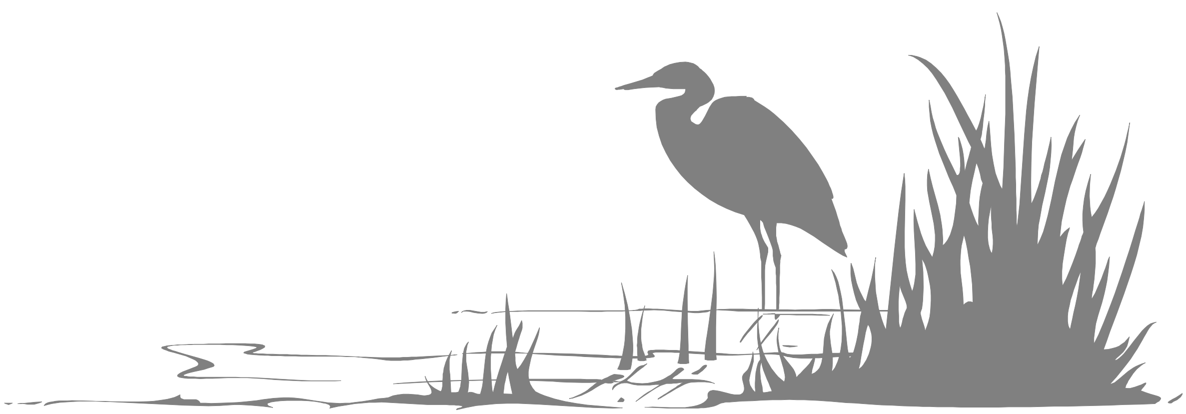
U.S. Fish and Wildlife Service
Region 2
Contaminants Program

Contaminants in Potential Prey of the Yuma Clapper Rail: Arizona and California, USA, and Sonora and Baja, Mexico, 1998-1999

by

Kirke A. King, Anthony L. Velasco,
Jaqueline Garcia-Hernandez[1], Brenda J. Zaun[2],
Jackie Record[3], and Julia Wesley[4]



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

April 2000

ABSTRACT

Potential Yuma clapper rail (*Rallus longirostris yumanensis*) food items including invertebrates and small fish were collected in 1998-1999 along the lower Colorado River and in rail habitats in California, Arizona, and the Colorado River delta in Mexico to assess contaminant concentrations and potential hazards of contaminants to rails. DDT-family compounds were the only organochlorine insecticides detected, and residues ($\leq$ 1.01 ppm) generally were below levels known to affect all but the most sensitive species of aquatic birds. Five metals including aluminum, barium, magnesium, selenium, and zinc were recovered in one or more samples at concentrations potentially toxic to birds. Elevated concentrations of selenium (>3.0 ppm dry weight) were present in 95% (36/38) of the samples. The mean selenium concentration in crayfish, the rail's primary food item, collected from eight U.S. sites was 8.91 ppm dry weight (5.78-15.5), almost three-times the potentially toxic level. Crayfish from the Ciénega de Santa Clara, an extensive marsh that contains the largest known population of Yuma clapper rails in North America, contained 4.21 ppm selenium, a level lower than those in the U.S., but still above the concern threshold. Concentrations of selenium reported in this study were generally two- to three-times higher than levels reported in similar samples collected from the same locations a decade earlier. If selenium concentrations continue to increase, Yuma clapper rail populations, as well as those of other invertebrate- and fish-eating birds could experience selenium-induced reproductive failure and subsequent population declines.

---

[1]Present address: Department of Soil, Water and Environmental Science, Environmental Research Laboratory, University of Arizona, Tucson, Arizona 85701-6985

[2]Present address: U.S. Fish and Wildlife Service, Cibola National Wildlife Refuge, Rt 2, Box 138, Cibola, AZ 85328

[3]Present address: U.S. Fish and Wildlife Service, Imperial National Wildlife Refuge, P.O. Box 72217, Martinez Lake, AZ 85365

[4]Present address: Weiherdammstrasse 24, 78176 Blumberg, Germany

The U.S. Fish and Wildlife Service has been evaluating the status of the Yuma clapper rail (*Rallus longirostris yumanensis*) to determine if reclassification from endangered to threatened, or to delist the rail is appropriate. Concerns about habitat loss along the Colorado River and potential contaminant impacts has resulted in no action to date. The contaminants issue arose through the discovery of elevated selenium concentrations in Yuma clapper rails found dead during a 1985-87 life history study (Eddleman 1989). Numerous investigations since then have documented high levels of selenium throughout the lower Colorado River ecosystem (Rusk 1991, King et al. 1993, Lusk 1993, Welsh and Maughan 1993, Martinez 1994, Villegas 1997, Prieto 1998). The Service's Arizona Ecological Services Field Office, Division of Environmental Contaminants, undertook a study in 1998-99 to gather and interpret data on pollutant levels in potential Yuma clapper rail food items. This report summarizes those findings.

STUDY AREA

Portions of the lower Colorado River from Havasu National Wildlife Refuge (NWR) to the Colorado River delta in Baja and Sonora, Mexico served as our primary study area. To determine specific collection sites, we examined results of Yuma clapper rail surveys (1990-1998) to assess areas where rail concentrations were greatest and focused our collecting efforts on those sites. In addition to sampling along the Colorado River, we also collected samples from other areas where rails were known to be relatively numerous including the Sonny Bono Salton Sea NWR, California's Imperial Wildlife Area located near the Salton Sea, and the lower Gila River. Since the largest population of Yuma clapper rails in North America is found in Sonora, Mexico (Piest and Campoy 1998, Hinojosa-Huerta pers. comm.), we collected additional samples in several wetlands in Sonora and along the Río Hardy in Baja, California. Precise collection locations, local names, latitude and longitude are listed in Table 1. Latitude and longitude coordinates were determined using a Rockwell Avionics Precision Lightweight GPS receiver. A brief description of each study area follows:

Sonny Bono Salton Sea NWR (Salton Sea NWR) and the Imperial Wildlife Area: These areas located near California's Salton Sea contain perhaps the densest population of Yuma clapper rails in the U.S. (USFWS unpub. data). Samples collected from the Salton Sea NWR were taken from the Refuge's Hazard 9 unit. Samples from the Imperial Wildlife Area were collected from the Wister Unit.

Gila River at HWY 85: This area does not contain a particularly large population of Yuma clapper rails, but it is important in that it is located well away from the main Colorado River population and may represent a remnant of a larger population that occupied much of the lower Gila River riparian ecosystem. There is a major concern for the welfare of all waterbirds in the lower Gila River related to the potential impact of environmentally significant residues of organochlorine insecticides (King et al. 1997). Samples were collected from the Gila River at HWY 85 bridge. This area is located at the eastern end of the concentration of rails resident in the Arlington Bend area.

Havasu NWR: Relatively high numbers of rails have been reported from Havasu NWR in recent years (Table 2). Samples were taken from Beal Lake, and from an area in Topock Gorge known as Disneyland Channel. Both areas contained extensive stands of cattails that represent suitable Yuma clapper rail nesting habitat.

Cibola NWR: Samples were collected from three areas on the refuge, Cibola Lake, the Growout Pond, and Three Fingers Lake. Each of these sites is a backwater lake of the Colorado River and potentially contains high selenium concentrations. Yuma clapper rails have been documented in or near all three sites on annual surveys.

Imperial NWR: Samples were collected from three backwater lakes, Butler, McAllister, and Martinez and from one managed impoundment called Ducks Unlimited #2 (DU#2). Samples were also taken from waters adjacent to a Colorado River sandbar.

