ASSESSING CONTAMINANT SENSITIVITY OF AMERICAN SHAD, ATLANTIC STURGEON AND SHORTNOSE STURGEON

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by

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NOTICE

This is the interim report of research funded in part by the New York Department of Environmental Conservation. Results and interpretation of toxicity tests in the final version of this report are subject to change. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

INTRODUCTION

The Hudson River Estuary supports one of the largest stocks of Atlantic sturgeon and American shad on the Atlantic coast. Production of juvenile sturgeon in the Hudson Estuary has declined dramatically in the last 20 years. The spawning population of American shad is at a historic low (K. Hattala and C. Walters, New York State Department of Environmental Conservation, personal communication). Causes of decline in both species include obvious over fishing. However, habitat change or exposure to environmental contaminants have been suggested a possible causes by as concerned scientists and citizens (Hudson River Estuary Advisory Committee, personal communication).

The Hudson Estuary extends north about 246 km from the Battery at New York City (km 0), to the Federal Dam at Troy (km 246). The river, by nature, is slow moving with freshwater flows being much smaller than tidal flows (Dramer 1969). The tides affect the entire length of the Estuary below the Federal Dam. Mean tidal ranges vary from 0.8 m near West Point to 1.4 m at Albany (U.S. Dept. of Commerce 1995). Current velocities range between 0.5 and 0.9 m/s, depending on tidal stage and section of river (U. S. Dept. of Commerce 1995).

Maximum widths of the Estuary range from 5.5 km wide in Haverstraw Bay to 2.5 km in Newburgh Bay. The estuary, north of Newburgh Bay, narrows to less than 1.6 km and is characterized by numerous shoals and sand bars throughout. A shipping channel is maintained at 9.8 m allowing passage of ocean-going commercial vessels to the Port of Albany (km 230). The deepest section of the river occurs near West Point, where depth averages 48.8 m. The location of the salt front varies seasonally with freshwater inflow. In late summer, the salt front usually extends as far north as Newburgh Bay (km 90), in drought years it can located as far north as

Poughkeepsie (km 125).

Adult American shad (*Alosa sapidissima*) typically enter the Hudson River Estuary in late March or early April (McFadden 1977). Peak migration into the Estuary occurs from mid-April through mid-May at water temperatures of 7-14°C (Talbot 1954). Spawning occurs at temperatures from 14 to 20°C from Port Ewen (km 145) to Coxsackie (km 232), but is concentrated near Catskill (km 182) (Talbot 1954). Following spawning, most adults leave the Estuary (McFadden 1977). Larvae and young-of-the-year shad disperse to nursery areas from Newburgh (km 88) to Albany (km 225) in early summer (Hattala et al 1988). Young-of-year shad leave the Atlantic coastal rivers when water temperatures drop below 15°C for several days (Leggett and Whitney 1972).

Adult Atlantic sturgeon (*Acipenser oxyrhynchus*) begin their spawning migration into the Hudson River Estuary in the month of May and continue until August (Dovel and Berggren 1983). Spawning occurs at temperatures from 14 to 20°C from Newburgh Bay (km 88) to Catskill (km 182). Concentration areas are not well known, but occur within this river reach. Following spawning, most adults leave the Estuary, but some remain within the Estuary form late summer through the early fall (M. Bain, personal communication). Nursery areas for larvae and young-of-the-year shad are not well known, but are assumed to be within the spawning reach. Juvenile Atlantic sturgeon remain in the Hudson River estuary for several years and slowly emigrate to ocean waters of the Atlantic coast from ages three to five (Dovel and Berggren 1983).

