Trace Element and Organochlorine Contamination in Prey and Habitat of the Yuma Clapper Rail in the Imperial Valley, California

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Executive Summary

The Yuma clapper rail (*Rallus longirostris yumanensis*) occurs along the Colorado River in Arizona and California, and in small marshes located around the Salton Sea in Imperial and Riverside Counties in California. The Yuma clapper rail was listed as a federal endangered species in 1967 (U.S. Department of the Interior 1967). Yuma clapper rails are highly territorial during the breeding season (Todd 1986). Contamination in a territory may result in greater impacts to the pair occupying that territory than would occur in more wide-ranging species, particularly if contamination occurs in crayfish which form the bulk of the diet for birds in the United States.

This study was designed to determine the potential for selenium exposure of the Yuma clapper rail inhabiting the Imperial Valley by investigating the amounts of selenium in its environment (sediments) and diet (crayfish). Available tissue samples were also analyzed in an effort to assess the potential for biomagnification. Samples collected for analysis of inorganics were also analyzed for organochlorine compounds to assess the potential for impacts from these compounds. Boron was found to bioaccumulate in most trophic levels studied in the Imperial Valley (Setmire et al. 1993). This element was considered a contaminant of potential concern for the Yuma clapper rail and evaluated in this study. Mercury has been found in eggs of the California clapper rail nesting in San Francisco Bay (Lonzarich et al. 1992), and may also be of concern for the Yuma clapper rail. Other trace elements considered here as contaminants of potential concern for the Yuma clapper rail are: arsenic, cadmium, chromium, copper, lead and zinc.

Sediments were analyzed for a suite of inorganics including arsenic, boron, cadmium, chromium, copper, lead, mercury, selenium and zinc. Maximum concentrations were 15.1, 30.3, 1.5, 25.5, 31.7, 20.1, 0.035, 9.6, and 74.6 parts per million (ppm) dry weight (DW), respectively. Of the elements considered, only mercury was not found in all 19 sediment samples. Mercury was found in 16 of the 19 sediment samples. Crayfish had detectable concentrations of these same analytes with the exception of lead which was not detected in any of the 19 samples. Maximum concentrations in ppm DW were: arsenic - 12.2, boron - 30.9, cadmium - 0.5, chromium - 2.0, copper - 127.5, mercury - 0.16, selenium - 4.7, and zinc - 107.1. Boron, mercury and selenium were detected in all rail egg and tissue samples with the exception of one egg sample which did not have detectable boron and the kidney sample which was only analyzed for selenium due to the small quantity of material. Maximum egg concentrations for boron, mercury, and selenium were 2.3, 1.1, and 7.8 ppm DW, respectively. Tissue concentrations for the same elements were 17.4, 3.7 and 11.8 ppm DW, respectively. Arsenic, cadmium, chromium, copper, lead and zinc were detected at low concentrations or not detected in the rail tissue samples.

Only four organochlorine compounds were detected in any of the sediment samples. Most concentrations measured were close to the detection limit with the highest detected concentration being for p,p' DDE at 0.13 ppm DW (0.099 ppm wet weight). The two rail eggs had concentrations of this compound of 0.27 and 0.34 ppm fresh wet weight, but only three of the 19 crayfish samples had detectable concentrations. The range for crayfish was <0.01-0.045 ppm wet weight (WW).

The results were reviewed considering two types of impacts. Indirect impacts to the Yuma clapper rail may be occurring as a result of direct impacts to crayfish, their main prey item. Concentrations in sediments were compared with available thresholds for invertebrate impacts. Direct impacts were evaluated by comparing crayfish concentrations and sediment concentrations (may be consumed incidentally in feeding) to available toxicity and reproductive threshold for birds.

Based on the results of this study concerns do remain regarding the potential for contaminant impacts to the Yuma clapper rail. Indirect impacts may be occurring as a result of DDT in these areas, but further study is required to determine if prey availability is diminished as a result of the measured concentrations of DDT or its metabolites. Boron is not expected to be problematic for crayfish populations, but measurement of waterborne concentrations would be helpful in making that determination. Indirect effects are not expected from any of the other constituents examined.

Of all the constituents examined, selenium is of greatest concern to the Yuma clapper rail. Even though concentrations in the primary prey item (crayfish) fell below most of the discussed dietary thresholds, concern still exists over the levels found for the following reasons. The irrigation source water in the Imperial Valley is Colorado River water with selenium levels (2 parts per billion) close to the peripherally hazardous waterborne threshold in birds. Most of the nesting areas for the Yuma clapper rail are shallow ponds with very low flow, the type of aquatic system most efficient at accumulating selenium (Lemly and Smith 1987). Eggs of the Yuma clapper rail that were collected from the Wister Unit when irrigation drainwater was being used had selenium concentrations that were elevated above background levels.

DDT and its metabolites are still of concern despite the low concentrations measured because of the possibility that eggshell thinning may have occurred in Yuma clapper rails nesting in the Wister Unit. A comprehensive review of eggshell thicknesses before and after the introduction of DDT is necessary to evaluate the importance of the eggshell thicknesses obtained in this study. Because tailwater runoff is believed to carry these sediment-sorbed contaminants from the fields where they were originally applied (Setmire et al. 1990), avoiding the use of drainwater in these wildlife areas will help to minimize future exposure.

Concerns remain that direct impacts to Yuma clapper rails may be occurring as a result of boron concentrations in the areas studied. One of the liver samples had an elevated concentration, and further study would be required to determine if a problem still exists now that irrigation drainwater is not being used in the area where the bird was collected. Chromium exposure may be a problem in these areas if clapper rails are more sensitive than poultry to its impacts. This would require specific research on rallids. Copper concentrations in the Imperial Valley may be causing chronic effects. Again, further study would be required to determine if the concentrations measured may be impacting rail populations in the Imperial Valley. Arsenic, cadmium, lead, mercury, and zinc are not expected to impact Yuma clapper rails directly in these areas.

The Service strongly recommends against the use of irrigation drainwater in wildlife habitat areas. As previously discussed, Colorado River water alone has the potential for impacts. Ohlendorf

(1989) provides a thorough review of studies conducted at Kesterson National Wildlife Refuge where irrigation drain water was used for wildlife habitat. The resultant impacts to breeding birds included embryotoxicity and developmental abnormalities in chicks. Use of irrigation drainwater will greatly increase the risk of impacts to the Yuma clapper rail. If the use of drainwater in the habitat of the endangered Yuma clapper rail is pursued, further discussions should take place with the USFWS in order to assure that any impacts are avoided, minimized and mitigated appropriately. If a Federal action is involved in any aspect of drainwater use, consultation will be required with the USFWS under section 7 of the Endangered Species Act of 1973.

Introduction

The Yuma clapper rail (*Rallus longirostris yumanensis*) occurs along the Colorado River in Arizona and California, and in small marshes located around the Salton Sea in Imperial and Riverside Counties in California. Todd (1986) identified Yuma clapper rail habitat as having a wet substrate covered with dense vegetation greater than 40 cm in height and broken by openings with ponds and channels with water less than 30 cm deep. Bennett and Ohmart (1978) found that arrival and departure dates for Yuma clapper rails corresponded closely with the availability of crayfish (*Procambarus* and *Orcopectes*) in the types of areas described above. In the Salton Sea ecosystem these areas are most prevalent in the Wister Unit of the California Department of Fish and Game's Imperial Wildlife Area, the Salton Sea National Wildlife Refuge, and a few irrigation drains in the Salton Sea area. The Yuma clapper rail was listed as a federal endangered species in 1967 (U.S. Department of the Interior 1967). It is listed as threatened by the State of California.

Yuma clapper rails are highly territorial during the breeding season (Todd 1986). Contamination in a territory may result in greater impacts to the pair occupying that territory than would occur in more wide-ranging species, particularly if contamination occurs in crayfish which form the bulk of the diet. Rusk (1991) did identify contaminant exposure, specifically to selenium, in Yuma clapper rails in the lower Colorado River, suggesting that Salton Sea Yuma clapper rails may also be at risk of exposure. That study found selenium liver concentrations (mean of 25.3 ppm DW) indicative of high risk of teratogenicity, but not high enough to be likely to result in adult mortality.

