U.S. Fish and Wildlife Service

Region 2

Contaminants Program

Contaminants in Fish and Wildlife Collected. from the Lower Colorado River and Irrigation Drains in the Yuma Valley, Arizona

by

Kirke A. King and Brenda J. Andrews

U.S. Fish and Wildlife Service
Arizona Ecological Services Field Office
2321 W. Royal Palm Road, Suite 103
Phoenix, Arizona 85021

May 1996

ABSTRACT- Fish, birds, freshwater clams, and cattails were collected at from nine sites from March to September 1995 along the lower Colorado River and in agricultural drains in the Yuma, Arizona area. DDE was detected in all fish and bird samples. Almost one-half of the fish contained DDE residues that were two-times higher than the 1984-85 national mean; 23% of the fish contained more than three-times the national mean. Fish from down-gradient portions of the Yuma Main Drain, sample sites closest to the U.S./Mexico International Boundary, had the highest levels of DDE. Although DDE in fish and bird carcasses and eggs was above background levels, residues were generally below thresholds associated with chronic poisoning and reproductive problems in fish and wildlife.

Concentrations of 18 metalloids were detected in cattail (*Typha* sp.) roots, freshwater clam (*Corbicula fluminea*), fish, and bird samples. Selenium in most fish and in livers of red-winged (*Agelaius phoeniceus*) and yellow-headed (*Xanthocephalus xanthocephalus*) blackbirds was above background levels but below toxic concentrations. In contrast, selenium was present in the killdeer liver sample at potentially toxic levels. With the exception of selenium in killdeer, arsenic, cadmium, mercury, and selenium did not occur with the frequency or at levels that would cause concern for fish and wildlife populations.

This study identified one contaminant "hot spot", the Yuma Main Drain at San Luis, where aluminum, chromium, copper, and nickel contamination was especially high. Common carp (*Cyprinus carpio*) from this site contained the highest mean levels of aluminum and chromium ever recorded in Arizona.

INTRODUCTION

This paper represents the U.S. Fish and Wildlife Service's contribution to a cooperative Service / U.S. Geological Survey report on contaminants in water, sediment, and biota associated with the lower Colorado River and irrigation drainage canals in the Yuma Valley, Arizona. Overall report synthesis is the responsibility of USGS. This paper describes contaminant levels in plants, invertebrates, fish, and birds and interprets residue data with respect to overall health of the ecosystem. We also identify contaminant "hot spots" where pollution is significantly higher than surrounding areas.

In a nationwide sampling program conducted in 1984 by the Service for contaminants in fish, the National Contaminant Biomonitoring Program (NCBP) revealed that five of the ten highest arithmetic mean selenium concentrations occurred in fish from the lower Colorado River (Schmitt and Brumbaugh 1990). Follow-up sampling in 1986-87 at numerous sites along the lower Colorado River confirmed that selenium concentrations in water exceeded the 75 % level of the national baseline data and selenium in fish approached concentrations associated with reproductive impairment (Radtke et al. 1988).

STUDY AREA

General site descriptions will be supplied by USGS. Following is a listing of specific sites where fish and wildlife samples were collected. The type of biotic samples collected at each location is listed in Table 1.

Site 1. Colorado River below Laguna Dam at USGS Gauging Station. All biota and cattail (*Typha* sp.) samples were collected about 200 m upriver of the gauging station.

Site 2. Drain 1A. upstream of the confluence with Colorado River. Common carp (*Cyprinus carpio*) were collected 1- to 1.6 km above the confluence of Drain 1A and the Colorado River. Freshwater clams (*Corbicula fluminea*) and cattails were collected from Drain 1 just above its confluence with Drain 1A. Yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) were collected along the banks of both drains 1 and 1A.

Site 3. Drain 4 upstream of its confluence with Colorado River. All samples were collected within 500 m of the junction of drain 4 and the Yuma Main Canal.

Site 4. Gila River upstream of its confluence with the Colorado River. Insufficient numbers of ***Corbicula*** were located in the Gila River at Site 4 for a sample. However, in the Colorado River immediately upstream of the Gila, numerous ***Corbicula*** were present. Our sample of ***Corbicula*** from this site was collected from the Colorado River, not the Gila River. Carp and cattails were collected from the Gila River within 1000 m of the Gila/Colorado confluence. Striped mullet (*Mugil cephalus*) and killdeer (*Charadrius vociferus*) were collected from the Gila River approximately 1 to 1.5 km upstream of its confluence with the Colorado River.

Site 5. Wellton Mohawk Canal east of Hwy 95. ***Carp*** and ***Corbicula*** were the only samples collected from this site. This steep-sided canal did not contain cattails.

Site 6. Yuma Main Drain down-gradient of East Drain. Carp, flathead catfish (*Pylodictis olivaris*), cattail roots and one common moorhen (*Gallinula chloropus*) egg were collected from this location. Adult red-winged blackbirds (*Agelaius phoeniceus*) were collected along the East Drain within 1 km of the East Drain/Yuma Main Drain confluence.

Site 7. Yuma Main Drain at Highway 95 east of Gadsden, Arizona. Cattails were the only sample materials collected at this site.

Site 8. Yuma Main Drain at San Luis. All fish samples were collected within 400 m of the U.S./Mexico international border. The cattail sample was collected about 800 m from the border.

Site 9. Lower Colorado River near the Winterhaven, California USGS gauging station. All samples were collected within 200-400 m upstream of the gauging station.

METHODS

<u>Sample collections</u>: All samples were collected between March and September 1995. Three cattail plants were collected at each location except Site 5 which was too steep-sided to support cattails. The roots were gently washed in drain or river water where collected to remove excess sediment. The roots were cut from the stem and combined into a single composite sample from each area. Each sample was then weighed, wrapped in aluminum foil and placed on wet ice until it could be transferred to a commercial freezer.

Clams were collected by sweeping bottom sediments by hand. Individuals were counted then opened and contents removed. Excess water was blotted from the tissue then the tissues were pooled on tared aluminum foil sheets and weighed. Fish were collected using a gill net, hook and line, or a .22 caliber rifle or pistol. Whole fish were individually weighed and measured. Carp and catfish samples were individually wrapped in aluminum foil. Mullet were collected from two sites. Five individual mullet from each site were weighed and measured then cornposited into a single sample by site. Birds were collected by shotgun using steel shotshells. Whole bodies were weighed then plucked and bill, feet, wingtips, and gastrointestinal tract removed and discarded. Bird livers were pooled into a single sample per site and analyzed for metals. Carcasses were cornposited by species at each site and analyzed for organochlorine pesticides. Clams, fish, and bird carcass and liver samples were wrapped in aluminum foil and placed on wet ice until transfer to a commercial freezer. Contents of a single clutch of yellow-headed blackbird eggs ($n=4$) were cornposited in an acid-rinsed jar and frozen for organochlorine analysis.