In order to evaluate the impact of a contaminant release into the environment, standardized toxicity tests are conducted using standard test organisms as surrogates for other species (EPA 1982). Inherent in these programs is the assumption that the test species used for toxicity assessments are predictive of other species. Surrogate species are typically organisms that are easily tested using standardized methods. However, these species may not be representative of all species. The wide use of pesticides and other commercial chemicals invariably poses a risk to aquatic species in decline since, by definition, their distribution is limited and further adverse effects on these populations could lead to extinction. Species may be under protected, or unnecessary regulatory programs may be implemented, if the sensitivity of these species is not evaluated. The following research project provides information for assessing contaminant sensitivity of American shad and Atlantic sturgeon. In addition, the sensitivity of shortnose sturgeon (*Acipenser brevirostrum*) was also evaluated. By identifying the sensitivity of these species to contaminant exposures, appropriate regulatory procedures can be implemented for their protection. Acute toxicity tests (96-h LC50) were conducted with American shad, Atlantic sturgeon, and shortnose sturgeon using five chemicals having different toxicological modes of action. Chemicals included carbaryl, copper, 4-nonylphenol, pentachlorophenol, and permethrin. These chemicals have been tested in previous cooperative research conducted between the EPA (1995), U.S. Fish and Wildlife Service, and USGS for the same five chemicals with rainbow trout, fathead minnows and 13 different threatened and endangered species - Apache trout, Lahontan cutthroat trout, greenback cutthroat trout, bonytail chub, Colorado squawfish, razorback sucker, fountain darter, greenthroat darter, shovelnose sturgeon, gila topminnow, boreal toad, spotfin chub, and Cape Fear shiner. In that research, similar test conditions were used (static acute toxicity tests, reconstituted ASTM hard water and 60% dilution series) with test temperatures appropriate for the species and selected from the series identified by ASTM (1998).

MATERIALS AND METHODS

Test organisms

American shad were obtained as fertilized eggs through the Pennsylvania Fish and Boat Commission, College Station, PA. Atlantic sturgeon were obtained as fry from the USFWS, Northeast Fisheries Center, Lamar, PA. Toxicity tests were also conducted with shortnose sturgeon as a surrogate for Atlantic sturgeon. Shortnose sturgeon were obtained from USFWS, Warm Springs Fish Technology Center, Warm Springs, GA. Sturgeon were held in well water (alkalinity 258 mg/L as $CaCO_3$, hardness 286 mg/L as $CaCO_3$, pH 7.8, 18ºC) at the Columbia Environmental Research Center (CERC, Columbia, MO) for about one week prior to testing. American shad were hatched at the end of May during both 1997 and 1998. Shad were then cultured in CERC well water and fed live brine shrimp and dried *Spirulina*. Tests with American shad were attempted in July of 1997 and August of 1998.

Before the start of a toxicity test, organisms were acclimated for a total of 96 h (EPA 1975, ASTM 1998). For the first 48 h, organisms were acclimated to the test water and temperature. The test organisms were then moved to other containers and held for an additional 48 h at the test temperature in 100% test water. Organisms were not fed during the 48 h of holding in 100% test water.

Chemicals

The chemicals used in testing were carbaryl, copper, 4-nonylphenol, pentachlorophenol, and permethrin (Table 1). Chemicals were selected to represent different classes of chemical and modes of toxic action. Organic chemical stock solutions were prepared by dissolving the chemical in reagent grade acetone, whereas stock solutions for copper were prepared by dissolving copper in deionized water. The maximum acetone concentration in any test container was 0.05 mL/L. Analytical results of stock concentrations will be included in the final report.

Toxicity tests

Static acute toxicity tests were conducted in basic accordance with procedures described in EPA (1975) and ASTM (1998). Sturgeon exposures were conducted in 19.6 L glass jars containing 15 L of test solution, while shad exposures were conducted in 3.8 L glass jars containing 3 L of test solution. Test water was reconstituted hard water (alkalinity 110 to120 mg/L as $CaCO_3$, hardness 160 to180 mg/L as $CaCO_3$; ASTM 1998). Tests were conducted under ambient lighting.

