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Region 2
Contaminants Program

ENVIRONMENTAL CONTAMINANTS IN FISH AND WILDLIFE OF THE LOWER GILA RIVER, ARIZONA

by

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ABSTRACT

Levels and potential effects of pesticides and metals on fish and wildlife of the lower Gila River and associated agricultural drainage canals in Maricopa County, Arizona, were investigated in 1994-95. Residues of DDT, an insecticide that has been suspended from use in Arizona for 25 years, are still present in fish, turtles, and birds. DDT was detected in 86, 62, and 50% of the fish collected from Buckeye Canal, Gillespie Dam, and Allenville, respectively. DDT was recovered in all turtles from Gillespie Dam, and in all black-crowned night-herons from Painted Rock.

DDE residues in fish from the lower Gila River drainage were the highest in the United States associated with agriculturally applied pesticides. Although DDE residues declined over the past decade; current levels remain extremely high. DDE was present at concentrations known to impact biotic resources. Fish collected from agricultural drainage canals generally contained higher DDE residues than fish from the river. DDE residues were highest in common carp (*Cyprinus carpio*) from Buckeye Canal (11.17 µg/g wet weight), an agricultural drain and tributary to the Gila River. The overall frequency of occurrence of organochlorine compounds is declining, however, as only 6 compounds were detected in samples collected in 1994-95 versus 16 recovered in samples collected from the same sites in 1985. Residues of all other pesticides and PCBs were below levels associated with adverse affects on fish and wildlife.

Concentrations of 11 potentially toxic metals were detected in fish. Carp collected near Allenville had the second highest aluminum concentration ever recorded in Arizona. Copper exceeded the national 85th percentile in 31 of 48 samples. Because of its occurrence at relatively high levels and its propensity to interact with other compounds and elements, copper remains a contaminant of concern. Concentrations of most metals remained unchanged from 1985 to 1994-95.

Spiny softshell turtles (*Trionyx spiniferus*) generally contained higher organochlorine and metal concentrations than fish. DDE and most metals were highest in turtles from the middle river sampling sites. Residues of DDE and chlordane declined by about one-half from 1985 to 1994-95. PCB, dieldrin, and DDT levels remained relatively constant over the past decade while copper, nickel, vanadium, and zinc concentrations declined. Levels of arsenic, mercury, and selenium in turtles collected in 1994-95 were statistically similar to concentrations in turtles collected in 1985.

Whiptail lizards (*Cnemodophorus* spp.) collected from areas adjacent to the lower Gila River contained higher organochlorine residues than lizards collected from other Arizona locations. DDE and selenium exceeded toxic threshold levels that could be hazardous to avian predators that consume a large proportion of lizards in their diet. Mean mercury concentrations

increased from 1985 to 1994-95 and were about 3- to 10-times higher in lizards collected in the Gila River basin than in lizards from other Arizona locations.

DDE, mercury, and selenium pose a significant environmental challenge to black-crowned night-herons (*Nycticorax nycticorax*) and possibly to other avian species nesting and wintering on the lower Gila River. All night-heron and two of four red-winged blackbird (*Agelaius phoeniceus*) carcasses contained >3.4 µg/g wet weight DDE; the level associated with impaired reproduction. One-half of the blackbird carcasses contained sufficiently high DDE residues to represent a hazard to predatory birds that regularly feed on blackbirds. Mercury concentrations in five of six night-heron livers approached or exceeded the toxic threshold and the maximum concentration, 28.07 µg/g dry weight, was 4.5-times higher than the toxic threshold. Selenium concentrations in night-heron livers (13 - 18 µg/g dry weight) indicate that adults are not at risk of selenium intoxication, but selenium impacts on reproduction are possible.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

INTRODUCTION

The development of a cotton monoculture during the 1950s in Arizona's lower Gila River Valley resulted in infestations by insect pests such as the pink bollworm (*Pectinophora gossypiella*) which, by the late-1950s, threatened to severely decimate the Valley's cotton crop (Stanton 1987). In an attempt to control the pink bollworm with insecticides, about 33,000 acres (13,355 ha) in the Valley's Buckeye-Avondale area were treated with 1.7 million pounds (772,727 kg) of technical DDT during 1958-1960 (Parsons 1987). As a result of multiple applications throughout the growing season, up to 23 pounds per acre (25.7 kg/ha) of technical DDT was applied per year. Soil tests conducted in 1985 by University of Arizona personnel revealed 1.5 µg/g DDE (a metabolite of DDT) and 0.4 µg/g DDT, about 20-times background concentrations, at levels 18-inches below the soil surface (N.A. Buck *in* Parsons 1987). The total farmland irrigated by DDT-contaminated drainwater exceeded 100,400 acres (40,632 ha), and an estimated 4,917 tons of DDT and metabolites (DDTr) reached the lower Gila River via agricultural drainwater return flow (Parsons 1987). Johnson and Lew (1970) concluded that, "the Gila River appears to be the most DDT-burdened stream of 20 sampled in the western United States."

Concern that pesticides may have adversely affected fish and wildlife was first expressed during the mid-1960s. Between 1966 and 1982, 460 samples were collected by four agencies for residue analyses (Ellingson 1984). European starlings (*Sturna vulgaris*) collected near the lower Gila River during a 1982 nationwide survey of 129 sites contained the highest (8.4 µg/g wet weight) DDE concentration in the United States (Bunck et al. 1987). A separate study reported that mallards (*Anas platyrhynchos*) taken in the same general area had the second highest DDT residue in the nation (Cain 1981). Subsequent reports by the Arizona Department of Health Services (ADHS) indicated that fish from the lower Gila River at Painted Rock Borrow Pit Lake (Painted Rock) were contaminated not only with pesticides, but by heavy metals such as arsenic, cadmium, lead, mercury, and zinc (ADHS 1991). Earth Technology Corporation (1993) concluded, "Based on TCLP analysis, fish and turtles (from Painted Rock) could be considered a hazardous waste and would require treatment and disposal." Of special concern was the potential adverse effects these pesticides could have on federally listed threatened and endangered species, such as the Yuma clapper rail (*Rallus longirostris yumanensis*), bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*) and brown pelican (*Pelecanus occidentalis*) that were present in the lower Gila River area.

The U.S. Fish and Wildlife Service (Service) completed a comprehensive investigation of organochlorine pesticide levels and potential effects of those compounds on lower Gila River fish and wildlife during 1985 (Kepner 1986, 1987). That report identified a significant threat to fish, wildlife, and human health. Based on Kepner's data, and those of the Arizona Game and Fish Department (AGFD), and the Arizona Department of Environmental Quality (ADEQ), fish consumption advisories were posted, and are currently still in effect, at several sites within the study area including portions of the Gila, Salt, and Hassayampa Rivers, and at Dysart Drain (ADHS 1991, ADEQ 1996).

The objectives of this study were to, 1) document and assess current levels of selected organochlorine and metal contaminants in fish and wildlife of the lower Gila River, 2) evaluate trends in contaminant concentrations spacially and temporally using current data and those collected from the same area a decade earlier (Kepner 1986, 1987), 3) compare the occurrence of selected contaminants in lower Gila River fish and wildlife with national averages using national monitoring networks (Schmitt and Brumbaugh 1990, Schmitt et al. 1990) and U.S. Environmental Protection Agency (USEPA) special national studies (USEPA 1992), and 4) assess the risk of exposure to known action levels for fish and wildlife.

STUDY AREA

The lower Gila River study area is located southwest of Phoenix, in southwestern Arizona (Figure 1). We attempted to replicate the 1985 Service study by collecting samples from the same general locations as described by Kepner (1987). Six study sites were located in the lower Gila River watershed along an 88 mile (142 km) stretch of river between 59th Avenue and Painted Rock. The most eastern site, 59th Avenue, is located on the lower Salt River 12 miles (20 km) upstream from its confluence with the Gila River. Four additional collection sites were located on the river at approximately equidistant intervals; the Gila River at Estrella Park, Allenville, Gillespie Dam, and Painted Rock. Samples collected at Painted Rock came from the 100-acre (40.5 ha.) borrow pit lake below the dam. A final set of samples was collected from Buckeye Canal, a canal that provides irrigation water to farmers and return run-off to the Gila River. A single incidental sample was taken at Dysart Drain, another agricultural drain that flows into the Gila River under run-off conditions.

METHODS

Sample collections: Fish, turtles, lizards, and birds were collected from the lower Gila River and Buckeye Canal from April to August 1994 and 1995. Channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), and largemouth bass (*Micropterus salmoides*) were caught using gill and cast nets. Fish were weighed and measured on site and individual whole body samples were wrapped in aluminum foil and stored on wet ice until they were transferred to a commercial freezer at the end of the day. In addition to whole body samples, fillets from both sides of carp and largemouth bass were taken at selected sites. Spiny softshell turtles (*Trionyx spiniferus*) were collected using a baited wire turtle trap and trot lines. Turtles were placed on wet ice until they became lethargic enough to be handled safely, then weighed and individually wrapped in aluminum foil. Turtles were then replaced on wet ice until transferred to a commercial freezer. Whiptail lizards (*Cnemodophorus* spp.) were sampled from four sites using a .22 caliber rifle or handgun and lead shotshells. Lizards were composited into a single sample at each site. All fish, turtles, and lizards were analyzed for organochlorine compounds and trace elements. Black-crowned night-herons (*Nycticorax nycticorax*) and red-winged blackbirds (*Agelaius phoeniceus*) were collected at selected sites using a shotgun and steel shotshells. Birds were weighed in the field then bills, legs, wingtips, feathers, and gastrointestinal tracts were removed and discarded. Carcass and liver samples were weighed then wrapped in aluminum foil and placed on wet ice until they were transferred to a commercial freezer. Carcasses were analyzed for organochlorines and trace elements while livers were analyzed only for trace elements. Red-winged blackbird carcasses were composited by site and black-crowned night-heron carcasses were analyzed individually.

Chemical analyses: All samples except bird livers were analyzed for organochlorine compounds including o,p'- and p,p'-DDE, o,p'- and p,p'-DDD, o,p'- and p,p'-DDT, dieldrin, heptachlor epoxide, hexachlorobenzene (HCB), alpha, beta, delta, and gamma BHC, alpha and gamma chlordane, oxychlordane, *trans*-nonachlor, *cis*-nonachlor, endrin, toxaphene,

mirex, and total polychlorinated biphenyls (PCB) at Hazleton Environmental Services, Inc. Madison, Wisconsin. For each analysis, the sample was homogenized and mixed with anhydrous sodium sulfate and soxhlet extracted with hexane for seven hours. The extract was then concentrated by rotary evaporation to dryness for lipid determination. The weighed lipid sample was dissolved in petroleum ether and extracted four times with acetonitrile saturated with petroleum ether. Lipids were removed by Florisil column chromatography (Cromartie et al. 1975). The column was then eluted with diethyl ether/petroleum ether and separated into two fractions. One fraction was concentrated to appropriate volume for quantification of residues by packed or capillary column electron capture gas chromatography. The other fraction was concentrated and transferred to a SilicAR acid chromatographic column for additional cleanup required for separation of PCBs from other organochlorines for quantification of residues by packed or megabore column, electron capture gas chromatography. The lower limit of quantification was 0.01 µg/g (parts per million) for most organochlorine pesticides and 0.05 µg/g for toxaphene and PCBs. Organochlorine compounds are expressed in µg/g wet weight unless otherwise specified. Organochlorine compounds are primarily stored in body lipids; therefore, lipid levels are presented for each sample.

Whole body fish, fish fillets, turtles, lizards, bird carcasses, and bird livers were analyzed for aluminum, arsenic, beryllium, boron, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, strontium, vanadium, and zinc at Hazleton Laboratories America, Inc. Mercury concentrations were quantified by cold vapor atomic absorption, arsenic and selenium were analyzed by hydride generation atomic absorption spectrophotometry. All other elements were analyzed following preconcentration to lower detection limits by using inductively coupled plasma emission spectroscopy (ICP). Trace element concentrations in fish samples are reported in µg/g wet weight to facilitate comparison of results with those of other studies. Percent moisture is presented to permit wet weight to dry weight conversions. Wet weight values can be converted to dry weight equivalents by dividing the wet weight values by one minus percent moisture as illustrated in the following equation:

$$\text{Dry weight} = \text{wet weight}/1 - \text{percent moisture}$$

Element concentrations in turtles, lizards, and birds are presented in µg/g dry weight. The lower limits of analytical quantification varied by element and by sample mass are listed in the appropriate tables.

Our 1994-95 data were compared with Schmitt and Brumbaugh's (1990) National Contaminant Biomonitoring Program (NCBP) findings to determine how trace element concentrations in fish from the lower Gila River compare to national levels. Concentrations of an element were considered elevated when they exceeded the NCBP 85th percentile of the nationwide geometric mean. The 85th percentile was not based on toxicity hazard to fish but provides a frame of reference to identify metals of potential concern.

While the NCBP 85th percentile was calculated for several elements (Schmitt and Brumbaugh 1990), it was not determined for organochlorine compounds (Schmitt et al. 1990). To facilitate comparison of our organochlorine data in fish with national levels, we calculated the 85th percentile for several compounds using raw data reported by Schmitt et al. (1990). We first ordered the data, then multiplied the total number of data points by 0.85. The corresponding residue was considered the 85th percentile level.

We also compared our data with those of the USEPA National Study of Chemical Residues in Fish which sampled fish from 314 "targeted" sites with known contaminant problems and from 74 relatively unpolluted (background) sites (USEPA 1992). While NCBP data covered years 1976 to 1984, the USEPA data were collected from 1986-1989.

We recognize that not all the elements listed in this report are "heavy metals" or even true metals. But for the sake of convenience, and to avoid often ambiguous terms such as "trace elements, metalloids, and heavy metals," we refer to all elements simply as metals.

Statistical analysis: Contaminant concentrations in fish were compared among areas, among species, and between years by using 1-way and 2-way ANOVAs. Residue data were normalized by log transformation before mean comparisons. Geometric means (Gmean) were calculated and contaminant concentrations assessed at those areas that contained three or more individuals per site. Area differences were determined using common carp because carp was the only species consistently collected at all locations. Fifty-ninth Avenue and Painted Rock were the only sites where we were able to collect enough carp and largemouth bass for species difference determinations. Similarly, carp/catfish comparisons were possible only at Gillespie Dam.

Organochlorine and metal concentrations in fish, turtle, lizard, and bird samples were also compared with levels detected in similar samples taken from the lower Gila River in 1985 to determine temporal patterns in residue accumulation. Samples collected in 1985 were analyzed for organochlorine compounds and metals. The organochlorine data were published (Kepner 1986, 1987), but the metals data were not. This report includes an expanded analysis of the 1985 organochlorine data and presents the metals data for the first time (Appendix A).