Chemical analysis: Samples 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, and gamma BHC, alpha and gamma chlordane, oxychlordane, *trans*-nonachlor, endrin, toxaphene, mirex, and total polychlorinated biphenyls (PCB) at Hazleton Environmental Services, Inc., Madison, Wisconsin. For each analysis, the sample was homogenized and a portion mixed with anhydrous sodium sulfate and extracted with hexane in a Soxhlet apparatus for 7 hours. Lipids were removed by Florisil column chromatography (Cromartie et al. 1975). Sep-pak Florisil cartridges were used for removal of lipids (Clark et al. 1983). The organochlorine compounds were separated into four fractions on a SilicAR column to ensure the separation of dieldrin or endrin into an individual fraction (Kaiser et al. 1980). The individual fractions were analyzed with a gas-liquid chromatograph equipped with an electron-capture detector and a 1.5/1.95% SP-2250/SP-2401 column. Residues in 10% of the samples were confirmed by gas chromatography/mass spectrometry. The lower limit of quantification varied with sample mass but was usually 0.01 μg/g for all organochlorine pesticides and 0.05 μg/g for PCBs. Organochlorine compounds are expressed in μg/g (parts per million) wet weight unless otherwise specified.

Bird livers, fish, clams, and cattail roots were also analyzed for aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, vanadium, and zinc. Arsenic and selenium concentrations were determined by graphite furnace atomic absorption spectrophotometry (EPA 1984). Mercury concentrations were quantified by cold vapor atomic absorption (EPA 1984). All other elements were analyzed by inductively coupled plasma atomic emission spectroscopy (Dahlquist and Knoll 1978, EPA 1987). Blanks, duplicates, and spiked samples were used to maintain laboratory quality assurance and quality control (QA/QC). QA/QC was monitored by Patuxent Analytical Control Facility (PACF). Analytical methodology and reports met or exceeded PACF QA/QC standards. Element concentrations in cattails, clams, and birds are reported in μg/g dry weight. Element concentrations in fish are expressed both in μg/g wet weight and dry weight to facilitate data comparison with published studies. Percent moisture is listed in Table 2 for readers who wish to convert dry weight values to wet weight equivalents.

Statistical analysis: Because of limited sample size, one sample per site, we were unable to statistically analyze contaminant residues in cattail, clam, mullet, and avian samples. Geometric mean DDE and metalloid concentrations in carp collected from eight locations were statistically compared using analysis of variance (ANOVA) to better define areas that may be sources pollution. Contaminant concentrations were transformed to logarithms for statistical comparisons; geometric means are presented in the tables. The Bonferroni multiple comparison method (Neter and Wasserman 1974) was used to test for mean separation when ANOVA showed significant differences.

Organochlorine residues in Yuma Valley fish were compared with those reported in the NCBP for fish collected in 1984-85 from 112 stations nationwide (Schmitt et al. 1990).

Organochlorine residues in Yuma Valley fish were compared with those reported in the NCBP for fish collected in 1984-85 from 112 stations nationwide (Schmitt et al. 1990). DDE was detected in fish tissue at 98% of the national sampling sites, thus the NCBP study provides a benchmark from which to compare pesticide contamination of the Yuma Valley rivers and irrigation drainwater areas in context with the rest of the country. Similarly, trace element concentrations in Yuma Valley fish were compared with the NCBP data compiled for fish collected from 109 stations in 1984-85 (Schmitt and Brumbaugh 1990). For trace elements, Schmitt and Brumbaugh (1990) calculated the 85th percentile for each element. Concentrations of an element were considered elevated when they exceeded the 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 elements of potential concern.

RESULTS

Organochlorines:

Organochlorines in fish: DDE residues were detected in all 22 fish samples and individual levels ranged from 0.05 to' 1.20 $\mu g/g$ wet weight (Table 2). Ten fish samples contained DDE at two-times the national mean (0.19 $\mu g/g$), and five samples contained more than three-times the national DDE mean. DDE residues were highest in fish from agricultural drainwater Sites 2, 4, 6, and 8 ($P = 0.0002$, ANOVA) and lowest at Site 1 (Table 3). PCBs were detected at low levels (≤ 0.13 $\mu g/g$ wet weight) in four fish samples (Table 2). Dieldrin and chlordane residues were recovered only in carp from Sites 6 and 8; the areas where DDE was highest. HCB was not detected in fish samples.

Organochlorines in birds: DDE was recovered in all bird carcass and egg samples and residues ranged from 0.17 $\mu g/g$ wet weight in a clutch of yellow-headed blackbird eggs to 5.90 $\mu g/g$ in the killdeer carcasses (Table 2). PCB (0.06 $\mu g/g$) and chlordane (0.013 $\mu g/g$) were present only in the killdeer carcass sample. Dieldrin was also detected at low levels in the red-winged blackbird and killdeer carcass samples but dieldrin was not recovered in the yellow-headed blackbird carcasses or eggs. HCB was detected at low levels (0.01-0.05 $\mu g/g$) in all bird carcasses.

Metals:

Metals in cattails: Concentrations of 18 metalloids were detected in cattail roots (Table 4). The following discussion is limited to nine EPA priority pollutants (arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, and zinc) recovered in cattail tissues. Arsenic was present in all cattail samples and concentrations varied greatly (2.24-21.47 $\mu g/g$ dry weight). Highest arsenic levels were recorded in cattails from Sites 1 and 9, the two sites located on the Colorado River. Beryllium was recovered at low levels in six of eight samples and cadmium was detected in only one cattail sample. Chromium and nickel concentrations were quite variable among sites with highest levels generally recorded in cattails collected from agricultural drains rather than the Colorado River. Copper concentrations were fairly consistent among sites varying less than one order of magnitude from lowest concentration to highest concentration. Lead was detected in 5 of 8 samples and selenium was present in 7 of 8 samples with highest concentrations of both elements in cattails from agricultural drain Site 2. Concentrations of zinc ranged from 29 to 46 μg/g and were fairly uniform among areas.

Metals in clams: Arsenic concentrations in clams were not as variable as those in cattail roots. Levels were highest in samples from drainage canals (Table 4) in contrast to arsenic cattail roots which was highest in samples from the Colorado River. Beryllium and lead did not bioaccumulate in clams. Cadmium was detected in all clam samples. The clam sample from Site 9, the Colorado River at Winterhaven, contained the highest cadmium concentration, 1.59 μg/g dry weight. Concentrations of chromium and copper varied only slightly among collection sites with the highest level of both elements recorded in samples from Colorado River sites rather than agricultural drains. Nickel was highly variable (1.41-15.02 μg/g) with highest residues detected in clams from the Yuma Main Drain (Site 6) and the Welton Mohawk Canal (Site 5). Clam selenium levels varied slightly more than one order of magnitude from lowest site (Site 6, 3.83 μg/g) to highest (Site 5, Welton Mohawk Canal, 8.70 μg/g). Zinc concentrations were relatively consistent and varied only slightly (68-94 μg/g) from site to site.

Metals in birds: Arsenic was considerably lower in bird tissues and eggs (0.19-0.50 μg/g dry weight) than in cattail roots (2.24-21.47 μg/g) and clams (7.41-11.53 μg/g, Table 4). The trend was similar for nickel; residues were considerably lower in bird tissues and eggs than in cattail roots and clams with little overlap in residues levels. Beryllium and lead were not detected in bird tissues and eggs. Cadmium was not recovered in either egg sample but was present in all three liver samples. Copper was present in all bird samples with highest concentrations in tissues and lowest concentrations in eggs. Selenium residues varied from 3.50-4.33 μg/g in eggs and from 4.06-13.57 μg/g in bird livers. Zinc concentrations were similar among bird tissues and also were similar to zinc levels in cattail roots and clams.