The exposure series consisted of six concentrations with a 60% dilution series tested in triplicate. When a solvent was used, both a solvent control (0.05 mL/L) and a dilution water control were included for each species. Individual test series were randomly assigned to a waterbath and location within a waterbath (complete block design).

Fishes were counted into two groups (3 to 5 organisms per group) and pooled for each exposure replicate (7 to 10 organisms/replicate depending on average weight of fish). Mortality was the endpoint measured at 6, 12, 24, 48, 72, and 96 h of exposure and was defined as the lack of movement for a 5-s observation with the unaided eye. Dead animals were removed at each observational time. The study design is summarized in Table 2.

Water quality

Alkalinity, hardness, and pH were measured on each batch of reconstituted water before the start of the exposures. The pH was measured on the control, low, medium, and high exposure concentrations at 0 h and in those same treatments if organisms survived to 96 h of exposure. Dissolved oxygen was measured on the control, low, medium, and high exposure concentrations at 0 h and in those same treatments if organisms survived to 48 and 96 h of exposure. Summary of water quality will be included in the final report.

Statistical analysis

The LC50 and 95% confidence interval for each test was usually calculated using probit analysis. However, when probit analysis was not appropriate (i.e., less than two partial mortalities), LC50s and confidence intervals were calculated using moving average or a non-linear interpolative procedure (Stephan 1977). The LC50s and confidence intervals were determined using nominal concentrations.

PRELIMINARY RESULTS AND DISCUSSION

Control survival

Toxicity tests with American shad were attempted in 1997 and 1998. During 1997 control survival at 48 h of exposure was 80% in the water-only control and 75% in the acetone control (Table 3). These control survivals are of concern since they are less than that which is normally considered an acceptable test (90%). Also, at 96 h of exposure with American shad, the water-only survival was 43% and the acetone control survival was 55%. Results at 96 h are considered unacceptable. Therefore, conclusions regarding the chemical sensitivity of the American shad obtained at 48 h of exposure will need to be carefully evaluated since these organisms were clearly stressed as indicated by the 96-h control results. During 1998, we cultured the American shad one month longer with the assumption that older organisms may provide acceptable control survival during the 96-h toxicity test. However, in 1998, during acclimation to the test waters, there was substantive mortality of American shad. During 1999, we plan to test American shad within days of hatching. While yolk-sac fry are often less sensitive to contaminant exposure than swim-up fry, we hope to be able to conduct the test and have acceptable control survival.

In the toxicity tests with Atlantic sturgeon, control survival was 100% in both the water-only and acetone controls (Table 3). At 96 h of exposure, the acetone control had a control survival of 70%, while the water-only control survival was 100%. Mortality in the acetone control was due to all fish dying in one replicate. We have observed, in other tests with sturgeon, that if a few fish die in a replicate the water quickly fouls and most or all of the fish then die in that replicate. These observations indicate that conclusions regarding the chemical sensitivity of the sturgeon will need to be carefully evaluated. However, because the control survival was acceptable at 48 h of exposure, and mortality was only observed in one replicate at 96 h of exposure, we have included results for the Atlantic sturgeon in this interim report.

Control survival for both the water-only and acetone controls in toxicity tests with the shortnose sturgeon was 100% at both 48 and 96 h of exposure (Table 3).

Tables 4 to 9 summarize the 48 and 96-h LC50s for all five chemicals and each species. In general, at 96-h of exposure, permethrin was the most toxic compound and carbaryl was the least toxic compound. These results were similar to those reported in a previous study (EPA 1995) with these five chemicals. The two phenolic compounds (4-nonylphenol and pentachlorophenol) and copper had LC50s in a similar range of concentrations.

