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Region 2

Contaminants Program

CONTAMINANTS IN POTENTIAL APLOMADO FALCON PREY FROM PROPOSED REINTRODUCTION SITES IN ARIZONA

by

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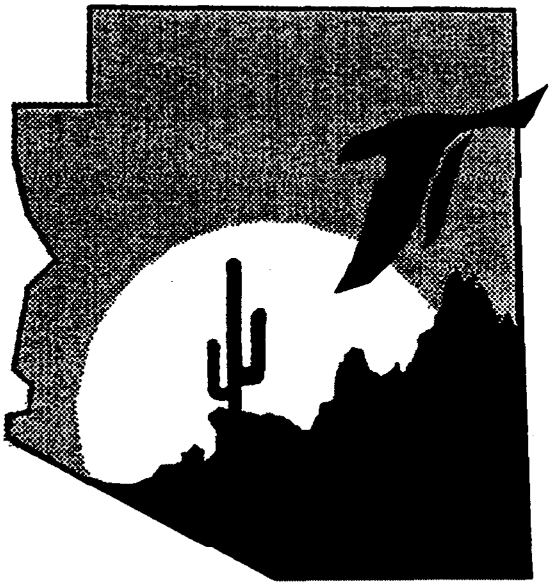

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ABSTRACT--Meadowlarks *(Sturnella spp.)*, mourning doves (*Zenaida macroura*), lizards (*Cnemidophorus spp.*), and grasshoppers (Caelifera) were collected in 1992 as representative samples of the aplomado falcon's prey base. A 2-way analysis of variance revealed no differences in contaminant levels among areas, but there were differences among species. DDE was the only organochlorine compound detected and concentrations were below those known to adversely affect reproduction even in the most sensitive avian species. With the possible exception of arsenic in some food items, the only contaminant of concern was selenium. Although selenium in avian prey items was well within the normal or background range (ı 10 µg/g dry . weight), selenium sensitive species may be affected by as little as 3-8 µg/g. Additional research or intensive field monitoring is needed to determine the relative sensitivity of aplomado falcons to selenium.

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INTRODUCTION

The historic range of the northern aplomado falcon (*Falco femoralis septentrionalis*) in the United States includes southeastern Arizona, southern New Mexico and southwest Texas (Figure 1). Common in the United States in the early 1900s, the aplomado falcon disappeared from most of its range by 1940 (Keddy Hector 1990); the last verified nesting of native aplomado falcons occurred in New Mexico in 1952 (Ligon 1961). The relative density of historic aplomado falcon populations in Arizona may never be known for certain. Lieutenant Harry C. Benson reported the falcon as “fairly common” in the vicinity of Fort Huachuca, Arizona; five active nests were located during a 20-day period during April-May 1887 (Bent 1961). However, Corman (1992) reported only two confirmed sightings between 1910 and 1940. The U.S. Fish and Wildlife Service (Service) listed the northern aplomado falcon as endangered March 27, 1986 (51 FR 6686; February 25, 1986) and the Arizona Game and Fish Department (AGFD) listed the falcon as endangered in 1988 (AGFD 1988).

Aplomado falcons are predators of small birds in grasslands and savannahs, and the falcons decline in the U.S. is largely attributed to habitat deterioration due to brush encroachment into grasslands (Keddy Hector 1990), possibly exacerbated by overgrazing. Habitat destruction due to expanding agricultural development was also a possible factor as was skin and egg collecting. Channelization and agricultural diversion of once permanent desert streams reduced or eliminated riparian habitat that provided important breeding areas for avian prey of the aplomado falcon (Hastings and Turner 1964). Pesticide contamination also may have compounded the aplomado falcon decline in the late-1940s and early-1950s (Keddy Hector 1990, Kiff et al. 1980, Peregrine Fund 1994). High concentrations of DDE, a metabolic breakdown product of the insecticide DDT, have been identified in numerous prey-sized migrant birds in western United States (DeWeese et al. 1986, Enderson et al. 1982, Henry 1992).

The Aplomado Falcon Recovery Plan (Plan) proposed a reintroduction of the falcon into portions of its former range in southwestern United States (Keddy Hector 1990). The Plan’s recovery outline listed several goals including the location of suitable habitat, assessing prey abundance, and monitoring and evaluating pesticides and other environmental contaminants. To address the first two goals, the AGFD initiated an investigation into the feasibility of reintroduction of the aplomado falcon into areas of former abundance in southeastern Arizona. The AGFD characterized habitat and potential prey abundance at IO proposed reintroduction sites (Corman 1992).

Our study focuses on the Plan’s goal to monitor and evaluate organochlorine and metalloid contamination in aplomado falcon potential prey items and make recommendations as to the most suitable areas in Arizona for reintroduction.

STUDY AREA

From seven potential reintroduction sites listed in the Plan (Keddy Hector 1990) and from 10 areas evaluated by the AGFD (Corman 1992), we selected five likely sites and focused our collecting efforts in those areas (Figure 2). In several instances, the proposed reintroduction sites listed in the Plan had also been selected by the AGFD for study. Three of our five study areas were included in both the Plan and the AGFD report; Fort Huachuca, San Simon Valley, and the San Pedro Riparian National Conservation Area (SPRNCA). The remaining two sites, San Bernardino/Leslie Canyon National Wildlife Refuge and the Empire Cienega Ranch were listed in the AGFD report and were highly recommended by Corman (pers. comm.).

