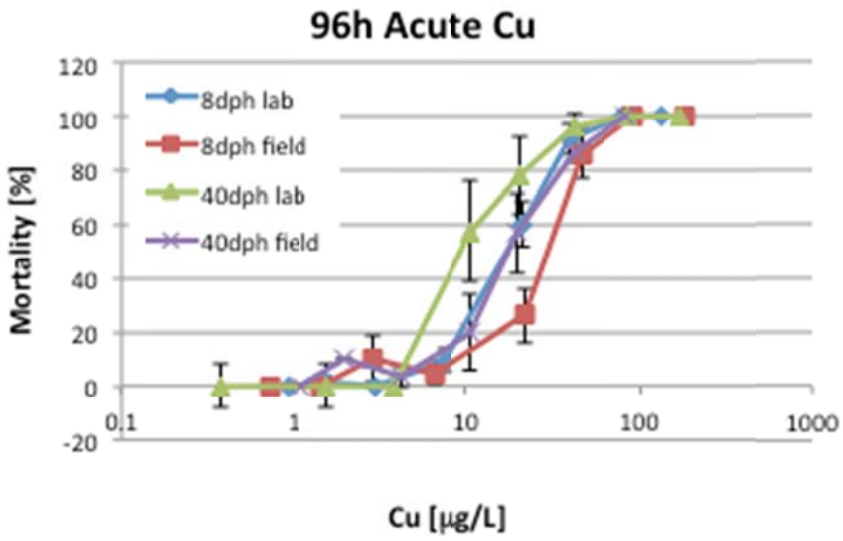
Asterisks = significant mortality relative to controls as determined using the Bonferroni test; $p < 0.05$ *; $p < 0.01$ **; $p < 0.001$ ***)

White sturgeon were approximately 1.5- to 2-times more sensitive to the exposure with copper when exposed at 40 dph compared to 8 dph (Table 5). Interestingly, there were opposite trends towards greater sensitivity at the earlier life-stage after exposure to lead in laboratory water. This could not be confirmed in the experiment conducted in river water as no statistically significant mortalities were observed up to the greatest test concentration of 486 µg/L. LC50s revealed that sturgeon were approximately 1.5- to 2-times less sensitive to exposure with copper and lead when exposed to CR water as compared to laboratory water (Table 5).

The biotic ligand model (BLM) (Di Toro et al. 2001; Santore et al. 2001, 2002; HydroQual 2007) was calibrated using the metal concentrations (Table 3) and associated toxicological responses (Table 5) for copper and lead effects to white sturgeon. The BLM is a predictive model that can explain how the chemistry of different exposure scenarios can affect metal toxicity. The purpose of this calibration is to develop parameter files that will allow the BLM to predict normalized acute effect concentrations for white sturgeon to copper and lead, thereby allowing the BLM to translate these effects from laboratory conditions to a wider variety of exposure scenarios where factors such as pH, DOC, hardness, and alkalinity may vary.

To perform the calibration, the BLM was run with measured (pH, DOC, temperature, chloride, sulfate, hardness, alkalinity) or estimated (calcium, magnesium, potassium, sodium) water quality parameters. Parameters that were not measured were estimated from the average concentrations measured in water samples used in related studies (Entrix 2010). Concentration-response relationships between dissolved metal and observed mortality are shown for copper on Figure 1 (Panel A) or as normalized for bioavailability by considering accumulation on the biotic ligand (Figure 2). Similar figures are shown for dissolved and biotic ligand-bound lead (Figure 1 [Panel B] and Figure 3). From the concentration-response on the biotic ligand, the critical accumulation associated with 50 percent mortality (LA50) can be estimated, and the value for each metal is shown on in the top left corner of Figures 2 and 3.