For the following discussion we have included data from the present study and data generated in previous cooperative research conducted between the EPA (1995), U.S. Fish and Wildlife Service, and USGS for the same five chemicals with rainbow trout, fathead minnows and 13 different threatened and endangered species - Apache trout, Lahontan cutthroat trout, greenback cutthroat trout, bonytail chub, Colorado squawfish, razorback sucker, fountain darter, greenthroat darter, shovelnose sturgeon, gila topminnow, boreal toad, spotfin chub, and Cape Fear shiner. In that research, similar test conditions were used (static acute toxicity tests, reconstituted ASTM hard water and 60% dilution series) with test temperatures appropriate for the species and selected from the series specified by ASTM (1998).

After 48 h of exposure to carbaryl, copper, pentachlorophenol and permethrin, the LC50s for the American shad are lower than the LC50s for the standard test organisms, rainbow trout and fathead minnow (Table 4). However, the confidence intervals for tests with American shad and rainbow trout for copper and permethrin overlap, indicating that the difference between American shad and rainbow trout may not be significant. Except for exposures to carbaryl, at 48 h of exposure, Atlantic sturgeon and shortnose sturgeon exhibited a similar sensitivity to chemical exposure. The 48-h LC50s for the shortnose and Atlantic sturgeon exposed to copper and pentachlorophenol were similar to the LC50s for rainbow trout. The two sturgeon species were more sensitive to 4-nonylphenol and permethrin than rainbow trout. While the Atlantic sturgeon and rainbow trout seem to be similar in sensitivity to carbaryl exposure, the shortnose sturgeon appears to be less sensitive to carbaryl. Collectively, these results indicate that the American shad, Atlantic and shortnose sturgeon are generally similar to or slightly more sensitive than the rainbow trout. As previously stated, the results for the American shad should be interpreted with caution given the high control mortality after 48 h of exposure.

In order to evaluate species sensitivity, within a chemical, we ranked 96-h LC50s for each species, including the shortnose and Atlantic sturgeon, from 1 (high sensitivity - low LC50) up to 16 (low sensitivity - high LC50). Ranks were then averaged across chemicals for each species (Table 10). The Atlantic sturgeon and shortnose sturgeon were the two most sensitive species of the 17 species evaluated in this comparison. Rainbow trout were the seventh most sensitive species. American shad were not included in the 96-h LC50 comparison since the control survival at 96 h was unacceptable.

In addition to relative species sensitivity, the magnitude of difference between LC50s is also important. Using data from the previous study for the six rainbow trout tests with each chemical (EPA 1995), we calculated two factors (lowest 96-h LC50 / mean 96-h LC50; mean 96-h LC50 / highest 96-h LC50) which encompassed the range of LC50s for that chemical. For example, for the six toxicity tests conducted with rainbow trout and carbaryl (EPA 1995), the lowest 96-h LC50 was 1.22 mg/L, the highest 96-h LC50 was 3.11, and the mean 96-h LC50 was 1.88 mg/L. Factors calculated for rainbow trout carbaryl exposures were 0.60 and 0.65 with a geometric mean of 0.62. For the five chemicals tested with rainbow trout, the geometric mean factor for all five chemicals was 0.69 with a range of 0.60 (permethrin) to 0.80 (pentachlorophenol). We followed the same procedure for fathead minnows and the five chemicals. Fathead minnows had an geometric mean factor for the five chemicals of 0.65 with a range of 0.57 (pentachlorophenol) to 0.73 (permethrin). If a factor of 0.67 is selected as representative of the normal range in LC50 (expected range = LC50 X 0.67 to LC50 / 0.67) for a specific chemical and species, then the sensitivities of listed species can be evaluated in terms of how often 96-h LC50s for the listed species differed by more than a factor of 0.67 from the 96-h

LC50 for either rainbow trout or fathead minnows.

For all possible comparisons of shortnose and Atlantic sturgeon to the range of 96-h LC50s that might be expected for fathead minnows (n=9), the two sturgeon species have LC50s less than the expected range. When the comparison is made to rainbow trout (n=9), the two sturgeon species have six 96-h LC50s less than the expected range of LC50s for rainbow trout Tables 5 to 9).