Fort Huachuca

Location: Southeastern Arizona adjacent to, and west of, the city of Sierra Vista.
General Site Description: This military base contains 31,400 ha (78,500 acres), mostly in large sections of primarily sacaton (*Sporobolus airoides*) grasslands interspersed with mesquite (*Prosopsis spp.*), and oak (*Quercus spp*). Releases are recommended in open draws on the northern one-half of the reservation (Keddy Hector 1990).
Land Ownership: Department of the Army
Collection sites: South Range, Areas E, X, and Y.
Legal Description: Sections 22 and 23 T22S R20E
Quadrangle: Fort Huachuca, Arizona 7.5

San Simon Valley

Location: North of the Chiricahua Mountains along the Arizona/New Mexico state line, the San Simon Valley extends north-northwest to the Gila River.
General Site Description: This 308,000 ha (760,000 acre) yucca (*Yucca spp.*) - grassland is an ideal area in terms of habitat quality (Keddy Hector 1990). The area is primarily Upper Sonoran zone desert grassland with rolling hills of mixed grasses and some annuals. Small shrubby mesquite, catclaw acacia (*Acacia greggii*), creosote (*Larrea tridentata*), and soaptree yucca (*Y. elata*) are scattered throughout this habitat (Corman 1992). Larger mesquite occur in the drainages. This site has much potential with extensive grassland surrounding the area (Corman 1992).
Land Ownership: Multiple ownership. Predominately Bureau of Land Management and Arizona State trust lands. Smaller holdings are in private ownership.
Collection Site: Robs Well
Area Coordinates: Section 23 T1 1 S R31 E
Quadrangle: San Simon, Arizona 15

San Pedro Riparian National Conservation Area

Location: East and west sides of the San Pedro River extending northward from the United States/Mexico international boundary to just south of the community of Saint David.
General Site Description: This 22,670 ha (56,000 acre) site contains large sections of sacaton grassland interspersed with mesquite, whitethorn acacia (*A. constricta*), and soaptree yucca. The grasslands are bordered by a lush Fremont cottonwood (*Populus fremontii*) and Gooding willow (*Salix gooddingii*) riparian area. The best potential release sites are at the southern one-half near the U.S./Mexico border (Keddy Hector 1990).
Collection site: West side of the San Pedro River between Highway 90 and the Hereford/Nicksville Road.
Land Ownership: Bureau of Land Management, (Safford District)
Area Coordinates: Sections 4 and 9, T23S R22E
Quadrangle: Hereford, Arizona 7.5

San Bernardino/Leslie Canyon National Wildlife Refuae (SB/LCNWR)

Location: West and north of the City of Douglas in the San Bernardino Valley and Swisshelm Mountains in Cochise County.
General Site Description: This refuge consists of two disjunct tracts of land, the 930 ha (2,300 acre) San Bernardino NWR and the 500 ha (1,240 acre) Leslie Canyon NWR. Both areas contain extensive grasslands with low shrubby mesquite, white-thorn acacia, creosote bush and soaptree yucca. Lush riparian habitats are located on both refuges with extensive stands of cottonwood and some willow.
Land Ownership: U.S. Fish and Wildlife Service.
Collection sites: Birds and grasshoppers were collected on San Bernardino NWR near Robertson Cienega. Lizards were collected at both Robertson Cienega and Leslie Canyon NWR.
Area Coordinates: Section 14 and 15 T24S R30E
Quadrangles: San Bernardino Ranch, Arizona 7.5

Empire Cieneaa Ranch

Location: Northeast of Sonoita in Pima and northern Santa Cruz Counties.
General Site Description: This 18,200 ha (45,000 acre) area contains mixed grassland interspersed with smaller areas of mesquite bosque, scattered mesquite and soaptree yucca, sacaton and tabosa grasslands, fallow agricultural fields and cottonwood and willow riparian association (Corman 1992).
Land Ownership: Bureau of Land Management, Tucson Resource Area (Safford District).
Collection sites: Bird prey items were collected near Cienega Creek and Smith Canyon. Lizards and grasshoppers were collected near Enzenberg North Well.
Area Coordinates: Sections 26, 27, and 35, T18S R17E
Quadrangle: Spring Water Canyon, Arizona 7.5

METHODS

Sample collections: Previous food habits studies of the aplomado falcon in eastern Mexico revealed that birds accounted for most of the prey biomass (Hector 1985, Montoya and Zwank 1995); therefore, we focused on collecting potential avian prey species. Species selected included the meadowlark *(Sturnella spp.)* and the mourning dove (*Zenaida macroura*). Both the eastern and western meadowlark occur in southeastern Arizona and no attempt was made to distinguish between the two species. From six to 10 meadowlarks were collected at each site. We also collected 10 mourning doves at each site, except at the SPRNCA study area, where we collected five mourning and five white-winged doves (*Z. asiatica*). Birds were collected by shotgun using steel shotshells. Whole bodies were weighed then plucked and bill, feet, wingtips and gastrointestinal tract removed and discarded. Livers were analyzed for metals. Carcasses were cornposited by species at each site and analyzed for organochlorine pesticides. White-winged dove carcasses were not included in the SPRNCA sample and were discarded to facilitate an unbiased analysis of only mourning dove carcasses. In addition to the meadowlarks and doves, three western kingbirds (*Tyrannus verticalis*) were collected at Fort Huachuca. Because of the limited mass of kingbird liver tissue, livers were analyzed only for arsenic and selenium.

A food habits study of aplomado falcons in Mexico indicated that insects (cicadas, butterflies, wasps, and grasshoppers) represented a significant portion of the falcons diet by frequency of occurrence (Hector 1985). Insects, primarily adult dragonflies (Aeshnidae), also appeared to be especially important dietary items for subadult aplomado falcons released in south Texas (Perez and Zwank 1995). For the insect component of our study, we collected grasshoppers at each site using insect sweep nets. Once collected, grasshoppers were counted, weighed, and measured (largest and smallest) then cornposited into a single sample by site. Samples were stored frozen in chemically cleaned glass jars for organochlorine and trace element chemical analyses. No attempt was made to taxonomically classify grasshoppers.