RESULTS

FISH

Organochlorines in whole fish: From three to five common carp were sampled at each site (Table 1). Channel catfish were taken at all sites except Estrella Park and sample size ranged from one to nine individuals per site. Five largemouth bass were collected at both 59th Avenue and Painted Rock.

Whole body fish samples contained residues of six organochlorine compounds (Table 1). DDE was present in all samples and individual residues ranged from 0.16 to 21.0 µg/g wet weight. Geometric mean DDE levels in carp were lowest in 59th Avenue samples (0.27 µg/g) and highest in carp from Buckeye Canal (11.17 µg/g, Table 2). Carp and largemouth bass geometric means were similar (P = 0.1750) for samples collected at 59th Avenue and Painted Rock; carp/catfish means were similar (P = 0.0581) for samples from Gillespie Dam. The geometric mean DDE residue in carp was significantly (P = 0.0007) lower in 1994-95 (1.29 µg/g wet weight) than in 1985 (2.65 µg/g, Figure 2); however, the frequency of occurrence (100%) was similar during both collection periods.

DDT was detected most frequently in fish from Buckeye Canal; six of seven samples (86%) contained DDT. The frequency of recovery of DDT in fish from other sites ranged from zero at 59th Avenue and Estrella Park, to 25% at Painted Rock, 50% at Allenville, and 62% at Gillespie Dam. The maximum DDT residue was 0.15 µg/g wet weight in a carp from Buckeye Canal. Only carp samples from Buckeye Canal, Gillespie Dam, and Painted Rock contained DDT at sufficient frequency (>50%) for statistical comparisons. Geometric mean residues were similar among areas (P = 0.0964), but differed between years (P = 0.0306, 2-way ANOVA, Table 2). None of the bass from 59th Avenue and Painted Rock contained DDT; therefore, residue comparisons between species (carp/bass) were not possible. Geometric mean DDT residues in carp collected from Gillespie Dam (0.014 µg/g wet weight) were similar (P = 0.1250) to those in catfish (0.007 µg/g) from the same area. Residues in carp collected in 1994-95 (Gmean = 0.03 µg/g) were one-tenth those in carp collected in 1985 (Gmean = 0.33 µg/g).

PCBs were detected in all fish samples from 59th Avenue, Estrella Park, and Buckeye Canal and were present in about 50% of the samples from the remaining collection sites (Table 1). Individual residues ranged to 0.70 µg/g wet weight. Geometric mean residues in carp were similar between years but were different among areas (P = 0.0042, 2-way ANOVA, Table 2). PCB concentrations in carp from Gillespie Dam were lower (P = 0.0014) than those in carp collected at three upstream sampling stations including 59th Avenue, Estrella Park, and Buckeye Canal (Table 2). PCB residues in carp from 59th Avenue (Gmean = 0.30 µg/g wet weight) were similar to those in largemouth bass (0.38 µg/g) from the same area. PCBs were not detected in a sufficient number of Painted Rock and Gillespie Dam carp samples to permit between species comparison of residue levels. The geometric mean PCB residue in carp collected in 1994-95 (0.15 µg/g wet weight) was similar to that in carp collected in 1985 (0.19 µg/g, P = 0.1868). The frequency of recovery of chlordane in fish samples ranged from 25% at Painted Rock to 86% at Buckeye Canal (Table 1). Overall, 29 of 52 (56%) whole body fish samples contained chlordane. Chlordane was present in fewer than one-half the carp samples at each study area except Buckeye Canal which negated a comparison of residue levels among collection sites and among species. In 1985, chlordane was detected in only 3 of 24 samples (Appendix A1); therefore, a comparison of residue levels between years was not possible. However, the frequency of occurrence of chlordane was greater in 1994-95 (56%) than in 1985 (12.5%).

Dieldrin was recovered in 16 of 52 fish samples with the highest recovery rate, 73% (8/11) in samples from 59th Avenue (Table 1). Like chlordane, dieldrin was recovered infrequently and statistical comparisons among species, among areas, and between years were not possible. The frequency of occurrence of dieldrin in samples collected in 1985 (83%) was greater than in 1994-95 (31%).

Toxaphene was not detected in carp but was present in 3 of 15 catfish and in all largemouth bass (Table 1). Residues ranged to 5.4 µg/g wet weight. Highest residues were recorded in two catfish samples from Buckeye Canal. Interspecific differences in toxaphene residues could not be determined because of the lack of detectable residues in carp. The geometric mean toxaphene residue in largemouth bass from 59th Avenue (0.26 µg/g wet weight) was similar (P = 0.1774) to that in bass from Painted Rock (0.21 µg/g, Table 2). Toxaphene was not detected in carp collected in 1994-95, but was present in 61% of the carp sampled in 1985.

Organochlorines in fish fillets: Fillets were taken from three carp collected at Buckeye Canal and from one carp and three largemouth bass from Painted Rock (Table 3). DDE, dieldrin, and toxaphene were the only organochlorine compounds detected in fillet samples. Individual DDE residues in Buckeye Canal carp fillets ranged from 1.30 to 4.50 µg/g wet weight. The single carp fillet sample from Painted Rock contained 0.33 µg/g DDE. DDE in Painted Rock bass fillets ranged from 0.85 to 2.87 µg/g. One of three carp samples from Buckeye Canal contained 0.01 µg/g wet weight dieldrin. Toxaphene was recovered in all Buckeye Canal carp fillets (0.31 to 0.81 µg/g wet weight) and in two bass fillets from Painted Rock (0.11 and 0.14 µg/g).

Metals in whole fish: Concentrations of 15 metals potentially toxic to fish are presented in Table 4. Aluminum was detected in 45 of 48 fish samples (94%) and levels ranged from <0.98 to 172 µg/g wet weight. Geometric mean levels, calculated on a dry weight basis, were lower in carp from Painted Rock than in carp from Estrella Park, Allenville, and Gillespie Dam (P = 0.0016, 1-way ANOVA, Table 5). Aluminum concentrations in carp from Painted Rock (Gmean = 17.0 µg/g dry weight) were significantly (P = 0.0028) higher than those in largemouth bass (7.9 µg/g) from the same area. Similarly, aluminum levels in carp from 59th Avenue (Gmean = 124 µg/g) were higher than those in bass (6.0 µg/g) from 59th Avenue. At Gillespie Dam, aluminum in carp (Gmean = 369 µg/g) was higher (P = 0.0001) than concentrations in catfish (8.6 µg/g). Fish collected in 1985 were not analyzed for aluminum; therefore, temporal patterns could not be assessed.

Arsenic was detected in 40 of 48 fish samples (83%) and concentrations ranged to 0.85 µg/g wet weight (Table 4). A comparison of geometric mean concentrations in carp from all collection sites indicated that among area concentrations were similar (P = 0.5525, Table 5). Arsenic in carp from 59th Avenue (Gmean = 0.41 µg/g dry weight) was significantly lower (P = 0.0105) than arsenic in largemouth bass (2.29 µg/g) from the same area. Carp/bass comparisons at Painted Rock were not possible because none of the carp from Painted Rock contained arsenic. Arsenic levels in carp

(Gmean = 0.39 µg/g dry weight) and catfish from Gillespie Dam (0.41 µg/g) were statistically similar (P = 0.9169). Arsenic concentrations in carp collected from all sites in 1994-95 (Gmean = 0.42 µg/g dry weight) were similar (P = 0.8913) to concentrations in carp (0.40 µg/g) collected in 1985 (Figure 3).

Boron was present in 46 of 48 (96%) of the fish samples (Table 4). Concentrations ranged from <0.39 to 2.84 µg/g wet weight. There were no statistical differences (P = 0.0804) in boron concentrations in carp among collection sites (Table 5). Boron concentrations in carp were similar (P = 0.0627) to those in bass at both 59th Avenue and Painted Rock. Boron concentrations in carp from Gillespie Dam (Gmean = 4.16 µg/g dry weight, Table 5) were similar to those in catfish (3.31 µg/g) from the same area. Boron was not quantified in fish samples collected in 1985; therefore, assessing trends over time was not possible.

Cadmium was present in one sample only; a carp from Gillespie Dam contained 0.07 µg/g wet weight cadmium. Cadmium was detected in 6 of 24 samples collected in 1985 (Appendix A-4). Lead was not detected in any 1994-95 samples but was recovered in 50% of the fish collected in 1985.

Chromium ranged from 0.22 to 0.92 µg/g wet weight and was present in all samples (Table 4). There were no statistical differences (P = 0.1535) in chromium concentrations among areas (Table 5). The geometric mean concentration in carp (2.25 µg/g dry weight) was significantly higher (P = 0.0001) than that in channel catfish (Gmean = 1.06 µg/g dry weight) at Gillespie Dam, but carp/bass levels at 59th Avenue and Painted Rock were statistically similar. Chromium was not quantified in samples collected in 1985.

Copper was recovered in all fish samples and concentrations ranged from 0.28 to 6.73 µg/g wet weight (Table 4). There were no differences (P = 0.2658) in copper levels among areas (Table 5). Geometric mean copper concentrations in carp (7.51 µg/g dry weight) and catfish (5.42 µg/g) from Gillespie Dam were similar, but concentrations in carp from 59th Avenue (7.21 µg/g) were significantly greater (P = 0.0017) than those in largemouth bass (1.65 µg/g) from the same area. At Painted Rock, Gmean concentrations in carp (4.43 µg/g) were similar (P = 0.3609) to those in bass (2.80 µg/g). Copper concentrations in carp remained at about the same level (P = 0.1828) from 1985 (Gmean = 5.76 µg/g dry weight) to 1994-95 (7.06 µg/g), although they appear more elevated in the upper river reaches compared to the previous study (Figure 4).

Mercury was detected in all samples and concentrations ranged from 0.03 to 0.41 µg/g wet weight (Table 4). Geometric mean mercury levels in carp were significantly different among areas (P = 0.0242), but similar between years (P= 0.9147, 2-way ANOVA, Table 5). Our relatively small sample size masked the Tukey's test for mean separation among areas. Sequential *t*-tests revealed area differences shown in Table 5. Mercury concentrations in carp from 59th Avenue (Gmean = 0.55 µg/g dry weight) were similar (P= 0.1256) to those in bass (0.28 µg/g). Mercury concentrations in carp (0.77 µg/g dry weight) and bass (1.03 µg/g) from Painted Rock were similar (P = 0.0507). Mercury concentrations in carp from Gillespie

Dam (0.26 µg/g) were similar (P = 0.5179) to those in catfish (0.23 µg/g) from the same area. Bass from Painted Rock had significantly (P = 0.0001) higher concentrations (1.03 µg/g) than those from 59th Avenue (0.28 µg/g). Mercury levels in carp collected in 1985 and 1994-95 are illustrated in Figure 5. Mercury concentrations in carp collected in 1994-95 (Gmean = 0.47 µg/g dry weight) were almost identical (P = 0.8751) to levels in carp (0.48 µg/g) collected in 1985.

Nickel was present in 22 of 48 samples (Table 4) and was recovered most frequently in fish from Estrella Park (100%) and Buckeye Canal (86%) and least frequently in fish from Painted Rock (8%). Geometric mean concentrations in carp were similar among areas (P = 0.5942), but were different between years (P = 0.0001). Levels present in carp collected in 1985 (3.54 µg/g dry weight) were 3-times higher than those in carp collected in 1994-95 (1.16 µg/g). Nickel was not present at sufficient frequencies to determine differences among species.

Selenium was recovered in 42 of 48 samples (Table 4). Individual concentrations ranged to 1.47 µg/g wet weight. Geometric mean selenium concentrations in carp differed among areas (P = 0.0043) but were similar between years (P = 0.1915). Although not statistically significant, geometric mean selenium levels were highest in carp from Allenville (3.92 µg/g dry weight) and lowest in carp from 59th Avenue (Table 5). Selenium levels in carp (Gmean = 0.97 µg/g dry weight) and bass (0.96 µg/g) from 59th Avenue were almost identical (P = 0.9912). At Painted Rock, selenium concentrations in carp (Gmean = 2.40 µg/g) were also statistically similar (P = 0.3025) to levels in bass (1.89 µg/g). Gillespie Dam carp (2.42 µg/g dry weight) contained significantly (P = 0.0053) higher levels of selenium than catfish (1.11 µg/g) from the same area. Comparative levels of selenium in carp collected in 1985 and 1994-95 are presented in Figure 6. Selenium concentrations in carp collected in 1994-95 (1.87 µg/g dry weight) were similar (P = 0.1915) to those in carp collected in 1985 (1.60 µg/g).

Strontium was detected in all samples and levels ranged from 18.0 to 96.5 µg/g wet weight (Table 4). Geometric mean concentrations were statistically lower in carp from 59th Avenue than in samples from all other sites except Estrella Park (Table 5). Concentrations in carp were significantly higher than those in bass at both 59th Avenue and Painted Rock. Strontium concentrations in carp (Gmean = 267 µg/g dry weight) were about 2.5-times higher (P = 0.0037) than those in catfish (Gmean = 105.2) at Gillespie Dam. Samples collected in 1985 were not analyzed for strontium.

Vanadium was detected in all carp and catfish samples but was present in only one of ten largemouth bass (Table 4). Levels ranged from <0.05 to 1.05 µg/g wet weight. A comparison of geometric mean concentrations in carp from all collection sites indicated that among area concentrations were similar (P = 0.4725, Table 5). Vanadium levels in carp from Gillespie Dam (Gmean = 1.40 µg/g dry weight) were almost 5-times higher than concentrations in catfish (0.30 µg/g) from the same area. Because vanadium was present in only one of 10 bass samples; carp/bass comparisons were not possible. Vanadium concentrations in carp collected in 1994-95 (Gmean = 1.02 µg/g dry weight) were significantly higher (P = 0.0135) than levels in carp (0.62 µg/g) collected in 1985 (Figure 7).

At Buckeye Canal however, mean vanadium concentrations were higher in carp collected in 1985 than in samples collected in 1994-95.

Zinc was present in all fish samples. Concentrations in individual fish ranged from 11.7 to 85.1 µg/g wet weight (Table 4). None of the catfish or largemouth bass contained zinc in excess of the NCBP 85th percentile level. No significant differences were detected in zinc concentrations in carp among areas (P = 0.3139, Table 5). Zinc concentrations in carp from 59th Avenue (200.7 µg/g dry weight) were more than three-times higher (P = 0.0001) than levels in largemouth bass (58.9 µg/g) collected from the same site. At Painted Rock, zinc concentrations were also higher (P = 0.0001) in carp (Gmean = 189 µg/g) than in bass (46.1 µg/g). For samples collected at Gillespie Dam, zinc concentrations were significantly (P = 0.0001) higher in carp (Gmean = 218 µg/g dry weight) than in catfish (57.7µg/g). Concentrations of zinc in carp collected in 1985 and 1994-95 are presented in Figure 8. The geometric mean zinc concentration in carp collected in 1994-95 (2.32 µg/g dry weight) was similar (P = 0.1619) to that collected almost a decade earlier in 1985 (2.37 µg/g).

