POTENTIAL EFFECTS OF ENVIRONMENTAL CONTAMINANTS ON RECOVERY OF THE APLOMADO FALCON IN SOUTH TEXAS

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Abstract: Efforts to reintroduce the aplomado falcon (*Falco femoralis*) into its former range in the southern part of Texas began in 1977. Not until 1993, however, were a significant number (26) of fledgling aplomado falcons released. The first nesting pair of aplomado falcons was reported near the Brownsville Ship Channel during 1995. Because of a long history of pesticide use in the Lower Rio Grande Valley, during 1993–94 we investigated the accumulation of environmental contaminants in plasma of aplomado falcons released at the Laguna Atascosa National Wildlife Refuge. We also assessed the potential contribution of typical prey species to aplomado falcon contaminant burdens. Organochlorine pesticides and PCBs were below detection limits (wet wt basis) in plasma; however, some organochlorines including 1.75 and 1.41 μg/g p,p′-DDE, and 0.49 and 1.52 μg/g total PCBs were detected in addled eggs collected in 1995 and 1996. Mercury also was detected at 1.5 and 4.1 μg/g dry weight in the addled eggs collected in 1995 and 1996. We detected DDE (range 0.02–0.25 μg/g) in carcasses of potential prey of the aplomado falcon. Trace metals also were detected in potential prey at levels which are not of concern, except for Hg, which was high in a few meadowlarks. Low levels of DDE and most trace metals in potential prey, including mourning doves (*Zenaida macroura*) and eastern meadowlarks (*Sturnella magna*), are not likely to result in adverse effects on the aplomado falcon in the Lower Rio Grande Valley. However, elevated Hg residues in meadowlarks (in a few cases) and potentially higher DDE levels in other prey species such as the great-tailed grackle (*Quiscalus mexicanus*) could result in negative effects on reproduction and survival of some aplomado falcons in south Texas.

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Key words: aplomado falcon, birds, contaminants, endangered species, *Falco femoralis*, Lower Rio Grande Valley, organochlorines, recovery, Texas, trace metals, wildlife toxicology.

The aplomado falcon was once a common resident species of the southwestern United States (Ligon 1961, Hector 1987). By the 1930s, however, the species had almost disappeared from its range in the United States and the last nesting record was reported near Deming, New Mexico in 1952 (Ligon 1961, Hector 1987). Causes of the decline of the aplomado falcon are mostly unknown, but habitat alteration, collecting pressure, and pesticide use are the most plausible hypotheses (Hector 1985, 1987).

Efforts to reintroduce the aplomado falcon into its former range in the southern part of Texas began in 1977 (Cade et al. 1991). Not until 1993, however, were fledgling aplomado falcons released in significant numbers. Twenty-six young aplomado falcons bred in captivity at The Peregrine Fund in Boise, Idaho were released in the Laguna Atascosa National Wildlife Refuge (LANWR) during 1993 and 12 more in 1994. Subsequent to the release, the first nesting pair of aplomado falcons was reported near the Brownsville Ship Channel, Cameron County, during 1995. This nest was the first reported in Texas in the last 54 years (The Peregrine Fund, unpubl. data).

The Lower Rio Grande Valley (LRGV), Texas, is an agricultural area with a long history of pesticide use (Jahrsdoerfer and Leslie 1988). Heavy pesticide use along the Rio Grande resulted in elevated concentrations of persistent organochlorines (OCs) in some regions of the LRGV (White et al. 1983), with some documented wildlife mortalities (White and Kolbe 1985). Nonetheless, in the last decade organochlorine pesticide concentrations have diminished significantly in some avian species (Mora 1995). However, continuing industrial development along the Rio Grande has resulted in exposure of wildlife to other highly persistent and toxic chlorinated hydrocarbons as well as other industrial chemical derivatives, including metals, which may have deleterious effects on wildlife.

