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Pesticide Residues in Arizona Peregrine Falcon Eggs and Prey

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Widespread declines of the peregrine falcon (Falco peregrinus) in the northern hemisphere were noted by the mid 1960's (Hickey 1969). In North America the peregrine was extirpated as a breeding bird east of the Great Plains and south of Canada (Berger et al. in Hickey 1969). Populations had also largely disappeared from the northern Rocky Mountain states (Enderson et al. 1982) and from the coastal and agricultural areas of California (Kiff in Cade et al. 1988). Persistent organochlorine pesticides were implicated as the major causative agent in these population declines (Risebrough and Peakall in Cade et al. 1988).

In the last decade, sizable peregrine populations have been discovered in Arizona and elsewhere in the southwestern U.S. (Porter et al. 1978; Ellis in Cade et al. 1988). Herein, we report data from Arizona collected from 1978-85 on eggshell thickness, fledging success, and contaminant levels for eggs and prey. Few data have been published previously on these subjects for Arizona (Springer et al. 1984; Ellis 1985).

METHODS

Peregrine falcon nesting pairs, located in surveys from 1975-85, were periodically revisited to record productivity so that by August 1985, we had documented reproductive performance for 126 pair-years (Ellis in Cade et al. 1988). Only nestlings observed within one week of fledging were counted as fledged.

Eggshell fragments, addled eggs, and prey remains were gathered in visits to the eyries following fledging. By rotating the sample of eyries entered, we had obtained by 1983 eggshell samples for 26 breeding attempts representing 17 territories.

Eggshell fragments were recovered with forceps from the eyrie floor, placed in acetone washed vials with aluminum foil covers, and stored. Those eggshell fragments not showing surface pigmentation (and therefore probably

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not representing the current breeding season) were discarded. We made no distinction between eggs that hatched and those that did not nor between polar and equatorial fragments. Changes in eggshell thickness caused by embryonic development, significant for some species (Bunck et al. 1985), are believed to be insignificant in peregrine falcons (Olsen and Olsen 1979; Burnham et al. 1984). Shell thickness was measured with a Model 35 Federal bench comparator thickness gauge.

In June and July 1981, we shot about 500 specimens of known or likely avian prey of peregrines in Arizona. Birds were individually tagged, foil wrapped, and frozen whole. The beaks, feet, feathers and gastrointestinal tracts were removed just before chemical analysis. Regional samples of a prey species were pooled in composites of 4-12 birds for analysis. Composites of prey were homogenized, extracted, and analyzed as described by Cain and Bunck (1983).

Eggs collected in 1978 and 1982 were homogenized and analyzed as reported by Springer et al. (1984). The detection limits varied from 0.02 to 0.03 ppm wet weight. The 1981 egg contents were prepared, extracted, and separated as described by Kaiser et al. (1980), except that fractions 1 and 2 were combined. Detection levels were 0.10 ppm for pesticides and 0.50 ppm for PCBs.

Some eggshell fragments were also analyzed for traces of pesticides. These were immersed in hexane overnight. Thereafter, the hexane extract was analysed without cleanup by gas-liquid chromatography as described by Peakall et al. (1983).

Geographical and temporal trends in eggshell thickness and number of young fledged were sought with SPSSX subroutines (SPSSX Inc. 1983) using the Pearson Product Moment Correlation statistic.

RESULTS AND DISCUSSION

A reproductive rate considered sufficient to sustain a peregrine population is 1.0 young fledged per attempt (Ratcliffe 1980:241). The Arizona population produced 2.1 young/attempt for 25 breeding attempts for which we have eggshell data (Table 1) and 1.7 young/attempt for 126 attempts from 1976-85 (Ellis in Cade et al. 1988).

Average shell thinning for the Arizona population (14.2%, Table 1) was somewhat below the critical level of 17-20% which has been associated with population declines (Peakall and Kiff in Cade et al. 1988). Within our sample no correlations between shell thickness and productivity were observed, nor were there significant

Table 1. Measurements of eggshell fragments and observations of productivity obtained from peregrine falcon eyries in Arizona, 1978-1983.