Other documented prey included lizards, frogs, bats, and various rodents as reviewed by Hector (1985). Whiptail lizards (*Cnemidophorus* spp.) were abundant at most study sites and are relatively sedentary; therefore, they and may be reliable indicators of local contamination. Whiptail lizards were collected using a .22 caliber rifle or pistol and lead shotshells. Lizards were weighed and measured then pooled into composite samples by site and frozen in plastic bags until chemically analyzed for metals.

Samples were analyzed for organochlorine compounds and metalloids at Hazleton Environmental Services, Inc., Madison, Wisconsin. Samples were analyzed for p,p'-DDE, p,p'-DDD, p,p'-DDT, dieldrin, heptachlor epoxide, hexachlorobenzene (HCB), oxychlordane, cis-chlordane, frans-nonachlor, cis-nonachlor, endrin, toxaphene, mirex, and polychlorinated biphenyls (PCB). For each organochlorine analysis, the sample was homogenized and a portion mixed with anhydrous sodium sulfate and extracted with hexane in a Soxhlet apparatus for 7 hours. Lipids were removed by Florisil column chromatography (Cromartie et al. 1975). Sep-pak Florisil cartridges were used for removal of lipids (Clark et al. 1983). The organochlorine compounds were separated into four fractions on a SilicAR column to ensure the separation of dieldrin or endrin into an individual fraction (Kaiser et al. 1980). The individual fractions were analyzed with a gas-liquid chromatograph equipped with an electron-capture detector and a 1.5/1.95% SP-2250/SP-2401 column. Residues in 10% of the samples were confirmed by gas chromatography/mass spectrometry. The lower limit of quantification was 0.1 μg/g for all organochlorine pesticides and 0.5 μg/g for PCB. Organochlorine compounds are expressed in μg/g (parts per million) wet weight.

Samples were also analyzed for aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, vanadium, and zinc. Atomic absorption spectroscopy hydride generation was used to quantitate selenium and arsenic. Mercury concentrations were determined by cold vapor atomic absorption. All other elements were analyzed by inductively coupled plasma atomic emission spectroscopy. Blanks, duplicates, and spiked samples were used to maintain laboratory quality assurance and quality control (QA/QC). QA/QC was monitored by Patuxent Analytical Control Facility (PACF). Analytical methodology and reports met or exceeded PACF QA/QC standards. Element concentrations are reported in μg/g dry weight. Percent moisture is listed in Table 1 for readers who wish to convert dry weight values to wet weight equivalents.

Organochlorine compounds and selected elements considered most toxic to birds (aluminum, arsenic, cadmium, lead, mercury, and selenium) were compared among areas and among species using a 2-way analysis of variance (ANOVA). Means were compared only when at least 50% of the samples had detectible concentrations. A value of one-half the limit of detection was substituted for the "not detected" values to facilitate calculations. Contaminant concentrations were transformed to logarithms for statistical comparisons; geometric means are presented in the tables. The Bonferroni multiple comparison method (Neter and Wasserman 1974) was used to test for mean separation when ANOVA showed significant differences.

RESULTS

Oraanochlorine compounds

The number of birds, grasshoppers, and lizards collected at each site and organochlorine concentrations in each sample is listed in Table 1. DDE was the only organochlorine compound detected and residues were present only in meadowlarks. DDE concentrations ranged from 0.019 μg/g wet weight in the meadowlark sample from Robs Well to 0.049 μg/g wet weight in the Fort Huachuca sample. Three western kingbird livers collected at Fort Huachuca contained 0.058 μg/g DDE.

Metalloids

Concentrations of 17 trace elements were detected in potential aplomado falcon prey items (Table 2). The only element not present was beryllium. Elements most likely to be toxic to avian predators include aluminum, arsenic, cadmium, lead, mercury, and selenium (Eisler 1985, 1987, 1988; Ohlendorf et al. 1988; Scheuhammer 1987). A two-way ANOVA revealed no differences in geometric mean concentrations of these elements among areas, but there were differences among species (Table 3).

Due to the highly variable concentrations of certain elements, particularly arsenic in lizard samples, the elemental content of "lead" shotshells was questioned. We were concerned that lizard samples were contaminated by elements other than lead in the shot. An analysis of a composite sample of shot from five shotshells indicated that the "lead" in shotshells also contained arsenic (4,447 μg/g), boron (11 μg/g), cadmium (1.8 μg/g), copper (65 μg/g), and iron (5.2 μg/g). Because environmental levels of iron were relatively high (≥ 174 μg/g) in lizards, additional tissue contamination from shot would be insignificant. The high level of probability that lizards collected with shotshells were contaminated by arsenic, boron, cadmium, and copper from the shot, makes interpretation of residue data difficult. Data for these elements are presented in Table 2 for information purposes only.

Aluminum was detected in all samples and geometric mean residues (Table 3) were higher ($P = 0.0001$) in lizards (316 μg/g) and grasshoppers (236 μg/g) than in meadowlarks (5.3 μg/g) and doves (6.4 μg/g).

Because of a potential arsenic bias, lizards were not included in the calculation of means and ANOVA statistical tests. Arsenic was detected in all samples (Tables 2 and 3) and a 2-way ANOVA revealed a significant difference among species ($P= 0.0008$), but not among areas ($P= 0.3353$). Geometric mean arsenic concentrations were higher in grasshoppers (0.823 μg/g) than in meadowlarks (0.213 μg/g) and doves (0.326 μg/g) (Table 3). Arsenic in a composite liver sample from three western kingbirds collected at Fort Huachuca was 0.55 μg/g.