Mittry Lake Wildlife Area: The Mittry Lake Wildlife Area designated as 'Yuma Proving Ground' on annual Yuma clapper rail surveys is an extensive cattail marsh located at the north end of Mittry Lake. Samples were collected near the middle of the marsh between the Colorado River and the Gila Main Canal. This site was formerly Department of Defense property which was transferred to Bureau of Reclamation and then to Bureau of Land Management (BLM). Fish and wildlife in the area are currently managed by the Arizona Game and Fish Department (AGFD) under cooperative agreement with BLM.

Río Hardy at Campo Mosqueda and El Mayor: Before extensive damming and diversion of water from of the Colorado River, the Colorado River delta in Baja and Sonora, Mexico may have been the center of abundance for the Yuma clapper rail (Piest and Campoy 1998). Currently, there is only about 100-200 ha of suitable rail habitat remaining in the Río Hardy wetlands (DeStefano and Shaw 1999). The 'headwaters' of the Hardy is a series of irrigation canals and agricultural drains; therefore, the Río Hardy acts as an irrigation sump for much of the farmland in the Mexicali Valley. We sampled a small backwater marsh west of Campo Mosqueda and another east of El Mayor.

Río Colorado: Relatively little cattail marshland remains along the Colorado River in Baja and Sonora. A small area of cattails located approximately 2 km northeast of Baja California (BC) Highway 4 and the adjacent railroad tracks was sampled.

El Doctor: The El Doctor wetlands are located in the southeastern portion of the delta near the Ciénega de Santa Clara. These isolated wetlands are fed by natural springs that support a 750 ha marsh (Zengel et al. 1995). We collected a single sample of mixed fish from this location.

MODE Drain: The Main Outlet Drain Extension (MODE) is an extension of the Wellton-

Mohawk Canal that delivers water to, and drains water from, farm lands in Arizona and Sonora. The MODE is a major source of fresh to brackish water for the Ciénega de Santa Clara. The lower reaches of the drain are surrounded by a dense cattail marsh which represents the northern reaches of the Ciénega. To assess contaminant input to the Ciénega via this agricultural drain, samples were collected directly from the MODE near the end of the service road that parallels the canal.

La Flor del Desierto: The canal leading from a natural spring called La Flor del Desierto to the eastern edge of the Ciénega de Santa Clara represents a relatively minor water source for the Ciénega. We sampled this canal to determine potential contaminant inputs from this source.

Ciénega de Santa Clara: The Ciénega de Santa Clara is a 4,200 ha wetland located on the Colorado River delta east of the mouth of the Colorado River (Glenn et al. 1996, Valdes-Casillas et al. 1998). The Ciénega is the largest freshwater wetland remaining in the lower Colorado River delta (Glenn et al. 1992). Most of the original marsh disappeared as a result of dam construction and water diversion along the Colorado River early in the 1900s. An influx of agricultural wastewater has restored marsh habitat in the northern part of the Ciénega in recent decades (Piest and Campoy 1998). The Ciénega currently provides habitat for the largest population of Yuma clapper rails in North America (Piest and Campoy 1998, Hinojosa-Huerta pers. comm.). Samples were collected at only one point in the Ciénega, at Fisherman's Camp near the community of Ejido Johnson, and may not be representative of contaminant concentrations throughout the marsh.

METHODS

<u>Sample collections</u>: Field work in Mexico extended from March 2-5, 1998. Samples were collected from U.S. locations between June 7 and August 12, 1999. Because the primary prey of the Yuma clapper rail is aquatic invertebrates, particularly crayfish, and small fish (Ohmart and Tomlinson 1977, Eddleman 1989), we focused on collecting crayfish (*Procambaris clarkii*) and mosquitofish (*Gambusia affinis*) at each location. At those sites where we were unable to collect a sufficient number of crayfish or mosquitofish, other species were substituted. Invertebrates and fish were taken by minnow trap, seine, and dip net. Samples for organochlorine pesticide analysis were placed in chemically cleaned jars, and those for metals analysis were stored in plastic bags. Samples were placed on wet ice in the field then later sorted, counted, and weighed in the laboratory before being stored in a commercial freezer until chemical analysis.

<u>Chemical analyses</u>: Invertebrates and fish were analyzed for organochlorine compounds at the Service's Patuxent Analytical Control Facility (PACF), Laurel, Maryland. Because previous studies conducted in the same general area revealed relatively low levels of organochlorine compound contamination, we analyzed fewer samples for organochlorines

than metals. The organochlorine scan included 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). The lower limit of quantification was 0.01 ppm (parts per million) for most organochlorine insecticides and 0.05 ppm for toxaphene and PCBs. Organochlorine compounds are expressed in ppm wet weight. Organochlorine compounds are primarily stored in body lipids; therefore, lipid levels are also presented for each sample.

The metals scan included aluminum, arsenic, beryllium, boron, cadmium, chromium, copper, iron, lead, mercury, molybdenum, nickel, selenium, strontium, vanadium, and zinc. Samples were analyzed for metals at Research Triangle Institute, Raleigh, North Carolina. Details of chemical methodology were identical to those reported by King et al. (1997). Blanks, duplicates, and spiked samples were used to maintain laboratory quality assurance and quality control (QA/QC). QA/QC was monitored by PACF. Analytical methodology and reports met or exceeded the Service's QA/QC standards. The lower limits of analytical quantification for each element varied from sample to sample and are listed in the appropriate tables. Concentrations of metals are expressed in ppm dry weight. Percent moisture is presented to permit dry weight to wet weight conversions.

RESULTS AND DISCUSSION

Nesting populations of the Yuma clapper rail in the United States are found primarily along the lower Colorado River below Davis Dam and at the Salton Sea (Powell 1990). Results of annual surveys conducted in the U.S. from 1990 to 1998 were highly variable and estimates of rail numbers, based on vocalization responses, varied from 553 individuals in 1998 to 1076 in 1993 (USFWS unpub. data) (Table 2). Until recently, little was known about population numbers in Mexico. The most thoroughly studied Mexican area in recent years is the Ciénega de Santa Clara where rail population estimates ranged from 5,300 to 6,000 individuals in 1998-1999 (Piest and Campoy 1998, Hinojosa-Huerta pers. comm.).

Observations of foods eaten by Yuma clapper rails are limited to examination of stomach contents of 16 individuals collected in June 1971 (Ohmart and Tomlinson 1977), identification of undigested material in regurgitated pellets (Eddleman 1989), and observations of foraging birds (Todd 1986). Stomachs of rails collected in the Colorado River area above Laguna Dam contained 94.7% crayfish by volume (Ohmart and Tomlinson 1977). Stomachs of four birds from the Colorado River delta contained water beetles (Hydrophilidae) (56.5%) and fish (31.8%) with the remainder consisting of miscellaneous invertebrates and plant material. Contents of 16 cast pellets, nine from Topock Gorge and seven from Mittry Lake, contained only crayfish remains. Todd (1986) observed a Yuma clapper rail eating small fish and tadpoles. Our sampling of crayfish, small fish, tadpoles, and invertebrates was representative of the Yuma clapper rail's diet throughout its range.
<u>Organochlorines</u>: DDT-family insecticides were the only organochlorine compounds

detected. DDE was recovered in 12 of 24 samples and residues ranged from 0.03 to 1.01 ppm wet weight (Table 3). Residues of DDE detected in crayfish collected from the Salton Sea NWR (0.19 ppm wet weight) and the Imperial Wildlife Area (0.35 ppm wet weight) were higher than concentrations reported by Roberts (1996) for crayfish collected in 1994 from the same areas. In Roberts' (1996) sampling effort, DDE was not detected in 16 of 19 samples, and the maximum DDE residue was 0.045 ppm.