Metals in fish fillets: Concentrations of 10 elements were detected in fish fillet samples (Table 6). The limited number of samples (three carp from Buckeye Canal and one carp and three largemouth bass and from Painted Rock) precluded meaningful statistical comparisons. Aluminum concentrations were highly variable and ranged from below detection levels in two samples to 122 µg/g wet weight. Arsenic in carp and bass fillets were 2.6- and 2.7-times higher than whole body concentrations. Boron in carp and bass was about 2-times higher in whole body samples than fillets. Chromium, copper, and selenium concentrations were similar (less than 2X difference) in both carp and bass whole body and fillet samples. The highest mercury concentration in fillet samples, 0.05 µg/g wet weight, was detected in a largemouth bass from Painted Rock, (Table 6).

Mercury in Buckeye Canal carp fillets (Gmean = 0.67 µg/g dry weight) was about 2.6-times higher than in carp whole body samples (0.26 µg/g) from the same area. Similarly, mercury concentrations in bass fillets from Painted Rock were about 2.2-times higher than in whole body samples. Strontium, which concentrates in bone, differed greatly between whole body and fillet samples; concentrations in carp whole body samples from Buckeye Canal (Gmean = 250 µg/g dry weight) were about 27-times higher than levels in fillets (9.4 µg/g). Differences in strontium concentrations were even greater (59-times) in bass whole body (Gmean = 135 µg/g dry weight) and fillet samples (2.3 µg/g). Zinc in Buckeye Canal whole body carp (Gmean = 237 µg/g dry weight) was 4.4-times higher than in carp fillet samples (53.7 µg/g) from the same area. Largemouth bass from Painted Rock contained a geometric mean whole body concentration of 46.1 µg/g dry weight zinc as compared to 21.1 µg/g in fillet samples.

TURTLES

Organochlorines in turtles: From one to six softshell turtles were collected per site (Table 7). Residues of five organochlorine compounds were recovered in whole body samples. DDE

residues were lowest in turtles from 59th Avenue (Gmean = 0.93 µg/g wet weight) and Painted Rock (1.89 µg/g, P = 0.0008, Table 8). The geometric mean DDE residue declined (P = 0.0118) from 1985 (4.28 µg/g wet weight) to 1994-95 (2.57 µg/g, Figure 9). DDE residues in turtles (Gmean = 2.57) were higher (P = 0.0207) than those in carp (Gmean = 1.27). Buckeye Canal was not included in the statistical analysis because only one turtle was collected from that site. PCBs were recovered in all turtle samples from upstream sites; but at the farthest downstream site, Painted Rock, PCBs were detected in only one of six samples. There was no difference in PCB residues among areas (P = 0.1807) or between years (P = 0.0825, Table 8). Chlordane and dieldrin were detected in all but one turtle sample. Geometric mean chlordane residues did not differ significantly among collection sites (P = 0.1894), but mean concentrations in turtles collected in 1985 (0.08 µg/g wet weight) were significantly higher (P = 0.0086) than chlordane residues in turtles collected in 1994-95 (0.04 µg/g). Dieldrin residues were lowest (P = 0.0012) in samples from Painted Rock (Gmean = 0.02 µg/g). Average dieldrin residues in turtles collected in 1994-95 (Gmean = 0.04 µg/g wet weight) were similar to those (0.03 µg/g) in turtles collected from the same areas in 1985 (P = 0.1741). DDT was present in 44% of the samples. Reportable residues were detected most frequently in turtles collected from the middle portions of the study area including Estrella Park downstream to Gillespie Dam. None of the turtles from the most upstream site (59th Avenue) or the farthest downstream site (Painted Rock) contained detectable DDT residues. The maximum DDT residue, 0.06 µg/g wet weight, was recorded in turtles from Allenville (n=2) and Gillespie Dam (n=1). Geometric mean DDT residues were similar among sites (P = 0.2794) and between the 1985 and 1994-95 collection period (P = 0.1355).

Metals in turtles: Aluminum was present in all whole body turtle samples and levels ranged from 16.4 to 150.4 µg/g dry weight (Table 9). Geometric mean concentrations (29.9 - 70.7 µg/g dry weight) did not differ among sites (P = 0.0986, 1-way ANOVA, Table 10). Aluminum was not quantified in turtles collected in 1985; therefore, trends over time cannot be assessed.

Arsenic was recovered in 21 of 27 (78%) turtle samples. Geometric means (0.25 to 0.43 µg/g dry weight) were statistically similar (P = 0.6799) among sites (Table 10). Arsenic concentrations in turtles collected in 1994-95 (Gmean = 0.29 µg/g dry weight) were almost identical to those collected in 1985 (Gmean = 0.30 µg/g).

Boron was detected in all turtles (Table 9). Mean levels were significantly higher (P = 0.0001) in samples from middle and downstream sites including Allenville and Gillespie Dam, than in turtles from 59th Avenue and Estrella Park (Table 10). Boron was not quantified in samples collected in 1985; therefore, trends were not assessed.

Cadmium was not detected in turtle samples and lead was present only in samples from 59th Avenue (n=2) and Estrella Park (n=4). Lead concentrations in individuals from those collection sites may have been biased by lead from .22 caliber bullets used for collection. None of the turtles trapped at Allenville, Buckeye Canal, Gillespie Dam, and Painted Rock contained lead.

Chromium was present in 21 of 27 turtle samples (Table 9). There was no difference in mean concentrations (Gmeans = 1.31 - 1.68 µg/g dry weight) among collection sites (Table 10). Chromium was not quantified in turtles collected in 1985.

Copper was recovered in all turtles and levels ranged from 1.25 to 1128.57 µg/g dry weight (Table 9). Some turtles captured on trot lines at 59th Avenue, Estrella Park, and Allenville were dispatched with a .22 caliber rifle. Because copper coated bullets may have biased chemical results, copper data for turtles from these areas were deleted from statistical analyses. Copper concentrations in turtles collected from Gillespie Dam (Gmean = 2.87 µg/g dry weight) were higher than levels in turtles from Painted Rock (Gmean = 1.69 µg/g, Table 10). Mean levels in turtles collected in 1994-95 at Gillespie Dam (Gmean = 2.87 µg/g dry weight) were significantly (P = 0.0444) lower than levels in turtles collected from the same area in 1985 (Gmean = 6.04 µg/g). Similarly, copper levels declined (P = 0.0009) from 1985 (Gmean = 4.40 µg/g) to 1994-95 (1.69 µg/g) in Painted Rock turtles.

Mercury was detected in all turtles (Table 9). Individual levels ranged from 0.02 to 1.42 µg/g dry weight. Geometric mean mercury concentrations differed among sites (P = 0.0001), but not between years (P = 0.0693). The lowest mean mercury concentration was recorded in turtles from 59th Avenue (Table 10). Levels in turtles from all other sites were statistically similar.

The frequency of recovery of nickel in turtles ranged from 20 to 100% (Table 9). Because of the low recovery rate at many sites, we were able to statistically compare nickel only in samples from Estrella Park and Painted Rock. Nickel concentrations were statistically different between areas and between years (P= 0.0001, 2-way ANOVA, Table 10). Concentrations were almost 10-times higher in turtle samples from Estrella Park (Gmean = 2.21 µg/g dry weight) than those in turtles from Painted Rock (0.23 µg/g). The geometric mean concentration in turtles collected in 1994-95 (0.72 µg/g dry weight) was significantly lower than that in turtles collected from the same areas in 1985 (7.16 µg/g).

Selenium was present in 19 of 27 (70%) of the turtle samples (Table 9). The frequency of recovery of selenium increased from upstream to downstream sites; one of five samples from 59th Avenue, two of five samples from Estrella Park, and four of five samples from Allenville contained detectable concentrations of selenium. All samples from the most downstream collection sites, Gillespie Dam and Painted Rock, contained selenium. Geometric mean concentrations were significantly different among areas (P = 0.0345), but not between years (P = 0.5757, Table 10). Mean concentrations of selenium in turtles from Gillespie Dam were higher than levels in turtles from Painted Rock but similar to levels at Allenville (Table 10). Mean concentrations in turtles collected in 1994-95 (Gmean = 1.53 µg/g dry weight) were similar (P = 0.5757) to those in turtles collected from the same areas in 1985 (Gmean = 1.34 µg/g).

Strontium was recovered in all turtle samples (Table 9). Geometric mean levels were significantly higher (P = 0.0018) in turtles collected from middle river collection sites

including Estrella Park, Allenville, and Gillespie Dam than at 59th Avenue or Painted Rock (Table 10). Strontium was not quantified in samples collected in 1985; therefore, between year comparisons were not possible.

Vanadium was present in all but five turtle samples and residues were generally low (0.89, Table 9). Geometric mean concentrations were statistically similar (P = 0.2728) among collection sites but were different (P = 0.0024) between years (Table 10). Vanadium concentrations in turtles collected in 1994-95 (Gmean = 0.23 µg/g dry weight) were less than one-half those (0.51 µg/g) in turtles collected in 1985.

Zinc was recovered in all turtles (Table 9). Geometric mean levels were similar among collection sites (Table 10) but differed between years (P = 0.0007, 2-way ANOVA). Zinc concentrations in turtles collected in 1994-95 (Gmean = 70.85 µg/g dry weight) were lower than those in turtles collected in 1985 (Gmean = 87.13 µg/g).

LIZARDS

Organochlorines in lizards: From three to five whiptail lizards were collected at Estrella Park, Allenville, Gillespie Dam, and Painted Rock. Only lizards from Estrella Park and Painted Rock were analyzed for organochlorines. DDE was the only compound detected (Table 11). Residues ranged from 0.12 µg/g wet weight in the composite sample from Estrella Park to 0.49 µg/g in the Painted Rock sample. Because only two samples were analyzed, we did not attempt statistical tests to determine differences between 1994-95 and 1985 means. However, lizards collected in 1985 from Estrella Park and Painted Rock contained an average of 0.59 and 0.06 µg/g wet weight DDE, respectively, in three composite samples (15 specimens) from each area (Kepner 1987).

Metals in lizards: Due to the highly variable concentrations of certain elements, particularly arsenic, the elemental content of "lead" shotshells was questioned. We were concerned that lizard samples were contaminated by elements other than lead in the shot. An analysis of a composite sample of shot from five shotshells indicated that the shot also contained arsenic (4,447 µg/g dry weight), boron (11 µg/g), cadmium (1.8 µg/g), and copper (65 µg/g). The high level of probability that lizards collected with shotshells were contaminated by arsenic, boron, cadmium, copper and lead from the shot, makes interpretation of residue data difficult. Data for these elements are presented in Table 12 for information purposes only. Because each site was represented by only one sample, no among site statistical comparisons were possible. Aluminum, boron, chromium, and strontium were quantified in 1994-95 samples only; therefore, we were unable to establish temporal trends for these elements. Despite the potential for contamination from cadmium in lead shotshells, none of the samples contained detectable levels of cadmium.

Mercury was recovered in only one of three lizard samples from both Allenville and Gillespie Dam in 1985; therefore, we deleted these areas from the 1985 data set for between-year

statistical comparisons. The geometric mean mercury concentration in 1994-95 samples (0.60 µg/g dry weight) was about three-times higher (P = 0.0031) than the mean for samples collected in 1985 (0.021 µg/g). Nickel concentrations in 1994-95 samples (Gmean = 1.01 µg/g dry weight) were similar (P = 0.1927) to samples collected in 1985 (Gmean = 1.59 µg/g). Selenium averaged 3.45 µg/g in 1994-95 samples and concentrations were more than two-times higher (P = 0.0022) than those collected a decade earlier (1.32 µg/g). Vanadium was present in all 1994-95 and 1985 samples. Geometric mean concentrations were similar (P = 0.4908) between 1994-95 (1.35 µg/g) and 1985 samples (1.63 µg/g). Zinc was recovered in all lizard samples. The geometric mean zinc level in lizards collected in 1994-95 (124.9 µg/g dry weight) was similar (P = 0.6340) to that (133.3 µg/g) collected 10 years earlier.

BIRDS

Organochlorines in birds: Five red-winged blackbirds were collected at each of four sites; 59th Avenue, Allenville, Estrella Park, and Gillespie Dam. One adult and five immature black-crowned night-herons were also collected at Painted Rock. Residues of five organochlorine compounds were detected in bird carcasses (Table 13). All bird carcasses contained DDE. DDE residues in heron carcasses (Gmean = 9.88 µg/g wet weight) were almost three-times greater (P = 0.0106) than those in red-winged blackbirds (3.45 µg/g). Because red-winged blackbird carcasses were composited into a single sample at each site, no among site statistical comparisons were possible. The geometric mean DDE residue in blackbird carcasses collected in 1985 (19.6 µg/g wet weight) was significantly (P = 0.002) higher than the mean in blackbird carcasses collected in 1994-95 (Gmean = 3.34 µg/g).

PCBs were present in all avian samples (0.08 to 0.67 µg/g wet weight) with the exception of one composite blackbird sample from Allenville (Table 13). The geometric mean PCB residue was significantly (P = 0.0025) higher in herons (0.41 µg/g wet weight) than in blackbirds (0.10 µg/g). PCBs were not detected in blackbirds collected in 1985, but PCBs were present in three of four composite samples collected in 1994-95. Chlordane, DDT, and toxaphene were not recovered in blackbird carcasses, but all black-crowned night-herons contained chlordane (Gmean = 0.06 µg/g) and DDT (Gmean = 0.06 µg/g). Dieldrin was present in three of four blackbird carcasses and in all heron samples (Gmean = 0.11 µg/g). DDT was recovered in all black-crowned night-herons (0.03 to 0.11 µg/g), but DDT was not detected in red-winged blackbird carcasses.

Metals in birds: Red-winged blackbird carcasses contained from 19.3 to 63.0 µg/g dry weight aluminum (Table 14). Aluminum, boron, chromium, and strontium were not quantified in blackbird samples collected in 1985; therefore, assessments of metal trends over-time were not possible. Arsenic was present in only one of three blackbird samples collected in 1994-95. Because fewer than one-half of the blackbird samples collected in 1994-95 contained arsenic, mean concentrations were not calculated and between year trends were not established. Copper was present in all red-winged blackbird samples. The geometric mean copper concentration of blackbirds collected in 1994-95 (9.15 µg/g) was similar (P = 0.7538) to that

collected in 1985 (9.50 µg/g). Mercury was present in all samples collected in 1994-95, but was detected in only 8 of 14 samples collected in 1985. Because mercury was detected in fewer than one-half of the 1985 samples, mean concentrations were not calculated and compared. Mean nickel concentrations declined 30-fold (P = 0.0087) from in 1985 (Gmean = 10.51 µg/g) to 1994-95 (0.35 µg/g). Vanadium was not present in 1994-95 samples, but was detected in 10 of 14 samples collected in 1985. Zinc was recovered in all samples and concentrations in 1994-95 (Gmean = 85.9 µg/g dry weight) were similar (P = 0.8119) to concentrations in blackbirds collected in 1985 (88.6 µg/g).