Four of five meadowlark liver samples and all five dove liver samples contained cadmium. Cadmium was not recovered in lizards and was present in only two of five grasshopper samples (Table 3). There were no differences in mean meadowlark and dove cadmium concentrations (P= 0.2389, Student's t-test).

Lead was not detected in meadowlarks, doves, and grasshoppers. Lizards were collected with lead shot therefore, these data are lead-biased and are not presented in Table 2.

Mercury was present in all meadowlark and lizard samples (Tables 2 and 3). Less than one-half of the dove (2/5) and grasshopper (1/5) samples contained detectible concentrations of mercury; therefore means were not calculated. Geometric mean mercury concentrations were significantly higher in meadowlark livers (0.154 μg/g) than in whole body lizards (0.060 μg/g) (P= 0.0321, Student's *t*-test). The maximum mercury concentration (0.39 μg/g) was recovered in a meadowlark collected from Fort Huachuca.

Selenium was detected in all liver samples and geometric mean residues ranged from 0.897 μg/g in grasshoppers to 4.422 μg/g in meadowlarks (Table 3). Selenium in meadowlarks and lizards was similar to that in mourning doves but higher than concentrations in grasshoppers (P= 0.0017, 2-way ANOVA). The maximum selenium concentration detected in a potential aplomado falcon prey item was 6.20 μg/g, recovered in a meadowlark from SPRNCA. A western kingbird composite liver sample from Fort Huachuca contained 0.55 μg/g selenium.

DISCUSSION

Evaluating the effects of eating contaminated prey requires estimating a chronic dietary concentration that should be considered hazardous to adult survival and reproduction. Our evaluations assume that the falcon consumes only the prey species we selected for study (meadowlarks, doves, lizards, and grasshoppers), which may not be the case. Under field conditions, birds and other wildlife consume a wide variety of foods with varying concentrations of contaminants. These contaminants could have additive, synergistic or possibly antagonistic effects. Results of our study must be interpreted with caution; organochlorine and trace element concentrations presented here should be viewed only as indicators of local contamination in potential prey items.

Sample selection

Birds: Little information is available on the aplomado falcon's prey base in Arizona. In Veracruz, Campeche, and Chiapas, Mexico, birds accounted for 97% of the total prey biomass (Hector 1985). Meadowlarks composed 4.3% of the falcons diet and mourning doves accounted for 16.4%. In a similar study of the falcons' food habits in Chihuahua, Mexico, meadowlarks were the most frequently consumed species and accounted for 19.5% of the total prey by frequency of occurrence (Montoya and Zwank 1995). Western kingbirds and mourning doves accounted for 8.5% and 6.1% of the falcons diet. We selected meadowlarks and mourning doves as target species based on food habits studies in Mexico indicating that they are major falcon food items (Hector 1985) and on relative abundance of meadowlarks and mourning doves in all our study areas (Corman 1992).

Bird density at potential aplomado falcon reintroduction sites in Arizona was generally lower than in sites studied in Mexico. The Arizona area with the greatest bird density, the Empire Cienega Ranch contained maximum densities of 100.83 and 165.11 birds per 40 ha in August and September 1991 (Corman 1992). Prey abundance transects conducted in falcon nesting territories in Mexico revealed 290 birds per 40 ha (Hector 1985). During certain periods when bird densities are relatively low, reptiles and invertebrates may become increasingly important food items for aplomado falcons.

Lizards: While lizards have been reported as aplomado falcon prey items (Wetmore 1965), food habits studies conducted in Mexico did not document lizards as prey (Hector 1985, Montoya and Zwank 1995). However, Hector (1985) suggested that in drier areas of the desert southwest, where ground cover is less dense and avian prey is scarce, aplomado falcons may have fed more frequently on reptiles than in eastern Mexico. Lizards may be excellent indicators of local terrestrial contamination as much of their diet consists of small invertebrates of local origin. Lizards are intermediate predators often consumed by numerous upper trophic level species.

Grasshoppers: A food habits study of aplomado falcons in eastern Mexico indicated that insects (grasshoppers, beetles, dragonflies and others) represented 65% of the aplomado falcon's prey by frequency of occurrence and 3% by total biomass (Hector 1985). Montoya and Zwank (1995) reported 7% of the falcons diet consisted of insects in a food habits study conducted in Chihuahua, Mexico. Recent observations of aplomado falcons reintroduced into south Texas suggest that insects are particularly important to subadult falcons (Perez and Zwank 1995). Compared to birds, grasshoppers have relatively small territories and therefore, may be good indicators of local contamination.

Oraanochlorine compounds

Many raptor species are susceptible to DDE-induced eggshell thinning and reproductive failure (Hickey and Anderson 1968, Lincer 1975, Ratcliff 1967). Dietary levels of 0.6 to 3.0 μg/g wet weight DDE can result in a significant degree of eggshell thinning in a variety of bird species including screech-owls (*Otus asio*) (McLane and Hall 1972), barn owls (*Tyto alba*) (Mendenhall et al. 1983), American kestrels (*Falco sparverius*) (Lincer 1975, Wiemeyer and Porter 1970), mallards (*Anas playrhynchos*) (Heath et al. 1969) and American black ducks (*A. rubripes*) (Longcore and Samson 1973). The dietary level in prey associated with critical eggshell thinning and decreased reproduction in the peregrine falcon (*F. peregrinus*) is between 1 - 3 μg/g (DeWeese et al. 1986, Enderson et al. 1982). The maximum level of DDE detected in potential prey items from this study was 0.049 μg/g wet weight; about 20 times lower than the lowest level known to adversely affect peregrine reproduction. A number of falcon species including the prairie falcon (*F. mexicanus*), merlin (*F. columbarius*) and aplomado falcon may be more sensitive to DDE-induced shell thinning than the peregrine (Fyfe et al. 1988). Even factoring in slight differences in sensitivity between species, our data suggest that organochlorine compounds do not present a significant hazard to aplomado falcons at any of the potential reintroduction sites studied. There is little likelihood that DDE, at levels found in this study, could adversely affect aplomado falcons reintroduced into Arizona.