This study focused on the Yuma clapper rail in the Imperial Valley. This area is dominated by agricultural activities, and irrigation drainwater is a major component of surface water in the valley. Previous studies conducted in the Imperial Valley (Setmire et al. 1993) indicated that high concentrations of selenium exist in some areas there and may impact the Yuma clapper rail. Of particular concern in the above study was the finding that biomagnification of selenium is occurring across trophic levels in the Salton Sea ecosystem. Ohlendorf (1989) found that ducks in the Imperial Valley had mean liver selenium concentrations that were three times concentrations seen in the same species from the Sacramento Valley. The Yuma clapper rail is a predatory species, feeding on a variety of aquatic species but predominantly crayfish if they are available. This study addressed the potential for exposure to elevated selenium in the environment (sediments) and the diet (crayfish). Available tissue samples were also analyzed in an effort to assess the potential for biomagnification.

DDT and its metabolites have been found in clapper rail eggs from several sites around the country (Klaas et al. 1980, Lonzarich et al. 1992, and Jarman et al. 1993). In the Imperial Valley DDT and its metabolites were found in several of the matrices studied by Setmire et al. (1993). Crayfish and clams collected from the rivers and drains had mean concentrations of p,p'DDE that were eight times greater than the mean concentration for Salton Sea invertebrates. Yuma clapper rails nesting in this area do use the river deltas and some drains in addition to the waterfowl ponds maintained by the U. S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG), raising concerns that they may be exposed to harmful concentrations of these compounds in their diet. Samples collected for analysis of inorganics were also analyzed for organochlorine compounds to assess the potential for impacts from these compounds.

Boron was found to bioaccumulate in most trophic levels studied in the Imperial Valley (Setmire et al. 1993). Although it did not appear to biomagnify, its presence in irrigation drainwater may pose a threat to aquatic birds. Smith and Anders (1989) found that dietary boron at concentrations below maximum concentrations found in food items in the San Joaquin Valley did cause reproductive problems in mallards. This element was considered a contaminant of potential concern for the Yuma clapper rail and evaluated in this study. Mercury has been found in eggs of the California clapper rail nesting in San Francisco Bay (Lonzarich et al. 1992), and may also be of concern for the Yuma clapper rail. Sediment, crayfish and egg samples were analyzed for mercury in order to assess its potential for impacts in this ecosystem. Other trace elements considered here as contaminants of potential concern for the Yuma clapper rail are: arsenic, cadmium, chromium, copper, lead and zinc.

Starting water for irrigation in the Imperial Valley is Colorado River water. Setmire et al. (1993) found a selenium concentration of 2 parts per billion (ppb) in Colorado River water in the East Highline Canal. Lemly and Smith (1987) found that waterborne selenium concentrations of 2-5 ppb can biomagnify in food chains and cause toxicity in fish and waterfowl. Skorupa and Ohlendorf (1991) consider drainage water containing 3-20 ppb selenium to be peripherally hazardous to aquatic birds. Concentrations as low as 7 ppb were found in the Imperial Valley drains (Setmire et al. 1990), but this still falls into that peripherally hazardous range. This suggests that the use of any irrigation drainwater in areas used by the Yuma clapper rail is likely to increase the risk of reproductive problems in rails using those areas.

Methods

Field Methods for the Yuma Clapper Rail Study

All areas used for collection of samples were identified as areas used by Yuma clapper rails in the course of the annual census work conducted by the CDFG on the Wister Unit of Imperial Wildlife Area and the USFWS Salton Sea National Wildlife Refuge on or adjacent to the refuge. Use areas were defined during the breeding season by means of call counts using tape recorded calls. One to three sample sites were chosen in occupied ponds based on accessibility and adequate depth for setting minnow traps.

Sediment samples were collected using a shovel or a post-digger for deeper water. The samples were removed from the shovel or post-digger using an aluminum foil wrapped stainless steel spoon. The foil was changed between sites. The sediments were placed in chemically-clean jars and placed on ice for transport to the field office. Excess water was removed from the samples, then the samples were weighed and frozen until submitted for chemical analysis.

The crayfish were collected using wire minnow traps. Two traps were set at each site (except two sites where single traps were set) for a minimum of six hours up to overnight. The traps were baited with canned cat food placed in perforated ziploc bags. If ten or less crayfish were caught, all were collected for the sample. If more than ten were caught, crayfish were taken from each trap (generally five from each) so that either ten were collected or the sample jar was full. Crayfish were removed from the traps using stainless steel tongs and placed in chemically-clean jars. The crayfish ranged in size from approximately 5-15 cm in length. Samples were placed on ice for transport to the field office. All samples were weighed then frozen until submitted for chemical analysis.

Attempts were made to collect addled eggs from the areas where sediment and crayfish samples were collected. Areas where nests had been identified in small patches of habitat via call counts were searched after the end of the nesting season. Likely as a result of the cryptic nature of Yuma clapper rail nests and the presence in the area of high numbers of mesopredators, particularly racoons, no nests were located. Therefore, no eggs from the 1994 nesting season were available for analysis.

The two eggs included in this study were collected in May, 1990 from the same nest during a telemetry study of Yuma clapper rails at the Wister Unit of Imperial Wildlife Area. The other eggs from this nest had hatched. The eggs were frozen in the shell and remained frozen until they were thawed for processing in August, 1994. The eggs were weighed and measured, and the contents were removed and placed in chemically clean jars. The contents were then refrozen until submitted for chemical analysis. Data from additional egg samples which were analyzed for another study but collected from the Wister Unit at the same time as these two eggs are included for discussion. Fresh wet weight determinations were made using the method of Stickel et al. (1973). The conversion factor used was developed for Light-footed clapper rails (David Ledig, pers. comm.).

The tissues collected were from salvaged individuals. YCRWAK1 (kidney) and YCRWAL1 (liver) were removed from an adult female collected in May, 1990. YCRWAL2 was a liver sample from an adult male also collected in May, 1990. YCRWC1, YCRWC2, and YCRWC3 were all three-day-old chicks collected in May, 1990. The head, wings, lower legs and skin had been removed from each for taxidermy. The remainder of each chick carcass was submitted as a single sample.

Analytical Methods for the Yuma Clapper Rail Study

INORGANICS

All inorganic analyses for this study were conducted by Hazleton Laboratories America, Inc. using the following techniques.

Elemental analysis was conducted via inductively coupled plasma spectroscopy (Dahlquist and Knoll 1978 and USEPA 1987). The following elements are included in this analysis: aluminum, boron, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, strontium, vanadium, and zinc. Digestion was carried out in nitric acid in a microwave digester. Emission intensities are compared to series of known standards for identification using a Thermo Jarrell Ash ICAP 61E spectrometer, and the spectrometer program corrects the data for background and interfering elements.

Mercury analysis was conducted using cold vapor atomic absorption (USEPA 1984). The samples were digested using sulfuric and nitric acids, and the mercury is reduced with sodium borohydride for determination. Mercury concentration is determined at wavelength of 253.7 nm using a Leeman Labs PS200 atomic absorption spectrophotometer with an MHS-20 hydride generation unit. The signal is compared to a series of standard solutions.

Arsenic and selenium concentrations are determined using a graphite furnace atomic absorption spectroscopy (USEPA 1984) on a Perkin-Elmer Zeeman 5100PC spectrophotometer. The samples are digested with nitric acid in a microwave digester. Arsenic is determined at a wavelength of 193.7 nm and selenium at 196.0 nm by comparison with standard solutions. The method of standard additions is used where interferences are indicated. Nickel matrix modification is employed in the analysis.

Percent moisture is determined by weighing the sample into a tared aluminum dish then drying in an oven at 100 °C until a constant weight is reached (AOAC 1990). This process takes approximately 12-18 hours.

ORGANICS

Organic analyses for the tissue samples in this study were also conducted by Hazelton Laboratories America, Inc. These methods cover the extraction and determination of organochlorine pesticides (OC's) and polychlorinated biphenyls (PCB's).