Geometric mean metal concentrations in red-winged blackbird livers were compared with those in black-crowned night-herons. Concentrations of boron, chromium, copper, vanadium, and zinc were similar (P> 0.05) between species. Arsenic, mercury, and selenium were 5.6-, 7.7-, and 1.6-times greater in heron livers than in blackbird livers. Strontium was 2.4-times higher in livers if blackbirds than in those of herons. Aluminum and nickel were not present in a sufficient number of liver samples to allow statistical comparisons.

Concentrations of three metals occurred at a liver to carcass ratio of greater than one to one; copper 2.6:1, mercury 8.3:1, and selenium 5.6:1. Boron occurred at a 1:1 liver to carcass ratio. Aluminum (0.67:1), chromium (0.52:1), strontium (0.03:1), and zinc (0.25:1) liver to carcass ratios were less than one. Concentrations of nickel and vanadium were detected in fewer than one-half of the samples; therefore, liver to carcass ratios were not determined.

Concentrations of 11 metals were detected in carcass and liver tissues of black-crowned night-herons (Table 15). The liver to carcass ratio for most metals was greater than one; arsenic 7.7:1, copper 5.9:1, mercury 4.8:1, and selenium 12.8:1. Boron (1.2:1) and zinc (1.25:1) ratios were close to 1:1. Chromium and strontium were the only elements with liver to carcass ratios of less than one, 0.62:1 and 0.009:1. Concentrations of aluminum and nickel were detected in fewer than one-half of the samples; therefore, liver to carcass ratios were not determined.

DISCUSSION

During normal flow periods, almost all water in the lower Salt and Gila Rivers in the Phoenix metropolitan area originates as discharge from waste water treatment plants (WWTPs). Perennial flow begins at the discharge point for the 23rd Avenue WWTP and additional effluent is received from the 91st Avenue WWTP. There are a total of 12 point source discharges in the lower Gila River basin within our study area identified by National Pollutant Discharge Elimination System (NPDES) permits (Earth Technology 1993). Agricultural drainwater return flow supplements the system. While agricultural drainwater is exempt from the NPDES permit process, it is not exempt from Arizona water quality standards. The lower Gila River is primarily an effluent dominated waterbody.

The presence of pollutants does not necessarily mean that environmental risk exists. Whenever possible, we attempt to equate levels of pollutants with potential hazards to fish and wildlife resources. Actual impacts of contamination are not well documented.

Chemical residue data indicate that fish and wildlife of the lower Gila River are accumulating a wide spectrum of potential toxicants including pesticides, industrial pollutants (PCBs), and metals. When assessing impacts of contaminants on fish and wildlife populations, we must consider the additive or synergistic toxicity of compounds and elements. For example, individuals or populations with appreciable but sublethal residues of DDT, DDE, chlordane, and possibly other chemical pollutants may be affected after additional exposure to these or similar compounds (Ludke 1976). The question arises as to which chemical or chemicals may adversely impact an individual or the population. The answer is not necessarily the chemical with the greatest residue, nor even one chemical alone; each may contribute relative to its toxicity. The potential for this type of interaction is greatest in areas such as the lower Gila River that are contaminated with a wide variety of agricultural and industrial compounds and metals.

FISH

Organochlorines in whole fish: The use of DDT in Arizona was restricted in 1968 and totally suspended in 1969 (Ware 1974). In fish tissue, DDT rapidly metabolizes to DDE; therefore, the occurrence of DDT in 1994-95 fish samples is of concern because it suggests that fish were recently exposed to that compound. DDT was detected most frequently in fish from Buckeye Canal (86%), Gillespie Dam (62%), and Allenville (50%).

The geometric mean DDE residue in all lower Gila River fish collected during 1994-95 was 4.6-times higher than the 1984 NCBP mean (Schmitt et al. 1990). The highest DDE residue recorded in this study, 21.0 µg/g wet weight, was more than three-times greater than the maximum (6.76 µg/g) recorded during the 1984 nationwide sampling program (Schmitt et al. 1990). USEPA (1992) conducted a similar national sampling of fish from 388 sites during 1986-1989 to determine the prevalence and sources of selected bioaccumulative pollutants. The USEPA screening program was not a random sampling; it focused on 314 sites thought to be influenced by various point and nonpoint pollutant sources. The investigation also included fish from 74 background locations to provide a chemical baseline from uncontaminated areas. The maximum DDE concentration reported in fish from highly contaminated sites was 14.0 µg/g wet weight. Four of seven samples from Buckeye Canal exceeded the USEPA (1992) reported maximum, although none of the fish from the lower Gila River approached that level. The mean DDE residue from 74 background sites was 0.056 µg/g (USEPA 1992); all fish samples from the lower Gila River exceeded the national background level.

All Service Environmental Contaminant Specialists in the nation were questioned via

e-mail to determine if other biologists have recently recorded DDE residues in fish that approached or exceeded levels detected in lower Gila River samples. Only fish from two superfund sites, both associated with the manufacture of DDT, had DDT/DDE residues greater than those in fish from the lower Gila River. Largemouth bass collected from the Tombigbee River downstream of the Ciba-Giegy Superfund Site, near McIntosh, Alabama where DDT was manufactured from 1952-1972 (USFWS 1996), exceeded concentrations recorded in lower Gila River samples. White croaker (*Genyonemus lineatus*) collected near the Palos Verdes outfall drain of the Montrose Chemical Company (Los Angeles, California), a former DDT manufacturing facility, contained an average of 23 µg/g wet weight DDT family compounds (DDTr) in muscle tissue (Los Angeles County Sanitation District 1997). No other records were located of fish populations with DDE residues higher than those in Gila River samples; therefore, we conclude that DDE residues in fish from the lower Gila River are the highest in the United States associated with agriculturally applied DDT.

Fish collected from agricultural drainage canals that are tributaries to the Gila River generally contained higher DDE residues than fish from the river. Mean DDE residues were highest in carp and catfish from Buckeye Canal which confirms findings of Kepner (1987) who also reported highest DDE residues in carp from Buckeye Canal. A composite sample of five carp collected in 1994 from another agricultural drain, Dysart Drain, contained 24 µg/g wet weight DDE, (Rector 1997). This level was almost two-times the maximum in fish collected during the 1986-89 USEPA nationwide sampling program (USEPA 1992). A composite sample of 50 mosquitofish (*Gambusia affinis*) collected from Dysart Drain in April 1994 contained 17.0 µg/g DDE (King unpub. data). Mosquitofish are a relatively short-lived species, 2 years under natural conditions, and it is remarkable that they bioaccumulate such high levels of DDE during their short life span.

Toxaphene use as a broad spectrum agricultural insecticide increased significantly following the national suspension of DDT (Kepner 1986). Toxaphene applications averaged 7.6 pounds per acre in Arizona in 1965 (Johnson and Lew 1970). Most domestic use of toxaphene and DDT was on cotton crops. Before the suspension of both products, toxaphene-DDT mixtures were frequently used to control insects pests. Toxaphene contamination in fish and wildlife was a major concern during the 1980s. Kepner (1986) reported residues as high as 8.4 µg/g wet weight in whole body carp and an overall frequency of occurrence of 61%. In 1994-95, toxaphene was not detected in carp suggesting a significant decline in environmental residues. However, toxaphene was present at low levels in all largemouth bass (0.34 µg/g wet weight) which may reflect a different bioaccumulation rate among species. Toxaphene was detected in 20 percent of the catfish. Catfish collected from Buckeye Canal contained relatively high toxaphene residues (2.6 and 5.4 µg/g wet weight). The lower level of detection for toxaphene ranged from 0.05 to 0.80 µg/g wet weight; therefore, all detectable residues were in excess of the 0.03 µg/g NCBP 85th percentile (Schmitt et al. 1990).

PCBs were generally highest at upstream collection sites, those closest to the Phoenix urban/industrial area. However, PCBs in all fish were below the NCBP 85th percentile (Schmitt et al. 1990). The frequency of occurrence of chlordane was greatest in fish from

Buckeye Canal (80%). Chlordane was present in less than one-half of the samples from other areas. None of the fish contained chlordane in excess of the NCBP 85th percentile level of 0.17 µg/g wet weight (Schmitt et al. 1990), although residues in one catfish from Buckeye Canal (0.14 µg/g) approached that level. Chlordane was present in 56% of the 1994-95 fish samples versus 12.5% in 1985 samples suggesting an increase in frequency of occurrence over the past decade. Conversely, dieldrin showed a downward trend during the same time period. Dieldrin was present in 83% of the 1985 fish samples but was detected in only 31% of the 1994-95 samples. Dieldrin was detected most frequently in fish from 59th Avenue, the collection site closest to Phoenix, indicating that urban use of this compound may have persisted longer than agricultural use. Four of five largemouth bass from 59th Avenue contained dieldrin in excess of the NCBP 85th percentile level (Schmitt et al. 1990). Carp, however, did not bioaccumulate dieldrin. Dieldrin was detected at low levels (0.27 µg/g wet weight) in only 7 of 27 samples. Current levels of PCBs, chlordane, and dieldrin are low and do not present a hazard to fish in the lower Gila River.

Metals in whole fish: Although aluminum is not an USEPA priority pollutant, the especially high levels recorded in fish from Allenville (Gmean = 434 µg/g dry weight) and Gillespie Dam (Gmean = 369 µg/g) warrant special attention. The geometric mean aluminum concentration in carp from Allenville was 25-times greater than the mean at Painted Rock, the area with the lowest aluminum concentrations. By comparison, aluminum in carp from several other southern Arizona lakes and rivers including Lake Pleasant, Alamo Lake, San Carlos Reservoir, and the Verde River ranged from 2.6 to 60.6 µg/g wet weight (King et al. 1991). Comparing the Allenville carp data with data from these and other Arizona studies (Radtke et al. 1988, King et al. 1993a, Baker and King 1994, Andrews et al. 1997, Tadayon et al. 1997) indicates that carp collected at Allenville had the second highest mean aluminum level ever recorded in Arizona. Only the concentration in carp (n=3) from one highly contaminated agricultural drain near San Luis in the Yuma Valley (mean = 895 µg/g wet weight, Tadayon et al. 1997) was higher than that in carp from Allenville (434 µg/g).

Arsenic acts as a cumulative poison (Jenkins 1981) and is listed by the USEPA as 1 of 129 priority pollutants (Keith and Telliard 1979). Background arsenic concentrations in biota are usually less than 1 µg/g wet weight (Eisler 1988a). Toxic effects of arsenicals on aquatic organisms have been reported at concentrations of 1.3 to 5.0 µg/g wet weight. Although 19% of the fish samples exceeded the NCBP 85th percentile (Schmitt and Brumbaugh 1990), none contained concentrations that approached the toxic threshold. There appears to be little potential for arsenic related problems in fish at the lower Gila River sites we sampled.

Cadmium was detected in only 1 of 48 fish samples; a lower frequency of occurrence than that reported by most other authors for fish collected from southern Arizona. Seventy-seven percent of the fish samples from three National Wildlife Refuges (NWR) on the Colorado River contained cadmium (King et al. 1993a). Cadmium was detected in 30 to 54% of fish collected from the upper and middle Gila River including Mineral Creek (Baker and King 1994, King and Baker 1995, Andrews and King 1997). Only one of three composite samples of carp, catfish, and bass collected in 1993 from Havasu NWR contained low (0.02 µg/g wet

weight) concentrations of cadmium (Andrews et al. 1997); cadmium was detected in 6% of the fish collected in 1995 from the lower Colorado River and irrigation drains in the Yuma Valley (Tadayon et al. 1997). We located only one study which documented a lower frequency of occurrence than what we encountered during our 1994-95 sampling effort; none of the carp collected in 1985 at 11 sites in the Yuma Valley area contained cadmium (Radtke et al. 1988). Cadmium is not a contaminant of concern for fish populations in the lower Gila River.

Chromium was not quantified in the NCBP program (Schmitt and Brumbaugh 1990); therefore, comparisons with national levels are not possible. The organs and tissues of fish and wildlife that contain >4.0 µg/g total chromium dry weight should be viewed as presumptive evidence of chromium contamination (Eisler 1986). None of the fish samples from the lower Gila River contained chromium in excess of 4.0 µg/g.

Copper is an essential dietary element for plants and animals, but elevated levels can be toxic to fish (USEPA 1980). Copper is one of the most common contaminants associated with urban runoff. Specific sources include industrial and sewage treatment plant discharges (USEPA 1980). Copper can combine with other contaminants such as ammonia (common in wastewater effluent), mercury, and zinc to produce additive toxic effects on fish (Skidmore 1964, Hilmy et al. 1987, Eisler 1997). Copper exceeded the NCBP 85th percentile (Schmitt and Brumbaugh 1990) in 31 of 48 fish samples and all samples from Estrella Park and Allenville exceeded the NCBP 85 percentile. Because of its occurrence at relatively high levels at some sites and its propensity to interact with other compounds and elements, copper remains a contaminant of concern in the lower Gila River.

The frequency of occurrence of lead in lower Gila River fish declined over the last decade. Lead was not detected in fish collected during 1994-95 (this study), but was present in 37% of the fish collected in 1985. Ten percent of the composite carp samples collected in 1985 from the lower Colorado and Gila Rivers by Radtke et al. (1988) contained lead, but concentrations were low (0.33 µg/g wet weight). Lead was not detected in any of the 31 fish collected in 1995 from the Colorado River and irrigation drains in the Yuma Valley (Tadayon et al. 1997). Lead is not a contaminant of concern for fish in the study area.

Mercury concentrations are of special concern because mercury can bioconcentrate in organisms and biomagnify through the aquatic food chain. Mercury has no known biological function and its presence in cells of living organisms is undesirable and potentially hazardous. Mercury in the environment exists in a wide range of inorganic and organic forms with varying degrees of stability and toxicity (Thompson 1996). It is generally accepted that methylmercury is the most stable form and the form most toxic to wildlife. From 95-99% of the mercury in fish is methylmercury (Wiener and Spray 1996). Even though thirty-one percent (15/48) of the fish samples exceeded the NCBP 85th percentile of 0.17 µg/g wet weight, the highest concentration of methylmercury (mercury) detected in lower Gila River fish, 0.41 µg/g wet weight, was well within the 1.0 µg/g range generally accepted as the concentration in biota from unpolluted environments (Eisler 1987). There is probably little

potential for adverse affects of mercury alone on adult fish survival or reproduction. Mercury, however, when ingested in combination with other compounds and elements such as parathion, cadmium, and copper can have additive or synergistic toxic effects (Hoffman et al. 1990, Calabrese and Baldwin 1993, Eisler 1997).