Organochlorine compound concentrations recovered in meadowlarks and doves collected during this study were much lower than those reported in great-tailed grackles (*Quiscalus mexicanus*) collected as potential aplomado falcon food items in and near cotton fields of the Safford (3.0 μg/g wet weight) and Wilcox (0.76 μg/g wet weight) Arizona areas (Henry 1992). Henry (1992) also reported that red-winged blackbird (*Agelaius phoeniceus*) whole body tissues from the Safford site contained 2.7 μg/g DDE wet weight. Meadowlarks and doves collected during our study were from rangeland areas and apparently did not accumulate organochlorine compounds as did grackles and blackbirds from agricultural areas as reported by Henry (1992).

Metalloids

Our study examined concentrations of potentially toxic elements in liver tissues of birds that are primary prey species of aplomado falcons. Because the liver is the major detoxifying organ in the body, contaminant concentrations are usually higher in liver than carcass tissues. Falcons consume most of the carcass, and therefore, metalloid residues presented in this study are biased and must be interpreted with caution. When available, liver to carcass ratios are presented to aid in the interpretation of residue data.

The elements most likely to be toxic to avian predators include aluminum, arsenic, cadmium, lead, mercury, and selenium (Eisler 1985, 1987, 1988; Ohlendorf et al. 1988; Scheuhammer 1987). Geometric mean aluminum concentrations were up to 60-times higher (P= 0.0002) in lizards and grasshoppers than in birds (Table 3). No data are available on potentially toxic levels of aluminum in the diet of birds of prey. Juvenile ringed turtle-doves (*Streptopelia risoria*) fed up to 1,500 μg/g dry weight aluminum for 63 days demonstrated no growth impairments (Scheuhammer 1987). Flycatchers (*Ficedula hypoleuca*) feeding on insects that contained 1,230 μg/g dry weight aluminum experienced severe eggshell defects, reduced clutch size, and a high incidence of mortality (Nyholm 1982, Nyholm and Myhrberg 1977). The highest aluminum concentration detected in our study, 532 μg/g dry weight, was below the lowest observed effect concentration reported in ringed turtle-doves and also less than the level determined to be toxic to flycatchers.

Since over 4,400 μg/g arsenic was detected in shot used to collect lizards, our arsenic/lizard data may be biased as some shot pellets may have been retained in some carcasses. In the remaining samples (meadowlarks, mourning doves, and grasshoppers), arsenic was lowest in birds and highest in grasshoppers. Chronic arsenic poisoning is seldom encountered in any species except man (Eisler 1988). Single oral doses of arsenicals fatal to 50% of sensitive species of birds ranged from 17 to 48 μg/g. In experimental studies where grasshoppers (*Melanophis spp.*) poisoned by arsenic were fed to nestling northern bobwhite quail (*Colinus virginianus*), northern mockingbirds (*Mimus polyglottos*), American robins (*Turdus migratorius*) and other songbirds, no deleterious effects were noted in the birds (NAS 1977). Up to 134 poisoned grasshoppers, containing a total of about 40 mg arsenic, were fed to individual nestlings without any apparent toxic effect. The lethal dose to 50% of the most sensitive bird species was 99.8 μg/g copper acetoarsenite. There is little likelihood that arsenic at levels found in our study (0.13-l. 14 μ g/g) would adversely affect aplomado falcon survival and reproduction.

There is little agreement in the literature regarding hazardous levels of cadmium in the food chain. Currently, various authors reported food chain concern levels for cadmium that vary from 0.1 μg/g wet weight (approximately 0.33 μg/g dry weight) to 100 μg/g dry weight (Beyer and Stafford 1993, Eisler 1985). Secondary hazards of cadmium poisoning in predators may be expected if dietary levels reach 0.1 μg/g wet weight (Eisler 1985), or about 0.33 μg/g dry weight assuming 70% average moisture. Beyer and Stafford (1993) suggest that 100 μg/g dry weight cadmium in earthworms to be hazardous to species that consume earthworms. Adult mallards (*Anas platyrhynchos*) experimentally dosed with 20 μg/g cadmium for 90 days showed little or no abnormalities although tissue accumulation was evident (White et al. 1978). Mallard ducklings however, fed a diet containing 20 μg/g cadmium exhibited mild to severe kidney lesions and depressed hematocrits (anemia) by 8-12 weeks (Cain et al. 1983). It may be that immature birds are more susceptible to toxic effects of cadmium than adults. The average cadmium concentration recorded in bird livers collected in this study was 0.88 μg/g dry weight. Carcass residues would probably be lower. We believe that exposure to cadmium at this low level would be unlikely to cause significant adverse effects to adult or nestling falcons.

Our investigation quantified mercury in the livers of potential bird prey items. In eight studies that compared carcass to liver concentrations, levels were lower in carcass tissues than in livers. Although highly variable, the carcass residues averaged about one-half those in livers (Gochfeld 1980, Honda et al. 1986, Lindsay and Dimmick 1983, Renzoni et al. 1973). In data summarized by Eisler (1987), concentrations of mercury usually varied from 3 to 4 times higher in livers than muscle of birds.