The sizable release of aplomado falcons in the LANWR during 1993 provided an opportunity to investigate the accumulation of environmental contaminants in the wild in an endangered species. The objectives of this study were: (1) to determine levels of OCs in blood of aplomado falcons before and after release; and (2) to assess the potential contribution of known aplomado falcon prey items to contaminant body burdens in aplomado falcons and their eggs, and the hazards associated with eating contaminated prey.

We appreciate the assistance provided during this study by personnel from the Laguna Atascosa National Wildlife Refuge. W. Heinrich helped trap aplomado falcons and collect blood in the Laguna Atascosa National Wildlife Refuge. L. Kradolfer and C. Sandfort collected blood at The Peregrine Fund headquarters. Support for the chemical analyses of blood plasma was provided by the Division of Environmental Contaminants, U.S. Fish and Wildlife Service, Region 2. R. Presley helped with the analysis of mercury in the aplomado falcon eggs. This manuscript was reviewed by L. J. Blus, D. E. Boellstorff, D. J. Hoffman, and L. F. Kiff. The mention of trade names of commercial products in this paper does not constitute endorsement or recommendation for use by the U.S. Geological Survey, U.S. Department of the Interior.

STUDY AREA AND METHODS

The study area was located in the LANWR and nearby Willamar and La Selva Verde tracts of the Lower Rio Grande Valley National Wildlife Refuge (LRGVNWR; Fig. 1).

Blood Collection

We collected the first blood samples in June-July 1993 at The Peregrine Fund headquarters in Boise, Idaho, 1 week before transportation of the birds for release at the LANWR. Two mL of blood were collected in heparinized tubes from the brachial vein of 26 fledglings. We collected a second blood sample from 8 individuals captured within the LANWR boundaries during November 1993, 3–5 months after release. We

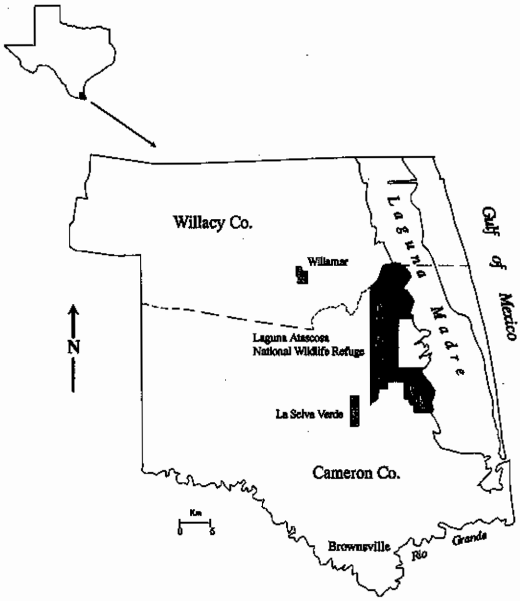

Fig. 1. Map of the study area indicating the release site for aplomados and sites of prey item collections.

collected a third sample from 1 male recaptured a second time during March 1994, 8 months after release. We used bal-chatri traps for the recapture of aplomado falcons in the field (Berger and Mueller 1959). Blood samples were kept on ice and taken to the laboratory where they were centrifuged at about 1,500 rpm for 15 minutes to obtain the plasma. We stored plasma samples in a freezer (−20 C) until chemical analyses were conducted.

Prey Collection

We collected potential prey of the aplomado falcon at 4 sites. Sites 1 and 2 corresponded to units 1 and 2 of the LANWR; and sites 3 and 4 corresponded to La Selva Verde tract and Willamar tract, of the LRGVNWR (Fig. 1). We collected 5 mourning doves and 5 eastern meadowlarks with a shotgun (stainless steel shot) at each of the 4 sites between 7 June and 23 August 1994. Meadowlarks were unavailable at the La Selva Verde tract; thus, we substituted northern bobwhites (*Colinus virginianus*) at this site. Using insect nets we also collected dragonflies (10 g) from the 4 sites and cicadas (11–17 g) from 3 sites.