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 ppm wet weight DDE in the diet 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 ppm wet weight in brown pelicans (*Pelecanus occidentalis*) (Blus et al. 1977, 1979, Blus 1996), ≤0.39 ppm in bald eagles (Wiemeyer et al. 1978), and 0.2 - 1.9 ppm in osprey (*Pandion haliaetus*) (Wiemeyer et al. 1975). There is a wide range among species in sensitivity to DDE-induced eggshell thinning, and little is known about the relative sensitivity of the Yuma clapper rail.

Ten samples contained DDE above the 0.15 ppm threshold associated with shell thinning in brown pelicans. The highest level, 1.01 ppm was recovered in a sample of mosquitofish collected from the Gila River (Table 3). None of the samples from the U.S. portion of the Colorado River contained >0.15 ppm DDE. DDE was detected most consistently in crayfish and fish from the Salton Sea and from Mexico. However, DDE was not present in samples from the Ciénega de Santa Clara, the area with a relatively large population of Yuma clapper rails.

The use of DDT in Arizona was restricted in 1968 and totally suspended in 1969 (Ware 1974). In Mexico, the use of DDT declined significantly during the 1970s but continued to be used in agriculture at least until 1978 (Mora et al. in review). During the 1980s, the use of DDT was restricted to wetlands to control mosquitos as vectors of malaria; DDT was no longer applied to croplands. In fish tissue, the parent compound, DDT, rapidly metabolizes to DDE; therefore, the occurrence of DDT in 1998-99 fish samples is of concern because it suggests that fish may have been recently exposed to that compound. DDT was recovered in one of 17 U.S. samples and in 4 of 7 samples from Mexico (Table 3).

<u>Metals</u>: Data for all metals recovered in potential rail food items are presented in Table 4. The elements most likely to be toxic to birds include cadmium, lead, mercury, and selenium (Eisler 1985, 1987, Scheuhammer 1987, Eisler 1988, Ohlendorf et al. 1988).

C*admium*: Cadmium was detected in 17 of 38 samples and concentrations ranged from 0.10 to 0.25 ppm dry weight (Table 4). None of the samples contained cadmium at concentrations that approached the potential toxic threshold of 0.4 ppm (Eisler 1985). Cadmium, by itself, apparently does not pose a potential threat to the survival and reproduction of the Yuma clapper rail in the areas sampled.

Lead: Lead has been known for centuries to be a cumulative metabolic poison. Acute exposure to environmental lead (as opposed to exposure to lead shot) is seldom a current issue, but continuous exposure to low concentrations is still of concern (Eisler 1988). Although lead is concentrated by biota from water, there is no evidence that environmental lead is transferred through the food web (Eisler 1988). Lead concentrations tend to decrease with increasing trophic level in the aquatic food base. Lead was present in 19 of 38 samples. Levels ranged from 0.34 to 6.92 ppm dry weight. The maximum concentration of lead (6.92 ppm) was well below the potential toxic threshold of >100 ppm (Scheuhammer 1987) in food chain organisms of fish-eating birds.

Mercury: Mercury concentrations are of special concern because mercury can bioaccumulate 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 (Eisler 1987). Mercury was recovered in 68% (26 of 38) of the samples. Concentrations ranged from 0.05 to 1.23 ppm dry weight. 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 (≈ 0.33 ppm dry weight), 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" (≈1.6 ppm dry weight). Seven of 38 (18%) invertebrate and fish samples approached or exceeded the most conservative threshold of 0.33 ppm dry weight mercury proposed by Eisler (1987). None of the samples contained mercury concentrations that exceeded the toxicity threshold suggested by Walsh et al. (1977).

Selenium: 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 ppm dry weight (Ohlendorf et al. 1990). The toxicity threshold for selenium is remarkably similar for fish and birds (Lemly 1995, 1996). The generally accepted toxic threshold in fish and other aquatic food items consumed by birds is 3 ppm dry weight (Lemly and Smith 1987, Lemly 1993). Twenty-one of twenty-two (95%) lower Colorado River invertebrate and fish samples contained selenium in excess of 3 ppm dry weight (Table 4). All samples collected in the Salton Sea area, Baja, and Sonora approached or exceeded the toxic threshold and three of four samples from the Gila River contained elevated (≥ 3 ppm) concentrations of selenium.

Selenium concentrations in crayfish found in this study (4.21 - 15.5 ppm dry weight) were about two- to three-times higher than those reported by Kepner (unpub. data), Rusk (1991), Welsh and Maughan (1993), Roberts (1996), and Prieto (1998) for crayfish collected from the same general locations almost a decade earlier, but similar to levels reported by Lusk (1993) for crayfish from Imperial NWR (Table 5). Crayfish collected in 1987 from Topock Gorge and Mittry Lake contained 3.7 and 4.6 ppm dry weight selenium (Kepner unpub. data). Rusk (1991) reported a mean of 2.24 ppm dry weight selenium (range 1.51 - 4.99 ppm) in crayfish collected in 1990 from six lower Colorado River backwaters from Havasu NWR to Mittry Lake. There were no statistically significant differences among areas. Welsh and Maughan (1993) reported 1.21 ppm dry weight selenium in crayfish samples from Cibola NWR seepage lakes and 2.45 ppm in crayfish from backwater lakes. Crayfish from the Salton Sea NWR and California's Imperial Wildlife Area contained a mean of 2.16 ppm dry weight selenium (Roberts 1996). Relatively 'clean' crayfish containing 0.3 to 0.7 ppm dry weight selenium when placed in a Colorado River backwater bioconcentrated selenium to a mean of 2.73 ppm (range = 1.4-4.7 ppm) in as little as four weeks (Prieto 1998).

Lusk (1993) recorded higher levels of selenium in crayfish, up to 35.8 ppm dry weight, than did Kepner (unpub. data), Rusk (1991), Welsh and Maughan (1993), Roberts (1996) and Prieto (1998). Crayfish collected in 1991 from seepage lakes on Imperial NWR contained 2.89 ppm dry weight selenium and crayfish from backwater areas contained an average of 11.75 ppm (Lusk 1993). The overall mean concentration of selenium in crayfish for all Imperial NWR locations was 7.70 ppm. Mosquitofish contained 6.2 ppm dry weight selenium (range = 1.6 - 13.0). In Lusk's 1991 study, ninety-four percent of whole fishes and invertebrates (n=185) contained concentrations of selenium that exceeded 3 ppm dry weight selenium, the maximum concentration suggested by the USFWS to protect aquatic birds from chronic selenium toxicity (Lusk 1993).

Other potentially toxic elements: Few other elements exceeded the toxic threshold (Table 4). Aluminum (1,267 ppm dry weight) was detected in a sample of bullfrog tadpoles from the Colorado River at the Mittry Lake Wildlife Area at 1.6-times the 800 ppm concern level. Barium was present at elevated levels in eight invertebrate samples, but none of the fish samples contained high levels of barium. Elevated barium concentrations occurred more frequently in samples from Havasu and Cibola NWRs than at downstream sites including Imperial NWR and Mexico locations. Magnesium exceeded the toxic threshold in 7 of 38 samples (18%), and zinc was detected at potentially toxic levels in 6 of 38 (16%) samples. Zinc accumulated to high levels primarily in tadpoles (3/3) and red shiners (*Notropis lutrensis*) (2/3). The sample of tadpoles from Martinez Lake contained an exceptionally high concentration of zinc, 1,323 ppm dry weight, more than 7-times the toxic threshold (Table 4).

