U.S. Fish and Wildlife Service
Region 2
Contaminants Program

ORGANOCHLORINE AND TRACE ELEMENT CONCENTRATIONS IN THE SAN PEDRO RIVER BASIN, ARIZONA

by

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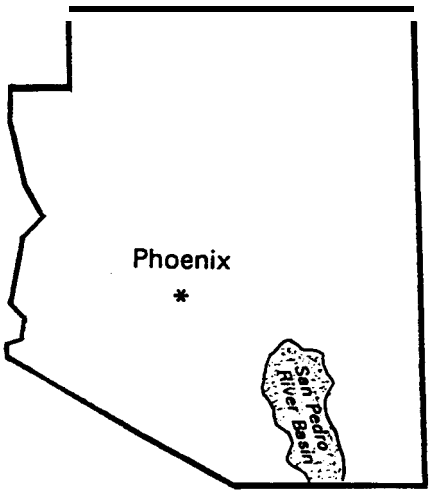

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ABSTRACT--The San Pedro River in southeastern Arizona sustains one of the richest, most diverse riparian areas in the United States. The San Pedro Riparian National Conservation Area is located near the headwaters of the river just north of the Arizona-Mexico border and includes nearly 112 kilometers (km) of prime habitat that is currently being considered for reintroduction of several endangered and threatened fish and mammal species.

Organochlorine compounds apparently do not pose a threat to resident fish and wildlife. Survival and reproduction of endangered species relocated to this area would not be affected by current organochlorine levels. However, because of questionable analytical results, the data regarding trace elements are unclear. After this study was initiated, Apache Powder Company, located adjacent to the study area, was added to the U.S. Environmental Protection Agency's superfund list of hazardous waste sites. Additional contaminant problems possibly associated with Apache Powder Company such as ammonia, nitrate and trace element input into the San Pedro River should be assessed. We recommend that, 1) the San Pedro be re-sampled for nutrients and trace elements at the earliest possible date, 2) a cooperative interagency group initiate a regular chemical residue monitoring and bioassessment program, and 3) any reintroduction program be approached with caution given the areas history of recurrent mine spills and other potential contamination problems.

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INTRODUCTION

The San Pedro River enters southeast Arizona from Sonora, Mexico, and flows northward for about 200 km before its confluence with the Gila River. It sustains one of the richest most diverse riparian areas in the United States. The 56,431-acre San Pedro Riparian National Conservation Area was established by Congress in November 1988 and includes nearly 112 km of the upper river from the Arizona-Mexico border to the town of St. David (Laurenzi 1991). This area supports 345 species of birds, 82 species of mammals and 47 species of reptiles and amphibians (Negri 1989). The San Pedro River is the type locality for the desert pupfish (*Cyprinodon macularius*) and historically supported 13 fish species of which eight persist as remnant populations in the drainage as a whole (Miller and Lowe 1964, Jackson et al. 1987). Only two native fishes, the longfin dace (*Agosia chrysogastger*) and the desert sucker (*Catostomus clarki*) are still found in the San Pedro mainstream. The Riparian National Conservation Area is being considered for the possible reintroduction of several once-resident fish species, such as the pupfish and Gila topminnow (*Poeciliopsis occidentalis*).

At least four pollution problems exist within the San Pedro watershed; 1) contamination from trace elements primarily related to copper mining, 2) agricultural pesticide pollution, 3) excessive ammonia and trace element loading, and 4) sewage effluent from Naco, Sonora. Water quality has been compromised by high trace element and low pH concentrations resulting from recurrent releases of impounded mine water from the Cananea Copper Mine in Sonora, Mexico. The Cananea Mine is situated near the headwaters of the San Pedro River and has experienced periodic operational problems particularly during periods of heavy rainfall. Several spills between December 1977 and April 1985 resulted in localized fish kills due to heavy metal and sulfate contamination and extremely acidic pH (Arizona Game and Fish Department 1980, Jackson et al. 1987). Major spills have, on occasion, eliminated all aquatic life within a 100 km reach north of the Arizona-Mexico border (Arizona Game and Fish Department 1980).

Concentrations of organochlorine pesticides have been recovered in fish collected from the San Pedro River. The U. S. Environmental Protection Agency (EPA) Priority Pollutant Program detected DDT and DDE in longfin dace samples collected within the study area near St. David in 1986. DDT values were 11 to 56 times greater than DDE suggesting recent use of DDT.

An explosives and fertilizer manufacturer, Apache Powder Company, located near St. David, has been identified as a possible source of ground and surface water contamination by ammonia and trace elements. Before 1971, industrial wastewater was discharged directly into the San Pedro River. Since that time, wastewater has been contained on-site in approximately 10 acres of unlined ponds. Average concentrations of ammonia (6,460 µg/L) in San Pedro River water collected near Apache Powder were 8.5 times greater than threshold levels above which effects on aquatic organisms can be expected (Clement International Corporation 1992). Average antimony levels (111 µg/L) in river water were 3.7 times greater than the threshold level. Maximum concentrations of arsenic (80 µg/L), lead (61 µg/L) and mercury (0.3 µg/L) also were greater than threshold levels. Potential surface entry of ammonia and trace elements associated with the manufacture of fertilizer and munitions is a significant concern.