Egg Collection

In May 1995, we collected 1 addled egg from the first aplomado falcon nest. In May 1996, we collected 1 addled egg and eggshell remains of an egg that presumably hatched from 1 of 2 nests observed this year in the LRGV. We wrapped the addled eggs in aluminum foil and stored them under refrigeration until further processing. We rinsed the eggshells with water and let them airdry for several hours, then measured eggshell thickness near the equator to 0.001 mm with a Starrett micrometer (The L. S. Starrett Co., Athol, Mass.). We took the average of 5 measurements as the thickness value.

Chemical Analysis

We placed dragonflies and cicadas into chemically cleaned jars immediately after collection. We took bird carcasses to a laboratory where they were prepared by removing the beak, tarsi, feathers, digestive tract, and livers. Bird carcasses from each site were pooled by species into 1 composite homogenate which was used for the chemical analysis. Bird carcasses, dragonflies, and cicadas were analyzed for OC pesticides and total PCBs. Bird livers were analyzed for heavy metals and trace elements. The aplomado falcon eggs were analyzed for organochlorine pesticides, congener specific PCBs and trace elements. The organochlorine pesticides analyzed included hexachlorobenzene (HCB), hexachlorocyclohexane (α, β, γ, and δ-HCH), chlordane (α and γ isomers), cis-nonachlor, trans-nonachlor, dieldrin, endrin, heptachlor epoxide, mirex, oxychlordane, toxaphene, and isomers of DDT, DDE, and DDD. The metals and trace elements analyzed included Al, As, B, Be, Cd, Cr, Cu, Fe, Mn, Hg, Mo, Ni, Pb, Se, Sr, Va, and Zn.

Organochlorines.—The plasma was analyzed by methods described previously (Mora et al. 1993), except with modifications of the analytical chromatography (Mora 1996*a*). Dragonflies, cicadas and pooled bird carcasses were extracted with acetonitrile and petroleum ether. Organochlorine fractions were eluted with combinations of diethyl ether and petroleum ether at ratios of 6:94 and 15:85. We separated PCBs from other organochlorines with a silicic acid column chromatography. Extracts were analyzed by capillary column gas chromatography. The aplomado falcon eggs were extracted as described in Mora (1996a) and were analyzed in duplicate with a gas chromatograph, Hewlett Packard 5880A, with split/splitless injection system, ^{63}Ni electron capture detector, and a DB-5 (30 × 0.25 mm ID) fused silica capillary column (J and W Scientific, Folsom, Calif.). Spike recoveries were above 80% in all cases; variation between duplicates was within 15%. The method detection limit was 1 ng/g wet weight (ww) for pesticides and PCBs.

Trace Elements.—Trace elements (including some heavy metals not considered trace elements) in bird livers and the aplomado falcon eggs were analyzed by atomic absorption and inductively coupled plasma (ICP) spectrophotometry. The aplomado falcon egg collected in 1996 was analyzed for Hg only by cold vapor atomic absorption. For the analysis of Hg, an aliquot (0.2 g) of the dry sample was digested with a mixture of nitric acid, sulfuric acid, and potassium permanganate-persulfate in a hot water bath. Following digestion, excess permanganate was reduced with hydroxylamine hydrochloride and the Hg(II) in solution was reduced to Hg(0) with stannous chloride. Mercury was then analyzed by the standard cold-vapor atomic absorption method with a laboratory data control mercury monitor. For the remaining metals, a separate dry aliquot (2 g) was wet digested with nitric and perchloric acids. We analyzed the resulting digest solution for As, Se, Pb, and Cd by graphite furnace atomic absorption by using a Perkin Elmer Z-3030 AA unit equipped with Zeeman background correction. All other elements (Al, B, Be, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Sr, V, Zn) were analyzed by ICP. The detection limits ranged from 0.1 μg/g dry weight (dw) for Hg to 5 μg/g dw for Al, Fe, and Mg.