Metals in fish: Concentrations of all trace elements detected in fish are presented in Table 5. NCBP data are available for seven elements; arsenic, cadmium, copper, lead, mercury, selenium, and zinc (Schmitt and Brumbaugh 1990).

Aluminum: Although aluminum is not an EPA priority pollutant, the especially high levels recorded in fish from Site 8, the Yuma Main Drain at San Luis, warrant special attention. Unfortunately, there are no NCBP background data for aluminum. Concentrations of aluminum in carp from Site 8 (Tables 5 & 7) varied from 681 to 1118 μg/g dry weight (wet weight range = 154-255 μg/g, mean = 205 μg/g). The mean aluminum level in carp from Site 8 was 5.5 times greater than the mean at next highest area. By comparison, aluminum levels in carp from several Arizona lakes and rivers including Lake Pleasant, Alamo Lake, San Carlos Reservoir, and the Verde River varied from 2.6 to 60.6 μg/g wet weight (King et al. 1991). The maximum aluminum concentration in carp from the highly contaminated effluent dominated lower Gila River was 172 μg/g wet weight (King et al. in prep.). Comparing the Yuma Main Drain Site 8 carp data with data from these and three other

Arizona studies (Baker and King 1994, King et al. 1993, Radtke et al. 1988) indicates that carp collected at Site 8 had the highest mean aluminum levels ever recorded in Arizona. These levels indicate an obvious point source of aluminum contamination in the Yuma Main Drain near the San Luis site.

Arsenic: Arsenic was recovered in all fish samples. Wet weight concentrations ranged from 0.06 to 1.70 μg/g (Table 6). The NCBP 85th percentile for arsenic was 0.27 μg/g (Schmitt and Brumbaugh 1990). Elevated arsenic residues (≥ NCBP 85th percentile) occurred most frequently (100%, 5/5) in carp from Site 1, the Colorado River below Laguna Dam (Table 6). Arsenic also exceeded the background level in two of three carp collected from the Wellton Mohawk Canal. A one-way ANOVA however, indicated that there were no among-area differences (P= 0.1497, Table 7).

Beryllium: Striped mullet were the only fish species that accumulated measurable concentrations of beryllium (Table 5). This may reflect the propensity of beryllium to accumulate in plant, but not animal, material (Table 4) and the mullet's primarily herbivorous food habits (Minckley 1979).

Cadmium: Cadmium was detected at 0.06 and 0.07 μg/g wet weight in the two carp samples from Site 9, the Colorado River below Winterhaven (Table 5). The NCBP 85th percentile for cadmium in fish is 0.05 μg/g (Schmitt and Brumbaugh 1990); therefore, where cadmium was detected (only in fish from Site 9), it was present at above background concentrations. This finding and the fact that cadmium was recovered only in clams from Site 9 suggests that there is a point source for cadmium input into the Colorado River upstream from this site.

Chromium: There are no NCBP background data for chromium. Geometric mean chromium concentrations were highest (P= 0.0005, ANOVA) in carp collected from the Yuma Main Drain at San Luis, Site 8 (Table 7). 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). Only one of three Site 8 carp samples and both mullet samples exceeded this concern level.

Copper: Copper was detected in all fish samples and concentrations ranged from 1.88 to 40.62 μg/g dry weight (Table 5). Copper exceeded the NCBP 85th percentile in one-half or more of the samples from Sites 2, 3, 4, 8, and 9 (Table 6). The sites most contaminated by copper (P= 0.0054, ANOVA) were Sites 2, 3, 4, 6, 8, and 9 (Table 7).

Lead: While lead was detected in cattails, lead did not bioaccumulate in tissues of clams or fish (Tables 4 & 5).

Mercury: Mercury was present in only 5 of 29 samples and concentrations were below the NCBP 85th percentile (Table 6).

Nickel: Nickel was recovered in all samples (Table 5). There are no national baseline data with which to compare the Yuma Valley fish samples. Mean levels were greatest in carp from Site 8, the Yuma Main Drain at San Luis ($P = 0.0002$, ANOVA, Table 7).

Selenium: Selenium was recovered in all samples and residues ranged from 0.61 to 2.04 $\mu g/g$ wet weight (Table 6). Selenium exceeded the NCBP 85th percentile in all carp from Sites 1, 2, 4, 5, and 8. The highest mean concentration occurred in carp from Site 1, the Colorado River below Laguna Dam (Table 7). There was little statistical difference in mean selenium concentrations in carp collected from the Colorado River and selenium in carp from irrigation drainwater canals; except that mean selenium concentrations in carp from Site 6 were significantly lower than levels in carp from Sites 1 and 2 ($P=0.0033$, ANOVA, Table 7). Mean levels of selenium in carp from the Yuma Valley were generally lower than levels in carp collected from the upstream portions of the Colorado River between Laguna Dam and Lake Mead (Table 8).

Zinc: Zinc was recovered in all samples and concentrations varied from 41 to 296 $\mu g/g$ dry weight (Table 5). Zinc tends to bioaccumulate more readily in carp than in most fish species (King et al. 1993, Lowe et al. 1985, Schmitt and Brumbaugh 1990) therefore, comparing zinc in carp with the national background level composed of many species of fish would not be a valid comparison. There were no among-area differences in zinc residues ($P = 0.0791$, ANOVA, Table 7)

DISCUSSION

Types of contamination:

Organochlorine pesticides: DDE residues in Yuma Valley fish collected in 1995 are higher than DDE in fish collected a decade earlier. Results of the NCBP 1984-85 monitoring effort revealed that the geometric mean DDE concentration for all fish from all sites nationwide was 0.19 $\mu g/g$ wet weight (Schmitt et al. 1990). The geometric mean DDE residue in Yuma Valley fish collected during this study was 0.25 $\mu g/g$ wet weight (range= 0.05-1.20).

Fish from the down-gradient portions of the Yuma Main Drain (Sites 6 and 8) had the highest levels of DDE ($P = 0.0002$, ANOVA Table 3). Only one fish sample contained concentrations of DDE that exceeded the National Academy of Sciences and National Academy of Engineering (1973) 1.0 $\mu g/g$ DDT and metabolites criterion established for protection of wildlife. Although current mean DDE levels are above background concentrations, overall residues were generally below levels associated with chronic poisoning and reproductive problems (Stickel 1973, Cromartie et al. 1975, Blus 1982, Blus 1984).

Metals: This study identified one “hot spot”, Site 8, the Yuma Main Drain at San Luis where contamination by four elements was especially high. Carp from Site 8 contained exceptionally high levels of aluminum; mean levels were the highest ever recorded in

Arizona. Carp from Site 8 also contained elevated concentrations of chromium, copper, and nickel. Mean chromium levels were also higher in carp from Site 8 than in carp from other Arizona lakes and streams (King et al. 1991, King et al. 1993, King et al. in prep., Lusk 1993). Only carp from one or two collection sites on the effluent dominated Gila River contained higher mean levels of copper and nickel than those detected in carp from Site 8.

Metals of special interest: Because of their ability to bioaccumulate or biomagnify through the aquatic food chain, the trace elements most likely to cause problems in fish and birds are arsenic, cadmium, mercury, and selenium.