Little research has been completed on mercury concentrations in food items of birds of prey. In contrast, there is a great deal of information available on levels and effects of mercury in aquatic ecosystems. For the protection of sensitive species of birds that regularly consume fish and other aquatic organisms, total mercury concentrations in these prey items should probably not exceed 0.1 μg/g wet weight (approximately 0.33 μg/g dry weight) (Eisler 1987). In an extensive review of the chronic toxicity of mercury in birds, Scheuhammer (1987) reported that the lowest level of mercury in food items to adversely affect birds was 0.3-0.4 μg/g wet weight. Egg laying and territorial fidelity of breeding loons (*Gavia immer*) was impaired with 0.3-0.4 μg/g wet weight mercury in primary prey items (Barr 1986). In terrestrial ecosystems, 3 μg/g mercury dry weight in earthworms should be considered hazardous to sensitive species that regularly eat earthworms (Beyer and Stafford 1993). Only the meadowlark liver sample collected at Fort Huachuca that contained 0.39 μg/g dry weight exceeded the threshold level suggested by Eisler (1987). None of the samples approached the concern level reported by Beyer and Stafford (1993).

Selenium usually averages less than 10 μg/g dry weight in livers of birds from selenium normal environments (Ohlendorf 1993, Schroeder et al. 1988, Skorupa et al. in review). Selenium in livers of doves and meadowlarks collected in our study were well within the “normal” or background range. A limited number of studies that compared selenium liver to carcass ratios indicated that selenium in muscle tissue is usually lower than that in livers, but ratios were highly variable depending on sex and ambient selenium levels in the environment (Heinz in press).

Limited data are available on the toxicity of selenium to birds of prey. In a laboratory study in which adult screech-owls were fed 4.4 μg/g wet weight (10 μg/g dry weight) selenium, as selenomethionine, overall reproductive success was not adversely affected by the selenium-supplemented diet (Wiemeyer and Hoffman *in press*). However, 5-day-old nestlings from adults pairs that received 10 μg/g selenium in the diet exhibited reduced femur length compared to controls. Also, hepatic oxidative stress was noted in the 10 μg/g dry weight treatment group indicating selenium-related toxicosis. Dietary concentrations of 10 μg/g selenium in kestrels were not apparently toxic to adults, although blood and egg selenium levels were similar to those in wild kestrels trapped at selenium contaminated Kesterson Reservoir, California (Santolo 1995).

Ironically, several field and laboratory studies indicated that even background selenium levels in food items, concentrations as low as 3-8 μg/g dry weight, could cause adverse reproductive effects in sensitive aquatic bird species (Hoffman et al. 1991, Lemley and Smith 1987, Skorupa and Ohlendorf 1991). Selenium concentrations in some aplomado falcon potential prey samples exceeded reproductive toxicity thresholds established for aquatic bird species, however, it is unknown whether these thresholds are applicable to terrestrial species. It is encouraging to note that aplomado falcons reintroduced into Texas successfully nested for the first time in May 1995 (D. Blankinship pers. comm.) and livers from avian prey items (mourning dove, meadowlark, and bobwhite quail) collected near the reintroduction site averaged 3.3 μg/g (range = 1.88-4.96) μg/g dry weight (C. Lee pers. comm.).

Residue implications for aplomado falcons Because there were no differences in contaminant levels among the areas, aplomado falcons theoretically could be reintroduced into any of the five study areas. DDE and other organochlorine pesticides, at levels detected in this study, no longer represent a hazard to falcon survival and reproduction. With the possible exception of arsenic in lizards, the only contaminant of concern was selenium. Selenium in avian prey items collected in this study was well within the normal or background range (ı 10 μg/g dry weight). However, selenium sensitive species may be affected by as little as 3-8 μg/g wet weight. Additional research or intensive field monitoring is needed to determine the relative sensitivity of aplomado falcons to selenium.

RECOMMENDATIONS

We recommend additional monitoring of aplomado falcon populations in Texas and Mexico to determine levels of contaminants, especially selenium, in prey items and eggs. Selenium and other potentially toxic element concentrations, should be correlated with reproductive success to determine potential no-effect levels. If laboratory tests using a surrogate falcon species such as kestrels are possible, we recommend determining the level of dietary selenium associated with reproductive failure.

If reintroduction efforts in Arizona proceed, we recommend closely monitoring reproductive success, because the effects of selenium toxicosis are most visible in embryos. We suggest a nest watch program be implemented similar to the current Bald Eagle Nest Watch Program in Arizona (Beaty et al. 1995). Abandoned or addled eggs should be salvaged and analyzed for selenium, and perhaps arsenic. Habitat quality and prey abundance should be the major considerations in a reintroduction effort.