Year, Site & Region	Number of Measurements[b]	Shell Thickness (mm) Range	Shell Thickness (mm) $\bar{x}$	Percent Thinning[c]	Young Fledged
1978					
A:S[a]	20	.283-.375	.307	16.8	2
B:S	20	.350-.375	.368	0	0
C:S	10	.333-.371	.353	4.3	3
D:C	10	.283-.295	.289	21.7	1
E:C	10	.288-.343	.314	14.9	2
1979					
F:S	15	.295-.356	.316	14.4	3
1980					
C:S	15	.337-.360	.348	5.7	2
G:S	15	.304-.331	.314	14.9	2
H:S	16	.276-.312	.292	20.9	2
I:S	15	.287-.324	.302	18.2	0
J:C	15	.271-.364	.289	21.7	3
1981					
K:C	15	.284-.365	.315	14.6	1
C:S	10	.313-.369	.344	6.8	3
L:N	25	.250-.375	.283	23.3	4
G:S	10	.256-.331	.314	14.9	4
J:C	10	.288-.313	.300	18.7	Unknown
1982					
M:N	10[d]	.343-.378	.361	2.2	3
E:C	4[d]	.312-.357	.335	9.2	0
L:N	10	.294-.292	.313	15.2	2
N:N	10	.289-.305	.299	19.0	3
D:C	10	.286-.347	.329	10.8	3
O:N	10	.263-.374	.295	20.1	3
A:S	10	.282-.305	.296	19.8	1
1983					
P:N	10	.290-.344	.327	11.4	2
L:N	10	.304-.350	.326	11.7	1
Q:N	10	.280-.323	.298	19.0	2

[a]Regional abbreviations: N=northern, C=central, S=southern.

[b]Measurements were taken from eggshell fragments determined by pigment and wear to have originated in the year of recovery.

[c]Percent thinning is based on 0.369 mm, the mean thickness for 100 eggs collected prior to 1947 in California (L. Kiff unpubl. data). A single fragmented egg collected in central Arizona on 3 June 1885 or 26 April 1886 (Edgar A. Mearns unpubl. field notes) averaged 0.361 mm (N=30, R=0.348-0.381).

[d]Measurements from four whole eggs.

temporal or geographic trends. Although shell fragments were collected opportunistically, rather than randomly, we believe that these data demonstrate that substantial, but not productivity limiting, shell thinning has occurred in the Arizona population.

Levels of DDE and DDT in eggshell membranes from fragments collected in 3 Arizona eyries were below detection limits. However, p,p-DDE was present in residues of organochlorine compounds quantified in 5 whole eggs from 3 clutches (Table 2). Although 15 organochlorine compounds were detected, all except DDE, beta HCH, and PCB occurred in <1 ppm (dry weight) concentrations. Mercury was also found in low concentrations. Except for DDE, none of the other compounds, considered singly, were within the range known to be biologically important (Stickel 1973; Wiemeyer et al. 1984). By comparison, peregrine falcon eggs from Colorado and New Mexico contained 8 to 65 ppm DDE (ca 34 to 280 ppm dry weight) and averaged 23 ppm (ca 100 ppm dry weight) during 1973-79 (Enderson et al. 1982).

We assayed 20 pooled samples of 14 avian species (Table 3) that are known or likely prey of the peregrine in Arizona. Although DDE concentrations in some samples

Table 2. Concentrations (ppm dry weight) of organochlorine compounds in five whole, addled peregrine falcon eggs collected in Arizona, 1978-1982[a].

Compound[c]	Concentrations[b] (year, site: region)				
	1978 B:S	1981 K:C	1982 E:C (3 eggs)		
p,p'-DDE	33	42	14	10	6.4
p,p'-DDT	0.50	0.53	0.07	0.07	0.11
beta-HCH[d]	0.49	-	0.83	0.84	1.31
PCB	0.96	2.23	1.1	0.79	1.03
Heptachlor epoxide	0.76	0.29	0.27	0.27	0.41
Oxychlordane	0.49	ND	0.09	0.13	0.19
Dieldrin	0.34	ND	0.12	0.10	0.10
Hexachlorobenzene	0.29	-	0.68	0.31	0.50
Endrin	0.20	ND	0.03	0.02	0.04

[a]Site codes correspond with those in Table 1.

[b]To convert values to wet or lipid basis (wet), multiply by 0.23 or 4.01 respectively. Blanks (-) indicate not quantified. ND indicates none detected at 0.01 ppm sensitivity.

[c]Also detected in amounts ≤0.20 ppm were alpha-HCH, gamma HCH, delta-HCH, mirex, trans- and cis-nonachlor, and mercury.

[d]Hexacyclochlorohexane.

Table 3. DDE concentrations (ppm wet weight) in composite samples of prey of the peregrine falcon in Arizona.