It is now well documented that aquatic birds nesting along the lower Colorado River that feed on fish and invertebrates are bioaccumulating potentially toxic concentrations of selenium in their tissues and eggs. Eighty-three percent of the fish- and aquatic invertebrate-feeding birds nesting on Imperial NWR contained liver selenium above the toxic threshold (Martinez 1994). Martinez (1994) concluded, "Selenium levels in birds collected from the lower Colorado River are above the biological toxic thresholds for the health and reproduction of aquatic birds." "Selenium levels in tissues of aquatic birds on Imperial NWR indicate acute exposure to elevated selenium levels." Lusk (1993), in his work to define selenium levels in fish and invertebrates of Imperial NWR reported, "Ninety-four percent of whole fishes and invertebrates (n=185) contained concentrations of selenium that exceed 3 ppm, a concentration recommended by the U.S. Fish and Wildlife Service to protect aquatic birds from chronic selenium toxicity." Rusk (1991) in her study of Virginia rails (*Rallus limicola*) and least bitterns (*Ixobrychus exilis*) collected from four locations on the lower Colorado River concluded, "Based on selenium levels in bird tissues and prey species, marsh birds in the lower Colorado River valley are at a low risk of adult mortality, but moderate to high risk of teratogenicity." Rusk also states, "Selenium levels in prey species of the Yuma clapper rail are at, or approaching, levels known to be toxic to birds." Crayfish selenium concentrations found in our 1998-99 study (4.21 - 15.5 ppm) were about 3 to 4-times higher than those (1.51 - 3.88 ppm) reported by Rusk (1991).

Bioaccumulation of selenium by the Yuma clapper rail has also been documented. Liver samples of four Yuma clapper rails collected in 1987 (salvaged trap mortalities) from Crystal Beach in Topock Gorge contained 8.6, 16.0, 37.0 and 38.9 ppm dry weight selenium (USFWS unpub. data). A single Yuma clapper rail from Mittry Lake, also salvaged in 1987 as a trap mortality, contained 26.0 ppm selenium in the liver (Radtke et al. 1988). Selenium usually averages 3 - 10 ppm dry weight in livers of birds from selenium normal environments (Skorupa et al. 1990, Ohlendorf 1993). Concentrations above 3 ppm wet weight (approximately 10 ppm dry weight) in the livers of laying females have been associated with reproductive impairment (Heinz 1996). Concentrations of selenium greater than 10 ppm wet weight (approximately 33 ppm dry weight) in the liver can be considered harmful to the health of young and adult birds. Selenium in livers of four of five Yuma clapper rails (16.0 - 38.9 ppm dry weight) were within the toxic range where adverse effects on reproduction could be expected.

Historic and current concentrations of selenium in the Yuma clapper rail's food chain are within the range that could cause adverse effects on reproduction. The few rail carcasses obtained, and carcasses of similar trophic level feeders, confirm that bioaccumulation of selenium to potentially harmful levels has occurred. Ironically, there have been no observations of reproductive failure, but such observations would be unlikely given the secretive nature of the rail and the lack of recent studies to monitor reproductive success of the rail or closely related species.

RECOMMENDATIONS

- Over the past decade, there has been an apparent two-to five-fold increase in selenium concentrations in crayfish, the primary prey species for the Yuma clapper rail. If selenium concentrations continue to increase, Yuma clapper rail populations, as well as those of other invertebrate- and fish-eating birds could experience selenium-induced reproductive failure and subsequent population declines. We recommend continued, and perhaps accelerated, water management studies in backwater areas with a goal of reducing overall selenium concentrations.

- The collection and chemical analysis of additional prey samples on a three- to five-year basis to monitor trends in selenium bioaccumulation is also recommended. If adult or nestling Yuma clapper rails are found dead, or if nests are located with unhatched eggs, we fully support and encourage the salvage of these samples for chemical analysis.

- Nest monitoring of Yuma clapper rails, or a similar rallid species, could be extremely helpful in determinations of reproductive success. Nest monitoring may also yield information on possible selenium-induced anomalies in young.

ACKNOWLEDGMENTS

We thank Matt Connolly (Havasu NWR), and Ken Sturm (Salton Sea NWR) for assistance with field work. Special acknowledgment is extended to John Moore of the Service's Patuxent Analytical Control Facility for his tenacious determination to maintain high QA/QC analytical standards. We also thank Lesley Fitzpatrick (USFWS) and Ron McKinstry (retired USFWS) for assistance in gathering background materials. This report was reviewed by Lesley Fitzpatrick, Carla Hurt (Arizona State Univ.), Joel Lusk (USFWS), and Linden Piest (AGFD) who made numerous helpful and constructive comments.

LITERATURE CITED

Blus, L.J. 1996. DDT, DDD, and DDE in birds. Pages 49-71 *in* Environmental Contaminants in Wildlife. W.N Beyer, G.H. Heinz, and A.W. Redmon-Norwood (eds.) SETAC Special Publications Series. CRC Lewis Publishers, New York.

Blus, L.J., T.G. Lamont, and B.S. Neely, Jr. 1979. Effects of organochlorine residues on eggshell thickness, reproduction, and population status of brown pelicans (*Pelecanus occidentalis*) in South Carolina and Florida. Pestic. Monit. J. 12:172-184.

Blus, L.J., B.S. Neely, Jr., T.G. Lamont, and B. Mulhern. 1977. Residues of organochlorines and heavy metals in tissues and eggs of brown pelicans, 1969-73. Pestic. Monit. J. 11:40-53.

DeStefano, S. and W.W. Shaw. 1999. Status, population ecology, and habitat of the Yuma clapper rail (*Rallus longirostris yumanensis*) in the wetlands of the Colorado River delta, Baja and Sonora, Mexico. Unpub. Rept. Univ. Arizona. Tucson 14 pp.

Eddleman, W.R. 1989. Biology of the Yuma clapper rail in the southwestern U.S. and northwestern Mexico. U.S. Bur. Reclam. Yuma Proj. Off. , Yuma, Arizona, and U.S. Fish and Wildl. Serv., Reg. 2 Albuquerque, New Mexico 127 pp.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.2), Washington, D.C. 46 pp.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.10), Washington, D.C. 90 pp.

Eisler, R. 1988. Lead hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.4), Washington, D.C. 134 pp.

Gearheart, R.A. and G.W. Waller. 1994. Hayward Metals Study: Literature Survey Environmental Resources Engineering Dept. Humbolt State Univ. Arcata, California 138 pp.

Glenn, E.P., C. Lee, R. Felger, and S. Zengel. 1996. Effects of water management on the wetlands of the Colorado River delta, Mexico. Conservation Biology. 10:1175-1186.

Heinz, G.H. 1996. Selenium in birds. Pages 447-458 *in* Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood (eds.) SETAC Special Publications Series. CRC Lewis Publishers, New York.

Hickey, J.J. and D.W. Anderson. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science 162:271-273.

King, K.A., B.J. Andrews, C.T. Martinez, and W.G. Kepner. 1997. Environmental contaminants in fish and wildlife of the lower Gila River, Arizona. U.S. Fish and Wildl. Serv. Arizona Ecological Services Field Office. Phoenix, 71 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. Arizona Ecological Services Office report. 24 pp.

Lemly, A.D. 1993. Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. Environ. Monit. Assess. 28:83-100.

Lemly, A.D. 1995. A protocol for aquatic hazard assessment of selenium. Ecotoxicol. Environ. Safety 32:280-288.

Lemly, A.D. 1996. Assessing the toxic threat of selenium to fish and aquatic birds. Environ. Monit. Assess. 43:19-35.

Lemly, A.D. and G.J. Smith. 1987. Aquatic cycling of selenium: implications for fish and wildlife. U.S. Fish and Wildlife Service, Washington DC. Fish and Wildlife Leaflet 12.

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

Martinez, C.T. 1994. Selenium levels in selected species of aquatic birds on Imperial National Wildlife Refuge. M.S. Thesis. Cooperative Fish and Wildlife Research Unit. University of Arizona, Tucson 74 pp.