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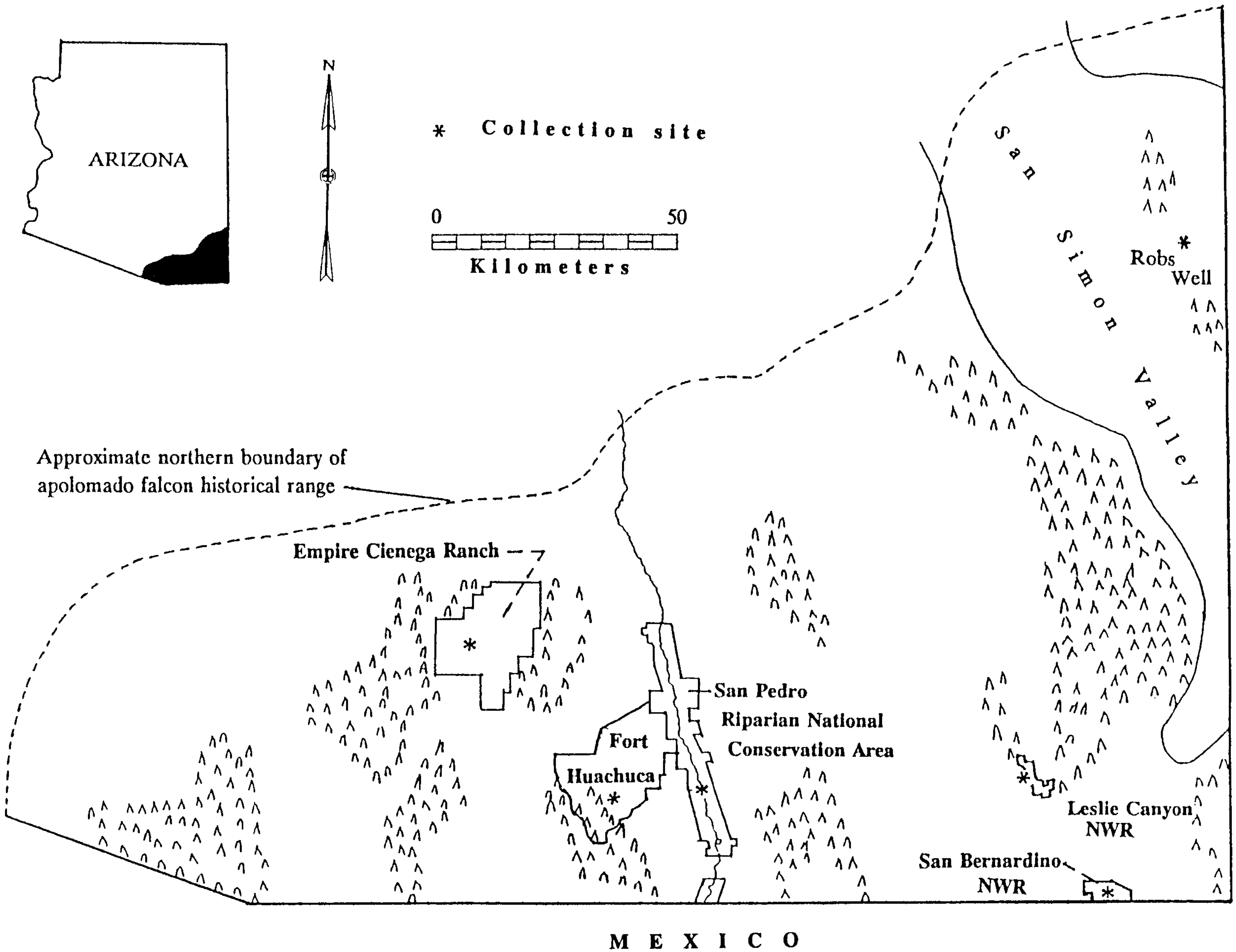
ARIZONA
N
* Collection site
0
50
Kilometers
Approximate northern boundary of
apolomado falcon historical range
Empire Cienega Ranch
Fort
Huachuca
San Pedro
Riparian National
Conservation Area
San Simon Valley
Robs
Well
Leslie Canyon
NWR
San Bernardino
NWR
NEW MEXICO
MEXICO

Table 1. Organochlorine residues in aplomado falcon potential prey items from southeastern Arizona, 1992

						µg/g p,p'-DDE	
Site'	Sample	N	Weight (g)	Prcnt moist	Prcnt lipid	wet wt.	dry wt.
SB	M. dove	10	a31	71.22	4.70	<0.01	co.035
SB	Meadowlark	6	419	70.89	4.26	0.026	0.098
SB	Lizard	7	a2	69.87	6.08	<0.01	co.033
SB	Grasshopper	132	75	69.71	2.82	<0.01	co.033
SP	M. dove	5	414	68.24	7.58	<0.01	<0.031
SP	Meadowlark	10	517	70.72	4.11	0.028	0.096
SP	Lizard	14	75	72.41	4.90	<0.01	<0.036
SP	Grasshopper	197	78	66.69	4.02	<0.01	<0.030
SP	W. W. dove	5	507	68.44	9.97	<0.01	<0.032
FH	M. dove	10	801	70.19	7.27	co.01	co.034
FH	Meadowlark	9	618	72.60	3.35	0.049	0.179
FH	Lizard	13	a3	70.17	5.97	0.017	0.057
FH	Grasshopper	109	38	NA[2]	NA	NA	NA
FH	W. kingbird	3	92	70.68	4.40	0.058	0.198
EC	M. dove	10	777	70.65	4.20	<0.01	co.034
EC	Meadowlark	7	419	72.20	2.68	0.029	0.104
EC	Lizard	4	32	NA	NA	NA	NA
EC	Grasshopper	133	129	70.69	2.60	<0.01	co.034
RW	M. dove	10	a40	70.66	6.37	<0.01	co.034
RW	Meadowlark	6	449	71.98	3.59	0.019	0.068
RW	Grasshopper	63	20	NA	NA	NA	NA

[1] Site names: SB= San Bernardino National Wildlife Refuge, SP= San Pedro National Riparian Conservation Area, FH= Fort Huachuca, EC= Empire Cienega Ranch, RW= Robe Well.

[2] NA= Not analyzed. Because of limited mass of sample material, some samples were analyzed for metalloids only.

Table 2. Metalloids in aplomado falcon potential prey items collected in southeastern Arizona, 1992.