Arsenic: Arsenic acts as a cumulative poison (Jenkins 1981) and is listed by the EPA as one of 129 priority pollutants (Keith et al. 1979). Our data confirm observations reported by Jenkins (1981) that the potential for bioaccumulation or bioconcentration of arsenic was moderate for fish and birds and high to very high for mollusks and higher plants. Arsenic whole-body levels above 0.5 $\mu g/g$ are considered to be harmful to fish and predators (Walsh et al. 1977). Only two samples exceeded this concern level. Background arsenic concentrations in biota are usually less than 1 $\mu g/g$ wet weight (3 - 4 $\mu g/g$ dry weight) (Eisler 1988). Only the composite mullet sample collected at the Gila/Colorado confluence exceeded this concern level. Although 39% of the fish samples exceeded NCBP background levels, there appears to be little potential for arsenic related problems in the Yuma Valley sites we sampled.

Cadmium: Cadmium, like arsenic, acts as a cumulative poison (Jenkins 1981) and also is listed by the EPA as a priority pollutant (Keith et al. 1979). Cadmium is very toxic to a variety of fish and wildlife. Cadmium causes behavior, growth, and physiological problems in aquatic life at sublethal concentrations (Rompala et al. 1984). Cadmium tends to bioaccumulate in fish (Rompala et al. 1984), clams (Schmitt et al. 1987), and algae (Munawar et al. 1984), especially in species living in close proximity to sediments contaminated by cadmium. Our data suggest that the potential for bioaccumulation or bioconcentration of cadmium was highest in clams (100%) and bird tissues (100%), and lowest in cattails and fish. None of the fish samples in our study contained cadmium whole-body levels above the 0.5 $\mu g/g$ threshold considered harmful to fish and predators (Walsh et al. 1977).

Mercury: Mercury concentrations are of special concern because mercury can bioconcentrate in organisms and biomagnify through the aquatic food chain. The highest concentration of mercury detected in Yuma Valley fish, 0.10 $\mu g/g$ wet weight, was well within the $\leq$ 1.0 $\mu g/g$ range generally accepted as the concentration in biota from unpolluted environments (Eisler 1987). Mercury concentrations in eggs $\leq$ 1 .O $\mu g/g$ are considered background levels (Ohlendorf 1993); therefore, the 0.17 $\mu g/g$ detected in the common moorhen egg was well within the background range. Overall, mercury did not occur with the frequency or at levels that would cause concern for fish and wildlife populations in the Yuma Valley.

Selenium: Selenium is anessential trace element in animal diets, but it is toxic at concentrations only slightly above required dietary levels. Although selenium concentrations in most fish were above background levels, selenium was generally below toxic concentrations that could affect fish and wildlife. The highest wet weight fish whole body selenium concentration recorded in this study was 2.04 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 7.79 μg/g; therefore, there is minimum potential for selenium toxicity to fish populations in the Colorado River near Yuma and in the Yuma Valley irrigation drainage canals.

In livers of birds from selenium normal environments, selenium usually averages less than 10 μg/g dry weight (Ohlendorf 1993, Schroeder et al. 1988, Skorupa et al. in review). Selenium in livers of red-winged and yellow-headed blackbirds collected in our study were well within the "normal" or background range. However, the 13.57 μg/g dry weight selenium detected in the killdeer liver was within the 10-30 μg/g range that may be considered toxic (Ohlendorf 1993).

Normal or background concentrations of selenium in eggs varies from l-3 μg/g dry weight and levels > 8 μg/g are considered toxic (Ohlendorf et al 1993). Selenium in the yellow-headed blackbird (3.50 μg/g) and common moorhen (4.33 μg/g) eggs was above background but below the toxic levels.

ACKNOWLEDGEMENTS

We thank personnel of the U.S. Geological Survey, Yuma, Arizona, especially Bill Roberts for field support. Appreciation is expressed to Lesley Fitzpatrick and Ted Cordery who reviewed this report and made numerous helpful and constructive comments.

LITERATURE CITED

Andrews, B.J., K.A. King, and D.L. Baker. Contaminant characteristics of Havasu National Wildlife Refuge. U.S. Fish and Wildlife Service Contaminant Report. Arizona Ecological Services Field Office, Phoenix (in prep.)

Baker, D.L. and K. A. King. 1994. Environmental contaminant investigation of water quality, sediment and biota of the upper Gila River basin, Arizona. U.S. Fish and Wildlife Service Contaminant Report. Arizona Ecological Services Field Office, Phoenix. 26 pp.

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

Blus, L.J. 1984. DDE in birds' eggs: comparison of two methods for estimating critical levels. Wilson Bull. 96:268-276.

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

Cromartie, E., W.L. Reichel, L.N. Locke, A.A. Belisle, T.E. Kaiser, T.G. Lamont, B.M. Mulhem, R.M. Prouty, and D.M. Swineford. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1971-72. Pestic. Monit. J. 9: 11-14.

Dahlquist, R.L. and J.W. Knoll. 1978. Inductively coupled plasma - atomic emission spectrometry: Analysis of biological materials and soils for major, trace- and ultra-trace elements. Applied Spectroscopy 32: l-29.

Eisler, R. 1986. Chromium hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85/1.6. 60 pp.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85/1. 10. 90 pp.

Eisler, R. 1988. Arsenic hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85/1. 12. 92 pp.

Environmental Protection Agency. 1984. Test Methods for Evaluating Solid Waste, EPA Publication No. SW-846, 2nd Ed., U.S. EPA: Washington, D.C.

Environmental Protection Agency. 1987. Test Methods for Evaluating Solid Waste, EPA Publication No. SW-846, 3rd Ed., U.S. EPA: Washington, D.C.

Gillespie, R.B. and P.C. Baumann. 1986. Effects of high tissue concentrations of selenium on reproduction by bluegills. Trans. Amer. Fish Soc. 115: 208-213.

Jenkins, Dale W. 1981. Biological Monitoring of Toxic Trace Elements. EPA Report 600/S3-80-090: l-9.

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

Keith, L.H. and W.A. Telliard. 1979. Priority Pollutants: I - a perspective view. Environ. Sci. and Toxicol. 13:416-423.

King, K.A., B.J. Andrews, and C.M. Martinez. Contaminants in fish and wildlife of the lower Gila River, Arizona. U.S. Fish and Wildlife Service Contaminant Report. Arizona Ecological Services Field Office, Phoenix (in prep.)

King, K.A., D. L. Baker, W. G. Kepner and J.D. Krausmann. 1991. Contaminants in prey of bald eagles nesting in Arizona. U.S. Fish and Wildlife Service Contaminant Report. Arizona Ecological Services Field Office, Phoenix, 16 pp.

King, K.A., D. L. Baker, W. G. Kepner and C. T. Martinez. 1993. Trace elements in sediments and fish from National Wildlife Refuges on the Colorado River, Arizona. U.S. Fish and Wildlife Service Contaminant Report. Arizona Ecological Services Field Phoenix, 24 pp.

Lemly, A.D. and G.J. Smith. 1987. Aquatic cycling of selenium: implications for fish and wildlife. U.S. Fish and Wildl. Serv. leaflet No. 12, Washington D.C. 10 pp.