McLane, M.A.R. and L.C. Hall. 1972. DDE thins screech owl eggshells. Bull. Environ. Contam. Toxicol. 8:65-68.

Mendenhall, V.M., E.E. Klass, and M.A.R. McLane. 1983. Breeding success of barn owls (*Tyto alba*) fed low levels of DDE and dieldrin. Arch. Environ. Contam. Toxicol. 12:235-240.

Mora, M.A., J. Garcia, M. de la Paz Carpio-Obeso, and K.A. King. Contaminants without borders: A regional assessment of the Colorado River delta. Presented at the International Congress on Ecosystem Health: Managing for Ecosystem Health, 15-20 1999, Sacramento, CA. 30 pp. In review.

Ohlendorf, H.M. 1989. Bioaccumulation and effects of selenium in wildlife. Pages 133-177 *in* Jacobs, L.W. (ed.), Selenium in agriculture and the environment. SSSA Spec. Publ. 23. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin.

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.

Ohlendorf, H.M., A.W. Kilness, J.L. Simmons, R.K. Stroud, D.J. Hoffman, and J.F. Moore. 1988. Selenium toxicosis in wild birds. J. Toxicol. Environ. Health 24:67-92.

Ohlendorf, H.M., R.L. Hothem, C.M. Bunck and K.C. Marois. 1990. Bioaccumulation of Selenium in birds at Kesterson Reservoir, California. Arch. Environ. Contam. Toxicol. 19:495-

Ohlendorf, H.M., E.E. Klass, and T.E. Kaiser. 1979. Environmental pollutants and eggshell thickness: anhingas and wading birds in the eastern United States. Fish and Wildl. Serv. Special Scientific Rept. - Wildlife No. 216. Washington, D.C. 25 pp.

Ohmart, R.D. and R.E. Tomlinson. 1977. Foods of western clapper rails. Wilson Bull. 89:332-336.

Piest, L. and J. Campoy. 1998. Report of Yuma clapper rail surveys at the Ciénega de Santa Clara, Sonora. Arizona Game and Fish Department, Yuma, Arizona 8 pp.

Powell, R.E. 1990. Yuma clapper rail census summary. 1987-1990. Yuma Clapper Rail Recovery Team, Blythe, California 5 pp.

Prieto, F.G. 1998. Selenium and water quality in three wetland types along the lower Colorado River - Imperial National Wildlife Refuge. M.S. Thesis. School of renewable Natural Resources, University of Arizona, Tucson 109 pp.

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, 1986-87. U.S. Geological Survey. Water Resources Investigation Report 88-4002, Tucson 77 pp.

Roberts, C.A. 1996. Trace element and organochlorine contamination in prey and habitat of the Yuma clapper rail in the Imperial Valley, California. U.S. Fish and Wildl. Serv. Carlsbad Ecological Services Field Office. Carlsbad, CA, 24 pp.

Rusk, M.K. 1991. Selenium risk to Yuma clapper rails and other marsh birds of the Lower Colorado River. MS Thesis. Cooperative Fish and Wildlife Research Unit. University of Arizona, Tucson 75 pp.

Scheuhammer, A.M. 1987. The chronic toxicity of aluminum, cadmium, mercury, and lead in birds: A review. Environmental Pollution 46:263-295.

Skorupa, J.P., H.M. Ohlendorf, and R.L. Hothem. 1990. Selenium bioaccumulation and biological risk: some interpretive guidelines for waterbirds derived from field sampling. Annual Conference, Western Section and Northwest Section, The Wildlife Society, 22-25 February 1990, Sparks, Nevada.

Todd, R.L. 1986. A saltwater marsh hen in Arizona: A history of the Yuma clapper rail (*Rallus longirostris yumanensis*). Arizona Game and Fish Department, Federal Aid Proj. W-95-R, Completion Rept., Phoenix 290 pp

USDI. 1998. United States Department of Interior. Guidelines for interpretation of the biological effects of selected constituents in biota, water, and sediment. National Irrigation Water Quality Program Information Report No. 3. Bureau of Reclamation, Denver 198 pp.

USGS. 1998. Detailed study of selenium and selected constituents in water, bottom-sediment, soil and biota associated with irrigation drainage in the San Juan River area, New Mexico, 1991-95. Water Resources Investigation Report 98-4213. Albuquerque, 84 pp..

Valdes-Casillas, C., E.P. Glenn., O. Hinojosa-Huerta-Huerta, Y. Carrillo-Guerrero, J. Garcia-Hernandez, F. Zamora-Arroyo, M. Munoz-Viveros, M. Briggs, C. Lee, E. Chavarria-Correa, J. Riley, D. Baumgartner, and C. Condon. 1998. Wetland Management and Restoration in the Colorado River Delta: The First Steps. Special Publication of CECARENA-ITESM Campus Guaymas and NAWCC. Mexico. 32 pp.

Villegas, S.V. 1997. Dynamics of selenium in Cibola Lake, Arizona. PhD. Dissert.

Cooperative Fish and Wildlife Research Unit. University of Arizona, Tucson 107 pp.

Ware, G.W. 1974. Ecological history of DDT in Arizona. Arizona Academy of Science 9:60-65.

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.

Welsh, D. and O.E. Maughan. 1993. Selenium in aquatic habitats at Cibola National Wildlife Refuge. Final Report. Cooperative Fish and Wildlife Research Unit. University of Arizona, Tucson 22 pp.

Wiemeyer, S.N., A.A. Belisle, and F.J. Gramlich. 1978. Organochlorine residues in potential food items of Maine bald eagles (*Haliaeetus leucocephalus*), 1966 and 1974. Bull. Environ. Contam. Toxicol. 19:64-72.

Wiemeyer, S.N. and R.D. Porter. 1970. DDE thins eggshells of captive American kestrels. Nature 227:737-738.

Wiemeyer, S.N., P.R. Spitzer, W.C. Krantz, T.G. Lamont, and E. Cromartie. 1975. Effects of environmental pollutants on Connecticut and Maryland ospreys. J. Wildl. Manage. 39:124-139.

Zengel, S.A., V.J. Meresky, E.P. Glenn, R.S. Felger, and D. Ortiz. 1995. Ciénega de Santa Clara, a remnant wetland in the Rio Colorado delta (Mexico): vegetation distribution and effects of water flow reduction. Ecological Engineering 4:19-36.

Table 1. Sample collection sites, Yuma clapper rail food item study, 1998-1999

Site name	State	Date	Location		Samples collected								Mixed fish
			Latitude	Longitude	Crayfish	Mosquitofish	Sailfin molly	Red shiner	Sunfish	Shrimp	Bullfrog tadpoles	GWB[1]	
Salton Sea NWR, Hazard 9 Unit	CA	07/21/99	N 33"11' 34"	W 115"35' 19"	X	X							
Imperial Wildlife Area, Wister Unit	CA	07/22/99	N 33"18' 25"	W 115"36' 51"	X	X							
Gila River at HWY 85	AZ	08/05/99	N 33"19' 57"	W 112"37' 24"		X	X	X	X				
Havasu NWR, Beal Lake	AZ	06/08/99	N 34"46' 27"	W 114"31' 31"	X								
Havasu NWR, Topock Gorge[2]	AZ	06/08/99	N 34"34' 47"	W 114" 24' 37"	X	X				X			
Cibola NWR, Cibola Lake	AZ	08/12/99	N 33"13' 32"	W 114"40' 16"	X	X			X				
Cibola NWR, Growout Ponds	AZ	08/12/99	N 33"20'11"	W 114"42' 05"							X		
Imperial NWR, Butler Lake	AZ	07/07/99	N 33"01' 26"	W 114"30' 27"	X	X							
Imperial NWR, McAllister Lake	AZ	07/07/99	N 33"01' 03"	W 114"30' 01"	X	X						X	
Imperial NWR, Martinez Lake	AZ	07/09/99	N 32"58' 37"	W 114"28' 52"					X		X		
Imperial NWR, River Sandbar	AZ	07/09/99	N 32"58' 08"	W 114"29' 16"		X		X					
Imperial NWR, DU #2	AZ	07/09/99	N 32"59' 26"	W 114"29' 37"		X							
Mittry Lake Wildlife Area	AZ	08/05/99	N 32"51' 19"	W 114"26' 56"	X				X		X		
Río Hardy at Campo Mosqueda	BC	03/03/98	N 32"08' 00 "	W 115"15' 05"									X
Río Hardy at El Mayor	BC	03/03/98	N 32"07' 00"	W 115"15' 05"									X
Río Colorado north of RR tracks	SON	03/03/98	N 32"12' 49"	W 115"03' 00"									X
El Doctor Wetlands	SON	03/04/98	N 32"01' 30"	W 114"51' 48"		X							
MODE Drain	SON	03/04/98	N 32"02' 17"	W 114"53' 46"									X
La Flor del Desierto	SON	03/04/98	N 32"01' 30"	W 114"52' 18"									X
Ciénega de Santa Clara	SON	03/05/98	N 32"02' 17"	W 114"53' 46"	X								X