Statistical Analysis

We determined differences in concentrations of DDE and trace metals between mourning doves and meadowlarks from 3 sites (LANWR units 1 and 2, and Willamar), by analysis of variance (ANOVA) of ranks, a procedure similar to the nonparametric Kruskal-Wallis test (SAS Inst. Inc. 1988). The Tukey multiple comparisons procedure was applied to ANOVA of ranks to determine which means were different. The level of significance was set at 0.05.

RESULTS

Contaminants in Plasma and Eggs

Eight young aplomado falcons bled between 25 June and 27 July 1993 before release, and resampled between 8 and 15 November 1993, 3 to 5 months after release had no detectable blood levels of OCs. A second blood sample collected from 1 bird on 10 March 1994, 8 months after release, also had no detectable levels of OCs. Organochlorine residues, however, were detected in 2 addled eggs collected in 1995 and 1996 in the LRGV. The first nesting pair of aplomado falcons in the LRGV in 54 years was discovered in May 1995 (The Peregrine Fund, unpubl. data). The nest was located on Brownsville Navigation District property, on a 20-m Central Power and Light Company pole. The aplomado falcon female laid 2 eggs, of which 1 hatched. The chick was banded by personnel from The Peregrine Fund. In 1996, 2 pair were observed nesting in the LRGV; one nest fledged 3 young and the other nest failed likely due to predation (The Peregrine Fund, unpubl. data). The OC residues in μg/g ww in the 1995 and 1996 eggs were: 1.75 and 1.41 p,p'-DDE, 0.01 p,p'-DDT, 0.49 and 1.52 total PCBs, 0.03 and 0.02 oxychlordane, and 0.01 and 0.2 heptachlor epoxide. The eggshell thicknesses (with membrane) were 0.305 and 0.285 mm for 1995 and 1996.

Because of the importance of each specific PCB congener in the PCB profile of the aplomado falcon eggs, individual PCB congeners are given in Table 1. The most abundant PCB congeners were 153, 180, and 138 (in order of predominance) and accounted for 47% of the total PCBs (Table 1). Also, hexachlorobiphenyls and heptachlorobiphenyls were the most abundant and contributed nearly 75% (40 and 33%) to total PCBs. Most trace elements in the 1995 wild egg were below detection limits except for Hg (1.5 μg/g dw), Cu (2.8 μg/g dw), Fe (57 μg/g dw), Mg (478 μg/g dw), Mn (0.6 μg/g dw), Sr (2.04 μg/g dw), and Zn (31.7 μg/g dw). The 1995 egg was not analyzed for Se. The 1996 egg had 4.1 μg/g dw Hg (the only element analyzed).

Contaminants in Potential Prey

Except for DDE, which was detected in about 70% of the samples of cicadas, dragonflies, and bird carcasses, other OCs (including total PCBs) were below detection limits. Among the insects, DDE was detected at low levels ($\leq$0.05 μg/g ww) only in dragonflies from La Selva Verde and Willamar tracts in the LRGV (Fig. 1). DDE was detected in all bird carcasses and ranged from 0.02 to 0.25 μg/g ww (Table 2). Concentrations of DDE were similar among locations within species, except for the Willamar tract where meadowlarks had DDE concentrations about 3.3 times higher than those in meadowlarks from the LANWR (Table 2). Overall, mean DDE levels in meadowlarks were 2.7 times higher than in mourning doves. Concentrations of DDE in mourning doves were similar to those in northern bobwhites. Mean DDE levels in aplomado falcon eggs were about 12 times higher than those observed in meadowlarks and 32 times higher than those in mourning dove carcasses.