Lowe, T.P., T.W. May, W.G. Brumbaugh, and D.A. Kane. 1985. National contaminant biomonitoring program: concentrations of seven elements in freshwater fish, 1978-81. Arch. Environ. Contam. Toxicol. 14:363-388.

Lusk, J.D. 1993. Selenium in aquatic habitats at Imperial National Wildlife Refuge. MS Thesis. Cooperative Fish and Wildlife Research Unit. University of Arizona. 151 pp.

Minckley, W.L. 1979. Department of Zoology. Aquatic habitats and fishes of the Lower Colorado River, Southwestern United States. Final Report (Contract No. 14-06-300-2529) to the U.S. Dept. Interior, Bur. Reclamation. Boulder City, NV 478 pp.

Munawar, M., R.L. Thomas, H. Shear, P. McKee and A. Murdoch. 1984. An overview of sediment-associated contaminant and their bioassessment. Canad. Tech. Rep. Fish. Aquatic Sci. 1253: 1-136.

National Academy of Sciences, National Academy of Engineering. 1973. Section III- freshwater aquatic life and wildlife, water quality criteria. Ecological Research Series, EPA-R3-73-033: 106-213.

Neter, J. and W. Wasserman. 1974. Applied linear models. Richard D. Irwin, Inc. Homewood, IL.

Ohlendorf, H.M. 1993. Marine birds and trace elements in the temperate North Pacific. ***in*** Vermeer, K.; Briggs, K.T.; Morgan, K.H. ; Siegel-Causey, D. (eds.). The status, ecology, and conservation of marine birds of the North Pacific. Canadian Wildl. Rev. Spec. Publ., Ottawa.

Radtke, D.B., W.G. Kepner, and R.J. Effertz. 1988. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Lower Colorado River Valley, Arizona. California, and Nevada. U.S. Geological Survey, Water-Resources Investigations Report 88-4002, Tucson, Arizona. 77 pp.

Rompala, J.M., F.W. Rutosky and D.J. Putnam. 1984. Concentrations of environmental contaminants from selected waters in Pennsylvania. U.S. Fish and Wildlife Service report. State College, Pennsylvania.

Ruiz, L. and O.E. Maughan. 1992. Contaminant characteristics of the Bill Williams National Wildlife Refuge. M.S. Thesis. Cooperative Fish and Wildlife Research Unit. University of Arizona. 160 pp.

Schmitt, C.J. and W.G. Brumbaugh. 1990. National contaminant biomonitoring program: concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976-1984. Arch. Environ. Contam. Toxicol. 19:731-747.

Schmitt, C.J., S.E. Finger, T.W. May and M.S. Kaiser. 1987. Bioavailability of lead and cadmium from mine tailings to the pocketbook mussel. Proceedings of the workshop on die-offs of freshwater mussels in the U.S., Richard J. Neves, (ed.), U.S. Fish and Wildlife Service, Columbia, MO.

Schmitt, C.J., J.L. Zajicek, and P.H. Peterman. 1990. National contaminant biomonitoring program: residues of organochlorine chemicals in U.S. freshwater fish, 1976-1984. Arch. Environ. Contam. Toxicol. 19:748-78 1.

Schroeder, R.A., D.U. Palawski and J.P. Skorupa. 1988. Reconnaissance investigation of water quality, bottom sediment and biota associated with irrigation drainage in the Tulare Lake Bed Area, Southern San Joaquin Valley, California, 1986-87. U.S. Geol. **SUN.** Water Resour. Invest. Report 88-4001. 86 pp.

Skorupa, J.P., H.M. Ohlendorf, and R.L. Hothem. Interpretive guidelines for field studies of selenium-exposed waterbirds. In review.

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

Walsh, D.F., B.L. Berger and J.R. Bean. 1977. Mercury, arsenic, lead, cadmium, and selenium residues in fish. 1971-1973-National Pesticide Monitoring Program. Pestic. Monit. J. 11: 115-34.

Table 1. Yuma Valley sampling sites and samples collected at each location.

	Collection site[1]								
Sample	1	2	3	4	5	6	7	8	9
Cattail[2]	X	X	X	X		X	X	X	X
Clam[3]	X	X			X	X		X	X
Fish[4]	X	X	X	X	X	X		X	X
Avian[5]	X		X		X				

[1]Collection site locations:
- Site 1 = Colorado River at USGS gauging station below Laguna Dam.
- Site 2 = Drain 1A above confluence with Colorado River.
- Site 3 = Drain 4 above confluence with Colorado River.
- Site 4 = Gila River above confluence with Colorado River.
- Site 5 = Welton Mohawk Canal east of HWY 95.
- Site 6 = Yuma Main Drain down-gradient of East Drain.
- Site 7 = Yuma Main Drain at HWY 95.
- Site 8 = Yuma Main Drain at San Luis.
- Site 9 = Colorado River at Winterhaven USGS gauging station.

[2]Composite sample of roots from three plants per site.

[3]Composite of 12-50 individuals per site.

[4]Common carp were collected from Sites l-6, 8, and 9. Five striped mullet were collected each from Sites 3 and 4 and composited into a single sample per site. Channel catfish and flathead catfish were collected from Sites 6 and 9, respectively.

[5]Yellow-headed blackbird carcass and egg samples were collected from Site 2, red-winged blackbird carcasses from Site 6, and killdeer from Site 4.

Table 2. Organochlorine residues in fish and birds collected in the Yuma Valley, Arizona, 1995

							concentration (µg/g wet weight)[1]				
site No.	Site[2]	Sample'	N[4]	Weight (g)	Prcnt moist	Prcnt lipid	Totl PCB	Dial.	p,p' DDE	HCB	Total chlor
1	CR	C carp	1	1416	70.7	3.63	ND'	ND	0.05	ND	ND
1	CR	C carp	1	1266	72.7	6.22	ND	ND	0.06	ND	ND
2	DR1	C carp	1	1782	76.0	1.90	ND	ND	0.42	ND	ND
2	DR1	C carp	1	1341	75.2	1.89	ND	ND	0.37	ND	ND
3	YMC	C carp	1	482	77.3	1.28	ND	ND	0.11	ND	ND
3	YMC	C carp	1	222	77.3	1.17	ND	ND	0.05	ND	ND
4	GCC	C carp	1	887	75.0	2.07	ND	ND	0.16	ND	ND
4	GCC	C carp	1	2070	73.1	3.35	ND	ND	0.38	ND	ND
5	WM	C carp	1	1936	65.3	12.63	ND	ND	0.08	ND	ND
5	WM	C carp	1	2400	65.0	10.55	ND	ND	0.10	ND	ND
6	YMDN	C carp	1	2330	66.7	lo.82	0.07	0.02	1.20	ND	0.01
6	YMDN	C carp	1	1700	66.1	a.22	0.07	0.02	0.92	ND	0.01
6	YMDN	C carp	1	1131	72.0	5.04	ND	0.01	0.47	ND	ND
6	YMDN	C carp	1	962	71.9	7.61	ND	0.01	0.44	ND	ND
a	SL	C carp	1	738	77.2	a.23	0.05	0.02	0.81	ND	0.01
8	SL	C carp	1	717	76.6	3.05	ND	ND	0.55	ND	ND
9	CRW	C carp	1	1508	71.9	5.59	ND	ND	0.10	ND	ND
9	CRW	C carp	1	1665	66.0	12.86	ND	ND	0.19	ND	ND
3	YMC	Mullet	5	2400	66.3	4.02	ND	ND	0.27	ND	ND
4	GCC	Mullet	5	1275	65.2	10.00	ND	ND	0.16	ND	ND
6	YMDN	C catfish	1	720	75.9	3.86	ND	ND	0.62	ND	0.04
9	CRW	F catfish	1	1715	72.1	6.59	0.13	ND	0.77	ND	ND
2	DR1	YHBBe	4	2.43	82.0	2.92	ND	ND	0.17	ND	ND
2	DR1	YHBBc	5	260	67.5	7.01	ND	ND	0.75	0.04	ND
6	YMDN	RWBBc	8	238	67.9	6.33	ND	0.02	1.20	0.01	ND
4	GCC	Killdeer	7	436	62.9	13.07	0.06	0.02	5.90	0.05	0.01

'Compounds not detected in any samples= alpha BHC, beta BHC, gamma BHC, endrin, heptachlor epoxide. mirex, and toxaphene.