[1]GWB = Giant water bug.
[2]Disneyland Channel.

Table 2. Yuma clapper rail census results 1990 - 1998[1]

Area	Number of years surveyed	Number of individuals[2]	
		Mean	Range
Salton Sea NWR, CA	9	61.6	13 - 102
Imperial Wildl. Area, CA (Wister)	9	248	90 - 331
Gila River near Hwy 85	9	31.1	7- 52
Havasu NWR (Topock Gorge)	7	74.4	20 - 122
Cibola NWR	7	52.1	29 - 109
Imperial NWR	8	60.6	24-127
Mittry Lake Wildlife Area	9	46.2	31 - 70
Ciénega de Santa Clara	NA[3]	NA	5,300 - 6,000[4]
Colorado River delta wetlands[5]	Not surveyed	NA	NA

[1]Census figures from unpublished USFWS data.
[2]Estimate of number of individuals based on number of responses to taped calls.
[3]Data not available.
[4]Recent (1998 - 1999) estimates (Piest and Campoy 1998, Hinojosa-Huerta pers. comm.).
[5]Colorado River delta wetlands have not been systematically surveyed. This area includes Río Hardy at Campo Mosqueda, Río Hardy at El Mayor, El Doctor, and the Río Colorado approximately 1 km northwest of Route BC 4.

Table 3. Organochlorine compounds, ppm wet weight, in potential Yuma Clapper rail food items collected from various locations in Arizona and California, USA, and Baja and Sonora, Mexico

Sample	Area collected	p,p'-DDE	p,p'-DDT	Prcnt moist	Prcnt lipid
mosquitofish	Salton Sea NWR, Hazard 9 Unit	0.19	ND[1]	76.2	12.6
crayfish	Salton Sea NWR, Hazard 9 Unit	0.19	ND	69.7	4.06
crayfish	Imperial Wildl. Mgmt. Area, Wister Unit	0.35	ND	70.5	2.34
mosquitofish	Imperial Wildl. Mgmt. Area, Wister Unit	0.19	0.32	76.5	9.6
mosquitofish	Gila River at HWY 85	1.01	ND	76.5	7.76
crayfish	Havasu NWR, Beal Lake	ND	ND	76.3	2.44
crayfish	Havasu NWR, Topock Gorge, Disneyland Chan.	ND	ND	72.2	4.13
mosquitofish	Havasu NWR, Topock Gorge, Disneyland Chan.	ND	ND	72	9.35
mosquitofish	Cibola NWR, Cibola Lake	ND	ND	74.6	8.8
crayfish	Cibola NWR, Cibola Lake	ND	ND	79.9	5.54
crayfish	Mittry Lake	ND	ND	75.5	0.76
crayfish	Imperial NWR, Butler/McAllister Lks.	ND	ND	76.8	3.02
mosquitofish	Imperial NWR, McAllister Lake	ND	ND	78.8	9.58
crayfish	Imperial NWR, McAllister Lake	ND	ND	65.5	1.57
mosquitofish	Imperial NWR, Butler Lake	ND	ND	79	13.1
mosquitofish	Imperial NWR, river sandbar	0.13	ND	84	10.5
mosquitofish	Imperial NWR, DU#2	ND	ND	53.3	4.78
fish[2]	Río Colorado, northeast of RR tracks	0.18	0.1	70.5	8.52
fish[3]	Río Hardy, El Mayor	0.34	0.1	87.3	10.3
fish[4]	Río Hardy, Campo Mosqueda	0.15	0.1	76.1	8.77
mosquitofish	El Doctor wetlands	0.32	ND	84.1	4
fish[5]	La Flor del Desierto	0.03	ND	60.9	12.2
fish[6]	MODE canal/drain	0.18	0.13	76.9	11.3
fish[7]	Ciénega de Santa Clara	ND	ND	71.6	7.83

[1]ND = Not detected.
[2]Mixed fish sample consists of mosquitofish (29 g) and red shiner (10 g).
[3]Mixed fish sample: mosquitofish (33 g) and sailfin molly (24g).
[4]Mixed fish sample: mosquitofish (48 g) and sailfin molly (11 g).
[5]Mixed fish sample: mosquitofish (37 g) and sailfin molly (44 g).
[6]Mixed fish sample: mosquitofish (2 g), sailfin molly (57g) and red shiner (5 g). This sample also contained 0.03 ppm DDD.
[7]Mixed fish sample: mosquitofish (3 g) and sailfin molly (53 g).

Table 4. Yuma clapper rail food item study: metals in invertebrates and fish, Arizona, California, Sonora, and Baja - 1998-99