Spiking solutions are added to the samples after the tissues are ground. Pesticide spiking solutions are added to the matrix and control spikes, and 2,4,5,6-tetrachloro-m-xylene is used as a surrogate spiking solution for all other samples. Tissue samples were then dried under a hood using anhydrous sodium sulfate. A soxhlet extractor is used with methylene chloride to extract the desired fractions from the samples (USEPA 1986). The resulting extract is then concentrated in a Kuderna-Danish apparatus to a volume of 5 ml on a hot water bath, then diluted to 10 ml with methylene chloride.

A 1 ml subsample is use for lipid determination. This sample is placed in a pre-weighed aluminum pan and placed under a hood to evaporate off the solvent. The pan is weighed again, and the following equation is used to calculate percent lipid: ((weight (g) of pan + lipid) - weight (g) of pan) x 10 ml x 100/grams of sample = %lipid grams extracted.

A volume of 5 ml of this sample is injected on an ABC Laboratories Model 1002B Gel-Permeation chromatography system for clean-up (USEPA 1990) using a column packed with 70 g of S-X3 Bio-beads with methylene chloride as the carrier solvent. This extract is concentrated again, this time to 5 ml. 50 ml of hexane is added to the sample and it is concentrated a third time, again to 5 ml. Additional clean-up and separation of the PCB's from the OC's is carried out in a silica gel column. The first fraction is eluted with petroleum ether and contains all PCB's, p,p'DDE, hexachlorobenzene and mirex. It may also include portions of p,p'DDT, o,p'DDE, o,p'DDT and trans-nonachlor. The remaining portions of these pesticides and all other OC's will be found in the second fraction extracted using a mixture of 1% acetonitrile, 19% hexane and 80% methylene chloride. Both fractions then undergo concentration using the Kuderna-Danish apparatus, followed by dilution with hexane and a repeat of the concentration step as described above. Quantification of the constituents is carried out using electron capture gas chromatography with a Hewlett-Packard 5890 gas chromatograph.

Percent moisture is determined by placing one to 10 g of sample in a pre-weighed aluminum pan and weighing again. The sample is dried in an oven at 105 °C for 16 hours and allowed to cool in a desiccator before being weighed again. The following equation is used to calculate the percent moisture: (mass (g) pan + wet sample) - (mass (g) pan + dry sample) x 100/grams of sample = % moisture grams of sample.

Patuxent Analytical Control Facility conducted the OC and PCB analyses on the sediment samples collected for this study. The analytical methods including the preparation, soxhlet extraction, and lipid removal were conducted as described in Cromartie et al. (1975). Glass extraction thimbles were used. The silica gel separation differed from the above reference in that four fractions were produced instead of three to separate dieldrin and endrin from the other pesticides. The OC's were quantified using a gas-liquid chromatograph (GLC) equipped with a 63Ni electron capture detector. The GLC column used was a 30m megabore coated with a 1.0 micron film of 7%cyanopropyl, 7% phenyl polysiloxane. Residues in 10% of the samples were confirmed by gas chromatography/mass spectrometry (GC/MS).

Percent weight was determined for these samples by adding an aliquot of sample to a tared pan and allowing it to dry for 24 hours in an oven at 93 °C. Samples are placed in a desiccator to cool and weighed again. The percent moisture is determined using the following formula:
% moisture=1-(pan+dry weight-pan weight/original aliquot)x100.

Results

INORGANICS

Sediments were analyzed for a suite of inorganics, but only those of concern as contaminants to the Yuma clapper rail are summarized in Table 1. Maximum sediment concentrations of each inorganic were 15.1 ppm DW arsenic, 30.3 ppm DW boron, 1.5 ppm DW cadmium, 25.5 ppm DW chromium, 31.7 ppm DW copper, 20.1 ppm DW lead, 0.035 ppm DW mercury, 9.6 ppm DW selenium, and 74.6 ppm DW zinc. Measurable or elevated concentrations of metals were observed in all samples, with the exception of mercury which was found in 16 of the 19 samples.

Crayfish had detectable concentrations of these same analytes with the exception of lead which was not detected in any of the 19 samples (Table 1). Only one crayfish sample had a detectable concentration of cadmium and 12 of 19 had detectable mercury concentrations, but all the other inorganic analytes were detected in all 19 of the samples. Maximum inorganic concentrations in the crayfish were: 12.2 ppm DW arsenic, 30.9 ppm DW boron, 0.46 ppm DW cadmium, 2.0 ppm DW chromium, 127.5 ppm DW copper, 0.16 ppm DW mercury, 4.7 ppm DW selenium, and 107.1 ppm DW zinc.

Boron, mercury and selenium were detected in all rail egg samples with the exception of one egg sample which did not have detectable boron (Table 1). All tissue samples also had detectable levels of these elements except one kidney sample which was only analyzed for selenium due to the small quantity of material (Table 1). Maximum egg concentrations for boron, mercury, and selenium were 2.27, 1.125, and 7.75 ppm DW (0.37, 0.19, and 1.27 fresh wet weight), respectively. Maximum tissue concentrations were 17.41 ppm DW boron, 3.68 ppm DW mercury and 11.78 ppm DW selenium. Arsenic, cadmium, chromium, copper, lead and zinc were detected at low concentrations or not detected in the rail tissue samples.

ORGANICS

Only four organochlorine compounds were detected in any of the sediment samples. Detections among the 19 samples ranged from one for o,p'DDT to 12 for p,p'DDE (Table 2). Most concentrations measured were close to the detection limit with the highest detected concentration being for p,p'DDE at 0.13 ppm DW (0.099 ppm wet weight).

Crayfish and rail eggs were analyzed for the same suite of organochlorine compounds with detectable concentrations found for p,p'DDE (Table 2). The two rail eggs had 0.27 and 0.34 ppm fresh wet weight p,p'DDE. Three of the 19 crayfish samples had detectable concentrations of p,p'DDE ranging up to 0.045 ppm WW. The other clapper rail tissue samples were not analyzed for organochlorine compounds.

The eggshells from the two eggs analyzed in this study measured 0.266 and 0.209 mm. The other Yuma clapper rail eggshells from six eggs previously collected for this office from the Imperial Valley in 1990 were also measured and the thicknesses were 0.224-0.246 mm (x=.232 mm, sd=.009).

Discussion

The impacts on the Yuma clapper rail from contaminants could occur in two forms: direct impacts on rails or their offspring from contaminants in the diet and indirect impacts resulting from reduced prey availability as a result of direct impacts to prey species (crayfish). Both types of impacts will be considered.

Indirect Impacts

To evalute the potential for impacts to prey species, sediment concentrations were compared to the National Status and Trends Program's Effects Range-Low (ER-L) and Effects Range-Medium (ER-M) from Long and Morgan (1990) and Long et al. (1995) which describe levels not expected and likely to result in impacts, respectively. The measured concentrations were also compared to the

Lowest Effects Levels (LEL) and the Severe Effects Levels (SEL) from the Ontario Ministry of Environment and Energy's Sediment Quality Criteria (Persaud et al. 1993). A summary of these sediment hazard screening values is given in Table 3. Where these thresholds are not available, sediment concentrations are considered relative to available toxicity information for invertebrates.

Selenium concentrations found in the crayfish are of the same order of magnitude as concentrations measured for plankton and insects in control sites, and well below the concentrations found in selenium contaminated sites (Eisler 1985a). The concentrations measured are also well below the toxic effects thresholds for selenium impacts on food-chain organisms of 20-700 ppm given by Lemly (1993). Below these thresholds, impacts to survival and reproduction of the food-chain organisms (crayfish in this case) are not expected. Therefore, indirect impacts of selenium to the Yuma clapper rail as a result of decreased food availability are not expected in the areas studied. It should be noted, however, that the site with the highest sediment concentration of selenium was also the site with the highest selenium concentration in the crayfish sample. The site (located near the intersection of Lack and Grumble Roads) is the only site in the study known to receive irrigation drainwater (Michel Remington, pers. comm.). A pair of Yuma clapper rails was identified as using this site by means of call counts in 1994.