A final evaluation would be to determine the greatest difference between the 96-h LC50s of the rainbow trout and Atlantic sturgeon and shortnose sturgeon. Within a chemical, we compared the lowest 96-h LC50 for either sturgeon to the geometric mean 96-h LC50 for rainbow trout. For Atlantic sturgeon, we were able to compare only two tests, copper and 4-nonylphenol. For copper the factor was 0.8 while for 4-nonylphenol the factor was 0.3. We were able to calculate a factor with shortnose sturgeon for carbaryl, copper, 4-nonylphenol and pentachlorophenol. The average factor for those four tests was 0.7 with a range of 0.4 to 1.0.

Overall, these assessments would indicate that the sturgeon are somewhat more sensitive to contaminant exposure than the rainbow trout. However, because of the difficulty in testing with sturgeon, conclusions regarding the chemical sensitivity of the sturgeon need to be carefully evaluated. If sturgeon are more sensitive than rainbow trout, then a factor could be used to estimate an LC50 for sturgeon from rainbow trout data. The most conservative approach would be to use the factor of 0.3 determined with Atlantic sturgeon exposed to 4-nonylphenol. Expected environmental concentrations (e.g. water quality criteria, pesticides) could be compared to this calculated LC50 and determinations if the Atlantic sturgeon is at risk could be made.

Future research

In the upcoming year, acute toxicity tests with American shad will be attempted just after hatching. Yolk-sac fry are often less sensitive to contaminant exposure than swim-up fry, however, previous attempts with older organisms have failed. Additionally, acute effluent tests with American shad, shortnose sturgeon, fathead minnows and *Ceriodaphnia dubia* will be attempted.

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Table 1. Source and percent active ingredient of chemicals used in toxicity tests.

Chemical	Source	Active Ingredient (%)	Use	Mode of Action
Carbaryl	Donated by Rhone-Pôulenc Agricultural Co., Research Triangle Park, NC	99.7	carbamate insecticide	inhibitor of cholinesterase activity
Copper sulfate	Fisher Chemical, St. Louis, MO	25.5	mining, industrial, fungicide	interferes in osmoregulation
4-nonylphenol	Fluka Chemical, New York, NY	85.0	nonylphenol ethoxylate detergents	narcotic and oxidative stressor
Pentachlorophenol	Aldrich Chemical, Milwaukee, WI	99.0	wood preservative, molluscicide	uncoupler of oxidative phosphorylation
Permethrin	Donated by ICI Americas Inc., Richmond, CA	95.2	pyrethroid insecticide	neurotoxin

Table 2. Summary of study design for the comparative toxicity of selected chemicals to listed species.

Test type:	Static acute
Test volume:	Shortnose sturgeon - 15 L Atlantic sturgeon - 15 L American shad - 3 L
Test temperature:	Shortnose sturgeon - 22ºC Atlantic sturgeon - 17ºC American shad - 22ºC
Water Quality:	Reconstituted ASTM hard (alkalinity 110 to 120 mg/L as $CaCO_3$, hardness 160 to 180 mg/L as $CaCO_3$)
Chemicals:	Carbaryl, copper, 4-nonylphenol, pentachlorophenol, permethrin
Dilution series:	60%
Replicates/number of organisms per replicate:	Shortnose sturgeon - 3 replicates/7 fish per replicate Atlantic sturgeon - 3 replicates/9 fish per replicate American shad - 3 replicates/10 fish per replicate
Average weight:	Shortnose sturgeon - 0.74 g (wet wt) Atlantic sturgeon - 1.11 g (wet wt) American shad - 0.006 g (dry wt)
Observations:	Mortality at 6, 12, 24, 48, 72, and 96 h of exposure

Table 3. Summary of control survival at 48 and 96 h of exposure for American shad, Atlantic sturgeon, and shortnose sturgeon.