Collection site	Sample[2]	Concentration (ppm dry weight)[1]																	Prcnt moist
		Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Zn	
Potential toxic threshold[3]	***fish/invert***	***800***	***30***	***120***	***80***	***0.4***	***10***	***300***	***4000***	***0.33-1.6***	***3000***	***2000***	***400***	***100***	***3.0***	***3000***	***40***	***178***	*NA*
Salton Sea NWR, Hazard 9	crayfish	194	5.22	37.9	**76.8**	0.14	ND[4]	31.5	188	ND	**4058**	41.7	ND	ND	**7.78**	1061	0.35	93.8	69.7
Salton Sea NWR, Hazard 9	mosquitofish	190	ND	ND	7.49	ND	1.33	4.74	298	0.11	1390	51.2	0.74	ND	**12.3**	139	0.43	96.5	76.2
Imperial Wildl. CA, Wister	crayfish	152	7.22	4.55	**92.4**	0.18	0.46	41.6	321	0.09	**3018**	107	1.15	ND	**8.09**	840	0.56	84	70.5
Imperial Wildl. CA, Wister	mosquitofish	**974**	6.14	2.02	32.9	0.14	1.75	7.5	1397	0.82	**3027**	60.3	1.45	0.95	**19.1**	259	1.93	109	76.5
Gila River at HWY 85	mosquitofish	193	0.77	3.14	8.55	ND	0.94	4.44	234	0.39	1962	39.4	ND	0.4	**10.1**	203	0.68	**160**	76.5
Gila River at HWY 85	sailfin molly	667	2.58	ND	10.7	ND	1.57	17.1	771	0.14	1839	52.1	0.9	0.5	**6.39**	170	1.69	95.3	71.7
Gila River at HWY 85	red shiner	38.8	0.21	ND	2.75	ND	0.57	11.2	93.7	0.17	1420	13.2	ND	0.52	**6.85**	196	0.58	**198**	68.2
Gila River at HWY 85	sunfish	7.5	0.11	3.05	1.06	ND	ND	11.1	20.3	0.07	763	3.78	ND	ND	2.41	94.1	ND	41.1	44.1
Havasu NWR, Beal Lake	crayfish	234	6.42	13.7	**313**	0.1	0.78	53.8	460	ND	**3217**	122	ND	ND	**8.12**	880	0.9	53.9	76.3
Havasu NWR, Topock Gorge	crayfish	68.7	6.56	22.3	**143**	0.11	0.51	41.2	259	ND	**2935**	98.2	ND	1.54	**11.3**	781	0.57	93.7	72
Havasu NWR, Topock Gorge	shrimp	81.2	4.79	10.7	**91.1**	0.19	0.48	27.2	171	0.21	2122	52.9	ND	ND	**20.6**	339	ND	86.8	81.5
Havasu NWR, Topock Gorge	mosquitofish	18.9	ND	2.12	5.66	ND	3.63	3.66	68.4	0.09	1356	11.6	1.24	0.99	**16.7**	84.1	ND	88.1	72
Cibola NWR, Cibola Lake	crayfish	80.9	14.4	15.9	**95.9**	0.13	0.49	56.5	225	0.2	2575	242	0.73	6.92	**15.5**	683	0.53	118	79.9
Cibola NWR, Cibola Lake	mosquitofish	28	0.8	ND	10.3	ND	0.49	5.44	99.8	0.26	1593	19.4	ND	ND	**9.76**	133	ND	113	74.6
Cibola NWR, Cibola Lake	sunfish	9.53	0.27	2.59	3.06	ND	ND	3.85	18.9	0.05	953	4.96	ND	ND	**2.9**	115	ND	52.6	42.2
Cibola NWR, Growout Pond	bullfrog tadpoles	430	26.2	3.51	**99.3**	0.25	1.88	6.91	958	0.21	1649	298	1.16	2.57	**32.4**	109	1.85	**186**	87.5
Cibola NWR, Three Finger Lk.	red shiner	31.1	ND	ND	3.6	0.1	0.83	2.18	62.4	0.34	1365	11.2	ND	1.36	**5.7**	146	ND	138	65.2
Mittry Lake Wildlife Area	crayfish	65.8	1.47	1.82	**112**	0.1	ND	24.1	111	ND	**2864**	74.2	ND	ND	**8.03**	1062	ND	94.5	75.5
Mittry Lake Wildlife Area	sunfish	59.9	ND	ND	8.26	ND	0.88	0.76	85.3	ND	1702	47.8	0.36	ND	**23.7**	234	ND	138	81.2
Mittry Lake Wildlife Area	bullfrog tadpoles	**1267**	15.6	4.25	38.4	ND	6.52	12.3	2018	ND	2319	344	6.21	1.81	**43.1**	140	2.67	**397**	89.7
Imperial NWR, Butler Lake	crayfish	20.7	6.17	23.3	59.1	0.17	0.34	13.6	53.9	0.11	**3748**	141	ND	ND	**6.67**	990	ND	97.6	76.8
Imperial NWR, Butler Lake	mosquitofish	4.05	ND	ND	3.59	ND	0.43	0.69	33.5	ND	1620	30.3	ND	ND	**4.15**	210	ND	57.8	79
Imperial NWR, McAllister Lake	mosquitofish	28	ND	4.63	3.68	ND	0.58	8.37	86.7	0.12	1926	23.6	ND	1.02	**16.6**	242	ND	109	78.8

Table 4. (cont.). Yuma clapper rail food item study: metals in invertebrates and fish, Arizona, California, Sonora, and Baja - 1998-99

Collection site	Sample[2]	Concentration (ppm dry weight)[1]																	Prcnt moist
		Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Zn	
Potential toxic threshold[3]	***fish/invert***	***800***	***30***	***120***	***80***	***0.4***	***10***	***300***	***4000***	***0.33-1.6***	***3000***	***2000***	***400***	***100***	***3.0***	***3000***	***40***	***178***	NA
Imperial NWR, McAllister Lake	crayfish	17.9	5.02	6.83	34.3	0.1	ND	17.7	49.8	0.1	**4799**	51.1	0.64	ND	**5.78**	757	ND	87.5	65.5
Imperial NWR. McAllister Lake	GWB	ND	0.36	11.4	ND	0.16	ND	11.3	40.3	0.16	831	13.8	ND	ND	**9.45**	16.1	ND	95.8	68.1
Imperial NWR, River Sandbar	red shiner	30.7	ND	ND	5.32	ND	0.46	1.65	71.8	ND	1331	22.4	ND	0.74	**18.4**	112	ND	**180**	81
Imperial NWR, Martinez Lake	sunfish	15.5	ND	22.8	4.61	ND	0.73	3.22	71.7	ND	1382	10.3	ND	0.99	**28.4**	142	ND	109	69.8
Imperial NWR, Martinez Lake	bullfrog tadpoles	752	33.6	15.5	29.1	0.1	1.48	8.46	955	0.24	1838	217	0.89	2.15	**134**	98.4	2.21	**1323**	89.2
Imperial NWR, DU # 2	mosquitofish	22.6	ND	1.18	3.33	ND	1.06	2.61	76.6	ND	924	6.04	0.66	0.96	**3.78**	109	0.33	66.9	53.3
Imperial NWR, River Sandbar	mosquitofish	29.5	ND	ND	8.28	ND	0.36	5.24	79.2	0.16	1583	26.7	ND	ND	**25.7**	138	0.43	143	84
Campo Mosqueda, Baja	fish[5]	529	0.92	8.82	14.2	ND	3.99	9.94	583	0.32	2061	33.7	2.7	0.9	**5.2**	271	0.95	108	76.1
Rio Hardy, Baja	fish[6]	234	ND	1.87	16.7	0.17	1.18	11	242	1.02	1873	26.3	ND	ND	**34.1**	220	0.47	84.9	87.3
El Doctor, Sonora	mosquitofish	53.8	2	7.24	15.6	ND	0.79	7.84	144	1.23	1979	27.8	ND	0.34	**3.6**	228	0.33	**195**	84.1
La Flor del Desierto, Sonora	fish[7]	101	0.31	5.37	7.09	ND	0.37	5.57	128	0.1	1208	56.1	ND	ND	**9.12**	168	ND	55.8	60.9
MODE drain, Sonora	fish[8]	255	18.2	4.95	9.62	0.1	1.57	23.6	499	0.22	1649	276	0.44	ND	**16.3**	184	1.54	135	76.9
Rio Colorado, Sonora	fish[9]	206	ND	1.39	13.4	ND	0.74	3.33	274	0.48	1865	34.4	34	ND	**11.4**	156	ND	172	70.5
Ciénega de Santa Clara, Sonora	crayfish	323	11.9	59.7	**95**	0.13	0.74	49.9	442	ND	**4534**	323	ND	0.75	**4.21**	1558	0.98	85.8	75.6
Ciénega de Santa Clara, Sonora	fish[10]	777	6.86	8.36	17	ND	2.73	11.1	1109	ND	2830	67.6	0.82	0.4	**12.7**	193	1.89	58.5	71.6