Concentrations of trace elements were higher (except for Hg and Sr) in livers of mourning doves and meadowlarks than in the 1995 aplomado falcon egg (Table 3). On average, Hg concentrations in the 1995 and 1996 aplomado eggs were 2 to 6 times higher than in livers of meadowlarks. Hg was not detected in mourning doves and bobwhite quail, but it was found in meadowlarks at 3 sites and ranged from 0.24 to 1.04 μg/g dw (Table 3). Sr was 1.5 and 2.6 times higher in the 1995 egg than in livers of mourning doves and meadowlarks. Concentrations of Al, Cd, Cr, Cu, Fe, Mg, Se, Sr, and Zn were not different between mourning doves and meadowlarks from the LANWR units 1 and 2 and the Willamar site ($P > 0.05$). The only significant differences between species from the 3 sites were for Mn and Mo, which were greater ($P < 0.01$) in mourning doves than in meadowlarks. Trace metal concentrations in northern bobwhite were similar to those of mourning doves from the same sites, except for Cd, Fe, and Mo. Cadmium was 8 times greater and Fe 2 times greater in mourning doves than in northern bobwhite. The only element greater in bobwhite than in mourning doves was Mo (about 2.7 fold). Boron was below detection limits in most cases. Lead was detected only in meadowlarks from unit 2 of LANWR and in mourning doves from La Selva Verde (Table 3)

DISCUSSION

Organochlorine residues were not detected in plasma of aplomado falcons before release perhaps because exposure was negligible under captive conditions. The food provided to young during the 5-week period before release was not analyzed for contaminants, however, 1 composite food sample analyzed earlier in the captive study program did not show any contaminants of concern. We were somewhat surprised that under environmental exposure in the LANWR, OCs including p,p'-DDE, were not detected in plasma from aplomados 3 to 8 months after re-

Table 1. Congener-specific PCB concentrations (μg/g ww) in 2 aplomado falcon eggs collected in 1995 and 1996 in the Lower Rio Grande Valley, Texas.[a]

Congener no.	1995	1996	% total PCBs	Congener no.	1995	1996	% total PCBs
Trichlorobiphenyls				138	65	140	11.3
25	1		0.1	158	6	32	1.7
28	1	2	0.2	129		1	0.05
33/53/20		2	0.1	128	6	20	1.3
Tetrachlorobiphenyls				167	5	27	1.4
52		3	0.1	156/171	9	38	2.2
49		1	0.05	Heptachlorobiphenyls			
47/48/75		2	0.1	176/137	4	6	0.6
44	1	3	0.2	178	4	9	0.7
40	1	3	0.2	187	33	70	5.7
74	3	8	0.6	183	10	42	2.4
66	2	5	0.4	185	2		0.2
56/60	4	9	0.7	174		1	0.05
Pentachlorobiphenyls				177	2	9	0.5
92		21	0.7	172	5	19	1.1
84		2	0.1	180	82	234	16.1
101/90		3	0.1	191	1	6	0.3
99	12	24	2.0	170/190	25	87	5.4
97	2	4	0.3	189	1	6	0.3
87/115		1	0.05	Octachlorobiphenyls			
110/77	6		0.6	201	13	46	2.8
82	2	25	1.0	203/196	15	58	3.4
107	4		0.4	195/208	4	17	1.0
118	23	63	4.4	194	16	61	3.6
105	6	28	1.5	205		4	0.1
Hexachlorobiphenyls				Nonachlorobiphenyls			
149/123	1	2	0.2	206	5	19	1.1
146	12	41	2.6	Decachlorobiphenyls			
153	93	302	19.5	209	3	7	0.3
141/179		2	0.1	Total	490	1,515	100

[a] 1995 egg had 4% lipid and 81% moisture, 1996 egg had 4.3% lipid and 78% moisture. PCB congeners are in elution order within each group. More than 1 PCB congener in same row indicates coelution of peaks.

Table 2. DDE residues (μg/g ww) in potential prey of the aplomado falcon collected in the Lower Rio Grande Valley, 1994.