Species	**Control type**	**Exposure time**	
		48 hours	**96 hours**
American shad	water	80	43
	acetone	75	55
Atlantic sturgeon	water	100	100
	acetone	100	70
Shortnose sturgeon	water	100	100
	acetone	100	100

Table 4. Calculated 48-h LC50 and confidence interval (parentheses) for American shad, Atlantic sturgeon and shortnose sturgeon. Also included is the 48-h LC50 for rainbow trout and fathead minnow (EPA 1995). For rainbow trout and fathead minnow the numbers in parentheses are the range of LC50s (n=6) for that species as reported in EPA (1995) using similar testing conditions.

Species	**Chemical**				
	Carbaryl	Copper	4-nonylphenol	Pentachlorophenol	Permethrin
American shad	<0.08	0.05 (0.04 - 0.06)	nc[1]	0.04 (0.03 - 0.05)	2.08 (1.78 - 2.37)
Atlantic sturgeon	1.28 (1.06 - 1.50)	0.15 (0.09 - 0.24)	0.08 (0.06 - 0.11)	0.19 (0.17 - 0.22)	<1.2
Shortnose sturgeon	4.23 (3.60 - 6.00)	0.15 (0.13 - 0.18)	0.08 (0.06 - 0.11)	0.16 (0.13 - 0.18)	<1.2
Rainbow trout	2.45 (1.27 - 3.50)	0.09 (0.06 - 0.17)	0.22 (0.17 - 0.27)	0.15 (0.11 - 0.19)	3.49 (1.65 - 6.00)
Fathead minnow	7.9 (1.88 - 10.00)	0.66 (0.50 - 1.16)	0.29 (0.17 - 0.40)	0.28 (0.14 - 0.50)	10.1 (8.55 - 16.8)

[1]nc - not calculated

Table 5. Acute toxicity of carbaryl (mg/L) to 16 fishes and one amphibian. Data includes the 96-h LC50 and the relative species rank sensitivity. Also included is an assessment to determine if the 96-h LC50 for a particular species is out of the average range of LC50s for either rainbow trout or fathead minnows. In addition, a factor is calculated which relates the geometric mean LC50 for rainbow trout (n=6, EPA 1995) to the LC50 for all other individual species.

Species	**Carbaryl**				
	LC50	**Rank**	**RBT <0.67>**	**RBT LC50 Ratio**	**FHM <0.67>**
Rainbow trout	1.88	5	-	1.0	X< >
Fathead minnow	5.21	14	< >X	2.8	-
Apache trout	1.54	2	<X>	0.8	X< >
Greenback cutthroat trout	1.55	3	<X>	0.8	X< >
Lahontan cutthroat trout	2.25	8	<X>	1.2	X< >
Bonytail chub	3.49	11	< >X	1.9	X< >
Colorado squawfish	3.07	9	< >X	1.6	X< >
Razorback sucker	4.35	12	< >X	2.3	<X>
Fountain darter	2.02	6	<X>	1.1	X< >
Greenthroat darter	2.14	7	<X>	1.1	X< >
Shovelnose sturgeon	nc[1]	-	-	-	-
Gila topminnow	>3.0	nr[2]	-	nc	-
Boreal toad	12.3	15	< >X	6.5	< >X
Shortnose sturgeon	1.81	4	<X>	1.0	X< >
Spotfin chub	3.41	10	< >X	1.8	X< >
Cape Fear shiner	4.51	13	< >X	2.4	<X>
Atlantic sturgeon	<0.8	1	X< >	-	X< >

[1]nc - not calculated
[2]nr - not ranked

Table 6. Acute toxicity of copper (mg/L) to 16 fishes and one amphibian. Data includes the 96-h LC50 and the relative species rank sensitivity. Also included is an assessment to determine if the 96-h LC50 for a particular species is out of the average range of LC50s for either rainbow trout or fathead minnows. In addition, a factor is calculated which relates the geometric mean LC50 for rainbow trout (n=6, EPA 1995) to the LC50 for all other individual species.