'Site locations:
- CR = Colorado River below Laguna Dam at USGS Gauging Station.
- DR1 = Drain 1A above confluence with Colorado River.
- YMC = Drain 4 above confluence with Colorado River.
- GCC = Gila River above its confluence with the Colorado River.
- WM = Wellton Mohawk Canal east of HWY 95.
- YMDN = Yuma Main Drain down-gradient of East Drain.
- SL = Yuma Main Drain at San Luis
- CRW = Colorado River at Winterhaven USGS Gauging Station.

[3]Sample: C Carp = common carp, mullet = striped mullet, C. catfish = channel catfish, F. catfish= flathead catfish, YHBBe= Yellow-headed blackbird egg, YHBBc = Yellow-headed blackbird carcass, RWBBc = red-winged blackbird carcass, Killdeer = killdeer carcass.

[4]Number if individuals composited per sample.

[5]ND = No residue detected at a lower limit of detection of 0.01 μg/g.

Table 3. Geometric mean DDE residues in common carp collected in the Yuma Valley, Arizona, 1995

	Collection site[1]							
	1	2	3	4	5	6	a	9
Geom. mean	0.055	0.394	0.074	0.247	0.089	0.691	0.667	0.138
Minimum	0.05	0.37	0.05	0.16	0.08	0.44	0.55	0.10
Maximum	0.06	0.42	0.11	0.38	0.10	1.20	0.81	0.19
Signif.[2]	AD	BC	BD	ABC	B	C	CE	ABE

[1]Collection site locations:
- Site 1 = Colorado River at USGS gauging station below Laguna Dam.
- Site 2 = Drain 1A above confluence with Colorado River.
- Site 3 = Drain 4 above confluence with Colorado River.
- Site 4 = Gila River above confluence with Colorado River.
- Site 5 = Welton Mohawk Canal east of HWY 95.
- Site 6 = Yuma Main Drain down-gradient of East Drain.
- Site 7 = Yuma Main Drain at HWY 95.
- Site a = Yuma Main Drain at San Luis.
- Site 9 = Colorado River at Winterhaven USGS gauging station.

[2]Collection sites sharing a letter are statistically similar (ANOVA, $P > 0.05$).

Table 4. Element concentrations in cattails, freshwater clams, and birds from the lower Colorado River and the Yuma Valley irrigation drainwater ditches, Arizona, 1995.

Site[1]		Element concentration, µg/g dry weight[2]																		
No.	Sample[3]	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mg	Mn	MO	Ni	Pb	Se	Sr	V	Zn
1	Cattail	2393	19.50	13.21	71.43	nd[4]	nd	5.26	9.79	6914	nd	3300	235	nd	6.06	4.16	2.71	128	7.64	29
2	Cattail	9548	10.48	20.83	86.31	0.32	nd	11.58	14.64	10167	0.65	6464	2679	nd	9.46	7.93	4.29	133	20.48	38
3	Cattail	11121	2.24	30.26	140.52	0.41	nd	14.48	10.00	13793	nd	9138	1509	nd	9.91	nd	1.55	163	21.90	37
4	Cattail	3805	5.74	12.13	47.22	0.14	nd	11.36	17.57	7633	nd	4047	365	nd	lo.83	nd	<0.83	95	24.56	30
6	Cattail	8010	10.89	15.92	105.76	0.33	nd	12.20	14.29	11204	nd	6963	1325	nd	11.31	3.34	1.57	134	16.07	30
7	Cattail	9938	4.84	la.39	109.32	0.37	nd	21.24	13.42	9317	nd	6770	807	nd	12.67	3.48	1.61	117	17.45	46
a	Cattail	13683	5.46	13.11	135.24	0.50	0.21	17.37	12.95	11746	nd	a540	1473	nd	10.86	3.33	0.95	152	20.73	34
9	Cattail	2284	21.47	19.14	43.88	nd	nd	7.78	ii.98	5474	nd	3241	624	nd	6.64	nd	1.47	97	14.14	31
1	Freshwater clam	249	7.73	2.07	5.59	nd	0.33	1.25	37.70	387	nd	668	30	nd	1.41	nd	6.01	11	0.58	a5
2	Freshwater clam	471	8.15	2.24	6.05	nd	0.32	1.99	25.84	752	nd	1017	64	nd	2.05	nd	7.27	13	1.20	a3
5	Freshwater clam	512	11.53	4.00	14.19	nd	0.46	1.85	35.40	841	nd	1047	51	nd	13.21	nd	a.70	32	1.27	94
6	Freshwater clam	1000	a.21	4.18	21.28	nd	0.34	2.06	21.83	1647	nd	1464	359	nd	15.02	nd	3.83	47	2.03	86
a	Freshwater clam	331	a.57	4.15	6.69	nd	0.31	1.20	23.94	603	nd	791	63	nd	4.84	nd	5.30	13	0.68	68
9	Freshwater clam	393	7.41	2.62	11.13	nd	1.59	3.20	34.85	669	nd	870	52	nd	4.73	nd	5.48	34	1.82	a9
2	YH blackbird liver	5	0.26	<1.16	co.58	nd	0.50	0.94	18.89	936	nd	659	4	2.44	0.48	nd	4.23	0.19	co.15	57
2	YH blackbird egg	7	0.50	3.84	2.28	nd	nd	1.52	3.72	160	nd	480	4	nd	1.23	nd	3.50	14	co.28	48
4	Killdeer liver	21	0.37	1.59	<0.62	nd	1.80	1.01	22.23	851	0.56	638	18	2.32	0.43	nd	13.57	0.74	<0.15	76
6	RW blackbird liver	12	0.19	1.23	<0.56	nd	0.87	0.87	15.75	700	nd	619	4	2.19	0.45	nd	4.06	0.54	co.14	54
6	C. Moorhen egg	<4.94	0.45	2.87	3.33	nd	nd	2.39	3.06	154	0.17	421	6	nd	1.49	nd	4.33	19	<0.25	50

‘Collection site locations:
Site 1 = Colorado River at USGS gauging station below Laguna Dam.
Site 2 = Drain 1A above confluence with Colorado River.
Site 3 = Drain 4 above confluence with Colorado River.
Site 4 = Gila River above confluence with Colorado River.
Site 5 = Welton Mohawk Canal east of BWY 95.
Site 6 = Yuma Main Drain down-gradient of East Drain.
Site 7 = Yuma Main Drain at BWY 95.
Site a = Yuma Main Drain at San Luis.
Site 9 = Colorado River at Winterhaven USGS gauging station.