Food chain accumulation of mercury from fish to fish-eating predators is also of concern. There is a great deal of conflicting literature regarding the threshold dietary food chain level above which mercury may adversely affect higher predators. Eisler (1987) states, "For the protection of sensitive species of mammals and birds that regularly consume fish and other aquatic organisms, total mercury concentrations in these prey items should probably not exceed 0.1 µg/g fresh weight for birds, and 1.1 µg/g for small mammals." Walsh et al. (1977) suggested, "To protect fish and predatory organisms, total mercury burdens in these organisms should not exceed 0.5 µg/g wet weight." Three µg/g mercury dry weight (0.9 µg/g wet weight) in earthworms should be considered hazardous to sensitive species that eat earthworms (Beyer and Stafford 1993). One-half of our fish samples exceeded the most conservative threshold, 0.1 µg/g, proposed by Eisler (1987), but none exceeded food chain toxicity thresholds suggested by Walsh et al. (1977) and Beyer and Stafford (1993). Bioaccumulation of mercury from fish to fish-eating birds is discussed in greater detail under the section on birds.

Nickel is listed by the USEPA as one of 129 priority pollutants (Keith and Telliard 1979). Freshwater fish from uncontaminated habitats usually contain <0.80 to 8.0 µg/g wet weight nickel (Jenkins 1980). Only two samples contained nickel in excess of 0.8 µg/g, a carp (1.76 µg/g) and catfish (1.19 µg/g) from Buckeye Canal. Nickel, by itself, is not a potentially threatening contaminant at current levels. Nickel, however, can combine with zinc to have additive toxic effects on fish (Eisler 1997)

Selenium is an essential trace element in animal diets, but it is toxic at concentrations only slightly above required dietary levels. Only 6 of 48 samples (12.5%) exceeded the NCBP 85th percentile (Schmitt and Brumbaugh 1990) level and selenium was generally below toxic concentrations likely to affect fish reproduction. The highest wet weight whole body selenium concentration recorded in this study was 1.74 µg/g, well below the 6.9 - 7.2 µg/g wet weight threshold associated with selenium induced reproductive failure of bluegills at selenium contaminated Hyco Reservoir in North Carolina (Gillespie and Baumann 1986). In a comprehensive summary of selenium threshold effect levels, Lemly and Smith (1987) reported that selenium induced reproductive failure in fish was associated with whole body selenium concentrations of 12 µg/g dry weight. The highest concentration of selenium in fish in our study was 6.45 µg/g dry weight; therefore, there is little potential for selenium toxicity to fish populations in the lower Gila River.

Zinc was present in 93% (25/27) of the carp samples at concentrations that exceeded the NCBP 85th percentile level of 34.2 µg/g wet weight (Schmitt and Brumbaugh 1990). Bioaccumulation rates for zinc were species specific; while 93% of the carp exceeded the NCBP 85th percentile, none of the catfish or bass contained elevated levels of zinc. This finding is consistent with conclusions of other authors who reported that common carp

apparently accumulate zinc to a greater extent than other species (Lowe et al. 1985, Schmitt and Brumbaugh 1990). Zinc levels in carp from the lower Gila River were within the range of concentrations in carp collected from other areas of Arizona (Radtke et al. 1988, King et al. 1991, Lusk 1993, Andrews et al. 1997, Tadayon et al. 1997). Zinc, however, may interact with other elements and compounds and the patterns of accumulation, metabolism, and toxicity from zinc interactions greatly differ from those produced by zinc alone. Zinc in combination with other elements can have antagonistic, additive, or synergistic effects as reviewed by Eisler (1993, 1997). Zinc is more toxic to embryos and juveniles of aquatic organisms than to adults, and zinc is more toxic in the presence of nickel, cadmium, chromium, copper, and mercury (Eisler 1997). The toxicity of zinc is also modified by ambient environmental factors. Zinc is more toxic under conditions of comparatively low dissolved oxygen (Spear 1981), a condition that occurs frequently at Painted Rock. Also, zinc is more toxic at elevated temperatures (NAS 1979, Spear 1981, Hilmy et al. 1987), a condition common in the desert southwest.

TURTLES

Organochlorines in turtles: DDT was detected in 44% of the softshell turtle samples. With few exceptions, residues of organochlorine compounds were considerably higher in turtles than those in fish collected from the same location. ADEQ (1996) reported similar results for turtles and fish collected at Painted Rock. Turtles generally have a longer lifespan than fish and therefore accumulate contaminants over a longer period of time. Significant among area differences were detected only for DDE and dieldrin. DDE was highest in the middle river sampling sites and mean dieldrin residues were lowest at the farthest downstream site, Painted Rock. DDE and chlordane residues, declined by about one-half from 1985 to 1994-95. Residues of PCB, dieldrin, and DDT remained relatively constant during the decade.

Metals in turtles: A comparison of spacial trends in turtles with those in fish revealed few site specific similarities other than the generalization that higher levels of metals were usually found at the middle river sampling stations. Although not statistically significant, geometric mean levels of boron, vanadium, and zinc were higher in turtles and fish collected at Allenville than at other sampling stations. Temporal trends were established for seven metals. Geometric mean concentrations of copper, nickel, vanadium, and zinc declined from 1985 to 1994-95. Levels of arsenic, mercury, and selenium remained unchanged over the study period.

LIZARDS

Organochlorines in lizards: Lizards may be excellent indicators of terrestrial contamination as much of their diet consists of small invertebrates of local origin. Lizards are intermediate predators often consumed by numerous upper trophic level species. Because only two composite lizard samples were analyzed for organochlorine compounds, interpreting residue data is difficult. DDE residues reported in this study (0.12 and 0.49 µg/g wet weight) are

similar to the mean (0.443 µg/g) reported for Texas spotted whiptail lizards (*C. gularis*) collected from agricultural areas in Texas, but lower than residues (mean = 1.00 µg/g, range = not detected to 9.6) in six-lined racerunner (*C. sexlineatus*) carcasses from Florida (Clark et al. 1995). Whiptail lizards collected from Estrella Park and Painted Rock generally contained higher organochlorine residues than lizards collected from other Arizona locations including southeastern Arizona and the upper and middle Gila Rivers (King et al. 1993b, Baker and King 1994, King and Baker 1995).

Metals in lizards: We compared priority pollutant concentrations in lizards collected in 1994-95 with concentrations in lizards collected in other areas of Arizona. Comparisons did not include arsenic, cadmium, copper, and lead because of possible contamination from lead shot. Chromium, selenium, and zinc concentrations in lower Gila River lizards were similar to, or lower than, concentrations in lizards from southeastern Arizona and from the upper and middle Gila Rivers (King et al. 1993b, Baker and King 1994, King and Baker 1995). Nickel in lizards from the lower Gila River was generally higher than in lizards from southeastern Arizona but comparable to levels in lizards from the upper and middle Gila River areas. Mercury concentrations were about 10-times higher in lizards collected from sites along the lower Gila River (mean = 0.60 µg/g dry weight, range = 0.27 - 1.36) than in lizards from southeastern Arizona (mean = 0.065 µg/g, range = 0.04 - 0.11) (King et al. 1993b) and were about 3-times higher than in lizards from the upper Gila (mean = 0.17 µg/g, range 0.10 - 0.26) (Baker and King 1994) and middle Gila River areas (mean = 0.18 µg/g, range = 0.04 - 0.70) (King and Baker 1995). Mean mercury concentrations in lizards increased from 1985 (0.021 µg/g dry weight) to 1994-95 (0.60 µg/g). We are at a loss to explain this 30-fold increase in mercury concentrations in lizards. None of the other segments of the lower Gila River ecosystem experienced such a dramatic 10-year increase in mercury levels. Selenium concentrations decreased over the same time period. Temporal trends for other metals remained unchanged or could not be assessed.

We found no biological effect threshold data in the literature to aid in interpretation of contaminant hazard to lizard survival and reproduction. Lizards are consumed by a wide variety of bird and mammal predators. Concentrations of DDE exceeded threshold levels above which DDE impacts on sensitive avian species are possible (please see the discussion of DDE concern levels in avian predators in the following section on birds). DDE residues in lizards could pose problems for avian predators that consume a large proportion of lizards in their diet.

Little research has been completed on mercury concentrations in food items of predatory birds likely to consume lizards. In contrast, there is a great deal of information available on levels and effects of mercury in aquatic ecosystems. For the protection of sensitive species of birds that regularly consume fish and other aquatic organisms, total mercury concentrations in prey items should probably not exceed 0.1 µg/g wet weight (approximately 0.33 µg/g dry weight) (Eisler 1987). In an extensive review of the chronic toxicity of mercury in birds, Scheuhammer (1987) reported that the lowest level of mercury in food items to adversely affect birds was 0.3 - 0.4 µg/g wet weight (approximately 1 - 1.3 µg/g dry weight). All lizard

samples exceeded Eisler's more conservative estimate and three of four exceeded Scheuhammer's (1987) proposed toxicity threshold.

Limited data are available on the toxicity of selenium to terrestrial birds. Ironically, several field and laboratory studies indicated that even background selenium levels in food items, concentrations as low as 3 to 8 µg/g dry weight, could cause adverse reproductive effects in sensitive aquatic bird species (Heinz et al. 1987, Lemly and Smith 1987, Hoffman et al. 1991, Skorupa and Ohlendorf 1991). Selenium concentrations in lizards (as potential prey) are within the lower end of the toxic range.

BIRDS

Assessing exposure of birds to environmental contaminants is difficult because birds are highly mobile, often migratory, and may accumulate contaminants over broad geographic areas. All red-winged blackbirds sampled were adults, and we cannot be certain that their contaminant burdens reflect local conditions. However, concentrations of contaminants in liver tissues usually reflect recent exposure. We were also unable to determine if the subadult black-crowned night-herons were hatched locally or were birds that wintered in the area. A heronry located on islands in Painted Rock Borrow Pit Lake in the early 1990s did not contain night-herons. Although an intensive effort was made to locate a night-heron colony near Painted Rock, none was found during the years of study through 1997 (Urquidez pers. comm.). Night-herons were common throughout the winter months in the Painted Rock area; at least 50% of the birds were sub-adults. Wild black-crowned night-herons initiate nesting on islands in urban Phoenix lakes in early April. We assume that if night-herons were nesting in the Painted Rock area, that the nesting period would be chronologically similar to that in nearby Phoenix colonies. If nesting was initiated in early April, it would have been impossible to collect fledged young-of-the-year herons hatched in local colonies in late April. Most probably, we collected sub-adult herons that were at least 10-months-of-age or older hatched from an unknown location.

Organochlorines in birds: Residues of all organochlorine compounds were higher in black-crowned night-herons than red-winged blackbirds which substantiates the finding that food habits and relative position on the food chain determines the risk for dietary contaminant exposure. In general, top level carnivores such as black-crowned night-herons accumulate higher residues of organochlorines than omnivores, e.g. red-winged blackbirds, which accumulate more than herbivores.

Organochlorine residues, particularly DDE, in birds collected from the southwestern United States have historically been higher than those from the rest of the nation (Cain 1981, Fleming and Cain 1985), Fleming et al. 1983, White and Krynitsky 1986, Bunck et al. 1987). European starlings (*Sturna vulgaris*) collected near the lower Gila River during a 1982 nationwide survey of 129 sites contained the highest (8.4 µg/g wet weight) DDE concentrations in the United States (Bunck et al. 1987). Residues in Gila River starlings far

exceeded the national geometric mean of 0.15 µg/g. DDE reported here for red-winged blackbird carcasses (1.9 - 7.4 µg/g wet weight) exceeded the upper 95% confidence interval (0.23 µg/g wet weight) reported by Bunck et al. (1987). Average DDE residues in blackbirds collected from the lower Gila River were higher than those in blackbirds (1.68 µg/g wet weight) and grackles (0.46 - 3.06 µg/g) collected in other areas of the desert southwest (Fleming et al. 1983, Fleming and Cain 1985) and northwestern Mexico (Mora and Anderson 1991).

Two of four red-winged blackbird samples contained >3.4 µg/g DDE wet weight; the level associated with poor reproductive performance in other species of birds, particularly the American black duck (*Anas rubripes*) (Longcore and Stendell 1977). Also, one-half of the blackbird carcasses contained more than 3.0 µg/g DDE, a level that represents a hazard to predatory birds that feed on blackbirds (Wiemeyer and Porter 1970, McLane and Hall 1972, Mendenhall et al. 1983). Red-winged blackbirds have been recorded in the diet of the endangered peregrine falcon (Enderson et al. 1982, DeWeese et al. 1986) and the Gila River study area is within the range of the peregrine falcon.

Blackbirds collected in 1994-95 did not contain residues of toxaphene. This finding is in sharp contrast to the occurrence of toxaphene in all 14 samples from five sites in 1985. There has been an obvious downward trend in the presence of toxaphene in avian samples over the past ten years.

A literature search failed to locate other southwestern United States investigations of contaminant levels in black-crowned night-heron carcass and liver tissues with which to compare our data. Night-heron carcasses from Painted Rock contained considerably higher DDE residues (5.2 - 15 µg/g wet weight) than carcasses (2.70 µg/g) of nestling double-crested cormorants (*Phalacrocorax auritis*) collected in 1994 from island colonies at Painted Rock (Rector 1997). Pre-fledging cormorants were sampled; therefore, they had been feeding on DDE-contaminated fish for less than six weeks. DDE concentrations in Painted Rock night-herons also were higher than those in carcasses of cormorants (2.1 - 6.6 µg/g) collected at three sites along the Colorado River (Radtke et al. 1988) and in the Yaqui (0.28 - 2.39 µg/g wet weight) and Culiacan (1.89 - 13.46 µg/g) valleys in western Mexico (Mora and Anderson 1991). A single cormorant collected in the Mexicali Valley near the United States - Mexico boundary; however, contained
11.46 µg/g DDE, a level similar to those recorded in night-herons from Painted Rock. All night-heron carcasses contained residues of DDE exceeding the 3.4 µg/g level associated with poor reproductive performance in black ducks (Longcore and Stendell 1977).