Of the organochlorine compounds, only DDT-related compounds (DDT-r) were detected in the sediments. The guidelines distinguish between the broad classes of DDT-r and include guidelines for the total. For the DDD group all four of the detected values exceeded LEL and ER-L. Two of the four detected values exceeded ER-M. Of the 12 samples in which DDE compounds were detected, all exceeded LEL and ER-L. Eight of the 12 exceeded ER-M levels. However, in the most recent guidelines provided by Long et al. (1995) the ER-M for DDE was higher (0.027 ppm) and only four of the 12 samples exceeded the new figure. Only one sample had a detectable level of a DDT compound, but the concentration did exceed LEL, ER-L and ER-M. Of the thirteen samples with detected total DDT concentrations, all thirteen were above LEL and ER-L. None exceeded ER-M or SEL, but two exceeded the new ER-M (0.0461 ppm) in Long et al. (1995). Of all contaminants detected in the sediment samples, this group was found at concentrations which have the greatest potential to impact crayfish populations. Because juvenile crayfish are more restricted to detritivory and herbivory (Thorp and Covich 1991), this life stage is most likely to be acutely impacted by these concentrations. Further investigation is necessary to determine if impacts are actually occurring to crayfish populations in these areas, and what impacts this may be having on Yuma clapper rails.

All measured concentrations of arsenic in sediments were below ER-L and SEL values with 15 of 19 exceeding LEL. In this case the ER-L and SEL are the same so it is not clear what the significance of the measured arsenic levels is in this case. The new ER-L guideline provided by Long et al. (1995) was lower than the original (8.2 ppm), and six of the 19 samples exceed this new figure. This places approximately 1/3 of the samples in the range where adverse effects would occassionally be seen. Eisler (1988) found that dietary levels of 100-1000 mg/kg were fatal to some beetle species, suggesting that the concentrations here (Table 1) may not present a problem, particularly considering that sediments would only comprise a portion of the diet for crayfish.

Boron concentrations found in crayfish in this study were in the same range as those found for aquatic insects in control areas in California (Eisler 1990). These concentrations were well below those for areas contaminated with irrigation drainwater. Dietary boron concentrations found to inhibit reproduction in house flies (the only invertebrate for which dietary concentrations were given in Eisler 1990) were much higher than this study measured in sediments. Measurement of boron in the water would be necessary to determine if impacts to crayfish populations are expected in these areas as a result of boron contamination. However, based on the evidence available, indirect impacts of boron to Yuma clapper rails as a result of decreased food availability are not expected.

Of cadmium concentrations measured, 11 of the 19 sediment samples were above the LEL. None of the samples were above ER-L or SEL. Two samples did exceed the ER-L guideline given by Long et al. (1995) of 1.2 ppm cadmium which places those samples at a level where adverse effects would occassionally be seen. However, the cadmium concentrations found are not elevated in comparison to the background level found for the pre-colonial horizon in the Great Lakes (Persaud et al. 1993), and all fell below the detection limit used in the Reconnaissance Study conducted in the Salton Sea area (Setmire et al. 1990). This suggests that the cadmium concentrations measured in this study are below the level of concern.

The copper concentrations measured all fell below ER-L and SEL values. However, 16 of the 19 were above the LEL. Only two of these were above the given background level for the Great Lakes (Persaud et al. 1993). Long et al. (1995) found that concentrations of 34 ppm were seldom associated with adverse effects. All measured sediment concentrations in this study fell below that level and are not expected to impact crayfish populations.

All measured concentrations of chromium, lead, mercury, and zinc were below LEL and ER-L. They also do not exceed the new guidelines presented by Long et al. (1995). None of these elements are expected to impact crayfish populations in these areas.

Direct Impacts

Impacts to Yuma clapper rails may occur as a result of exposure to contaminants in the diet. This includes crayfish as the main component of the diet and sediments picked up in the course of foraging. Therefore, crayfish and sediment contaminant concentrations are considered relative to known dietary thresholds for birds. The dietary thresholds frequently referred to in the discussion are summarized in Table 4. Sediments are expected to form a small portion of the diet, but are considered here because they may function as a direct route of exposure.

Selenium has been found to accumulate to unnaturally high levels in wetland areas receiving agricultural drainwater (Skorupa et al. 1996). Selenium can cause high rates of embryo mortality and teratogenicity (Ohlendorf 1989), raising concerns that birds breeding in areas of the Imperial Valley subject to irrigation drainwater may be suffering reproductive effects. According to Eisler (1985a) domestic chickens (*Gallus domesticus*) showed reduced hatchability of eggs at dietary concentrations as low as 6 ppm DW. Ducks showed normal development at 5 ppm or less of dietary selenite. Puls (1988) considered dietary levels of 3-5 ppm DW to be high and >5 ppm to be toxic to poultry. The National Academy of Sciences (1980) Tolerable Level for poultry was 2 ppm DW. This is also the sublethal physiological response threshold identified by Skorupa et al. (1996). While Eisler (1985a) considers chickens to be extremely sensitive to reproductive effects, no data is currently available for clapper rails and these thresholds should be protective. In a variety of studies summarized by Skorupa and Ohlendorf (1991), a critical dietary threshold of 5 ppm was identified for birds. Skorupa et al. (1996) summarized the available data and found that reproductive impairment in birds is associated with diets containing as little as 2.5-8 ppm selenium. Only one sediment concentration measured in this study was within this range, and only the sample with the highest concentration (9.57 ppm DW) exceeded it. That highest concentration was from the sample collected from the only site currently receiving irrigation drainwater. The only other sediment sample which exceeded the Skorupa and Ohlendorf (1991) critical level was a sample (5.49 ppm DW) collected from an area which receives tail water runoff from the local fields (Clark Bloom, pers. comm.). All but one of the sediment samples taken from areas not currently receiving irrigation drainwater or tailwater had selenium concentrations below the National Academy of Sciences Tolerable Level, and that one sample (2.18 ppm DW) only exceeded that level by a small amount. None of the concentrations exceeded the level of 10-15ppm DW discussed by Skorupa et al. (1996) as protective of juvenile and adult birds against fatal dietary exposure during winter stress. Particularly considering the incidental nature of sediment consumption in the Yuma clapper rail, sediment-borne selenium in the diet is not of great concern in the major nesting areas.

Crayfish concentrations are of concern because they form the major component of the diet and the mean concentration for the crayfish samples exceeded the Tolerable Level for poultry (National Academy of Sciences 1980). While none exceeded the 5 ppm threshold described by Skorupa and Ohlendorf (1991), ten of the 19 samples were within the dietary range of 2.5-8 ppm DW where reproductive impairment was seen in birds (Skorupa et al. 1996). As mentioned above, the concentrations found in the crayfish samples are not expected to impact the crayfish populations, but are of concern for the clapper rails consuming them. Rusk (1991) found similar concentrations of selenium in crayfish in the lower Colorado River (means were 1.51-3.88 ppm DW). These concentrations along with the mean found in this study (2.16 ppm DW) do fall near or above previously mentioned threshold levels. Rusk (1991) also found that liver burdens of the birds using these areas were high enough to suggest that birds in the lower Colorado River were at high risk of teratogenicity, even though crayfish concentrations were well below those found for prey items at Kesterson Reservoir (26.0-119 ppm DW) where several indicators of reproductive impairment were seen (Hothem and Ohlendorf 1989). While the problem may not be as severe as that found at Kesterson, the results of Rusk (1991) and crayfish concentrations measured in this study indicate that there is potential for selenium impacts in this system.