‘EPA designated priority pollutant elements are underlined.

‘Samples: Cattail, freshwater clam (*Corbicula fluminea*), YH blackbird = yellow-headed blackbird, RW blackbird = red-winged blackbird, C. moorhen = common moorhen.

[4]nd = no residue detected. Lower limits of detection = Be ≤0.11, Cd ≤0.52, Hg ≤0.22 µg/g for vegetation and ≤0.12 µg/g for tissue, Mo 13.39 and Pb ≤4.23 µg/g for vegetation and ≤2.79 µg/g for tissue.

Table 5. Element concentrations in fish from the lower Colorado River and the Yuma Valley irrigation drainwater ditches, Arizona, 1995.

Site’		Element concentration, µg/g dry weight’																		
NO.	Sample³	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
1	C. carp	173	1.68	1.84	13.13	nd’	nd	1.53	3.77	420	nd	1191	42	nd	0.88	nd	7.79	146	0.73	187
1	C. carp	69	2.03	1.40	12.20	nd	nd	1.76	3.12	212	nd	1351	22	nd	1.17	nd	5.05	249	0.46	156
1	C. carp	212	0.96	<1.36	16.45	nd	’nd	2.16	2.77	350	nd	1652	25	nd	0.65	nd	6.21	275	0.72	176
1	C. carp	196	1.65	2.96	11.14	nd	nd	1.88	4.54	271	nd	1396	46	nd	0.76	nd	4.36	188	0.74	150
1	C. carp	134	1.43	1.99	10.60	nd	nd	1.87	3.60	226	nd	1506	26	nd	0.65	nd	4.53	276	0.42	187
2	C. carp	237	1.04	2.76	11.71	nd	nd	2.00	4.50	403	nd	1554	34	nd	0.90	nd	4.75	175	0.73	238
2	C. carp	193	0.96	2.25	25.15	nd	nd	2.50	4.81	293	0.22	1569	32	nd	1.02	nd	3.46	212	0.72	196
2	C. carp	46	0.29	2.75	12.82	nd	nd	2.46	2.83	231	nd	1780	18	nd	0.87	nd	5.50	272	0.25	263
2	C. carp	295	1.25	2.99	20.85	nd	nd	2.34	5.28	365	nd	1956	27	nd	0.73	nd	7.74	328	0.75	236
3	C. carp	114	0.62	3.57	6.26	nd	nd	2.70	5.64	225	nd	1899	30	nd	0.82	nd	4.01	243	0.30	168
3	C. carp	17	0.70	2.82	7.51	nd	nd	2.33	6.03	89	nd	1856	24	nd	0.64	nd	2.66	255	co.21	185
3	C. carp	704	0.80	2.69	19.92	nd	nd	3.19	5.80	760	nd	2496	101	nd	1.22	nd	3.60	276	1.30	257
3	C. carp	167	0.48	3.85	8.85	nd	nd	3.28	3.83	400	0.12	2128	43	nd	1.53	nd	2.42	227	0.33	288
4	C. carp	44	0.56	3.45	7.00	nd	nd	0.76	5.52	119	0.20	1712	17	nd	0.78	nd	3.56	236	0.50	220
4	C. carp	130	0.82	1.74	3.24	nd	nd	1.68	3.90	230	0.20	1257	15	nd	1.75	nd	3.12	155	0.57	102
5	C. carp	72	1.12	1.58	6.95	nd	nd	0.64	2.86	188	nd	1006	9	nd	0.72	nd	4.96	139	0.29	238
5	C. carp	486	0.60	1.85	0.77	nd	nd	1.87	2.97	663	nd	1151	20	nd	1.05	nd	3.77	113	1.29	139
5	C. carp	90	1.19	3.44	0.27	nd	nd	1.71	2.62	224	nd	1112	9	nd	0.76	nd	5.34	144	0.40	156
6	C. carp	04	1.02	1.31	4.32	nd	nd	1.49	2.06	173	nd	1129	19	nd	0.50	nd	3.40	155	0.21	296
6	C. carp	102	0.50	1.90	4.07	nd	nd	1.45	1.88	162	nd	1106	12	nd	0.49	nd	2.36	137	0.19	251
6	C. carp	44	0.71	2.73	3.64	nd	nd	2.19	3.35	132	nd	1282	18	nd	0.95	nd	1.82	145	CO.18	194
6	C. carp	73	1.64	1.88	3.33	nd	nd	1.47	3.12	225	nd	1110	16	nd	0.65	nd	3.10	111	<0.18	279
8	C. carp	681	0.53	2.14	9.29	nd	nd	3.54	40.62	686	nd	1796	74	nd	5.75	nd	3.76	185	1.15	211
8	C. carp	1118	1.10	3.59	15.09	nd	nd	3.38	7.24	1092	nd	1965	117	nd	2.35	nd	3.29	215	1.89	195
8	C. carp	885	0.81	3.90	10.30	nd	nd	4.27	5.56	709	nd	1868	91	nd	2.24	nd	3.72	178	1.62	239
9	c. carp	32	0.93	<1.42	7.22	nd	0.22	1.87	3.24	170	0.09	1470	10	nd	0.64	nd	3.74	175	0.37	200
9	C. carp	31	0.71	1.36	5.35	nd	0.21	1.54	3.35	126	0.12	1174	9	nd	0.54	nd	2.71	144	0.56	161
3	Mullet	2641	2.70	1.58	35.31	0.11	nd	4.72	6.41	3264	nd	3442	424	nd	2.52	nd	2.08	149	5.22	42
4	Mullet	1557	4.89	3.02	47.99	0.06	nd	3.42	8.22	2365	nd	2075	237	nd	2.03	nd	4.54	178	6.75	41
6	F. catfish	210	0.75	3.20	2.68	nd	nd	1.91	12.70	216	nd	1365	16	nd	2.25	nd	3.20	121	0.43	57
9	C. catfish	62	0.39	1.63	2.86	nd	nd	1.70	2.29	137	0.34	1168	6	nd	0.53	nd	2.37	130	0.48	55

Table 6. Comparison of element concentrations in fish from the Yuma Valley, Arizona with the National Contaminant Biomonitoring Program (NCBP) 85th percentile (Schmitt and Brumbaugh 1990)