Although limited information on the presence of certain industrial and agricultural chemicals is available on specific reaches of the San Pedro, no coordinated effort has been made to evaluate the impacts of environmental pollutants on fish and wildlife resources. This report quantifies organochlorine concentrations and discusses trace element levels in San Pedro River sediment and resident biota. Specific recommendations to minimize adverse impacts to fish and wildlife resources follow this report.

STUDY AREA AND METHODS

Sediment and biota were collected at nine sites (Table 1, Fig. 1.) during July and August 1987. Five sediment samples were taken by stainless steel spoon at each site and the material combined into a single composite sample. Approximately the top 10 cm of sediment was collected with each grab. Fish were collected by electroshocking and seine. Samples were pooled into composites of near equal length and weight for each species. Fish were weighed and measured following collection, wrapped in aluminum foil and chilled on wet ice. Samples were later transferred to a commercial freezer and stored frozen until chemical analyses. Abert's towhee (*Pipilo alberti*) and western kingbird (*Tyrannus verticalis*) were collected using a shotgun and steel shotshells. Lizards (*Cnemidophorus spp.*) were collected with .22 caliber

firearms using lead shot.

Sediment and tissue samples were analyzed for organochlorine compounds at Mississippi State Chemical Laboratory. Samples were analyzed for p,p'-DDE, o,p'-DDE, p,p'-DDD, o,p'-DDD, p,p'-DDT, o,p'-DDT, dieldrin, endrin, heptachlor epoxide, hexachlorobenzene (HCB), benzene hexachloride (BHC), oxychlordane, *r*-chlordane, *t*-nonachlor, cis-nonachlor, endrin, toxaphene, mirex and total polychlorinated biphenyls (PCB). For each organochlorine analysis, the sample was homogenized and a portion mixed with anhydrous sodium sulfate and extracted with hexane in a Soxhlet apparatus for 7 hours. Lipids were removed by Florisil column chromatography (Cromartie et al. 1975). Sep-pak Florisil cartridges were used for removal of lipids (Clark et al. 1983). The organochlorine compounds were separated into four fractions on a SilicAR column (rather than three fractions) to ensure the separation of dieldrin or endrin into an individual fraction (Kaiser et al. 1980). The individual fractions were analyzed with a gas-liquid chromatograph equipped with an electron-capture detector and a 1.5/1.95% SP-2250/SP-2401 column. Residues in 10% of the samples were confirmed by gas chromatography/mass spectrometry. Because high levels of DDE were recently detected in some Arizona wildlife (Kepner 1987), a special effort was made to assess the levels of dicofol. The principal commercial dicofol product (Kelthane) contained as much as 15% DDT family compounds (DDT, DDD, DDE and chloro-DDT) in 1982 (Clark 1990). The lower limit of quantification was 0.01 μg/g wet weight for all organochlorine insecticides, PCB and dicofol. Quality assurance and control was confirmed by Patuxent Analytical Control Facility (Patuxent).

Samples were analyzed for selected trace elements including aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, vanadium and zinc at Versar, Inc., Springfield, Virginia. Patuxent reported that Versar, Inc. analytical accuracy seemed acceptable for most analytes, however, selenium and mercury results were biased low. The bias in selenium data was estimated by Patuxent to be approximately -30% and the bias in mercury data was -25%. Patuxent concluded that "great care must be taken in interpreting these data" relative to selenium and mercury.

Arsenic and selenium were analyzed by hydride generation atomic absorption

spectrophotometry and mercury by cold vapor reduction. All other trace elements were analyzed by inductively coupled plasma atomic emission spectroscopy (ICP) following preconcentration to lower detection limits. Organochlorine and trace element residues are reported on a wet weight basis with percent moisture listed for each sample to facilitate wet weight to dry weight conversions. To convert wet weight values to dry weight equivalents, the wet weight values are divided by 1 minus the percent moisture.

The spatial relationship of contaminants along the San Pedro River was analyzed by linear regression. Residues in tributary creeks were not included in these analyses. Trace element levels in sediments were compared with Arizona background levels using Student's f-test. The significance level for all statistical tests was P = 0.05.

RESULTS AND DISCUSSION

Oraanochlorine compounds- Organochlorine compounds were not detected in sediments. DDE and chlordane isomers were the only organochlorines recovered in San Pedro River fauna (Tables 2 - 3). DDE was detected most frequently in Abert's towhee and longfin dace; all samples contained low ($\leq$0.06 μg/g) concentrations. The mean DDE residue in Abert's towhee was 0.035 μg/g (0.02-0.06) and did not vary with collection location (P$_C$ 0.05). DDE residues in Abert's towhee carcasses were generally below levels associated with chronic poisoning and reproductive problems in most species of birds (Stickel 1973, Blus 1982). Dicofol, a compound of special concern that may contain up to 15% DDT family compounds, was not detected in any samples.