Site	Sample type[a]	Composite weight (g)	% moisture	% lipid	p,p′-DDE
LA[b] unit 1	Cicadas	12.0		3.68	<0.01
LA unit 2	Cicadas	14.1		4.28	0.01
La Selva Verde	Cicadas	17.4		6.2	<0.01
LA unit 1	Dragonflies	11.0		4.31	<0.01
LA unit 2	Dragonflies	11.0		4.61	0.01
La Selva Verde	Dragonflies	10.9		5.36	0.05
Willamar	Dragonflies	8.7		5.19	0.01
LA unit 1	Mourning dove	379.0	72.5	3.41	0.05
LA unit 2	Mourning dove	458.0	70.5	5.47	0.03
La Selva Verde	Mourning dove	424.0	72.0	2.25	0.10
Willamar	Mourning dove	383.0	72.5	4.53	0.02
LA unit 1	Meadowlark	311.0	74.5	2.99	0.04
LA unit 2	Meadowlark	346.0	73.5	2.35	0.11
Willamar	Meadowlark	399.0	72.5	3.0	0.25
La Selva Verde	Bobwhite	321.0	73.5	3.58	0.02

[a] 8–50 cicadas, 30–60 dragonflies, and 5 birds/composite sample.
[b] Laguna Atascosa.

Table 3. Trace element concentrations (µg/g dw) in potential prey of the aplomado falcon collected in the Lower Rio Grande Valley, 1994.

Site and species	*N*	Al	B	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Pb	Se	Sr	Zn
		Trace elements													
LA[a] unit 1															
Mourning dove	5	5.73	<1.99	0.99	0.73	18.74	1135	<0.10	916.5	15.65	4.18	<0.99	2.44	0.38	170.5
Meadowlark	5	14.49	<1.97	1.98	<0.50	17.60	867	0.676	803.8	3.95	2.16	<0.99	3.57	1.59	87.7
LA unit 2															
Mourning dove	5	7.22	2.32	1.25	<0.50	15.89	1042	<0.10	500.9	11.07	3.79	<0.99	4.96	0.20	174.5
Meadowlark	5	5.82	<1.99	3.30	0.56	22.60	1084	1.04	963.2	6.94	3.73	1.50	4.96	1.50	132.4
La Selva Verde															
Mourning dove	5	7.38	2.10	2.14	1.06	17.24	1462	<0.10	790.0	12.10	3.73	1.48	1.88	0.56	123.3
Northern bobwhite	5	8.53	<1.99	0.26	2.39	20.00	819	<0.10	845.8	17.38	9.94	<1.0	2.49	1.26	181.7
Willamar															
Mourning dove	5	5.75	<2.00	0.98	1.45	16.45	1291	<0.10	735.2	12.59	3.90	<1.0	1.94	0.28	103.2
Meadowlark	6	<4.91	<1.96	0.99	0.80	17.68	1036	0.239	734.6	4.34	2.49	<0.98	4.34	0.31	103.1

[a] Laguna Atascosa.

lease. The LRGV is an important agricultural area where organochlorine compounds, including DDT, were used heavily in the past (Jahrsdoerfer and Leslie 1988); thus DDE might still be present in the environment. DDE presence is further supported by the detection in 1993–94 of up to 0.25 µg/g ww DDE in carcasses of meadowlarks and 0.7 µg/g ww in eggs of aquatic birds from the same area (Mora 1996*b*). The virtual absence of DDE and all OCs in the plasma samples collected 3–8 months post-release could indicate that during that period none of the persistent compounds had accumulated yet in any tissue or that residue accumulation was at concentrations that could not be detected in the small volume of plasma (≤1 mL). Concentrations of DDE in plasma of peregrine falcons (*Falco peregrinus*) captured in South Padre Island during 1994 averaged 0.34 µg/g ww (Henny et al. 1996). Differences in concentrations of DDE in plasma between peregrine and aplomado falcons may be explained because peregrine falcons were adults (second yr or after second yr); whereas aplomado falcons were first year hatchlings that had been in the LRGV for only a few months since their release in the summer. Hatch-year peregrines showed lower levels of OCs in plasma than adults (Henny et al. 1996).

Significance of Contaminants in the Diet and Eggs

Because efforts to release young aplomado falcons in the LRGV have increased significantly since 1993 (106 young were released during 1993–96, The Peregrine Fund unpubl. data), it is important to determine the risks that some contaminants in prey and eggs may represent for the survival and recovery of the species.