Many fish-eating and raptorial bird species are susceptible to DDE-induced eggshell-thinning and reproductive failure (Hickey and Anderson 1968, Ohlendorf et al. 1979, Blus 1996). In laboratory studies, as little as 3.0 µg/g wet weight DDE in the diet has resulted in a significant degree of eggshell thinning in a variety of birds (Wiemeyer and Porter 1970, McLane and Hall 1972, Mendenhall et al. 1983). Under field conditions, however, much lower levels of DDE in the diet have been associated with eggshell thinning and population

declines of fish-eating birds including 0.15 µg/g wet weight in brown pelicans (*Pelecanus occidentalis*) (Blus 1996, Blus et al. 1977, 1979), 0.39 µg/g in bald eagles (Wiemeyer et al. 1978), and 0.2 - 1.9 µg/g in osprey (*Pandion haliaetus*) (Wiemeyer et al. 1975). It was not the purpose of this study to assess the food-chain accumulation of contaminants in fish-eating birds, but certainly DDE residues up to 21 µg/g wet weight in carp from Buckeye Canal and 17.0 µg/g DDE in mosquitofish from Dysart Drain are good indications that harmful food-chain accumulation is possible. DDE residues in fish from all lower Gila River collection sites exceeded the level associated with eggshell thinning in sensitive avian species. Brown pelicans, bald eagles, and osprey are DDE sensitive species and all have been observed feeding in the lower Gila River watershed.

Metals in birds: The elements most likely to be toxic to birds include cadmium, lead, mercury, and selenium (Eisler 1985a, 1987, Eisler 1988b, Scheuhammer 1987, Ohlendorf et al. 1988). Because aluminum was detected at relatively high levels in lower Gila River fish, we will briefly discuss the potential for food chain accumulation of aluminum from fish to fish-eating birds. No data are available on potentially toxic levels of aluminum in the diet of fish-eating birds and information is limited for other trophic level species. Juvenile ringed turtle-doves (*Streptopelia risoria*) fed up to 1,500 µg/g dry weight aluminum for 63 days demonstrated no growth impairments (Scheuhammer 1987). Flycatchers (*Ficedula hypoleuca*) feeding on insects that contained 1,230 µg/g dry weight aluminum experienced severe eggshell defects, reduced clutch size, and a high incidence of mortality (Nyholm 1982, Nyholm and Myhrberg 1977). The highest aluminum concentration detected in a potential food fish, 614 µg/g dry weight, was below the lowest observed effect concentration reported in ringed turtle-doves and also less than the level determined to be toxic to flycatchers. Additional research is needed to determine the relative sensitivity of fish-eating birds to aluminum.

The concentration of cadmium in liver tissues of birds considered to represent normal background levels is <3 µg/g dry weight (Ohlendorf 1993). Cadmium was recovered in all three blackbird samples, but levels were low, 1.22 µg/g dry weight. Cadmium was not present in night-heron tissues and is not considered a contaminant of concern for birds nesting and wintering in the lower Gila River ecosystem.

Normal background levels of lead in livers of adult birds living in relatively uncontaminated environments are 0.5 to 5.0 µg/g dry weight (Scheuhammer 1987, Ohlendorf 1993). The liver is the tissue of choice for assessing recent exposure to lead; whereas, bone is preferred for assessing long-term exposure. Lead was not detected in red-winged blackbird and black-crowned night-heron livers indicating minimal recent exposure. There is little evidence to indicate that lead is a contaminant of concern for birds on the lower Gila River.

Background concentrations of mercury in bird livers are <1 - 10 µg/g dry weight, but concentrations greater than 6 µg/g dry weight may be toxic to some species (Ohlendorf 1993). The maximum concentration of mercury in blackbird livers was 2.89 µg/g, well within the background range. Mercury concentrations in five of six night-heron livers approached or exceeded the toxic threshold of 6 µg/g dry weight. The liver of the single adult night-heron

(28.07 µg/g dry weight) was 4.5-times higher than the toxic threshold established by Ohlendorf (1993). Mercury may present a serious threat to the health and reproductive success of fish-eating birds nesting along the lower Gila River.

Selenium-induced reproductive failure of aquatic birds has been documented throughout the western United States (Ohlendorf et al. 1988, Ohlendorf 1989, Skorupa et al. 1990). Normal food chain selenium levels in the aquatic environment are 2.0 µg/g dry weight (Ohlendorf et al. 1990). The generally accepted toxic threshold in fish and other aquatic food items consumed by birds is 3 to 4 µg/g dry weight (Lemly and Smith 1987, Lemly 1993). Ten percent of the lower Gila River fish contained selenium in excess of 3 µg/g dry weight. Bioconcentration of selenium from fish to fish-eating birds is discussed in greater detail in the following section on birds.

Selenium usually averages 3 - 10 µg/g dry weight in livers of birds from selenium normal environments (Eisler 1985b, Ohlendorf 1989, Skorupa et al. 1990, Ohlendorf 1993). Concentrations of selenium greater than 10 µg/g wet weight (approximately 33 µg/g dry weight) in the liver can be considered harmful to the health of young and adult birds; concentrations above 3 µg/g wet weight (approximately 10 µg/g dry weight) in the livers of laying females has been associated with reproductive impairment (Heinz 1996). Selenium in livers of red-winged blackbirds was well within the normal or background range. Selenium concentrations in the livers of black-crowned night-herons (13 - 18 µg/g dry weight) indicate that adult and fledged young are not at risk of acute selenium toxicity, but selenium impacts on reproduction are possible. These data support findings of Martinez (1994) who reported that 81% of the fish-eating birds nesting in backwater lakes farther downstream in the Gila-Colorado River drainage system had selenium concentrations in liver tissues above the effect threshold for reproductive impairment or embryotoxicity. Additional field study is needed to assess the effects of selenium on fish-eating birds nesting at Painted Rock and elsewhere in the lower Gila River system.

HUMAN HEALTH CONCERNS

Our study was designed to address impacts of contaminants on fish and wildlife rather than on human health; therefore, we analyzed few fish fillet samples. Consumption guidelines developed for the protection of human health focus on edible portions of fish and wildlife. ADHS's (1991) human health risk assessment, based on USEPA guidelines (USEPA 1989) concluded, "elevated and potentially health-threatening levels of organochlorine pesticide and methylmercury were found in the edible portion of various species of (Painted Rock) lake fish." Painted Rock bass fillet samples collected in 1994-95 contained a mean of 0.32 µg/g wet weight DDE, a level similar to the mean (0.27 µg/g) for DDTr reported by ADHS (1991) for bass samples collected from Painted Rock in 1986, 1987, and 1989. Our limited 1994-95 data reveal that DDE in bass fillets from Painted Rock and carp fillets from Buckeye Canal (2.57 µg/g) still exceed the 0.3 µg/g wet weight screening value currently proposed by USEPA (1995) and adopted by ADHS and ADEQ. Screening values were developed to identify concentrations of chemical contaminants in edible portions of commonly consumed

fish that indicate a potential for significant health risks to human consumers. Toxaphene residues in all carp fillet samples from Buckeye Canal (0.31 - 0.81 µg/g wet weight) exceeded the USEPA screening value of 0.1 µg/g. Toxaphene in two of four fish samples from Painted Rock (0.11, 0.14 µg/g wet weight) also exceeds the screening value. Mercury concentrations in Painted Rock bass fillets (mean = 0.47 µg/g, 0.44 - 0.50) were 1.5-times higher than the mean (0.31 µg/g) reported by ADHS (1991) for bass collected from the same area in the late-1980s. However, mercury concentrations were below the USEPA screening value of 0.6 µg/g wet weight. Based on current USEPA guidelines, consumption of fish from Painted Rock and Buckeye Canal continues to pose a hazard to human health at, least with respect to DDE and toxaphene.

Elevated contaminant levels in whole body turtle samples do not necessarily relate to edible (fillet) tissues and concentrations therefore, should be interpreted with caution. DDE in all whole body turtle samples exceeded the USEPA's screening value of 0.3 µg/g wet weight. The maximum mercury residue in whole body turtles was 0.75 µg/g. Since mercury tends to concentrate in muscle tissue, additional work is needed to assess the risk to human health from eating softshell turtles from the lower Gila River.

CONCLUSIONS

- Residues of DDT, an insecticide that has been suspended from use in Arizona for more than 25 years, are still present in fish and wildlife. DDT was detected in 86, 62, and 50% of the fish collected from Buckeye Canal, Gillespie Dam, and Allenville, respectively. DDT was present in all turtles from Gillespie Dam, and in all black-crowned night-herons from Painted Rock.

- DDE residues in fish are the highest in the United States associated with agriculturally applied DDT. Although DDE residues have declined over the past decade; current levels remain extremely high when compared to national averages. DDE is present at concentrations known to impact biotic resources.

- DDE residues were greatest in fish from agricultural drains that are tributaries to the lower Gila River. Agricultural drains, particularly Buckeye Canal and Dysart Drain, may be point sources for DDE input into the river.

- The number of pesticide compounds detected in biota have declined dramatically over the past decade. Only 6 of 22 organochlorines were present in samples collected in 1994-95 versus 16 compounds in samples from 1985.

- The frequency of occurrence of chlordane in carp and turtles increased from 1985 to 1994-95. In 1985, chlordane was present in 11 and 83% of the carp and turtle samples. By 1994-94, the frequency of occurrence increased to 37 and 96%, respectively.

- The presence of toxaphene in fish and wildlife tissues declined dramatically from 1985 to 1994-95. Toxaphene was recovered in 61 and 94% of the carp and turtles collected in 1985, but toxaphene was not detected in 1994-95 carp and turtle samples. Toxaphene, however, was present at low levels in all largemouth bass. Catfish collected from Buckeye Canal contained relatively high (2.6 and 5.4 µg/g wet weight) toxaphene residues.

- Eleven potentially toxic metals were detected in biota. Concentrations of most metals remained unchanged from 1985 to 1994-95. Carp collected near Allenville had the second highest mean aluminum concentration ever recorded in Arizona.

- Copper concentrations in 65% of the fish exceeded the national average. Because of its occurrence at relatively high levels at some sites and its propensity to interact with other compounds and elements, copper remains a contaminant of concern.

- Softshell turtles generally were more contaminated with pesticides and metals than fish. DDE and most metals were highest in turtles from the middle river sampling sites.

- Concentrations of mercury and selenium, elements that often present significant environmental hazards to fish and wildlife, were relatively low and do not pose a threat to fish.

- The greatest potential impact of contaminants is to top-level predators such as black-crowned night-herons. DDE, mercury, and selenium present significant hazards to night-herons and possibly to other avian species nesting and wintering in the area. All night-herons contained DDE at levels associated with impaired reproduction. Mercury in five of six night-herons approached or exceeded the toxic threshold. The maximum mercury concentration was 4.5-times higher than the toxic threshold. Adult night-herons are not at risk of selenium toxicity, but selenium impacts on reproduction are possible.

- This study focused on contaminant threats to fish and wildlife, but hazards to human health were also obvious. Potentially health threatening levels of DDE were present in fish fillets from Buckeye Canal and Painted Rock. DDE in fish fillets from Painted Rock and Buckeye Canal still exceed the screening value currently proposed by USEPA and ADEQ for the protection of human health.

- None of the fish fillet samples exceeded the USEPA standard for mercury. However, mercury concentrations in Painted Rock bass fillets were two-times higher than the average reported by ADEQ for bass collected from the same area in the late-1980s.

RECOMMENDATIONS

Point sources of DDT/DDE input into agricultural drains should be identified. Assistance may be available through Arizona's Water Quality Assurance Revolving Fund (WQARF)

administered by ADEQ. This state funded program has declared portions of the Gila River within the boundaries of our 1994-95 study, a WQARF Superfund site (WQARF Decision Record Lower/Middle Gila River, 1989). One purpose of WQARF is to finance immediate remedial action necessary to prevent, minimize, and mitigate danger to public health and the environment. The fund specifically allows for study, management, and cleanup of hazardous substances. Funds and personnel may be provided to intensively sample the entire agricultural drainage system to locate, then mitigate, point sources of pollution.

Since many contaminant problems are associated with return of agricultural drainwater to the lower Gila River, an agricultural engineering perspective is needed to better manage irrigation practice, especially drainwater removal. Water conservation efforts should focus on diverting a minimal amount of water from the Gila River for irrigation purposes with emphasis on maximizing water use on crops so that there is little or no runoff. By initially removing only the optimum amount of water from the Gila River, maximum downstream flows would be ensured.

Many synthetic organic compounds have the potential to disrupt the endocrine system of fish and wildlife; these compounds include organochlorine pesticides, polyaromatic hydrocarbons, phthalates and phenols (Colborn and Clement 1992, Colborn et al. 1993). Many of these compounds are associated with wastewater treatment plant effluent. This study documented high levels of organochlorine insecticides in fish and wildlife tissues. Future investigations should quantify the presence of endocrine disrupting compounds and document histopathological parameters in lower Gila River fish and turtles.

Additional research is needed to assess levels and potential effects of contaminants in populations of fish-eating birds nesting and wintering in the lower Gila River ecosystem. DDE, mercury, and selenium were detected at sufficiently high levels in night-heron carcass and liver tissues to suggest that harmful impacts on reproduction are possible.