The mean DDE concentration in longfin dace was 0.02 μg/g (0.01-0.03) and levels did not vary with collection location (P < 0.05). The maximum concentration, 0.03 μg/g, was well below the national geometric mean (background level) of 0.19 μg/g as established by the National Contaminant Biomonitoring Program (Schmitt et al. 1990). Longfin dace had significantly (P < 0.05, ANOVA) higher lipid levels (mean = 10.8, n = 8) than other fish species; desert sucker (C. *clarki*) (mean = 6.1, n = 4), Sonora sucker (C. *insignis*) (mean = 4.0, n = 1), green sunfish (*Lepomis cyanellus*) (mean = 3.3, n = 2) and black bullhead (*Ictalurus melas*) (mean = 2.2, n = 1). The higher levels of lipid in

longfin dace may explain, at least in part, why highly lipotrophic DDE was recovered more frequently in this species.

DDE was sporadically recovered in the remaining faunal samples (Table 3). The highest level of DDE recorded was 0.09 μg/g in a desert grassland whiptail lizard (C. *uniparens*) and western kingbird sample.

Longfin dace and western whiptail lizards (C. *tigris*) contained low (<0.02 μg/g) residues of chlordane components. Longfin dace from Highway 80 and dace from San Manuel contained 0.01 μg/g t-nonachlor. A whiptail lizard from Dudleyville had 0.02 μg/g t-nonachlor. Oxychlordane was detected in the Dudleyville whiptail lizard sample at 0.02 μg/g.

Organochlorine levels reported in this study are generally low and suggest that fauna resident in the San Pedro River Basin are probably not affected by local organochlorine contamination.

Trace elements- As previously stated, trace element analysis did not meet Patuxent's quality control standards for mercury and selenium as recoveries in laboratory spiked samples were at least 25% below known levels. Concentrations of 10 other trace elements also were significantly ($P < 0.05$, *t*-test) below expected, or background, concentrations (Table 4). Due to the influence of mining in the San Pedro vs. the Rio Yaqui watershed, it was expected that most trace element levels in San Pedro River sediments would be higher than those reported by Kepner (1988) in sediments from San Bernardino National Wildlife Refuge in the Rio Yaqui watershed. However, several trace elements (aluminum, barium, beryllium, chromium, iron, lead, magnesium, nickel, vanadium and zinc) were far lower in San Pedro sediments than San Bernardino Refuge samples. In view of Patuxent Wildlife Research Center's report of sub-standard chemical analysis for two trace elements (mercury and selenium) coupled with our findings that ten of 15 additional trace elements were significantly ($P < 0.05$) below Arizona background levels, we feel that the entire trace element portion of this study is suspect. Therefore, lacking confidence in the chemical results, we decline further interpretation of trace element data. Trace element data are presented for information purposes only in Tables 4 - 5.

RECOMMENDATIONS

Organochlorine compounds apparently do not pose a threat to species resident in the San Pedro watershed. Survival and reproduction of endangered species relocated to this area, particularly within the San Pedro National Riparian Conservation Area, would probably not be affected by current organochlorine levels. However, because of questionable analytical results, the data regarding trace elements are unclear. Since this study was initiated in 1987, Apache Powder Company was added to the EPA's super-fund list of hazardous waste sites. Additional contaminant problems possibly associated with Apache Powder Company such as ammonia and trace element input into the San Pedro River shoud be documented. We recommend that, 1) the San Pedro be re-sampled for trace elements at the earliest possible date, 2) reintroduction programs be approached with caution in view of the areas history of recurrent mine spills and other potential contamination and, 3) a cooperative interagency group (FWS, BLM, Arizona Department of Environmental Quality and Arizona Game and Fish Department) initiate a regular chemical residue monitoring program at fixed sites along the San Pedro and couple the monitoring program with some measure of bioassessment.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Arizona Game and Fish Department. 1980. Statewide Fishery Investigation, 1978-1979. Federal Aid Fishery Project F-7-R-21, Phoenix, Arizona.

Blus, L. J. 1982. Further interpretation of the relation of organochlorine residues in brown pelican eggs to reproductive success. Environ. Pollut. 28:15-33.

Clark, D. R. JR. 1990. Dicofol (Kelthane) as an environmental contaminant: a review. Fish and Wildlife Service. Fish and Wildlife Technical Report 29. Washington, D.C. 37 pp.

Clark, D. R. JR., R. L. Clawson, and C. J. Stafford. 1983. Gray bats killed by dieldrin at two Missouri caves: aquatic microinvertebrates found dead. Bull. Environ. Contam. Toxicol., 30:214-218.

Clement International Corporation. 1992. Ecological Risk Assessment for the Apache Powder Superfund Site. Clement International Corporation. Denver, Colorado.

Cromartie, E., W. L. Reichel, L. N. Locke, A. A. Belisle, T. E. Kaiser, T. G. Lamont, B. M. Mulhern, R. M. Prouty and D. M. Swineford. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1971-72. Pestic. Monit. J., 9:1 l-14.