Species	Prey Rank[a]	Size	Composite[b] Location:Elevation	Concentration[c]
Aeronautes saxatalis	1	11	NW:1500	1.52[d]
		11	C:1400	3.05[d]
Zenaidura macroura	2	10	SE: 900	0.04
		11	NW:1500	0.03
Eremophila alpestris	3	9	SE:1200	0.03
Sturnella sp.	4	9	SE:1200	0.08
		9	NE:2100	0.59[d]
Turdus migratorius	5	7	C:2200	0.21[d]
Molothrus ater	5	4	SE: 900	0.43
		8	NW:1500	0.28
Cyanocitta stelleri	6	9	C:2200	0.05
Euphagus cyanocephalus	7	7	NE:2100	1.42
		12	C:2200	0.47
Zenaida asiatica	8	5	SE: 900	0.01
Icterus cucullatus	8	8	SE: 900	0.26[d]
Charadrius vociferus	9	6	SE,C,EC	8.78[d]
Petrochelidon pyrrhonota	10	12	SE: 900	3.20[d]
		12	NE:2300	3.70[d]
Myiarchus cinerascens	11	5	SE: 900	0.06
Agelaius phoeniceus	11	5	SE:1200	5.55

[a] Prey preference rank is based on frequency of occurrence (most frequent is number 1: not yet detected as prey in Arizona is 11) in a sample representing over 700 avian prey items identified from remains (feathers, feet, bills and bones) recovered from eyries.

[b] Composite size reports the number of carcasses in the pooled sample. Specific collection locations are on file with the first two authors. Location abbreviations indicate zone of origin by ninth of state (e.g., NW=northwest, C=central). Approximate mean elevation (m) is reported if the sample is from one location.

[c] Average and (S.D.) for proportion lipids was 0.05 (0.02) and for dry matter was 0.32 (0.03). Divide the reported residues by these proportions to convert to lipid or dry weight values.

[d] Seven other organochlorine chemicals were identified at concentrations >0.1 ppm (except for 0.2 and 0.3 ppm for PCBs) in these 6 composites. The chemicals and their frequency were: PCBs 4, beta-HCH 3, oxychlordane 3, heptachlor epoxide 2, and 1 each of alpha-HCH, dieldrin and trans-nonachlor.

for infrequently taken prey were elevated, the most significant findings were the high DDE levels in white-throated swifts (Aeronautes saxatalis), the most important prey species for the peregrine in Arizona (Ellis unpubl. data).

It has been shown experimentally that exposure to DDE in the diet caused wild prairie falcons (Falco mexicanus) to produce thin-shelled eggs (Enderson and Wrege 1973). Captive eastern screech owls (Otus asio) and American kestrels (Falco sparverius) fed 2.8 ppm DDE (wet basis) laid eggs 10-13% thinner than controls (Wiemeyer and Porter 1970; McLane and Hall 1972). Lincer (1975) demonstrated a dose-dependent relation of DDE-induced eggshell thinning in the American kestrel. If peregrines respond similarly, then five of the species in Table 3 could pose a significant threat to the peregrine. However, only one of these is taken frequently.

Except for the red-winged blackbird (Agelaius phoeniceus), those species showing elevated DDE levels in Table 3 were the same species exhibiting high DDE levels in 1977-80 surveys of peregrine prey in 8 western states (Monk 1981; Enderson et al. 1982; DeWeese et al. 1986). In these studies, migratory shorebirds were usually the most contaminated, followed by migratory insectivores. Nonmigratory species typically had low contaminant levels except nonmigrants in known DDE "hot spots" including western Texas, southeastern New Mexico, and south-central Arizona (Clark and Krynitsky 1983; Fleming and Cain 1985; White and Krynitsky 1986). Great variation in contaminant levels within a species and among sites characterized samples from these studies as well as our own.

Likely sources of DDE in Arizona peregrines include: residual (pre-1972) DDT in the environment, DDE ingested by peregrines wintering in Mexico, DDE obtained from migratory prey, global fallout, any recent illegal DDT uses, and derivation from Kelthane. Ducks fed Kelthane, a miticide containing p,p'-dicofol as its principal component and minor amounts of Chloro-DDT, exhibited elevated DDE levels (Risebrough et al. 1986). The metabolically formed DDE could have come from Chloro-DDT, but conversion of DDE from dicofol is also possible. Kelthane is used in cotton and citrus growing areas of the Southwest.

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