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Table 1. Organochlorine residues in individual whole body fish collected from the lower Gila River, Arizona, 1994-95

Site and sample[2]	Weight (g)	Prcnt lipid	Concentration (µg/g wet weight)[1] P,P' DDE	Totl PCB	Totl chlor[3]	Diel-drin	Toxa-phene	p,p' DDT
NCBP 85th %[4]	NA[5]	NA	0.33	0.80	0.17	0.05	0.03	0.03
59th Avenue								
C Carp	1311	8.25	0.21	0.65	<0.01	0.02	<0.05	<0.01
C Carp	755	9.15	0.18	0.38	<0.01	0.01	<0.05	<0.01
C Carp	1673	2.38	0.63	0.29	0.01	<0.01	<0.06	<0.01
C Carp	899	3.76	0.38	0.24	0.03	<0.01	<0.09	<0.01
C Carp	912	1.28	0.16	0.14	<0.01	<0.01	<0.05	<0.01
C catfish	377	4.53	0.47	0.11	0.02	0.01	<0.05	<0.01
LM bass	238	5.65	0.26	0.07	0.04	0.05	0.26	<0.01
LM bass	355	7.64	0.37	0.70	0.07	0.09	0.34	<0.01
LM bass	193	5.61	0.27	0.67	0.07	0.05	0.27	<0.01
LM bass	267	4.23	0.24	0.42	0.04	0.03	0.17	<0.01
LM bass	403	8.43	0.32	0.61	0.06	0.07	0.27	<0.01
Estrella Park								
C Carp	1413	4.55	1.50	0.29	<0.01	<0.01	<0.05	<0.01
C Carp	548	4.36	2.00	0.20	0.01	<0.01	<0.40	<0.01
C Carp	1466	3.90	0.44	0.24	0.03	<0.01	<0.05	<0.01
C Carp	818	5.18	0.89	0.19	<0.01	<0.01	<0.05	<0.01
C Carp	397	3.23	0.30	0.09	<0.01	<0.01	<0.05	<0.01
Allenville								
C Carp	780	3.32	1.10	<0.05	<0.01	<0.01	<0.08	<0.01
C Carp	463	3.33	1.10	<0.05	<0.01	<0.01	<0.09	<0.01
C Carp	280	4.26	6.10	0.07	0.01	<0.01	<0.50	0.02
C catfish	1597	6.78	7.90	0.15	0.16	0.04	<4.00	0.15
Buckeye Canal								
C Carp	400	3.96	9.40	0.13	0.05	0.02	<0.40	0.08
C Carp	451	1.93	14.00	0.14	0.05	<0.01	<0.40	0.04
C Carp	325	4.11	21.00	0.26	0.08	<0.01	<0.40	0.15
C Carp	227	7.29	14.00	0.29	0.09	<0.01	<0.40	0.13
C Carp	235	1.40	4.50	0.07	<0.01	<0.01	<0.40	<0.01
C catfish	254	4.32	9.80	0.06	0.05	<0.03	2.60	0.02
C catfish	287	6.56	20.00	0.17	0.14	<0.06	5.40	0.04

Table 1. (Cont). Organochlorine residues in individual whole body fish collected from the lower Gila River, Arizona, 1994-95

Site and sample[2]	Weight (g)	Prcnt lipid	Concentration (µg/g wet weight)[1] p,p' DDE	Totl PCB	Totl chlor[3]	Diel-drin	Toxa-phene	p,p' DDT
NCBP 85th %[4]	NA[5]	NA	0.33	0.80	0.17	0.05	0.03	0.03
Gillespie Dam								
C Carp	269	3.52	1.30	0.07	<0.01	<0.01	<0.25	0.02
C Carp	338	2.92	0.67	<0.05	<0.01	<0.01	<0.25	0.02
C Carp	2395	4.49	1.00	0.10	0.01	0.01	<0.25	<0.01
C Carp	365	5.49	0.73	<0.05	<0.01	<0.01	<0.25	0.02
C catfish	1487	6.98	7.90	0.18	0.01	<0.01	<0.80	0.09
C catfish	1544	10.04	4.60	0.12	0.01	<0.01	<0.80	0.11
C catfish	1621	14.40	4.20	0.10	0.01	<0.01	<0.80	0.08
C catfish	1564	9.31	8.40	0.11	<0.01	<0.01	<0.80	0.07
C catfish	444	11.85	1.30	<0.05	0.02	<0.01	<0.05	<0.01
C catfish	957	7.77	0.96	<0.05	0.03	<0.01	<0.05	0.02
C catfish	364	1.58	0.35	<0.05	<0.01	<0.01	<0.05	<0.01
C catfish	590	16.31	0.84	<0.05	0.04	<0.01	<0.05	<0.01
C catfish	1901	14.09	3.50	0.06	0.04	<0.04	1.80	<0.01
Painted Rock								
C Carp	913	1.88	0.94	<0.05	<0.01	<0.01	<0.05	<0.01
C Carp	1209	2.62	1.60	0.05	<0.01	0.01	<0.25	<0.01
C Carp	1684	4.90	0.72	<0.05	<0.01	0.27	<0.25	0.02
C Carp	956	1.25	0.64	<0.05	<0.01	<0.01	<0.05	<0.01
C Carp	845	6.96	2.00	0.08	<0.01	0.02	<0.05	0.04
C catfish	472	20.12	1.15	<0.05	0.04	<0.01	<0.05	0.02
C catfish	467	18.10	1.15	<0.05	0.04	<0.01	<0.05	<0.01
LM bass	435	9.14	1.90	0.08	<0.01	<0.01	0.26	<0.01
LM bass	697	5.15	1.80	0.09	<0.01	<0.01	0.19	<0.01
LM bass	856	5.87	1.60	0.07	<0.01	<0.01	0.18	<0.01
LM bass	536	7.27	1.20	<0.05	<0.01	0.01	0.24	<0.01
LM bass	666	10.70	2.00	0.08	0.01	0.01	0.19	<0.01

[1] No other organochlorine compounds were detected other than those listed.

[2] C carp = common carp, C catfish = channel catfish, and LM bass = largemouth bass.

[3] Total chlordane = the sum of all chlordane isomers (alpha chlordane, oxychlordane + *cis*-chlordane + *trans*-nonachlor + *cis*-nonachlor).

[4] The 85th percentile for each compound was calculated using data listed in Schmitt et al. (1990).

[5] NA = Data not available.

Table 2. Organochlorine compounds in common carp collected from the lower Gila River, Arizona, 1994-95: a comparison among collection sites

Area	N[3]	Geometric mean concentration[1] (µg/g wet weight) DDE	PCB	Chlordane	Dieldrin	DDT n[2]/range
59th Avenue	5	0.27 (5) A[4] 0.16-0.63	0.30 (5) A 0.14-0.65	----[5] (2) ND - 0.03	---- (2) ND - 0.02	---- (0)
Estrella Park	5	0.81 (5) AB 0.30-2.00	0.19 (5) A 0.09-0.29	---- (2) ND - 0.03	---- (0)	---- (0)
Allen-ville	3	1.95 (3) B 1.10-6.10	---- (1) ND - 0.07	---- (1) 0.01	---- (0)	---- (1) 0.02
Buckeye Canal	5	11.17 (5) C 4.50-21.0	0.16 (5) A 0.07-0.29	0.04 (4) ND - 0.09	---- (1) 0.02	0.05 (4) ND - 0.15
Gillespie Dam	4	0.89 (4) AB 0.67-1.30	0.05 (4) B 0.03-0.10	---- (1) 0.01	---- (1) 0.01	0.01 (3) ND - 0.02
Painted Rock	5	1.07 (5) B 0.64-2.00	---- (2) ND - 0.08	---- (0)	0.02 (3) 0.01-0.27	---- (2) ND - 0.04

[1] Toxaphene was detected only in catfish collected from Buckeye Canal and Gillespie Dam (Gmeans = 3.78, 4.71 µg/g) and in largemouth bass from 59th Avenue and Painted Rock (Gmeans = 0.26 and 0.21 µg/g). Toxaphene was not detected in carp.

[2] n = number of fish with detectable residues.

[3] N = number of fish in each sample.

[4] Means sharing the same letter are statistically similar (P >0.05).

[5] Means were not calculated because fewer than one-half of the samples had detectable residu

Table 3. Organochlorine residues in fish fillet samples collected from the lower Gila River, Arizona, 1994-95

Site and sample	Wt. (g)	Prcnt lipid	µg/g wet weight[1] p,p' DDE	Diel-drin	Toxa-phene
Buckeye Canal					
Common carp	231	1.28	1.90	0.01	0.81
Common carp	234	1.01	4.50	<0.01	0.74
Common carp	228	0.64	1.30	<0.01	0.31
Painted Rock					
Common carp	141	0.81	0.33	<0.01	<0.05
Largemouth bass	497	2.87	0.38	<0.01	0.11
Largemouth bass	311	2.57	0.39	<0.01	0.14
Largemouth bass	558	0.85	0.19	<0.01	<0.05

[1] No other organochlorine compounds were detected other than those listed.

Table 4. Metals in individual whole body fish collected from the lower Gila River, Arizona, 1994-95

Area and species[2]	Prcnt moist	Element concentration (µg/g wet weight)[1]							
		Al	As	B	Cu	Cr	Hg	Ni	Se
Sr	V	Zn							
NCBP 85th %[3]	NA	NA[4]	0.27	NA	1.0	NA	0.17	NA	0.73
NA	NA	34.2							
59th Avenue									
C carp	68.8	61.30	<0.05	0.47	5.62	0.92	0.07	0.37	<0.20
44.7	1.05	85.1							
C carp	71.1	47.00	0.09	0.40	1.43	0.48	0.06	0.17	<0.20
33.8	0.30	53.6							
C carp	76.3	29.20	0.09	<0.39	1.27	0.31	0.16	<0.12	0.40
32.1	0.18	47.6							
C carp	77.9	26.70	0.32	1.28	1.39	0.24	0.28	<0.12	0.37
18.0	0.15	45.3							
C carp	79.4	12.60	0.18	<0.39	1.33	0.22	0.24	<0.12	0.57
22.2	0.08	32.2							
LM bass	72.6	1.68	0.69	0.41	0.93	0.44	0.07	<0.12	<0.20
25.8	<0.05	16.1							
LM bass	70.6	1.55	0.39	0.66	0.35	0.49	0.08	<0.12	0.31
30.0	<0.05	17.2							
LM bass	73.4	2.05	0.59	0.62	0.39	0.43	0.09	<0.12	0.26
23.5	<0.05	17.3							
LM bass	73.4	1.55	0.82	0.90	0.55	0.47	0.07	0.30	<0.20
29.7	<0.05	18.1							
LM bass	69.2	1.62	0.85	0.59	0.31	0.46	0.08	<0.12	0.29
26.9	<0.05	14.4							
C catfish	76.7	10.40	0.09	0.60	0.36	0.53	0.03	<0.12	<0.20
33.9	0.13	21.6							
Estrella Park									
C carp	74.2	3.92	0.10	0.44	1.51	0.37	0.23	0.16	0.33
52.2	0.16	30.4							
C carp	74.2	61.80	0.11	0.50	1.80	0.60	0.11	0.23	0.39
59.9	0.45	68.2							
C carp	76.2	108.00	0.12	0.54	6.73	0.66	0.09	0.32	0.65
34.6	0.52	41.4							
C carp	76.2	52.20	0.16	0.60	3.45	0.42	0.10	0.21	0.29
44.7	0.22	40.8							
C carp	76.3	72.80	0.12	0.89	1.68	0.59	0.09	0.22	0.43
56.6	0.43	56.4							
Allenville									
C carp	77.2	99.70	0.16	0.50	6.02	0.44	0.13	0.68	1.47
46.1	0.31	75.3							

C carp	77.2	111.00	0.17	0.57	2.11	0.45	0.14	0.15	0.84	50.6	0.36	51.7
C carp	76.4	90.70	0.35	0.84	1.69	0.42	0.41	<0.12	0.60	63.1	0.38	50.2
C catfish	72.8	<0.99	0.08	0.77	2.43	0.23	0.11	<0.12	0.66	43.8	0.07	14.5
Buckeye Canal												
C carp	74.6	14.00	0.09	0.61	1.30	0.42	0.04	0.23	0.87	56.3	0.08	64.7
C carp	77.9	19.80	0.07	0.50	1.10	0.46	0.05	0.22	0.25	57.9	0.08	67.4
C carp	75.0	11.10	0.09	0.48	1.15	0.39	0.25	<0.12	0.43	49.0	0.10	77.2
C carp	70.1	18.60	<0.05	0.65	1.37	0.52	0.05	0.15	0.33	79.6	0.23	38.8
C carp	78.3	16.50	0.06	1.11	1.54	0.47	0.04	1.76	0.38	70.0	0.09	52.3
C catfish	78.1	147.00	0.19	2.69	2.86	0.62	0.07	1.19	0.24	26.9	0.43	18.0
C catfish	76.7	107.00	0.14	1.96	0.71	0.57	0.11	0.19	<0.20	32.7	0.33	20.3
Gillespie Dam												
C carp	72.9	96.90	0.09	1.05	1.82	0.75	0.08	0.25	0.83	91.7	0.63	75.4
C carp	75.1	57.40	0.05	1.17	1.29	0.49	0.07	0.20	0.56	96.5	0.18	46.1
C carp	72.0	172.00	0.17	0.91	5.44	0.59	0.08	0.31	0.58	38.8	0.44	72.8
C carp	72.4	101.00	0.16	1.40	1.30	0.58	0.05	0.21	0.66	77.2	0.41	46.3
C catfish	72.6	3.54	0.46	2.84	0.50	0.36	0.06	<0.12	0.23	36.4	0.16	14.3
C catfish	67.6	2.66	0.06	0.81	5.99	0.31	0.09	<0.12	0.41	29.2	0.09	19.6
C catfish	68.8	3.96	0.10	1.09	1.57	0.41	0.08	<0.12	0.39	43.3	0.10	20.9
C catfish	69.4	1.78	0.12	0.90	0.53	0.28	0.06	0.13	0.27	31.9	0.07	15.8
C catfish	65.7	2.06	0.10	0.52	5.49	0.31	0.07	<0.12	0.48	25.5	0.07	20.1

Table 4. (Cont.). Metals in individual whole body fish collected from the lower Gila River, Arizona, 1994-95

Area and species[2]	Prcnt moist	Element concentration (µg/g wet weight)[1] Al	As	B	Cu	Cr	Hg	Ni	Se	Sr	V	Zn
NCBP 85th %[3]	NA	NA[4]	0.27	NA	1.0	NA	0.17	NA	0.73	NA	NA	34.2
Painted Rock												
C carp	77.7	1.02	<0.05	0.77	0.93	0.42	0.18	<0.12	0.55	57.0	0.27	38.4
C carp	76.9	82.90	<0.05	0.44	2.12	0.34	0.15	0.13	0.62	46.6	0.28	61.2
C carp	72.1	2.14	<0.05	0.45	1.12	0.35	0.24	<0.12	0.88	51.7	0.18	51.0
C carp	78.3	5.53	<0.05	0.56	0.73	0.43	0.21	<0.12	0.60	50.2	0.25	53.0
C carp	71.0	1.26	<0.05	0.47	0.96	0.46	0.16	<0.12	0.40	81.2	0.93	34.6
C catfish	63.6	1.01	0.05	0.60	0.28	0.33	0.20	<0.12	0.46	34.2	0.10	15.5
C catfish	63.2	1.58	<0.05	1.39	0.30	0.37	0.18	<0.12	0.27	35.6	0.17	16.9
LM bass	68.1	1.78	0.46	1.53	0.40	0.52	0.29	<0.12	0.33	49.6	0.06	17.0
LM bass	73.0	5.98	0.24	1.28	1.94	0.42	0.32	<0.12	0.51	33.1	<0.05	12.6
LM bass	70.3	1.21	0.17	0.70	2.60	0.50	0.36	<0.12	0.85	40.7	<0.05	14.8
LM bass	69.5	<0.99	0.28	1.08	0.59	0.49	0.28	<0.12	0.65	50.0	<0.05	14.5
LM bass	67.0	<0.98	0.13	0.89	0.38	0.41	0.32	<0.12	0.67	34.5	<0.05	11.7

[1] Not detected in any samples: beryllium lower limit of detection (LLD) 0.02, lead LLD 0.5, and molybdenum LLD 0.4. Cadmium was present in one Gillespie Dam carp at 0.07 µg/g.