[1]Beryllium was detected only in the tadpole sample from Mittry Lake Wildlife Area 0.08 ppm. Molybdenum was present only in tadpoles from YPG (1.32 ppm) and in fish from Campo Mosqueda (1.34 ppm).
[2]Sample: sunfish = *Lepomis spp*. GWB = giant water bug.
[3]Potential toxic threshold = concentration potentially toxic to upper trophic level feeders such as fish-eating birds including the Yuma clapper rail. Data from Eisler 1985, 1987, 1988, Gearheart and Waller 1994, Scheuhammer 1987, USDI 1998, USGS 1998. Figures in **red** exceed the toxic concern level. Figures in **blue** are within 90% of the toxic concern level.
[4]ND = not detected. Lower limit of detection: Al$\leq$3.25, As$\leq$0.51, B$\leq$1.33, Ba$\leq$0.65, Cd$\leq$0.07, Cr$\leq$0.33, Hg$\leq$0.25, Ni$\leq$0.33,V$\leq$0.33.
[5]Mixed species sample from Campo Mosqueda = mosquitofish (48 g) and sailfin molly (11 g).
[6]Mixed species sample from the Rio Hardy = mosquitofish (33 g) and sailfin molly (24g).
[7]Mixed species sample from La Flor del Desierto = mosquitofish (37 g) and sailfin molly (44 g).
[8]Mixed species sample from the MODE drain mosquitofish (2 g), sailfin molly (57g) and red shiner (5 g).
[9]Mixed species sample from the Rio Colorado north of the RR track crossing. Mosquitofish (29 g) and red shiner (10 g).
[10]Mixed species sample from Ciénega de Santa Clara = Mosquitofish (3 g) and sailfin molly (53 g).

Table 5. Selenium concentrations in crayfish and mosquitofish collected from the lower Colorado River: a comparison among studies

Sample	Area	Year	Selenium (ppm dw) Mean	Range	Study
Crayfish	Cibola Lake	1989	2.60	1.4 - 4.6	Welsh and Maughan (1992)
	Cibola Lake	1990	2.80	NA	Rusk (1991)
	Cibola Lake	1999	15.5	NA	this study
	Mittry Lake	1987	4.60	NA	Kepner unpub. data
	Mittry Lake	1990	1.76	NA	Rusk (1991)
	Mittry Lake	1999	8.03	NA	this study
	McAllister Lake	1991	4.28	3.22 - 5.10	Lusk (1993)
	McAllister Lake	1999	5.78	NA	this study
	Butler Lake	1991	1.63	1.47 - 1.77	Lusk (1993)
	Butler Lake	1999	6.67	NA	this study
	Topock Gorge	1987	3.70	NA	Kepner unpub. data
	Topock Gorge	1999	11.3	NA	this study
Mosquitofish	McAllister Lake	1991	4.98	3.94 - 6.36	Lusk (1993)
	McAllister Lake	1999	16.6	NA	this study
	Butler Lake	1991	3.97	2.85 - 5.73	Lusk (1993)
	Butler Lake	1999	4.15	NA	this study

Reprint requests:

Dr. Steve Hamilton USGS, BRD Columbia Environmental Research Laboratory Ecotoxicology Research Station 31247 436th Ave. Yankton, SD 57078-6364	1	5/22/00
Brenda Zaun U.S. Fish and Wildlife Service Cibola National Wildlife Refuge Rt. 2, Box 138 Cibola AZ 85328	3	5/22/00
Matt Connolly U.S. Fish and Wildlife Service Havasu NWR P.O. Box 3009 Needles, CA 92363-2045	1	5/22/00
Carol Roberts U.S. Fish and Wildlife Service 2730 Locker Ave. Carlesbad, CA 92008	1	5/22/00
Jaqueline Garcia-Hernandez 1529 E. Glenn St. Tucson, AZ 85719.	3	5/22/00
Jackie Record U.S. Fish and Wildlife Service Imperial National Wildlife Refuge P.O. Box 72217 Martinez Lake, AZ 85326	3	5/22/00
Julia Wesley bie Norbert Nickl Feuerbachstrasse 2 14471 Potsdam GERMANY	3	5/22/00
Robert J. McKerman	1	5/24/2000

San Bernardino County Museum 2024 Orange Tree Lane Redlands, CA 92374		
Janine A. Spencer 132 Park Ave. Prescott, AZ 86303	1	5/24/2000
Brian Woolridge SWC Associates, Inc. 100 W. Coolage St. Phoenix, AZ 85013	1	5/24/2000
Bill Grosi Bureau of Land Management 222 N. Central Ave. Phoenix, AZ 85004	1	5/24/2000
Ted Cordery Bureau of Land Management 222 N. Central Ave. Phoenix, AZ 85004	1	5/24/2000
Don Ellsworth Bureau of Land Management Lake Havasu Field Office 2610 Sweetwater Ave. Lake Havasu City, AZ 85406	1	5/24/2000
Gail Acheson Bureau of Land Management Yuma field Office 2555 E. Gila Ridge Rd. Yuma, AZ 85365	1	5/24/2000
Barbara Raulston Bureau of Reclamation P.O. Box 61470 Boulder City, NV 89006	1	5/24/2000
Wendy Servass U.S. Department of Agriculture 2224 W. Desert Cove Ave., Suite 209 Phoenix, AZ 85029	1	5/24/2000
Richard Gilbert	1	6/8/2000

U.S. Fish and Wildlife Service Bill Williams NWR 60911 Highway 95 Parker, AZ 85344		
Mike Hawkes Cibola NWR Rt. 2, Box 138 Cibola, AZ 85328	1	6/8/2000
Janet Bair U.S. Fish and Wildlife Service Ecological Services Office 1510 N. Decatur Ave. Las Vegas, NV 89108	1	6/8/2000
Greg Wolf U.S. Fish and Wildlife Service Havasu NWR P.O. Box 3009 Needles, CA 92363-2045	1	6/8/2000
Mitch Ellis U.S. Fish and Wildlife Service Imperial NWR P.O. Box 72217 Yuma, AZ 85365	1	6/8/2000
Steve Johnson U.S. Fish and Wildlife Service Sono Bono Salton Sea National Wildlife Refuge 905 W. Sinclair Rd. Calipatria, CA 92233-974	1	6/8/2000
Robert Witzeman Maricopa Audubon Society 4619 E. Acadia Lane Phoenix, AZ 85018	1	6/8/2000
Richard Todd 5111 Gelding Dr. Glendale, AZ 85306	1	6/8/2000
Bill Burger Arizona Game and Fish Department	1	6/8/2000

7200 E. University Dr. Mesa, AZ 85207		
Linden Piest Arizona Game and Fish Department 9140 E. County 10 ½ St. Yuma, AZ 85365	1	6/8/2000
Gerald P. Mulcahy Calif. Dept. Fish and Game P.O. Box 2160 Blythe, CA 92225-2160	1	6/8/2000
John Gustafson Calif. Dept. Fish and Game 1416 Ninth St., Room 1280 Sacramento, CA 95814	1	6/8/2000
Paul Jorgensen California State Parks 200 Palm Canyon Dr. Borrego Springs, CA 95814	1	6/8/2000
Steve Miyamoto Imperial Wildlife Area 8700 Davis Rd. Niland, CA 92257	1	6/8/2000
Cris Tomlinson Nevada Division of Wildlife 4747 W. Vegas Dr. Las Vegas, NV 89108	1	6/8/2000
Mike Fransis Colorado River Indian Tribes P.O. Box 777 Parker, AZ 85344	1	6/8/2000
Osvel M. Hinojosa-Huerta University of Arizona School of Renewable Resources Tucson, AZ 85721	1	6/8/2000
Dr. Courtney Conway Washington State University - Tri Cities	1	6/8/2000

2321 Camas Ave.
Richland, WA 99352

Kathleen Blair U.S. Fish and Wildlife Service Bill Williams River National Wildlife Refuge 60911 Highway 95 Parker, AZ 85344	1	6/8/2000
Ken Sturm U.S. Fish and Wildlife Service Sono Bono Salton Sea National Wildlife Refuge 905 W. Sinclair Rd. Calipatria, CA 92233-974	1	6/8/2000