Site No.	Site Name[1]	Sample[2]	As	Cu	Hg	Se	Zn
			Element concentration (µg/g wet wt)				
NCBP 85 Percent			0.27	1.00	0.17	0.73	34.2
1	CR	Carp	0.44	0.66	ND	2.04	49.1
1	CR	Carp	0.59	0.91	ND	1.47	45.3
1	CR	Carp	0.28	0.81	ND	1.82	51.6
1	CR	Carp	0.45	1.24	ND	1.19	40.9
1	CR	Carp	0.38	0.96	ND	1.20	49.6
2	DR1	Carp	0.25	1.08	ND	1.14	57.2
2	DR1	Carp	0.25	1.25	0.06	0.90	51.0
2	DR1	Carp	0.06	0.59	ND	1.15	55.0
2	DR1	Carp	0.31	1.31	ND	1.92	58.6
3	YMC	Carp	0.14	1.28	ND	0.91	38.2
3	YMC	Carp	0.16	1.38	ND	0.61	42.3
3	YMC	Carp	0.20	1.45	ND	0.90	64.2
3	YMC	Carp	0.11	0.87	0.03	0.55	65.3
4	GCC	Carp	0.14	1.38	0.05	0.89	55.1
4	GCC	Carp	0.22	1.08	0.05	0.84	27.4
5	WM	Carp	0.39	0.99	ND	1.72	82.5
5	WM	Carp	0.21	1.04	ND	1.32	48.8
5	WM	Carp	0.35	0.77	ND	1.57	45.9
6	YMDN	Carp	0.20	0.94	ND	0.51	54.3
6	YMDN	Carp	0.46	0.88	ND	0.87	78.3
6	YMDN	Carp	0.34	0.95	ND	1.16	98.5
6	YMDN	Carp	0.17	0.64	ND	0.80	85.2
8	SL	Carp	0.12	9.18	ND	0.85	47.6
8	SL	Carp	0.25	1.65	ND	0.75	44.5
8	SL	Carp	0.19	1.13	ND	0.87	56.0
9	CRW	Carp	0.26	0.91	0.02	1.05	56.2
9	CRW	Carp	0.24	1.14	0.04	0.92	54.8
3	YMC	Mullet	0.91	2.16	ND	0.70	14.2
4	GCC	Mullet	1.70	2.86	ND	1.58	14.3
6	MDN	F. catfish	0.18	3.06	ND	0.77	13.7
9	CRW	C. catfish	0.11	0.64	0.10	0.66	15.3

[1]Site locations:
- Site 1 = Colorado River at USGS gauging station below Laguna Dam.
- Site 2 = Drain 1A above confluence with Colorado River.
- Site 3 = Drain 4 above confluence with Colorado River.
- Site 4 = Gila River above confluence with Colorado River.
- Site 5 = Welton Mohawk Canal east of HWY 95.
- Site 6 = Yuma Main Drain down-gradient of East Drain.
- Site 8 = Yuma Main Drain at San Luis.
- Site 9 = Colorado River at Winterhaven USGS gauging station.

[2]Sample: Carp = common carp, Mullet = striped mullet, F. catfish = flathead catfish, C. catfish = channel catfish. Carp and catfish are individual whole body samples. Five mullet were cornposited into a single sample at sites 3 and 4.

Table 7. Metalloids in common carp collected from the lower Colorado River and irrigation drains in the Yuma Valley, Arizona, 1995

Site No.[3]	N[4]	Aluminum	Arsenic	Chromium	Copper	Nickel	Selenium	Zinc
		Geometric mean concentration,[1] µg/g dry weight, (n)[2] / range						
1	5	146 (5) AB[5] 69-212	1.51 (5) A 0.96-2.03	1.83 (5) ABC 1.53-2.16	3.51 (5) A 2.77-4.54	0.80 (5) A 0.65-1.17	5.45 (5) A 4.36-7.79	170 (5) A 150-187
2	4	158 (4) AB 46-295	0.76 (4) A 0.26-1.25	2.32 (4) ABC 2.00-2.50	4.24 (4) AB 2.83-5.28	0.87 (4) A 0.73-1.02	5.14 (4) A 3.46-7.74	232 (4) A 196-263
3	4	123 (4) AB 17-704	0.64 (4) A 0.48-0.80	2.87 (4) ADC 2.33-3.28	5.24 (4) AB 3.83-6.03	0.99 (4) A 0.64-1.53	3.10 (4) AB 2.42-4.01	219 (4) A 168-288
4	2	76 (2) AB 44-130	0.68 (2) A 0.56-0.82	1.13 (2) B 0.76-1.68	4.64 (2) AB 3.90-5.52	1.16 (2) AB 0.78-1.75	3.33 (2) AB 3.12-3.56	150 (2) A 102-220
5	3	151 (3) AB 72-486	0.93 (3) A 0.60-1.19	1.27 (3) B 0.64-1.87	2.81 (3) A 2.62-2.97	0.83 (3) A 0.72-1.05	4.64 (3) AB 3.77-5.34	173 (3) A 139-238
6	4	72 (4) A 44-102	0.88 (4) A 0.50-1.64	1.62 (4) AB 1.45-2.19	2.73 (4) A 1.88-3.35	0.62 (4) A 0.49-0.95	2.61 (4) B 1.82-3.48	252 (4) A 194-296
8	3	877 (3) B 681-1118	0.78 (3) A 0.53-1.10	3.71 (3) CD 3.38-4.27	11.78 (3) B 5.56-40.6	3.11 (3) B 2.24-5.75	3.58 (3) AB 3.29-3.76	214 (3) A 195-211
9	2	31 (2) A 31-32	0.81 (2) A 0.71-0.93	1.70 (2) BD 1.54-1.87	3.29 (2) AB 3.24-3.35	0.59 (2) A 0.54-0.64	3.18 (2) AB 2.71-3.74	179 (2) A 161-200

[1]All elements are EPA designated priority pollutants except aluminum. Other priority pollutants including antimony, beryllium, cadmium, lead, silver, and thallium were not detected in any samples.

[2]n = number of samples that contained detectible concentrations.

[3]Collection site locations:
- Site 1 = Colorado River at USGS gauging station below Laguna Dam.
- Site 2 = Drain 1A above confluence with Colorado River.
- Site 3 = Drain 4 above confluence with Colorado River.
- Site 4 = Gila River above confluence with Colorado River.
- Site 5 = Welton Mohawk Canal east of HWY 95.
- Site 6 = Yuma Main Drain down-gradient of East Drain.
- Site 7 = Yuma Main Drain at BWY 95.
- Site 8 = Yuma Main Drain at San Luis.
- Site 9 = Colorado River at Winterhaven USGS gauging station.

[4]N = number of samples analyzed.

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

Table 8. Comparison of selenium concentrations (µg/g wet weight) in whole carp collected from various Arizona locations.

Location	Year	N	Mean	Range	Reference
Havasu National Wildlife Refuge	1994	3	2.17	1.8-2.4	Andrews et al. (in prep.)
Imperial National Wildlife Refuge	1991	16	2.10	1.0-3.5	Lusk 1993
National Wildlife Refuges (n=4)	1988-89	4	1.75	1.2-2.4	King et al. 1993
Lower Colorado River Valley	1986	31	1.49	0.6-4.0	Radtke et al. 1988
Yuma Valley Colorado River	1995	7	1.38	0.9-2.0	this study[1]
Yuma Valley Irriga. drainwater	1995	20	1.01	0.6-1.9	this study[2]
Lower Gila River	1994-95	28	0.64	0.1-1.5	King et al. (in prep.)
Bill Williams River National Wildl. Ref.	1991	7	0.63	0.5-0.9	Ruiz and Maughan 1992
Interior Arizona[3]	1988	7	0.55	0.4-1.0	King et al. 1991

[1]Colorado River Sites 1 & 9.

[2]Irrigation drainwater sites 2, 3, 4, 5, 6, and 8.

[3]Includes Lake Pleasant, Alamo Lake, Roosevelt Lake, San Carlos Reservoir, Verde and Salt Rivers.