Area and sample[1]	N[3]	Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
		Trace element concentration, µg/g dry weight[2]																
Grasshopper																		
Empire Cienega	133	355	0.69	14.38	20.26	0.39	0.84	70.4	287	<0.03	1289	21.1	<1.32	3.95	0.69	16.02	0.91	133
Robs Well	63	370	0.79	15.29	13.94	<0.17	0.62	111.7	391	0.03	1038	28.2	<1.14	1.02	1.52	23.60	0.95	126
Fort Huachuca	109	233	0.50	11.96	11.54	0.25	0.66	75.7	246	<0.03	914	15.9	<1.18	1.39	1.04	14.00	0.55	147
San Bernardino	132	119	0.99	18.67	7.65	<0.19	0.76	69.3	148	<0.03	1133	20.1	<1.24	1.37	0.90	31.89	0.42	152
San Pedro	197	203	1.40	3.29	5.25	<0.19	0.57	117.4	250	<0.03	1366	14.2	<1.24	0.42	0.59	7.67	0.41	145
Lizard																		
Empire Cienega	4	484	13.72	3.11	645.16	<0.17	3.70	6.1	390	0.05	1041	15.5	<1.16	0.60	4.11	21.00	0.92	113
Fort Huachuca	10	133	87.07	1.57	7.65	<0.20	1.24	6.0	174	0.06	1160	12.3	<1.36	<0.41	4.39	31.94	0.28	117
San Bernardino	10	292	6.79	2.15	6.59	<0.19	1.41	13.4	273	0.04	1065	11.2	<1.30	0.95	0.84	34.09	0.74	115
San Pedro	10	532	5.40	<1.51	9.25	<0.23	1.64	9.9	679	0.11	1294	29.1	<1.51	0.71	3.28	14.87	1.43	148
Mourning dove[4]																		
Empire Cienega	10	7	0.32	ND	1.58	2.73	0.56	17.7	1993	<0.04	658	14.4	3.88	<0.42	1.80	0.49	0.51	114
Fort Huachuca	10	8	0.30	ND	<0.72	0.58	0.49	15.4	1196	0.03	598	10.0	4.02	<0.44	3.38	0.32	<0.18	74
Robs Well	10	6	0.23	ND	<0.65	0.80	0.44	11.8	1490	<0.03	565	9.3	3.25	<0.39	2.78	0.43	0.28	66
San Bernardino	10	11	0.42	ND	<0.76	1.42	0.78	16.4	1077	0.04	753	11.6	4.25	<0.46	2.05	0.42	<0.19	94
San Pedro	10	3	0.40	ND	<0.51	0.35	0.40	11.3	935	<0.03	514	4.8	2.01	<0.31	1.18	<0.13	0.22	62
Meadowlark																		
Empire Cienega	10	5	0.13	ND	1.36	0.86	0.66	23.1	1073	0.19	719	6.6	2.82	1.51	4.30	<0.17	0.19	81
Fort Huachuca	10	5	0.20	ND	<0.70	0.98	0.57	24.5	1455	0.39	811	6.0	3.43	<0.42	3.37	<0.18	0.28	95
Robs Well	10	14	0.39	ND	<0.64	<0.19	0.61	21.0	897	0.09	684	5.7	2.55	<0.38	4.19	0.78	<0.16	78
San Bernardino	10	4	0.16	ND	<0.63	0.51	0.54	23.8	782	0.12	667	4.8	3.03	<0.38	4.49	0.29	<0.16	78
San Pedro	10	3	0.27	ND	<0.76	0.47	0.95	20.6	1182	0.11	698	9.6	2.59	0.79	6.20	0.62	0.26	71

[1]Samples consisted of whole body composites for grasshoppers and lizards and liver composites for mourning doves and meadowlarks.

[2]Beryllium (Be) was not detected in any samples. The lower limit of detection (LLOD) for Be was 10.08 µg/g. Lead was not detected in grasshoppers (LLOD= 11.47 µg/g), mourning doves, and meadowlarks (LLOD= ≤1.88 µg/g). Lizards were collected with lead shot, therefore the data are biased. Three western kingbirds collected at Fort Huachuca were analyzed for only arsenic (As) and selenium (Se). Kingbird livers contained 0.55 µg/g As and 3.77 µg/g Se.

[3]N= number of individuals collected at each site.

[4]Five mourning and five white-winged doves were collected from the San Pedro area and livers combined into a single composite sample.

Table 3. Trace element concentrations in potential aplomado falcon prey items from southeastern Arizona, 1992

		Geometric mean concentration µg/g dry weight, sample size (n) and range'				
Sample	N	Aluminum	Arsenic	Cadmium	Mercury	Selenium
meadowlark	5	5.3 (5) (A)' 3.0-14.0	0.213 (5) (A) 0.13-0.39	0.449 (4) (A) 0.09-0.98	0.154 (5) (A) 0.09-0.39	4.422 (5) (A) 3.37-6.20
mourning dove	5	6.4 (5) (A) 3.0-11.0	0.326 (5) (A) 0.23-0.42	0.912 (5) (A) 0.35-2.73	NA[3] (2) ND'-0.04	2.100 (5) (AB) 1.18-3.38
lizard	4	316 (4) (B) 133-532	----[5] (4) 5.40-87.1	NA (0)	0.060 (4) (B) 0.04-0.11	2.655 (4) (A) 0.84-4.39
grasshopper	5	236 (5) (B) 119-370	0.823 (5) (B) 0.50-1.14	NA (2) ND-0.39	NA (1) ND-0.03	0.897 (5) (B) 0.59-1.52

'Geometric mean, (n) = number of samples with detectable residues, range is high and low extremes of detected residues.

'Means sharing the same letter are statistically similar ($p > 0.05$). Aluminum, arsenic, selenium data analyzed by ANOVA; level of significance: aluminum P= 0.0002, arsenic P= 0.0017, and selenium P= 0.0023. Cadmium and mercury data were analyzed by Student's t-test; with the following levels of significance: cadmium P= 0.0788 and mercury P= 0.0472.

[3]NA = not applicable. Means were not calculated because less than 50% of the sample contained detectable concentrations.

'ND = not detected.

'The mean was not calculated because of the likelihood of sample contamination.