DDE Effects.—The lowest DDE dietary concentrations at which adverse effects in raptor species have been observed range between 1 and 3 µg/g (Wiemeyer and Porter 1970, Enderson et al. 1982, Mendenhall et al. 1983). Peregrine falcons feeding on prey with DDE levels of ≥1 µg/g should be expected to produce thin-shelled eggs (Enderson et al. 1982). The mean DDE levels in carcasses of mourning doves and meadowlarks were 10–20 times below the threshold in the diet of peregrine falcons at which negative reproductive effects were suggested. Mourning doves and meadowlarks were not observed in the diet of the nesting pair of aplomado falcons during 1995, nor in the young aplomados released in 1993 and 1994 (Perez 1995). Young aplomado falcons tracked with radiotransmitters during 1993–94 remained within a small area in the valley (range 36–281 km^2) and foraged primarily on dragonflies (47%) and birds (28%; Perez 1995). During 1995, a pair of breeding adults brought primarily birds (96%, 45 of 47 kills observed) to their young. Among the prey (16 of 45 prey were identified) brought to the nest were: common nighthawks (44%, n = 7: *Chordeiles minor*), horned larks (19%, n = 3: *Eremophila alpestris*), bronzed cowbirds (12%, n = 2: *Molothrus aeneus*), tropical kingbirds (6.2%, n = 1: *Tyrannus melancolicus*), great-tailed grackles (6.2%, n = 1), killdeer (6.2%, n = 1: *Charadrius vociferus*) and golden-fronted woodpeckers (6.2%, n = 1: *Melanerpes aurifrons*) (The Peregrine Fund, unpubl. data). Nonetheless, Hector (1985) reported mourning doves being taken often by aplomado falcons in eastern Mexico. Because of the low levels of DDE in mourning doves and meadowlarks, we do not think that aplomado falcons would accumulate DDE at sublethal concentrations by feeding on these 2 species or on cicadas and dragonflies from the LANWR area. However, carcasses of great-tailed grackles collected during 1991 in south Texas averaged DDE levels of 2.8 μg/g (Henry 1992), above the threshold level in the diet at which sublethal effects could be observed.

Concentrations of DDE in addled aplomado falcon eggs were nearly as high as DDE in 3 addled eggs (mean =2.12 μg/g ww) from great blue herons (*Ardea herodias*) collected during 1994 in the lower Laguna Madre (Mora, unpubl. data) Levels of DDE in eggs of aplomado falcons were about 5 times below the lowest critical level in eggs (7 μg/g ww) at which significant eggshell thinning in wild raptors (prairie falcon, *Falco mexicanus*) has been reported (Enderson and Wrege 1973). The eggshell thicknesses of the aplomado falcon eggs were apparently normal and were 1.26–1.34 times thicker than eggshells from aplomado falcons collected in Veracruz, Mexico in 1977 (Kiff et al. 1980).

PCB Effects.—PCBs were below detection limits (<0.05 μg/g) in potential prey of the aplomado falcon. Dietary levels of 3 μg/g PCB (as Aroclor® 1248) fed to eastern screech-owls (*Otus asio*) did not have any effects on reproduction or eggshell thinning (McLane and Hughes 1980). Concentrations of PCB in eggs of dosed birds ranged 4–18 μg/g ww. Total PCBs in the aplomado falcon egg collected in 1995 were within the range observed in eggs of Caspian terns and great blue herons (0.4–0.6 μg/g ww) during 1993–94 (Mora 1996*b*); however, total PCBs were 3 times higher in the egg collected in 1996. Nonetheless, total PCB levels in the aplomado eggs were 3–36 times lower than those observed in eggs of screech-owls at which no adverse effects were observed (McLane and Hughes 1980), therefore the accumulation of PCBs in aplomado falcons may not be of concern.