Skorupa et al. (1996) developed a range of species specific teratogenesis thresholds for egg selenium in birds of 15-50 ppm DW, and clutch viability impacts were seen in stilts at an even lower range of 6-15 ppm DW. The one of the two eggs analyzed in this study (4.98 and 7.75 ppm DW) was within the latter range, and both were above the reference interquartile boundaries of 1.4 and 2.7 ppm DW considered to be uncontaminated by Skorupa and Ohlendorf (1991). Five eggs previously submitted for analysis by this office which were collected in the same site and year had concentrations which were similar to those in this study at 2.83-5.63 ppm DW (geometric mean = 3.94 ppm DW). These are also above the uncontaminated range given by Skorupa and Ohlendorf (1991). At the time all of the egg samples were collected, irrigation drainwater was being used in the Wister Unit for their ponds (Chris Gonzales, pers. comm.) and may have resulted in higher dietary concentrations of selenium than those found in this study (drainwater is not being used in these ponds now; Chris Gonzales, pers. comm.). The two liver concentrations measured, however, were below the range of 12-16 ppm DW given by Ohlendorf et al. (1986) as indicative of areas without selenium contamination.

Starting water for irrigation in the Imperial Valley is Colorado River water. Setmire et al. (1993) found a selenium concentration of 2 ppb in Colorado River water in the East Highline Canal. Lemly and Smith (1987) found that waterborne selenium concentrations of 2-5 ppb can biomagnify in food chains and cause toxicity in fish and waterfowl. Skorupa et al. 1996 found that thresholds for bioaccumulative toxicity have been observed at 1.5-3 ppb in selenate and selenite dominated waters. Skorupa and Ohlendorf (1991) consider drainage water containing 3-20 ppb selenium to be peripherally hazardous to aquatic birds. Drainwater containing greater than 20 ppb selenium was considered widely hazardous to birds. Analysis of water from subsurface drains in the Imperial Valley (Setmire et al. 1993) showed concentrations as high as 360 ppb. Concentrations of up to 330 ppb were measured at Kesterson by Saiki and Lowe (1987). Concentrations as low as 7 ppb were found in the Imperial Valley drains (Setmire et al. 1990), but this still falls into the peripherally hazardous range of Skorupa and Ohlendorf (1991). This suggests that the use of any irrigation drainwater in areas used by the Yuma clapper rail is likely to increase the risk of reproductive problems in rails using those areas.

Acute toxicity of DDT and its derivatives to Yuma clapper rails is not expected as a result of consuming either the crayfish or sediments found in this area. Van Velzen and Kreitzer (1975) found that a 5-day LC50 for clapper rails consuming p,p'DDT in the diet was 1,612-1,882 ppm. Detected concentrations in sediments ranged only as high as 0.099 ppm WW and in crayfish as high as 0.045 ppm WW, both for p,p'DDE. The crayfish samples did not have detectable concentrations of any other organochlorine compounds, but a few of the sediment samples did have measurable concentrations of three of the other DDT derivatives: o,p'DDD, o,p'DDT, and p,p'DDD.

Reproductive effects have been associated with much lower levels than those for acute toxicity. Blus (1984) found a critical value for DDE in eggs associated with marked declines in reproduction of brown pelicans (*Pelecanus occidentalis*) of 3 ppm. Henny and Herron (1989) found decreased productivity of white-faced ibis (*Plegadis chihi*) when egg concentrations reached 4 ppm, and especially at levels above 8 ppm. Henny et al. (1984) found decreased productivity in black-crowned night-herons (*Nycticorax nycticorax*) when egg residues reached 8 ppm. Little specific information on DDE-related eggshell thinning is available for rails, but Klaas et al. (1980) found no changes in eggshell thickness for clapper rail eggs with DDE concentrations up to 1.3 ppm. The concentrations measured in this study fall below all of these thresholds. Addled Yuma clapper rail eggs that were previously analyzed for this office had p,p'DDE concentrations similar to those measured in this study. Six eggs were analyzed and the range of p,p'DDE concentrations was 0.17-0.54 ppm fresh WW and the geometric mean was 0.28 ppm fresh WW. This suggests that the Yuma clapper rails using these areas are not being exposed to dietary concentrations which are high enough to result in reproductive impacts.

Concern still remains over p,p'DDE concentrations in the eggs from the Yuma clapper rail. While the range seen of 0.17-0.54 ppm fresh WW appears to be relatively low, eggshell thickness measurements for some of these eggs were also low. The eggshell thicknesses for the eight eggs included here were 0.209-0.266 mm, with a mean of 0.234 mm. In comparison to values given by Klaas et al. (1980) for clapper rails in the eastern United States of 0.241- 0.258 mm, the thicknesses of several eggs measured here are of concern. In a recent study of Light-footed clapper rails conducted by this office (Goodbred et al. 1996), eggshell thicknesses for Mugu Lagoon, Seal Beach and Tijuana Slough averaged 0.247, 0.267 and 0.273 mm, respectively. Pre-DDT era eggshells from Light-footed clapper rails throughout Southern California averaged 0.251 mm. An increased sample size of eggshells of the Yuma clapper rail throughout its range from pre- and post-DDT eras is needed to determine if the thicknesses found here are representative of this population and may be the result of contaminant exposure.

Arsenic was found in all crayfish and sediment samples collected. The concentrations found (geometric mean = 5.00 ppm for crayfish and 7.25 ppm for sediments) fall below recommended dietary limits given by Eisler (1988a) such as the 30mg/kg level where growth reduction was seen in mallard chicks. Concentrations provided by Eisler for a variety of marine crustaceans (no freshwater invertebrate data were given) were similar to the levels seen in the crayfish samples for this study. The concentrations measured in the sediments fell within levels found in the Upper Mississippi River, Lake Michigan and in uncontaminated soils throughout the United States (Eisler 1988a). Puls (1988) gave a value of 100 mg/kg of the organic form of arsenic as a normal level in poultry or waterfowl diets. This is the same as that given by the National Academy of Science (1980) as the maximum tolerable level in poultry. Crayfish and sediment concentrations measured in this study (although the form is not known) fall well below this level and should not present a dietary arsenic hazard to the Yuma clapper rail. Hoffman et al. (1992) found reduced growth in mallard ducklings as a result of arsenic in the diet. The concentrations tested, however, were 200-300 ppm which were well above the concentrations measured in this study. Clapper rail tissue concentrations found in this study (0.05-0.31 ppm WW) support that impacts are not expected from arsenic as these concentrations fall within background levels given by Eisler (1988a) which range from 0.07 - 13.2 ppm fresh weight.

The boron concentrations found in crayfish and sediments in this study are below those found to result in decreased growth and well below those which were found to cause duckling mortality by Smith and Anders (1989). Concentrations found in both crayfish and sediments fell within ranges described by Eisler (1990) as concentrations in the diets of controls in avian studies and the crayfish concentrations were similar to those found in aquatic insects in a control area in California. Boron was found to result in greater growth impairment under conditions of restricted dietary protein by Hoffman et al. (1991). The measured concentrations fall below the level tested by two to three orders of magnitude. Particularly if dietary protein is not restricted, the dietary boron concentrations measured are not of concern. The concentrations measured in the two addled clapper rail eggs were below the mean found for mallard eggs laid by females on a diet supplemented with 30 ppm boron in that study. However, one of the livers analyzed did have a concentration in the same range as mallards fed 300 ppm boron. It is possible that dietary levels were higher in 1990 when the birds were collected. At that time irrigation drainwater was being used in the Wister Unit for their ponds (Chris Gonzales, pers. comm.), and may have resulted in higher dietary concentrations of boron. At the time the crayfish samples were collected for this study, drainwater was no longer being used in these ponds (Chris Gonzales, pers. comm.) suggesting that the ultimate source of boron in clapper rails may be irrigation drainwater. If additional samples of Yuma clapper rail tissues become available from these areas where irrigation drainwater is not being used, these should be analyzed to confirm the role of drainwater in boron body burdens in Yuma clapper rails.