Species	**Copper**				
	LC50	**Rank**	**RBT <0.67>**	**RBT LC50 Ratio**	**FHM <0.67>**
Rainbow trout	0.08	5.5	-	1.0	X< >
Fathead minnow	0.47	16	< >X	5.9	-
Apache trout	0.07	3.5	<X>	0.9	X< >
Greenback cutthroat trout	>0.03	nr[2]	-	-	-
Lahontan cutthroat trout	0.07	3.5	<X>	0.9	X< >
Bonytail chub	0.22	12	< >X	2.8	X< >
Colorado squawfish	0.43	15	< >X	5.4	<X>
Razorback sucker	0.27	14	< >X	3.4	X< >
Fountain darter	0.06	1.5	<X>	0.8	X< >
Greenthroat darter	0.26	13	< >X	3.3	X< >
Shovelnose sturgeon	0.16	10.5	< >X	2.0	X< >
Gila topminnow	0.16	10.5	< >X	2.0	X< >
Boreal toad	0.12	9	<X>	1.5	X< >
Shortnose sturgeon	0.08	5.5	<X>	1.0	X< >
Spotfin chub	0.09	7	<X>	1.1	X< >
Cape Fear shiner	0.11	8	<X>	1.4	X< >
Atlantic sturgeon	0.06	1.5	<X>	0.8	X< >

[1]nc - not calculated
[2]nr - not ranked

Table 7. Acute toxicity of 4-nonylphenol (mg/L) to 16 fishes and one amphibian. Data includes the 96-h LC50 and the relative species rank sensitivity. Also included is an assessment to determine if the 96-h LC50 for a particular species is out of the average range of LC50s for either rainbow trout or fathead minnows. In addition, a factor is calculated which relates the geometric mean LC50 for rainbow trout (n=6, EPA 1995) to the LC50 for all other individual species.

Species	4-Nonylphenol				
	LC50	Rank	RBT <0.67>	RBT LC50 Ratio	FHM <0.67>
Rainbow trout	0.19	11.5	-	1.0	<X>
Fathead minnow	0.27	15	<X>	1.4	-
Apache trout	0.17	8.5	<X>	0.9	X< >
Greenback cutthroat trout	0.15	7	<X>	0.8	X< >
Lahontan cutthroat trout	0.18	10	<X>	0.9	<X>
Bonytail chub	0.29	16	< >X	1.5	<X>
Colorado squawfish	0.26	14	<X>	1.4	<X>
Razorback sucker	0.17	8.5	<X>	0.9	X< >
Fountain darter	0.11	4	X< >	0.6	X< >
Greenthroat darter	0.19	11.5	<X>	1.0	<X>
Shovelnose sturgeon	<0.13	nr[2]	-	-	X< >
Gila topminnow	0.23	13	<X>	1.2	<X>
Boreal toad	0.12	5	X< >	0.6	X< >
Shortnose sturgeon	0.08	2.5	X< >	0.4	X< >
Spotfin chub	0.08	2.5	X< >	0.4	X< >
Cape Fear shiner	0.14	6	<X>	0.7	X< >
Atlantic sturgeon	0.05	1	X< >	0.3	X< >

[1]nc - not calculated
[2]nr - not ranked

Table 8. Acute toxicity of pentachlorophenol (mg/L) to 16 fishes and one amphibian. Data includes the 96-h LC50 and the relative species rank sensitivity. Also included is an assessment to determine if the 96-h LC50 for a particular species is out of the average range of LC50s for either rainbow trout or fathead minnows. In addition, a factor is calculated which relates the geometric mean LC50 for rainbow trout (n=6, EPA 1995) to the LC50 for all other individual species.