Congener-specific PCB and chlorobiphenyl profiles were also similar among aquatic birds and the aplomado falcon egg. Congeners 153, 180, and 138, as well as other hexachlorobiphenyls and heptachlorobiphenyls were as predominant in the aplomado falcon eggs as they were in the fish-eating species (Mora 1996*a*). The similarities in PCB congener profiles in eggs of the aplomado falcon and those of 2 fish-eating birds from the same area could be explained by greater bioaccumulation of higher-chlorinated biphenyls than lower-chlorinated biphenyls in species at higher trophic levels (Focardi et al. 1988).

Trace Element Effects.—In this study, Hg was not detected in mourning doves but residues in livers of meadowlarks reached 1.04 μg/g dw. Mercury concentrations as low as 1–1.2 μg/g dw in prey of common loons (*Gavia immer*) were associated with reduced clutch size, increased nest desertion, and decline of nesting territories (Barr 1986). These are the lowest levels of Hg in prey that have been associated with reproductive anomalies in wildlife (Scheuhammer 1991). Unhatched eggs of ring-necked pheasants (*Phasianus colchicus*) contained 0.5–1.5 μg/g Hg when parents were fed a diet containing methylmercury (Fimreite 1971). Mercury residues in the unhatched aplomado falcon eggs were above the range observed in unhatched pheasant eggs; thus, suggesting significant exposure to Hg in the diet.

Sensitivities of birds to Hg vary widely, however, even within birds of prey. Mercury concentrations in the range of 1.6–4 μg/g dw in eggs were associated with hatching failure in bald eagles (*Haliaeetus leucocephalus*), but the association was also linked with high concentrations of DDE (Wiemeyer et al. 1984). Similarly, Hg concentrations ≥3 μg/g dw in eggs were associated with reduced brood size in merlins

(*Falco columbarius*; Newton and Haas 1988). However, up to 4.6 μg/g dw Hg in eggs had no negative effects on reproduction of white-tailed eagles (*H. albicilla*; Koivusaari et al. 1980, Helander et al. 1982). Thus, Hg residues in the 1995 aplomado falcon egg seem to be below the level at which negative effects were observed in these raptors. The concentration of 4.1 μg/g dw Hg in the 1996 egg, however, was above the level at which negative effects were observed in reproduction of merlins and bald eagles, but below the level at which no effects on reproduction were observed in white-tailed eagles. Therefore, there is a clear need for continuous monitoring of aplomado Hg intake to further assess the potential negative reproductive or chronic effects of mercury in this species.

Concentrations of Al, Cd, Cr, Pb, Se, and other trace metals in mourning doves and meadowlarks were below the threshold in diet at which reproductive effects in some aquatic birds and raptors have been reported (Heinz and Haseltine 1981, Cain et al. 1983, Heinz et al. 1983, Scheuhammer 1987, Skorupa and Ohlendorf 1991, Wiemeyer and Hoffman 1996).

MANAGEMENT IMPLICATIONS

Except for Hg, all the contaminants observed in potential prey of the aplomado falcon and in the aplomado eggs seem to be below the threshold for adverse biological effects. However, a more adequate estimate of the frequency in the diet of species with higher DDE (and possibly Hg) residue levels, such as the great-tailed grackle (and possibly killdeer), will be necessary to determine the contribution of certain contaminants by these species. Great-tailed grackles accumulate nearly 20 times more DDE than mourning doves (Mora and Anderson 1991). Thus, feeding on grackles by aplomados, even infrequently, might contribute significantly to the total contaminant burdens and potential detrimental effects. Among the trace metals, concentrations of Hg need to be monitored closely in any prey species of the aplomado falcon, particularly since the Hg value in the 1996 egg was at the threshold at which negative effects on reproduction were observed in other raptors. Additional studies of nesting success, habitat use, foraging behavior, diet, and continuous monitoring of contaminants in plasma of the aplomado falcon would further contribute to the evaluation of the recovery of this endangered species in the LRGV. Finally, it is encouraging that productivity of 2 young/nest (1 nest) in 1995 and 1.5 young/nest (2 nests) in 1996 was considered normal and it may indicate that the aplomado falcon is on its way to recovery in the Lower Rio Grande Valley.

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