Eisler (1985b) recommends concern when wildlife dietary levels of cadmium exceed 0.1 mg/kg on a sustained basis. Cain et al. (1983) found that a dietary concentration of 20 ppm caused kidney lesions in mallard ducklings after twelve weeks of exposure. Levels of 5 and 10 ppm did not produce discernable kidney damage. Mayack et al. (1981) had similar results when testing dietary concentrations of 1, 10, and 100 ppm in wood ducks. Only the diet containing 100 ppm cadmium caused visible lesions in the kidneys. Scheuhammer (1987) surmised that a long-term exposure to dietary concentrations of 5-10 ppm may become toxic to mallards due to bioaccumulation in the kidneys. Only one of the 19 crayfish samples had a detectable concentration of cadmium. Although this concentration (0.46 ppm) did exceed the Eisler recommendation, a single detected value out of 19 samples would not appear to constitute a sustained exposure for the rails. While cadmium concentrations in the sediment samples collected did exceed the Eisler recommendation (geometric mean = 0.64 ppm), measured concentrations did fall well below histopathological effects levels found for mallards and wood ducks and the long-term toxicity threshold for mallards. Because consumption of sediments is incidental, it should constitute only a small portion of the diet for clapper rail adults and chicks. Cadmium in crayfish and sediments is not expected to present a risk to Yuma clapper rails in the areas studied. Measured liver concentrations (0.08-0.14 ppm WW) fall within background levels given by Eisler (1985b) of 0.6-0.9 ppm fresh weight in bird livers. All other tissues did not have detectable concentrations of cadmium.

Eisler (1986) found a wide range of effects between forms of chromium and for different taxonomic groups, to the point that a single dietary threshold could not be recommended. Dietary levels of 10 mg/kg were found to adversely affect young black ducks, which is of concern because the concentrations found here for sediments (geometric mean = 16.28 ppm) do fall in that range. However, the crayfish samples had much lower concentrations (geometric mean = 1.21 ppm) and are of less concern. Puls (1988) identified the normal dietary range for poultry and waterfowl as 5-20 ppm with toxic levels for this group of >300 ppm chromium. The National Academy of Sciences (1980) maximum tolerable level for poultry was 1000 ppm chromium. All of the tissue samples which were submitted for chemical analysis had tissue residues of chromium (0.13-0.66 ppm DW) that were below what Eisler described as being indicative of chromium contamination (>4 mg/kg DW) and those given for duck and gull species as background levels (<1.0 ppm DW). If rail sensitivity to chromium levels is similar to that for poultry, the concentrations found in the Salton Sea area should not be problematic. The sediments which are of concern are likely to comprise only a small portion of the diet. Research into the specific sensitivity of the rallids to chromium would be necessary to conclusively evaluate the potential impacts of the measured concentrations.

Puls (1988) provides a range for copper in the diet of poultry and waterfowl as 10-50 ppm with toxicity at >200 ppm copper. The National Academy of Sciences (1980) maximum tolerable level for poultry is 300 ppm copper. All of the sediment concentrations fall well below these toxic levels and the Puls high level (100-200 ppm). All of the crayfish samples exceed the normal range of Puls, and one falls into the high range. Acute toxicity is not expected provided clapper rails are similar to poultry in their sensitivity to this element. However, additional studies would be required to determine if chronic effects are occurring in clapper rails at these dietary levels. Copper sources in the Salton Sea should be investigated for the potential to control introduction of this element into the ecosystem.

Lead was not found at detectable concentrations in any of the crayfish samples collected in this study. Dietary lead consumption is therefore expected to be through incidental consumption of sediments while foraging. Eisler (1988b) noted that minimal effects were seen in cases where dietary lead was 10 ppm DW. The mean and maximum sediment lead concentrations found in this study were above this level but not by a large amount. Puls (1988) considered a dietary concentration of 25 ppm to be high, and the National Academy of Sciences (1980) Maximum Tolerable Level for lead was 30 ppm. All sediment concentrations fell below both of these levels. Because sediment is expected to comprise a small portion of the diet, overall dietary lead concentrations should fall below that from Eisler (1988b) and impacts are not expected. The two liver samples analyzed in this study did not have detectable lead concentrations, also suggesting that lead is not likely to be a problem for this population. Eisler (1988b) found that liver concentrations >10 ppm DW were considered elevated and were of concern. The samples analyzed here had detection limits of 0.49 and 1.98 ppm.

Mercury concentrations in the crayfish and sediment samples were below the dietary no effect level of 0.05 ppm (fresh weight) given for chickens by Eisler (1987). The normal range given by Puls (1988) was <0.1 ppm, and levels of 5-100 ppm were considered toxic for poultry and waterfowl. The National Academy of Sciences (1980) figure for poultry toxicity is 2 ppm. Because the measured concentrations for crayfish and sediments fall well below these toxic thresholds, consumption of crayfish or sediments in these areas is not expected to result in impacts to Yuma clapper rails from the mercury content. Mercury concentrations found in tissues this study ranged as high as 1.193 ppm DW. Eisler (1987) found that fresh weight concentrations in biota were generally <1.0 ppm in areas not impacted by anthropogenic sources of mercury. The concentrations obtained in this study (0.14-0.91 ppm WW) all fall below that level.

Zinc concentrations in the crayfish samples collected (geometric mean = 79.14 ppm DW) were slightly higher than those in the sediment samples collected for this study (geometric mean = 52.96 ppm DW). All concentrations measured, however, fell below the recommended dietary limit of 178 ppm provided by Eisler (1993) and were within the normal range described by Puls (1998) of 98-200 ppm. The National Academy of Sciences (1980) Maximum Tolerable Level for zinc was 1000 ppm. Zinc is therefore not expected to present any risk to Imperial Valley Yuma clapper rails.

Summary and Conclusions

Of all the constituents examined, selenium is of greatest concern to the Yuma clapper rail. Even though concentrations in the primary prey item (crayfish) fell below most of the discussed dietary thresholds, concern still exists over the levels found for the following reasons:

> The source water for irrigation drainwater in the Imperial Valley is Colorado River water with selenium levels (2 ppb) close to the peripherally hazardous waterborne threshold in aquatic birds.
>
> Most of the nesting areas for the Yuma clapper rail are shallow ponds with very low flow, the type of aquatic system most efficient at accumulating selenium (Lemly and Smith 1987).
>
> Eggs of the Yuma clapper rail collected from the Wister Unit when irrigation drainwater was being used had selenium concentrations that were elevated above background levels.

This study has documented that sediments, prey items, and Yuma clapper rail eggs and tissues are all contaminated with selenium at or approaching levels of concern for reproductive impacts.

Based on the results of this study concerns do remain regarding the potential for organochlorine contaminant impacts to the Yuma clapper rail. Indirect impacts may be occurring as a result of DDT in these areas, but further study is required to determine if prey availability is diminished as a result of the measured concentrations of DDT or its metabolites. DDT and its metabolites are still of concern despite the low concentrations measured because of the possibility that eggshell thinning may have occurred in Yuma clapper rails nesting in the Wister Unit. A comprehensive review of eggshell thicknesses before and after the introduction of DDT is necessary to evaluate the importance of the eggshell thicknesses obtained in this study. Because tailwater runoff is believed to carry these sediment-sorbed contaminants from the fields where they were originally applied (Setmire et al. 1990), avoiding the use of drainwater in these wildlife areas will help to minimize future exposure.

Boron is not expected to be problematic for crayfish populations, but measurement of waterborne concentrations would be helpful in making that determination. Concerns remain that direct impacts to Yuma clapper rails may be occurring as a result of boron concentrations in the areas studied. One of the liver samples had an elevated concentration, and further study would be required to determine if a problem still exists now that irrigation drainwater is not being used in the area where the bird was collected. Chromium exposure may be a problem in these areas if clapper rails are more sensitive than poultry to its impacts. This would require specific research on rallids. No indirect impacts are expected from chromium. Copper concentrations in the Imperial Valley are not likely to be causing indirect effects, but may be causing chronic effects. Again, further study would be require to determine if the concentrations measured may be impacting rail populations in the Imperial Valley. Arsenic, cadmium, lead, mercury, and zinc are not expected to impact Yuma clapper rails directly or indirectly in these areas.