Jackson, W., T. Martinez, P. Cuplin, W. L. Minkley, B. Shelby, P. Summers, D. McGlothlin and B. Van Haveren. 1987. Assessment of Water Conditions and Management Opportunities in Support of Riparian Values: BLM San Pedro River Properties, Arizona Project Completion Report. BLM/YA/PT-88/004+7200. U.S. Dept. Interior, Bureau of Land Manage., Service Center, P.O. Box 2547, Denver, Colorado 80225-0047. 180 pp.

Kaiser, T. E., W. L. Reichel, L. N. Locke, E. Cromartie, A. J. Krynitsky, T. G. Lamont, B. M. Mulhern, R. M. Prouty, C. J. Stafford, and D. M. Swineford. 1980. Organochlorine pesticide, PCB, PBB residues and necropsy data for bald eagles from 29 states- 1975-77. Pestic. Monit. J., 13:145-149.

Kepner, W. G. 1987. Organochlorine contaminant investigation of the lower Gila River. Fish and Wildlife Service Report. Phoenix, Arizona 18 pp.

Kepner W. G. 1988. San Bernardino National Wildlife Refuge Contaminant Study. Fish and Wildlife Service Report. Phoenix, Arizona 18pp.

Laurenzi, A. 1991. Conservancy and BLM launch cooperative land acquisition effort in San Pedro River Basin. The Nature Conservancy Newsletter (Arizona Chapter) 13:6

Miller, R. R. and C. H. Lowe. 1964. Annotated checklist of the fishes of Arizona. Part 2. pp. 133-151 *in* C. H. Lowe (ed.). The Vertebrates of Arizona. Univ. Ariz. Press, Tucson.

Negri, S. 1989. The San Pedro Riparian Area. Arizona Highways 65:18-33.

Schmitt, C. J., J. M. Zajicek, and P. H. Peterman. 1990. National contaminant biomonitoring program: residues of organochlorine chemicals in U.S. freshwater fish, 197684. Arch. Environ. Contam. Toxicol. 19:748-781.

Shomo, L. S. and 0. E. Maughan. 1991. An investigation of selenium in aquatic systems associated with a coal fired power plant in the arid southwest. Completion Report. University of Arizona. Arizona Cooperative Fish and Wildlife Research Unit. Tucson, Arizona.

Stickel, L. F. 1973. Pesticide residues in birds and mammals. pp. 254-312 *in C.* A. Edwards (ed.). Environmental Pollution by Pesticides. Plenum Press, New York.