[2] Species: C carp = common carp, LM bass = largemouth bass, C catfish = channel catfish.

[3] National Contaminant Biomonitoring Program 85th percentile (Schmitt and Brumbaugh 1990)

[4] NA = NCBP samples were not analyzed for this element.

Table 5. Metals in common carp collected from the lower Gila River, Arizona, 1994-95: a comparison among collection sites

Area	N[2]	Geometric mean concentration (µg/g dry weight) n[1]/range Aluminum	Arsenic	Boron	Copper	Chromium	Mercury
59th Avenue	5 61 - 196	124 (5) AB[3] ND - 1.45	0.41 (4) A ND - 5.79	2.31 (3) A 4.95-18.0	7.21 (5) A 1.05-2.94	1.48 (5) A 0.22-1.27	0.55 (5) AB
Estrella Park	5 15 - 453	162 (5) A 0.39-0.67	0.49 (5) A 1.69-3.77	2.34 (5) A 5.85-28.3	10.35 (5) A 1.42-2.79	2.10 (5) A 0.39-0.88	0.49 (5) AB
Allen-ville	3 384 - 487	434 (3) A 0.70-1.48	0.92 (3) A 2.14-3.55	2.67 (3) A 7.16-26.4	12.05 (3) A 1.78-1.97	1.89 (3) A 0.59-1.72	0.85 (3) A
Buckeye Canal	5 44 - 90	64 (5) AB ND - 0.36	0.25 (4) A 1.90-5.12	2.59 (5) A 4.58-7.10	5.20 (5) A 1.54-2.18	1.81 (5) A 0.15-1.00	0.26 (5) B
Gillespie Dam	4 230 - 614	369 (4) A 0.20-0.61	0.39 (4) A 3.24-5.07	4.16 (4) A 4.71-19.4	7.51 (4) A 1.98-2.76	2.25 (4) A 0.20-0.31	0.26 (4) B
Painted Rock	5 4.3 - 359	17 (5) B ND	----[4] (0) 1.61-3.44	2.13 (5) A 3.30-9.18	4.43 (5) A 1.25-1.97	1.61 (5) A 0.54-0.98	0.77 (5) A

[1] n = number of fish with detectable residues.

[2] N = number of individual fish in each sample.

[3] Means sharing the same letter are statistically similar (P >0.05).

[4] Means were not calculated because fewer than one-half of the samples had detectable residues.

Table 5. (Cont.). Metals in common carp collected from the lower Gila River, Arizona, 1994-95: a comparison among collection sites

Area	N[2]	Geometric mean (µg/g dry weight) Nickel	Selenium	Strontium	Vanadium	Zinc
	n[1]/range					
59th Avenue	5	----[3] (2) ND - 1.18	0.97 (3) A[4] ND - 2.77	125 (5) A 108-143	0.94 (5) A 0.41 3.37	201 (5) A 156-273
Estrella Park	5	1.64 (5) A 0.64-1.34	1.64 (5) AB 1.24-2.74	198 (5) AB 145-239	1.32 (5) A 0.63-2.18	185 (5) A 118-264
Allen-ville	3	1.26 (2) A ND - 2.99	3.92 (3) B 2.54-6.45	229 (3) B 202-267	1.51 (3) A 1.35-1.61	252 (3) A 212-330
Buckeye Canal	5	1.78 (4) A ND - 8.11	1.67 (5) AB 1.12-3.41	250 (5) B 196-323	0.42 (5) A 0.30-0.77	237 (5) A 129-308
Gillespie Dam	4	1.74 (4) A 0.77-1.10	2.42 (4) AB 0.77-1.10	267 (4) B 139-388	1.40 (4) A 0.71-2.31	218 (4) A 108-278
Painted Rock	5	---- (1) ND - 0.54	2.40 (5) AB 1.38-3.16	228 (5) B 185-280	1.28 (5) A 0.63-3.20	189 (5) A 119-265

[1] n = number of fish with detectable residues.

[2] N = number of fish in each sample.

[3] Means were not calculated because fewer than one-half of the samples had

detectable residues.

[4] Means sharing the same letter are statistically similar (P >0.05).

Table 6. Metals in common carp and largemouth bass fillet samples collected from the lower Gila River, Arizona, 1994-95

Area and species[2]	Prcnt moist	Element concentration (µg/g wet weight)[1] Al	As	B	Cr	Cu	Hg	Se	Sr	Zn
Buckeye Canal										
C carp	79.2	1.55	0.11	0.70	0.15	1.07	0.13	0.37	1.41	10.60
C carp	78.8	21.60	0.14	0.58	0.19	2.28	0.18	0.44	2.85	7.64
C carp	80.6	1.88	0.15	0.84	0.16	0.80	0.11	0.44	1.68	16.40
Painted Rock										
C carp	79.3	73.20	0.22	<0.39	0.25	0.52	0.42	0.48	1.85	4.68
LM bass	77.9	<0.99	0.29	0.91	0.13	0.82	0.44	0.40	0.45	4.63
LM bass	77.2	122.00	0.47	0.52	0.19	2.27	0.47	0.58	0.78	5.45
LM bass	78.4	<1.00	0.82	0.70	0.15	0.34	0.50	0.52	0.34	4.06

[1] The following elements were not detected in any fillet samples: beryllium lower limit of detection (LLD) 0.02 µg/g wet weight, cadmium LLD 0.02 µg/g, molybdenum LLD = 0.40 µg/g, lead LLD = 0.50 µg/g, and vanadium LLD = 0.05 µg/g. One Painted Rock largemouth bass fillet sample contained 0.26 µg/g nickel.

[2] Species: C carp = common carp, LM bass = largemouth bass.

Table 7. Organochlorine residues in individual softshell turtles collected from the lower Gila River, Arizona, 1994-95

Site and sample	Weight (g)	Prcnt lipid	Concentration (µg/g wet weight) [1] p,p' DDE	Totl PCB	Totl chlor[2]	Diel-drin	p,p' DDT
59th Avenue							
Sample 1	1857	12.13	1.40	0.11	0.05	0.07	<0.01
Sample 2	2164	20.99	1.20	0.15	0.06	0.04	<0.01
Sample 3	1562	11.39	0.32	0.10	0.03	<0.01	<0.01
Sample 4	1058	12.71	0.52	0.31	0.01	0.04	<0.01
Sample 5	3550	21.75	2.50	6.70	0.24	0.19	<0.03
Estrella Park							
Sample 1	2159	11.27	5.90	0.40	0.07	0.06	0.02
Sample 2	2745	12.72	4.50	0.85	0.19	0.10	0.02
Sample 3	1671	11.39	8.60	0.41	0.10	0.11	<0.01
Sample 4	1997	17.39	1.40	0.46	0.05	0.05	<0.01
Sample 5	2897	18.88	2.20	0.27	0.09	0.07	0.05
Allenville							
Sample 1	417	6.01	4.90	0.27	0.05	0.03	<0.01
Sample 2	508	10.49	6.40	0.38	0.08	0.05	<0.01
Sample 3	2351	11.92	4.80	0.18	0.05	0.04	0.06
Sample 4	529	6.13	6.70	0.23	0.05	0.06	0.06
Sample 5	364	2.87	3.00	0.14	0.03	0.03	0.03
Buckeye Canal							
Sample 1	463	1.83	5.30	0.57	0.13	0.06	0.04
Gillespie Dam							
Sample 1	332	9.37	2.70	0.10	0.04	0.05	0.06
Sample 2	416	6.79	6.50	0.13	0.05	0.06	0.05
Sample 3	455	4.38	2.50	0.11	0.02	0.03	0.03
Sample 4	513	2.47	2.30	0.07	0.01	0.02	0.02
Sample 5	872	8.51	3.20	0.10	0.01	0.04	0.05
Painted Rock							
Sample 1	1612	15.14	2.80	0.06	0.02	0.02	<0.01
Sample 2	1503	20.69	2.10	<0.05	0.02	0.01	<0.01
Sample 3	2110	16.05	2.30	<0.05	0.02	0.01	<0.01
Sample 4	1851	17.54	1.70	<0.05	0.02	0.01	<0.01
Sample 5	4433	23.81	1.20	<0.05	0.05	0.02	<0.05
Sample 6	3327	19.96	1.70	<0.05	<0.01	0.02	<0.03

[1] No other organochlorine compounds were detected.

[2] Total chlordane = the sum of all chlordane isomers (alpha chlordane, oxychlordane + *cis*-chlordane + *trans*-nonachlor + *cis*-nonachlor).

Table 8. Geometric mean concentrations of organochlorine compounds in softshell turtles collected on the lower Gila River, Arizona, 1994-95

Area	N[2]	Geometric mean concentration (µg/g wet weight) n[1]/range DDE	PCB	Chlordane	Dieldrin	DDT
59th Avenue	5	0.93 (5) A[3] 0.32-2.50	0.32 (5) A 0.10-6.70	0.05 (5) A 0.01-0.24	0.07 (4) A 0.04-0.19	---- (0) ND
Estrella Park	5	3.71 (5) B 1.40-8.60	0.44 (5) A 0.27-0.85	0.08 (5) A 0.05-0.19	0.08 (5) A 0.05-0.11	0.01 (3) 0.02-0.05
Allen-ville	5	4.97 (5) B 3.00-6.70	0.23 (5) A 0.14-0.38	0.05 (5) A 0.03-0.08	0.04 (5) A 0.03-0.06	0.02 (3) ND - 0.06
Buckeye Canal	1	----[4] (1) 5.30	---- (1) 0.57	---- (1) 0.13	---- (1) 0.07	---- (1) 0.04
Gillespie Dam	5	3.18 (5) B 2.30-5.60	0.10 (5) A 0.07-0.13	0.02 (5) A 0.01-0.05	0.04 (5) A 0.03-0.06	0.04 (5) 0.02-0.06
Painted Rock	6	1.89 (6) AB 1.20-2.80	---- (1) ND - 0.06	0.02 (5) A 0.02-0.05	0.02 (6) B 0.01-0.02	---- (0) ND

[1] n = number of turtles with detectable residues.

[2] N = number of turtles in each sample.

[3] Means sharing the same letter are statistically similar (P >0.05).

[4] Means were not calculated because fewer than one-half of the samples had detectable residues.

Table 9. Trace element concentrations (g/g dry weight) in individual whole body softshell turtles collected from the lower Gila River, Arizona, 1994-95.

Area and sample	Concentration, µg/g dry weight[1]									
	Al	As	B	Cr	Cu	Hg	Ni	Se	Sr	V
	Zn	Prcnt moist								
59th Avenue										
Sample 1	36.9	<0.13	1.37	2.08	12.53	0.03	2.04	<0.52	161.	0.15
	62.0	62.1								
Sample 2	39.1	<0.12	1.25	1.58	303.96	0.02	1.98	<0.49	120.	0.35
	58.7	59.6								
Sample 3	34.5	0.21	4.90	1.65	2.21	0.22	<0.35	0.72	170.	0.32
	76.7	66.1								
Sample 4	25.6	0.33	2.31	1.43	1.62	0.17	<0.31	<0.51	134.	0.22
	62.8	61.0								
Sample 5	33.4	<0.16	2.93	1.71	2.39	0.21	<0.39	<0.65	144.	0.20
	79.7	69.5								
Estrella Park										
Sample 1	41.3	0.45	3.72	1.89	384.62	0.62	2.71	<0.64	242.	<0.16
	84.6	68.8								
Sample 2	123.0	0.38	3.20	1.82	149.10	0.43	1.70	<0.51	194.	0.51
	73.9	60.9								
Sample 3	96.4	0.57	3.18	1.52	1128.57	0.45	8.11	<0.70	167.	0.34
	100.0	72.0								
Sample 4	148.5	<0.14	2.44	1.87	17.45	0.17	1.04	0.81	154.	0.47
	61.8	63.1								
Sample 5	24.3	0.13	1.87	1.33	167.74	0.37	1.38	0.98	187.	<0.13
	54.8	62.8								
Allenville										
Sample 1	55.1	0.25	7.82	2.56	64.24	0.20	0.86	<0.63	421.	0.37
	101.3	68.4								
Sample 2	62.5	0.20	10.14	2.72	4.60	0.33	0.56	0.95	338.	0.19
	101.4	64.8								
Sample 3	27.5	<0.22	3.78	<0.31	1.76	0.43	<0.37	2.60	161.	0.24
	51.4	67.7								
Sample 4	59.4	0.67	6.93	<0.39	2.40	0.41	<0.47	2.76	208.	0.38
	76.0	74.6								
Sample 5	150.4	0.31	6.43	<0.44	4.04	0.63	<0.53	3.97	189.	0.89
	79.5	77.6								
Buckeye Canal										

Sample 1	50.0	0.37	3.81	1.16	5.09	1.42	<0.56	4.44	163.	0.27	86.4	78.6
Gillespie Dam												
Sample 1	52.7	<0.16	5.62	1.73	6.37	0.37	2.75	2.51	217.	<0.15	74.8	68.3
Sample 2	31.7	0.53	13.51	<0.37	2.33	0.69	<0.45	3.13	214.	0.27	77.7	73.5
Sample 3	19.8	0.49	10.04	<0.37	2.06	0.44	<0.44	2.57	217.	<0.18	80.2	73.2
Sample 4	27.6	0.65	5.60	0.96	2.26	0.63	<0.51	2.11	157.	0.26	58.2	76.8
Sample 5	59.1	1.08	5.02	<0.38	2.83	0.49	<0.46	2.24	191.	0.31	69.1	74.1
Painted Rock												
Sample 1	57.3	0.24	3.63	1.60	1.93	0.73	<0.38	1.57	123.	0.36	67.1	67.2
Sample 2	24.7	0.35	3.32	1.05	1.73	0.29	0.46	0.98	105.	0.26	57.2	62.6
Sample 3	92.5	0.26	4.34	1.71	2.35	0.66	0.32	0.98	150.	0.49	76.3	61.1
Sample 4	18.1	0.25	3.37	1.21	1.69	0.47	0.33	0.58	108.	<0.14	61.4	63.5
Sample 5	18.3	0.18	3.12	1.15	1.42	0.49	<0.26	0.71	136.	0.15	57.6	55.4
Sample 6	16.4	0.24	5.07	1.29	1.25	0.65	<0.28	1.11	177.	0.18	62.8	57.8

[1] Cadmium was not detected in turtle samples. An unknown number of turtles from 59th Avenue and Estrella Park were shot with lead bullets which biased chemical analysis for lead. Lead data for these sites are not presented. None of turtles trapped at the remaining collection sites contained lead.