The Service strongly recommends against the use of irrigation drainwater in wildlife habitat areas. As previously discussed, Colorado River water alone has the potential for impacts to aquatic birds. Ohlendorf (1989) provides a thorough review of studies conducted at Kesterson National Wildlife Refuge where irrigation drain water was used for wildlife habitat. The resultant impacts to breeding birds included embryotoxicity and developmental abnormalities in chicks. Use of irrigation drainwater will greatly increase the risk of impacts to the Yuma clapper rail. If the use of drainwater in the habitat of the endangered Yuma clapper rail is pursued, further discussions should take place with the USFWS to assure that any impacts are avoided, minimized and mitigated appropriately. If a Federal action is involved in any aspect of drainwater use, consultation will be required with the USFWS under section 7 of the Endangered Species Act of 1973.

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References

Assoc. of Off. Analytical Chemists (AOAC). 1990. Official Methods of Analysis, 15th Ed., Methods 926.08 and 925.09. Arlington, Virginia.

Bennett, W.W. and R.D. Ohmart. 1978. Habitat Requirements and Population Characteristics of the Clapper Rail (*Rallus longirostris yumanensis*) in the Imperial Valley of California. Submitted to the University of California Lawrence Livermore Laboratory.

Blus, L.J. 1984. DDE in birds' eggs: comparison of two methods for estimating critical levels. Wilson Bull. 96(2):268-276.

Cain, B.W., L. Sileo, J.C. Franson, and J. Moore. 1983. Effects of dietary cadmium on mallard ducklings. Environ. Res. 32:286-297.

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

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(1):1-29.

Eisler, R. 1993. Zinc Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 10. Washington D.C.

_______. 1990. Boron Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.20). Washington D.C.

_______. 1988a. Arsenic Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.12). Washington D.C.

_______. 1988b. Lead Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.14). Washington D.C.

_______. 1987. Mercury Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.10). Washington D.C.

_______. 1986. Chromium Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.6). Washington D.C.

_______. 1985a. Selenium Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.5). Washington D.C.

_______. 1985b. Cadmium Hazards to Fish, Wildlife and Invertebrates: a Synoptic Review. U.S. Fish and Wildlife Service; Biological Report 85(1.2). Washington D.C.

Goodbred, S.L., D.B. Ledig, and C.A. Roberts. 1996. Organochlorine Contamination in Eggs, Prey and Habitat of Light-footed Clapper Rails in Three Southern California Marshes. Report submitted to the Division of Environmental Contaminants, U.S. Fish and Wildlife Service, Washington D.C.

Henny, C.J., L.J. Blus, A.J Krynitsky, and C.M. Bunck. 1984. Current impact of DDE on black-crowned night-herons in the intermountain west. J. Wildl. Manage. 48(1):1-13.

Henny, C.J. and G.B. Herron. 1989. DDE, selenium, mercury, and white-faced ibis reproduction at Carson Lake, Nevada. J. Wildl. Manage. 54(3):1032-1045.

Hoffman, D.J., C.J. Sanderson, L.J. LeCaptain, E. Cromartie, and G.W. Pendleton. 1992. Interactive effects of arsenate, selenium, and dietary protein on survival, growth and physiology in mallard ducklings. Arch. Environ. Contam. Toxicol. 22:55-62.

Hothem, R.L. and H.M. Ohlendorf. 1989. Contaminants in foods of aquatic birds at Kesterson Reservoir, California, 1985. Arch. Environ. Contam. Toxicol. 18:773-786.

Jarman, W.M., R.J. Norstrom, M. Simon, S.A. Burns, C.A. Bacon, and B.R.T. Simoneit. 1993. Organochlorines, including chlordane compounds and their metabolites, in peregrine falcon, prairie-falcon, and clapper rail eggs from the USA. Environ. Pollut. 81:127-136.

Klaas, T.E., H.M. Ohlendorf, and E. Cromartie. 1980. Organochlorine residues and shell thicknesses in eggs of the clapper rail, common gallinule, purple gallinule, and limpkin (Class Aves), Eastern and Southern United States, 1972-74. Pestic. Monit. J. 14(3):90-94.

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

Lemly, A.D. and G.J. Smith. 1987. Aquatic Cycling of Selenium: Implications for Fish and Wildlife. U.S. Fish and Wildlife Service , Fish and Wildlife Leaflet 12, Washington D.C.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Manage. 19(1):81-97.

Long, E.R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program. National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 52, Seattle, Washington.

Lonzarich, D.G., T.E. Harvey, and J.E. Takekawa. 1992. Trace element and organochlorine concentrations in California clapper rail (*Rallus longirostris obsoletus*) eggs. Arch. Environ. Contam. Toxicol. 23:147-153.

Mayack, L.A., P.B. Bush, O.J. Fletcher, R.K. Page, and T.T. Fendley. 1981. Tissue residues of dietary cadmium in wood ducks. Arch. Environ. Contam. Toxicol. 10:637-645.

National Academy of Sciences. 1980. Mineral Tolerance of Domestic Animals. Washington D.C.

Ohlendorf, H.M. 1989. Bioaccumulation and Effects of Selenium in Wildlife. In *Selenium in Agriculture and the Environment*, Soil Science Society of America Special Publication no. 23, Madison, Wisconsin.

Ohlendorf, H.M., D.J. Hoffman, M.E. Saiki, and T.W. Aldrich. 1986. Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drainwater. Science Total Environ. 52:49-63.

Persaud, D., R. Jaagumagi, and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of the Environment and Energy, Ontario, Canada.

Puls, R. 1988. Mineral Levels in Animal Health, Diagnostic Data. Sherpa International, Clearbrook, B.C.

Rusk, M.K. 1991. Selenium Risk to Yuma Clapper Rails and Other Marsh Birds of the Lower Colorado River. Masters Thesis presented to the School of Renewable Natural Resources, University of Arizona.

Saiki, M.K. and T.P. Lowe. 1987. Selenium in aquatic organisms from subsurface agricultural drainage water, San Joaquin Valley, California. Arch. Environ. Contam. Toxicol. 16:657-670.

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

Setmire, J.G., R.A. Schroeder, J.N. Densmore, S.L. Goodbred, D.J. Audet, and W.R. Radke. 1993. Detailed Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1988-90. U.S. Geological Survey Water-Resources Investigations Report 93-4014, Sacramento, California.

Setmire, J.G., J.C. Wolfe, and R.K. Stroud. 1990. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1986-87. U.S. Geological Survey Water-Resources Investigations Report 89-4102, Sacramento, California.

Skorupa, J.P., S.A. Morman, and J.S. Sefchick-Edwards. 1996. Guidelines for Interpreting Selenium Exposures of Biota Associated with Nonmarine Aquatic Habitats. U.S. Fish and Wildlife Service, Sacramento Field Office Report for the National Irrigation Water Quality Program.

Skorupa, J.P. and H.M. Ohlendorf. 1991. Contaminants in Drainage Water and Avian Risk Thresholds. In Ariel Dinar and David Zilberman (eds.) *The Economics and Management of Water and Drainage in Agriculture*. Kluwer Academic Publishers.

Smith, G.J. and V.P. Anders. 1989. Toxic effects of boron on mallard reproduction. Environ. Toxicol. Chem. 8:943-950.

Stickel, L.F., S.N. Weimeyer, and L.J. Blus. 1973. Pesticide residues in eggs of wild birds: adjustment for loss of moisture and lipid. Bull. Environ. Contam. Toxicol. 9(4):193-196.

Thorp, J.H. and A.P. Covich. *Ecology and Classification of North American Invertebrates*. Academic Press, Inc., San Diego.

Todd, R.L. 1986. A Saltwater Marsh Hen in Arizona, a History of the Yuma Clapper Rail (*Rallus longirostris yumanensis*). A Federal Aid Project W-95-R, Completion Report.

U.S. Department of the Interior. 1967. Office of the Secretary Native Fish and Wildlife Endangered Species. Fed. Reg. 32(48):4001.

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

U. S. Environmental Protection Agency (USEPA). 1986. Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, EPA Publication No. SW-846. Office of Solid Waste and Emergency Response: Washington, D.C.

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

U. S. Environmental Protection Agency (USEPA). 1990. Contract Laboratory Program, Statement of Work for organic analysis, multi-media, multi-concentration. Document Numbers OLM01.0 (March 1990), OLM01.1 (December 1990), and OLM01.2 (January 1991).