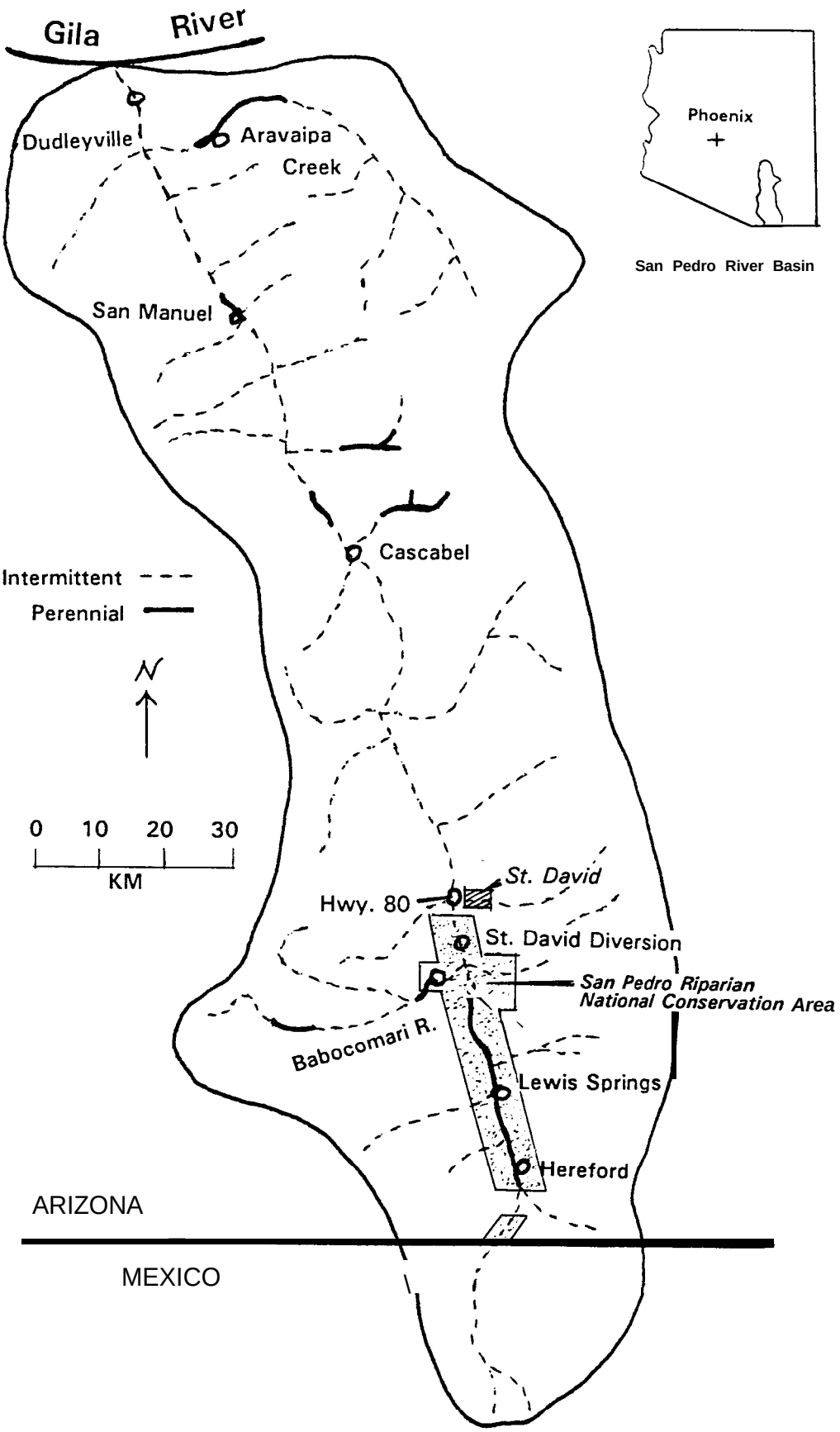

Figure 1. Location of collection sites in the San Pedro River Basin.

Table 1. List of sampling sites within the San Pedro River Riparian Area (also see Fig. 1.).

1. San Pedro River at Hereford.
2. San Pedro River at Lewis Springs bridge.
3. Babocomari River above its confluence with the San Pedro River (Bowers Rd.).
4. San Pedro River at St. David Diversion.
5. San Pedro River at Highway 80 bridge.
6. San Pedro River at Cascabel.
7. San Pedro River at San Manuel.
8. Aravaipa Creek above its confluence with the San Pedro River.
9. San Pedro River at Dudleyville.

Table 2. Grganochlorine contaminants (μg/g wet weight) in fauna collected from the San Pedro River basin, Arizona, July 1987. Data arranged by collection location.

Collection location[1]	Matrix[2]	N[3]	Mean weight	Mean length	Prcnt moist	lipid	PIP' DDE
Hereford	sediment	3	68.7	NA[4]	17.4	NA	ND
Hereford	A towhee	5	52.6	NA	70.2	4.0	0.03
Hereford	L dace	50	3.9	69.4	72.4	12.1	0.02
Hereford	L dace	50	4.4	73.1	68.4	11.9	0.02
Hereford	Dg whiptail	2	6.6	NA	69.0	5.0	0.01
Hereford	D sucker	25	6.9	89.3	72.2	3.9	ND
Hereford	D sucker	25	5.0	80.1	73.6	3.9	ND
Hereford	Bullfrog	5	101.5	108.4	76.8	1.8	ND
LewisSpg	eediment	3	76.0	NA	17.2	NA	ND
LewisSpg	A towhee	5	48.2	NA	71.6	4.1	0.06
LewisSpg	L dace	50	5.1	73.4	72.2	10.1	0.01
LewisSpg	Dg whiptail	5	7.6	212.0	66.2	5.5	ND
LewisSpg	D sucker	25	16.5	109.2	76.4	3.2	0.01
LewisSpg	B bullhead	3	66.0	165.0	78.0	2.2	ND
LewisSpg	Bullfrog	4	246.4	148.7	77.8	0.4	ND
St.David	sediment	3	71.7	NA	21.6	NA	ND
St.David	A towhee	5	50.8	NA	70.2	3.0	0.02
St.David	A towhee	5	47.5	NA	70.8	2.8	0.02
St.David	Dg whiptail	5	8.4	214.4	67.7	6.0	ND
St.David	W kingbird	5	40.8	NA	68.6	3.7	0.09
BabocoRv	sediment	3	51.7	NA	47.4	NA	ND
BabocoRv	crayfish	5	18.8	NA	78.2	1.8	ND
BabocoRv	G sunfish	5	4.6	68.4	76.7	3.4	ND
Hiway80	sediment	3	55.7	NA	32.4	NA	ND
Hiway80	L dace[5]	50	2.9	64.5	68.0	11.4	0.02
Hiway80	Dg whiptail	5	7.0	NA	69.9	4.6	ND
Hiway80	Dg whiptail	5	9.0	NA	70.6	4.8	ND
Cascabel	sediment	3	74.0	NA	20.0	NA	ND
Cascabel	A towhee	5	48.4	NA	70.0	2.7	0.05
Cascabel	L dace	50	3.3	69.7	70.5	6.5	0.01
SnManuel	sediment	3	58.7	NA	28.6	NA	ND
SnManuel	A towhee	5	45.4	NA	70.0	2.2	0.02
SnManuel	L dace[5]	50	2.6	63.2	72.8	9.3	0.02
Aravaipa	sediment	3	87.3	NA	14.2	NA	ND
Aravaipa	A towhee	5	48.2	NA	70.8	2.9	0.05
Aravaipa	L dace	50	4.1	70.0	65.0	16.0	0.02
Aravaipa	W whiptail	5	11.4	NA	70.1	4.0	0.02
Aravaipa	S sucker	5	36.4	144.4	72.0	4.0	ND
Aravaipa	D sucker	5	39.0	145.4	66.6	13.4	ND
Aravaipa	D sucker	25	14.0	107.7	72.0	8.3	0.01
Dudleyvl	sediment	3	80.7	NA	17.2	NA	ND
Dudleyvl	A towhee	5	53.6	NA	72.4	3.2	0.03
Dudleyvl	L dace	50	3.5	68.8	72.8	9.3	0.03
Dudleyvl	W whiptail[5]	5	11.2	NA	72.2	3.4	0.09
Dudleyvl	G sunfish	4	23.0	106.7	73.6	3.3	0.02