Species	Pentachlorophenol				
	LC50	Rank	RBT <0.67>	RBT LC50 Ratio	FHM <0.67>
Rainbow trout	0.16	4	-	1.0	<X>
Fathead minnow	0.25	10	< >X	1.6	-
Apache trout	0.11	2.5	<X>	0.7	<X>
Greenback cutthroat trout	>0.01	nr[2]	-	-	-
Lahontan cutthroat trout	0.17	5	<X>	1.1	<X>
Bonytail chub	0.23	8	<X>	1.4	<X>
Colorado squawfish	0.24	9	<X>	1.5	<X>
Razorback sucker	0.28	12	< >X	1.8	<X>
Fountain darter	0.11	2.5	<X>	0.7	X< >
Greenthroat darter	0.18	6	<X>	1.1	<X>
Shovelnose sturgeon	nc[1]	-	-	-	-
Gila topminnow	0.34	13	< >X	2.1	<X>
Boreal toad	0.37	14	< >X	2.3	<X>
Shortnose sturgeon	0.07	1	X< >	0.4	X< >
Spotfin chub	0.26	11	< >X	1.6	<X>
Cape Fear shiner	0.19	7	<X>	1.2	<X>
Atlantic sturgeon	nc	-	-	-	-

[1]nc - not calculated
[2]nr - not ranked

Table 9. Acute toxicity of permethrin (ug/L) to 16 fishes and one amphibian. Data includes the 96-h LC50 and the relative species rank sensitivity. Also included is an assessment to determine if the 96-h LC50 for a particular species is out of the average range of LC50s for either rainbow trout or fathead minnows. In addition, a factor is calculated which relates the geometric mean LC50 for rainbow trout (n=6, EPA 1995) to the LC50 for all other individual species.

Species	Permethrin				
	LC50	Rank	RBT <0.67>	RBT LC50 Ratio	FHM <0.67>
Rainbow trout	3.31	7	-	1.0	X< >
Fathead minnow	9.38	11	< >X	2.8	-
Apache trout	1.71	5	X< >	0.5	X< >
Greenback cutthroat trout	>1.0	nr	-	-	-
Lahontan cutthroat trout	1.58	3	X< >	0.5	X< >
Bonytail chub	>25.0	13	< >X	-	< >X
Colorado squawfish	24.4	12	< >X	7.4	< >X
Razorback sucker	5.95	10	< >X	1.8	X< >
Fountain darter	3.34	8	<X>	1.0	X< >
Greenthroat darter	2.71	6	<X>	0.8	X< >
Shovelnose sturgeon	nc[1]	nr[2]	-	-	-
Gila topminnow	>10.0	nr	< >X	-	-
Boreal toad	>10.0	nr	< >X	-	-
Shortnose sturgeon	<1.2	1.5	X< >	-	X< >
Spotfin chub	1.70	4	X< >	0.5	X< >
Cape Fear shiner	4.16	9	<X>	1.3	X< >
Atlantic sturgeon	<1.2	1.5	X< >	-	X< >

[1]nc - not calculated
[2]nr - not ranked

Table 10. Summary rank for 16 fishes and one amphibian. The summary rank was calculated by averaging the individual ranks obtained for each species (Tables 5 to 9) within a chemical and then reranking.

Family	Species	Summary rank
Salmonidae	Rainbow trout	7
Cyprinidae	Fathead minnow	17
Salmonidae	Apache trout	3
Salmonidae	Greenback cutthroat trout	5
Salmonidae	Lahontan cutthroat trout	6
Cyprinidae	Bonytail chub	15
Cyprinidae	Colorado squawfish	14
Catostomidae	Razorback sucker	13
Percidae	Fountain darter	4
Percidae	Greenthroat darter	10
Acipenseridae	Shovelnose sturgeon	11
Poeciliidae	Gila topminnow	16
Bufonidae	Boreal toad	12
Acipenseridae	Shortnose sturgeon	2
Cyprinidae	Spotfin chub	8
Cyprinidae	Cape Fear shiner	9
Acipenseridae	Atlantic sturgeon	1