Van Velzen, A. and J.F. Kreitzer. 1975. The toxicity of p,p'DDT to the clapper rail. J. Wildl. Manage. 39(2):1975.

Table 1. Detection Frequency and Summary Stistics for Inorganics of Potential Siginificance to the Yuma Clapper Rail

Matrix	Analyte	Number of Samples	Number of Detections	Range[1]	Mean[2]
Sediments	arsenic	19	19	4.09-15.12	7.25
Sediments	boron	19	19	8.00-30.30	16.12
Sediments	cadmium	19	19	0.37-1.48	0.64
Sediments	chromium	19	19	9.50-25.52	16.28
Sediments	copper	19	19	9.59-31.69	19.29
Sediments	lead	19	19	6.11-20.06	12.26
Sediments	mercury	19	16	<0.013-0.035	0.023
Sediments	selenium	19	19	0.55-9.57	1.43
Sediments	zinc	19	19	32.99-74.57	52.96
Crayfish	arsenic	19	19	2.56-12.16	5.00
Crayfish	boron	19	19	2.20-30.87	7.33
Crayfish	cadmium	19	1	<0.14-0.46	-
Crayfish	chromium	19	19	0.76-1.99	1.21
Crayfish	copper	19	19	25.81-127.46	59.23
Crayfish	lead	19	0	-	-
Crayfish	mercury	19	12	<0.033-0.164	0.042
Crayfish	selenium	19	19	0.92-4.67	2.16
Crayfish	zinc	19	19	33.69-107.14	79.14
Rail eggs	boron	2	1	<1.49-2.27	-
Rail eggs	mercury	2	2	0.523-1.125	-
Rail eggs	selenium	2	2	4.98-7.75	-
Rail chicks	boron	3	3	7.37-9.56	8.07
Rail chicks	mercury	3	3	0.235-0.265	0.250
Rail chicks	selenium	3	3	1.13-1.81	1.44
Rail livers	boron	2	2	4.96-17.41	-
Rail livers	mercury	2	2	0.646-3.68	-
Rail livers	selenium	2	2	3.09-11.78	-
Rail kidney	selenium	1	1	3.69	-

[1] Data values are given in parts per million (ppm) dry weight

[2] Means were calculated as geometric means. For values below the detection limit, a value of ½ of the detections limit was used to calculate the mean provided the non-detects were <50%

Table 2. Detection Frequency and Summar Statistics for Organochlorine Compounds of Potential Significance to the Yuma Clapper Rail

Matrix	Analyte	Number of Samples	Number of Detections	Range[1]	Mean[2]
Sediments	o,p'DDD	19	2	<0.0143-0.0172	-
Sediments	o,p'DDT	19	1	<0.0134-0.0618	-
Sediments	p,p'DDD	19	4	<0.0148-0.0618	-
Sediments	p,p'DDE	19	12	<0.0143-0.132	.0229
Crayfish	p,p'DDE	19	3	<0.01-0.045	-
Rail eggs	p,p'DDE	2	2	0.27-0.34[3]	-

[1] Data values are given in parts per million (ppm) dry weight for sediments and ppm wet weight for crayfish and rail eggs.

[2] Means were calculated as geometric means. For values below the detection limit, a value of ½ the detection limit was used to calculate the mean provided the non-detects were <50%

[3] Egg concentrations were converted to fresh wet weight using the technique of Stickel et al. (1973). The conversion factor used was calculated for Light-footed clapper rail eggs (D.Ledig, pers. comm.)

Table 3. Summary of Sediment Screening[1] Levels Developed by the Ontario Ministry of the Environmental and Energy (Persaud et al. 1993), NOAA (Long and Morgan, 1990) and updates by Long et al. (1995).

Substance	Ontario-LEL[2]	NST-ERL[3]	1995 ERL[4]	Ontario-SEL[5]	NST-ERM[6]	1995-ERM[7]
Arsenic	6	33	8.2	33	85	70
Cadmium	0.6	5	1.2	10	9	9.6
Chromium	26	80	81	110	145	370
Copper	16	70	34	110	390	270
Lead	31	35	46.7	250	110	218
Mercury	0.2	0.15	-	2	1.3	0.71
Zinc	120	120	150	820	270	410
p,p'DDE	0.005	0.002	0.0022	19[8]	0.015	0.027
Total DDT's	0.007	0.003	0.00158	12[8]	0.350	0.0461

[1] Values are for bulk sediment chemistry in ppm on a dry-weight basis.

[2] The Ontario-LEL is the Lowest Effect Level, defined as the concentration in sediment indicating a level of contamination which has the potential to affect some sensitive benthic organisms. The level is derived from the 5th percentile of the Species Level Concentration Distribution (Ontario, Canada).

[3] The ERL is the National Status and Trends, Effects Range Low. It is the concentration below which adverse effects are seldom expected. It is developed by taking the 10th percentile of the ranked adverse effects data in the Long and Morgan database (Long and Morgan, 1990).

[4] The 1995 ERL is the Effects Range Low from Long et al. (1995). It is defined as above for the National Status and Trends.

[5] The Ontario-SEL is the Severe Effect Level, defined as the concentration in sediment indicating a level of contamination which significantly affects benthic organisms. The level is derived from the 95th percentile of the Species Screening Level Concentration Distribution.

[6] The ERM is the National Status and Trends, Effects Range Medium. It is that concentration above which adverse effects are likely. It is developed by taking the 50th percentile of the ranked adverse effects data in the Long and Morgan data base (Long and Morgan, 1990).

[7] The 1995 ERM is the Effects Range Medium from Long et al. (1995). It is defined as above for the National Status and Trends.

[8] Given for ug/g organic carbon

Table 4. Assessment values for concentrations of inorganics (mg/kg) in bird diets.

Element	Reference/Sources				
	Eisler[a] Acceptable	Puls[b]			National Academy of Sciences[c] Tolerable Level
		Normal/ Adequate	High	Toxic	
Aluminum	NA	<500	NA	>1,500	200[d]
Arsenic[e]	<100 DW[f]	100[f]	NA	NA	100[f]
Barium	NA	NA	NA	NA	(20)[d]
Boron	<13 FW	NA	NA	NA	(150)
Cadmium	<0.1 FW	<5	10-20	>20	0.5[g]
Chromium	<10 DW	5-20	NA	>300	1,000
Copper	NA	10-50	100-200	>200	300[e]
Iron	NA	80	NA	200-2,000	1,000
Lead	<10 DW	NA	25[h]	NA	30[g]
Magnesium	NA	600-3,000	3,000-9,000	6,400-12,800	(3,000)
Manganese	NA	60-200	1,000-4,000	>4000	2,000
Mercury	<0.1 FW	<0.1	1-50	5-100	2[g]
Molybdenum	<200 DW	0.03-1.0	3-10	>200	100
Nickel	NA	0.1-3.0	100-300	700-1,000	300
Selenium	<6 DW(i)	0.3-1.1	3-5	>5	2
Silver	NA	10-100	100	NA	100
Strontium	NA	NA	NA	>3,000	3,000
Vanadium	NA	0.1-3.0	6-50	100-800	10
Zinc	<178 DW	98-200	800-2,000	>2,000	1,000

[a] Eisler, 1985a, 1985b, 1986a, 1987a, 1988a, 1988b, 1989, 1990a, 1993.

[b] Puls, 1988; all values given as DW for poultry or waterfowl (when available).

[c] NAS, 1980; all values given as DW for poultry; values in parentheses were extrapolated from other species.

[d] As Soluble salts of high bioavailability. Higher levels of less soluble forms found in natural substances can be tolerated.

[e] Based also on Phillips, 1990, and Stanley et al., 1994.

[f] Arsenic in organic form, which is less toxic than inorganic arsenic

[g] Level based on human food residue considerations.

[h] Maximum no effect level for waterfowl.

[i] Based also on Ohlendorf, 1989

NA=Not Applicable
DW=Dry Weight
FW=Fresh Weight