'Collection location= Hereford, Lewis Springs, Babocomari River, St. David Diversion, Highway 80, Cascabel, Aravaipa Creek, San Manuel, and Dudleyville.

[2]A towhee= Abert's towhee, L dace= longfin dace, D sucker= desert sucker, Dg whiptail= desert grassland whiptail lizard, G sunfish= green sunfish, W kingbird= western kingbird, S sucker= Sonora sucker, W whiptail= western whiptail lizard.

[3]N = Number of individuals in each composite sample.

%A = Data not available.

'Three samples contained t-nonachlor; longfin dace from Highway 80 and San Manuel (0.01 µg/g), and whiptail lizard from Dudleyville (0.02 µg/g). Oxychlordane was also detected in the Dudleyville whiptail lizard sample at 0.02 µg/g.

Table 3. Organochlorine contaminants (μg/g wet weight) in San Pedro River basin fauna, July 1987. Data arranged by species.

Collection location[1]	Matrix[2]	N[3]	Mean weight	Mean length	Prcnt moist	lipid	p,p' DDE
Hereford	A towhee	5	52.6	NA[4]	70.2	4.0	0.03
LewisSpg	A towhee	5	48.2	NA	71.6	4.1	0.06
St.David	A towhee	5	50.8	NA	70.2	3.0	0.02
St.David	A towhee	5	47.5	NA	70.8	2.8	0.02
Cascabel	A towhee	5	48.4	NA	70.0	2.7	0.05
SnManuel	A towhee	5	45.4	NA	70.0	2.2	0.02
Aravaipa	A towhee	5	48.2	NA	70.8	2.9	0.05
Dudleyvl	A towhee	5	53.6	NA	72.4	3.2	0.03
Hereford	L dace	50	3.9	69.4	72.4	12.1	0.02
Hereford	L dace	50	4.4	73.1	68.4	11.9	0.02
LewisSpg	L dace	50	5.1	73.4	72.2	10.1	0.01
Hiway80	L dace[5]	50	2.9	64.5	68.0	11.4	0.02
Cascabel	L dace	50	3.3	69.7	70.5	6.5	0.01
SnManuel	L dace[5]	50	2.6	63.2	72.8	9.3	0.02
Aravaipa	L dace	50	4.1	70.0	65.0	16.0	0.02
Dudleyvl	L dace	50	3.5	68.8	72.8	9.3	0.03
Hereford	D sucker	25	6.9	89.3	72.2	3.9	ND
Hereford	D sucker	25	5.0	80.1	73.6	3.9	ND
LewisSpg	D sucker	25	16.5	109.2	76.4	3.2	0.01
Aravaipa	D sucker	5	39.0	145.4	66.6	13.4	ND
Hereford	sediment	3	68.7	NA	17.4	NA	ND
LewisSpg	sediment	3	76.0	NA	17.2	NA	ND
LewisSpg	sediment	3	77.0	NA	17.4	NA	ND
St.David	sediment	3	71.7	NA	21.6	NA	ND
BabocoRv	sediment	3	51.7	NA	47.4	NA	ND
Hiway80	sediment	3	55.7	NA	32.4	NA	ND
Cascabel	sediment	3	74.0	NA	20.0	NA	ND
SnManuel	sediment	3	58.7	NA	28.6	NA	ND
Aravaipa	sediment	3	87.3	NA	14.2	NA	ND
Dudleyvl	sediment	3	80.7	NA	17.2	NA	ND
Hereford	Dg whiptail	2	6.6	NA	69.0	5.0	0.01
LewisSpg	Dg whiptail	5	7.6	212.0	66.2	5.5	ND
St.David	Dg whiptail	5	8.4	214.4	67.7	6.0	ND
Hiway80	Dg whiptail	5	7.0	NA	69.9	4.6	ND
Hiway80	Dg whiptail	5	9.0	NA	70.6	4.8	ND
Hereford	Bullfrog	5	101.5	108.4	76.8	1.8	ND
LewisSpg	Bullfrog	4	246.4	148.7	77.8	0.4	ND
BabocoRv	G sunfish	5	4.6	68.4	76.7	3.4	ND
Dudleyvl	G sunfish	4	23.0	106.7	73.6	3.3	O.O2
Aravaipa	W whiptail	5	11.4	NA	70.1	4.0	0.02
Dudleyvl	W whiptail'	5	11.2	NA	72.2	3.4	0.09
LewisSpg	B bullhead	3	66.0	165.0	78.0	2.2	ND
BabocoRv	Crayfish	5	18.8	NA	78.2	1.8	ND
St.David	W kingbird	5	40.8	NA	68.6	3.7	0.09
Aravaipa	S sucker	5	36.4	144.4	72.0	4.0	ND