Panel A



Panel B

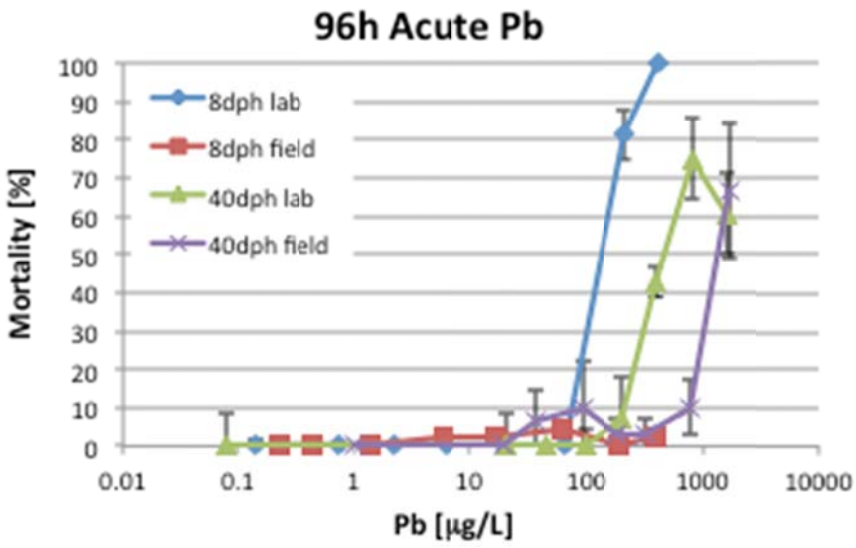


Figure 1. Average Percent Mortality of White Sturgeon Fry Exposed from 8 through 12 dph (blue & red), and 40 through 44 dph (green & purple) to Copper (Panel A) and Lead (Panel B) Under Static Renewal Conditions in Laboratory (blue & green) and River (red & purple) Water

Note: Exposure concentration represents measured concentrations of metals. Error bars = 1 SD

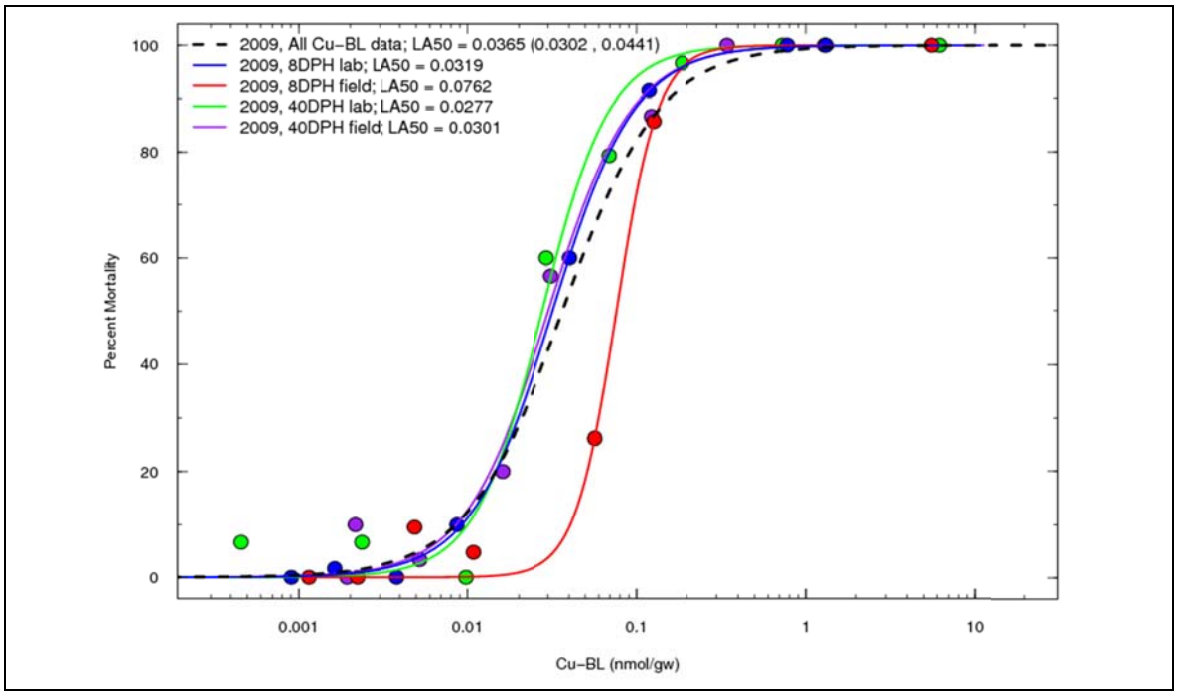


Figure 2. Concentration-response Relationships for Copper in 96-hour Exposures of White Sturgeon; Based on BLM Predicted Concentration of Accumulated Copper at Biotic Ligand Sites

Note: Separate curves are shown for the different exposure scenarios, consistent with the description provided for Figure 1.