[1]Collection location= Hereford, Lewis Springs, Babocomari River, St. David Diversion, Highway 80, Caacabel, Aravaipa Creek, San Manuel, and Dudleyville.

[2]A towhee= Abert's towhee, L dace= longfin dace, D sucker- desert sucker, DG whiptail= desert grassland whiptail lizard, G sunfish= green sunfish, W kingbird= western kingbird, S sucker= Sonora sucker, W whiptail= western whiptail lizard.

[3]N = Number of individuals in each composite sample.

[4]NA = Data not available.

[5]Three samples contained t-nonachlor; longfin dace from Highway 80 and San Manuel (0.01 µg/g), and whiptail lizard from Dudleyville (0.02 µg/g). Oxychlordane was also detected in the Dudleyville whiptail lizard sample at 0.02 µg/g.

Table 4. Comparison of trace elements in sediments of the San Pedro River with sediment background levels from other Arizona locations.

Collection location	Trace element concentration, µg/g dry weight[1]														
	Al	As	Ba	Be	B	Cr	Cu	Fe	Pb	Mg	Mn	Ni	Sr	V	Zn
San Pedro R.															
Hereford	2820	6.0	59	0.25	<1.0	2.4	30.0	4790	6.1	1690	162	3.6	36	8.0	31
LewisSpg	2010	3.5	41	0.22	<1.0	2.3	16.0	3670	<5.0	1320	144	2.3	29	5.3	20
St.David	5570	6.6	164	0.48	<10	4.5	40.0	7230	15.0	3920	372	6.5	131	10.0	35
BabocoRv[2]	8540	5.3	288	0.66	<10	5.9	19.0	8720	21.0	5060	825	6.5	133	10.0	46
Hiway80	7740	5.8	138	0.78	<10	6.9	13.0	7800	36.0	5940	454	7.9	203	9.4	33
Cascabel	1250	2.1	26	0.10	<1.0	1.4	3.4	1920	<5.0	1130	176	2.3	28	3.0	8
SnManuel	3740	3.4	126	0.40	1.2	2.1	11.0	3020	6.1	2130	219	3.2	190	5.2	14
Aravaipa[1]	3610	1.6	36	0.13	<1.0	2.0	8.3	6340	5.8	3210	128	8.8	30	7.2	17
Dudleyvl	2860	2.2	86	0.21	<1.0	1.9	5.5	2410	<5.0	1500	272	4.3	101	4.2	11
mean	4244[1]	4.1	107[1]	0.36[1]	NA	3.3[1]	16.2	5100[1]	10.8[1]	2878[1]	306	4.9[1]	98	6.9[1]	24[1]
std dev	2533	1.7	a4	0.24		2.0	12.0	2507	11.4	1757	224	2.5	71	2.6	13
Backaround[1]															
mean	23695[1]	5.8	289[1]	0.82[1]	NA	31.3[1]	26.6	18443[1]	22.4[1]	10602[1]	484	17.0[1]	191	38.6[1]	55[1]
std dev	7543	1.7	150	0.67		16.0	20.1	5750	2.6	3619	122	3.7	154	14.5	12

[1]Trace elements not detected in any samples = antimony, cadmium, molybdenum. silver, thallium, tin, mercury, and selenium.

[1]Tributaries to the San Pedro River.

[1]Arizona background data from Kepner 1988, Radtke et al. 1988, Shomo and Maughan 1991, King and Baker unpub. data. Total studies = 5.

* = Significant difference between means, P< 0.05, t-test.

Table 5. Trace element levels in San Pedro River basin fauna, July 1987'.