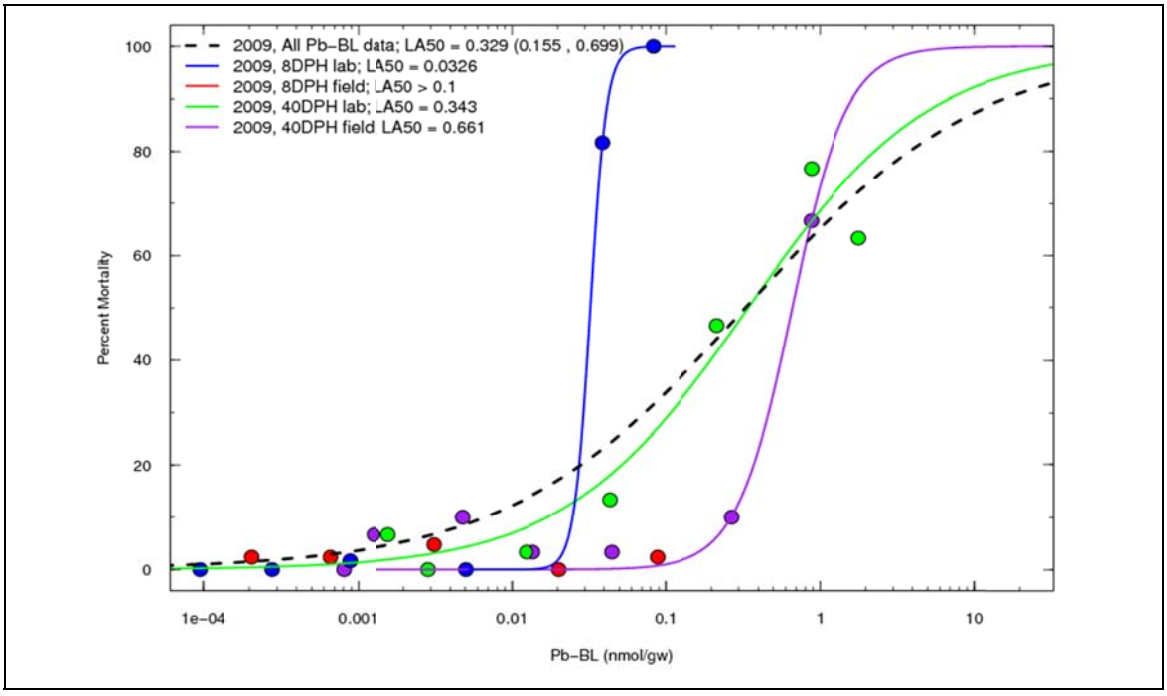


Figure 3. Concentration-response Relationships for Lead in 96-hour Exposures of White Sturgeon; Based on BLM Predicted Concentration of Accumulated Lead at Biotic Ligand Sites

Note: Separate curves are shown for the different exposure scenarios, consistent with the description provided for Figure 1.

Values for acute water quality criteria for the State of Washington and for EPA are shown in Table 6. For each of these metals, both the state and EPA acute water quality criteria are less than the acute LC50 for sturgeon (Table 5), indicating that the acute criteria for copper and lead are protective for acute exposures of these metals to sturgeon.

Table 6. Acute Water Quality Criteria for Dissolved Metals in the State of Washington (WAC 173-201A-240) and by EPA

Dissolved Metal	Age and Water Source	Hardness mg/L as $CaCO_3$	Acute Criterion (µg/L) - WA[a]	Acute Criterion (µg/L) - EPA[b]
Copper	8 dph – Lab	59	10.4	9.4
	8 dph – Field	56	9.9	8.3
	40 dph – Lab	54	9.5	7.4
	40 dph – Field	59	10.4	9.9
Lead	8 dph – Lab	59	28.7	
	8 dph – Field	57	27.4	27.4
	40 dph – Lab	53	25.0	25.0
	40 dph – Field	58	28.0	28.0

Notes:

[a] Acute criteria for the State of Washington are calculated based on an average water hardness using the following equations:

Copper WQC = $0.960(e^{(0.9422[\ln(\text{hardness})] - 1.464)})$
Lead WQC = $0.687(e^{(1.273[\ln(\text{hardness})] -1.46)})$

[b] Acute criteria for EPA are calculated based on pH, DOC and major ions using the BLM for copper (USEPA 2007), or using an average water hardness the following equation for lead

Lead WQC = $0.687(e^{(1.273[\ln(\text{hardness})] -4.705)})$

WA – State of Washington

4 CONCLUSIONS

Acute exposures of copper to ELS of white sturgeon resulted in acute toxicity (LC50s) at concentrations of 18 and 9.9 µg/L at 8 and 40 dph, respectively, in laboratory water, and concentrations of 29 and 18 µg/L at 8 and 40 dph, respectively, in river water. In all cases, these values are greater than the acute water quality criteria for these metals in the State of Washington, which correspond to 9.5 to 10.4 µg/L for copper and 25 to 29 µg/L lead, respectively, thereby indicating that acute criteria are protective for acute exposures of copper and lead to white sturgeon. For these test waters, BLM calculated water quality criteria for copper are slightly lower than criteria for the State of Washington.

BLM calibrations were performed for these exposures, and concentration-response relationships on the biotic ligand suggest that accumulation on the biotic ligand can be correlated with effects. These concentration-response relationships were used to derive critical accumulation levels (LA50s) that can be used in parameter files to allow

application of the BLM to predict how acute effects for these metals to white sturgeon will change with changing water chemistry.

5 REFERENCES

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