Species'	N[4]	Coll.[5] location	Trace element concentrations, µg/g wet weight'														Prcnt. moist.
			Al	Be	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Sn	Zn	As	Se'	Hg[1]	
A. Towhee	5	Hereford	65	ND'	0.28	ND	7.8	292	9	7.1	ND	0.8	68	ND	0.63	ND	70.6
L. Dace	10	Hereford	157	ND	0.16	ND	8.3	170	56	a.5	ND	ND	113	ND	1.6	ND	69.0
L. Dace	10	Hereford	151	ND	0.18	ND	9.7	166	57	0.8	ND	ND	117	ND	1.9	ND	68.9
D. Sucker	10	Hereford	1210	0.07	0.19	1.8	7.3	818	178	8.2	0.7	ND	92	1.9	0.71	ND	71.9
S. Sucker	10	Hereford	1240	0.07	0.21	2.4	7.8	882	188	7.2	1.7	ND	93	1.2	0.71	ND	72.3
B. Frog	5	Hereford	28	ND	ND	ND	4.9	91	14	ND	ND	4.9	63	ND	0.50	ND	75.4
Dg Lizard	5	Hereford	313	ND	0.08	4.3	5.6	239	8	1.7	NA	ND	164	NA	NA	NA	68.0
Towhee	5	LewisSpg	126	ND	0.62	ND	8.0	286	10	3.6	1.7	ND	79	1.2	1.2	ND	71.1
L. Dace	10	LewisSpg	270	ND	0.16	NO	a.4	290	123	4.2	0.8	0.7	110	ND	1.5	ND	71.5
S. Sucker	10	LewisSpg	1110	0.08	0.19	1.4	10.0	745	211	0.6	1.0	14.0	90	ND	0.79	ND	76.4
Bullhead	3	LewisSpg	307	ND	0.12	0.7	17.0	304	80	0.2	ND	6.9	67	ND	1.5	ND	78.4
Dg Lizard	5	LewisSpg	339	ND	0.19	1.0	11.0	264	9	0.4	NA	0.7	163	ND	1.0	ND	66.5
Bullfrog	4	LewisSpg	377	0.11	0.11	2.2	8.5	300	14	0.8	1.8	9.6	70	ND	1.2	0.30	77.8
Sunfish	5	BabocoRv	55	ND	0.15	1.0	4.1	57	53	0.2	2.8	ND	84	NA	NA	0.50	75.7
Crawfish	5	BabocoRv	342	ND	0.26	ND	57.0	291	371	39.0	ND	ND	46	1.0	ND	0.11	78.0
Towhee	5	St.David	106	ND	0.09	ND	11.0	232	6	2.3	1.5	ND	74	ND	1.1	NO	70.9
Towhee	5	St.David	105	ND	ND	ND	11.0	221	7	26.0	1.3	ND	76	ND	1.2	ND	71.3
W. Kingb	5	St.David	17	ND	0.10	ND	6.3	133	4	5.9	0.8	ND	47	ND	0.91	ND	68.9
Dg Lizard	5	St.David	130	ND	0.35	ND	6.4	193	7	38.0	NA	ND	123	ND	0.58	ND	68.0
Dg Lizard	5	Hiway80	252	ND	0.10	3.0	13.0	293	12	2.2	NA	ND	134	2.4	1.1	ND	70.1
L. Dace	10	Hiway80	703	0.03	0.07	1.0	4.8	520	38	3.6	49.0	ND	104	ND	1.5	ND	69.0
Dg Lizard	5	Hiway80	224	NO	0.05	4.2	13.0	299	10	3.3	NA	ND	129	NA	NA	ND	69.0
L. dace	10	Cascabel	177	ND	0.10	ND	5.6	198	92	6.0	ND	ND	134	ND	1.2	0.25	73.4
Towhee	5	Cascabel	75	ND	0.05	1.0	7.2	251	6	16.0	ND	ND	80	ND	1.5	ND	83.4
L. Dace	5	SnManuel	285	ND	0.07	0.9	6.0	275	67	3.9	ND	0.9	137	ND	1.2	ND	70.0
Towhee	5	SnManuel	119	ND	ND	0.9	9.9	572	a	0.7	0.8	16.0	78	ND	1.1	ND	70.8
L. Dace	10	Aravaipa	141	ND	0.11	ND	3.7	239	27	1.1	ND	ND	107	ND	2.0	ND	66.4
S. Sucker	10	Aravaipa	104	ND	0.17	ND	3.9	144	17	4.6	ND	ND	65	ND	1.0	ND	75.7
S. Sucker	10	Aravaipa	168	0.07	0.13	1.4	2.4	306	24	1.7	1.6	0.7	65	ND	ND	ND	66.8
S. Sucker	10	Aravaipa	1530	0.06	0.18	1.9	5.1	1150	53	1.9	2.4	9.1	65	ND	0.66	ND	71.8
Ww Lizard	5	Aravaipa	473	ND	0.10	1.9	7.4	874	16	98.0	NA	ND	126	ND	1.2	ND	68.5
A. Towhee	5	Aravaipa	120	ND	0.14	1.8	10.0	448	9	93.0	0.8	0.9	70	ND	1.0	ND	71.4
L. Dace	10	Dudleyvl	146	ND	0.24	ND	9.8	180	36	7.7	1.4	ND	137	ND	2.2	ND	72.8
Sunfish	6	Dudleyvl	49	ND	0.14	1.0	5.8	95	17	11.0	ND	ND	91	N D	2.2	0.23	73.9
A. Towhee	5	Dudleyvl	238	0.03	0.18	1.9	10.0	540	24	18.0	21.0	ND	77	ND	0.96	ND	71.1
Ww Lizard	5	Dudleyvl	359	ND	0.14	1.7	11.0	516	20	7.9	NA	ND	147	2.0	0.96	ND	70.5