

Organochlorines and Eggshell Thinning in Peregrine Falcon *Falco peregrinus* Eggs from the Eastern United States, 1986 - 1988

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ABSTRACT

Comparisons of DDE and PCB concentrations (n=37) and shell thicknesses (n=112) of addled Peregrine Falcon, *Falco peregrinus*, eggs collected from the East Coast of the United States in 1986-1988 with earlier data indicated no detectable changes in residue levels or shell thickness over the decade. Geometric means of *p,p'*-DDE and the sum of the PCB congeners in the eggs, 7.8 and 8.9 mg/kg (wet weight) respectively, and the geometric mean shell thickness of all eggs collected between 1985 and 1988 (0.32 mm, or 11% thinning) were below and above, respectively, threshold levels considered critical for reproductive success. Although local variations in contamination patterns were detected, concentrations of the organochlorines measured over the region were significantly correlated with each other, indicating that a general contamination pattern exists over the region.

INTRODUCTION

In 1976, 12 years after Berger *et al.* (1969) had failed to find any active eyries of Peregrine Falcons in eastern North America, and 4 years after DDT use ended in the United States, personnel from The Peregrine Fund Inc. began an intensive effort to re-establish the Peregrine Falcon in North America using captive breeding and other management techniques (Barclay & Cade 1983). Gilroy & Barclay (1988) have presented data on DDE and PCB residues and on shell thicknesses of addled eggs produced by the introduced population in the early 1980s. In this paper we present data on levels of these and other organochlorine contaminants in eggs of Eastern Peregrines obtained in 1986-1988, and on shell thicknesses, in part to determine whether detectable changes in environmental levels have occurred over the decade, and in part to determine the present contamination patterns in this population.

MATERIALS AND METHODS

Collection

The eggs and shell fragments were collected by personnel from The Peregrine Fund, Inc. as part of the long-term Peregrine Falcon management program in the eastern US. Only eggs that failed to hatch were used for the organochlorine analysis in this study. The collection areas (Figure 1) consisted of four historic inland cliff nest sites (Northern Region), and 22 sites in the mid-Atlantic region, one of which, the Delaware Memorial Bridge, had two eyries. The state of New Jersey contained two subregions: Delaware Bay and River ($n=5$), and the New Jersey coast ($n=8$). The eggs were collected from Peregrine nests on cliffs, bridges, buildings, towers erected for release purposes, and a water tower.

Extraction and Analysis

The contents of 37 addled eggs collected between 1986 and 1988 were analyzed for organochlorine compounds at the University of California Santa Cruz, Long Marine Laboratory. When more than one addled egg was collected from a nest, one egg was randomly chosen and analyzed. For a detailed account of the method see Jarman *et al.* (1993a). Briefly, a homogenized aliquot was extracted with dichloromethane in a soxhlet apparatus, lipid was then applied to a florisil column, and the extracts were analyzed using a gas chromatograph (GC/ECD) equipped with two columns.

Eggshell thickness measurements

Eggshells ($n=112$) were measured at the Western Foundation of Vertebrate Zoology, Camarillo, California. The measurements were made with a model 35 PS Federal bench comparator thickness gauge. Whole eggs were measured on the equator through the blow-hole near the middle of one side. If no membrane was attached to the shell, a compensation factor of 0.063 mm was added, which was the mean thickness of the eggshell membranes of 20 pre-1947 Peregrine eggs.

RESULTS AND DISCUSSION

Eggshell thickness

The log DDE residue values were negatively correlated with shell thickness ($r = -0.387$, $P < 0.05$; Pearson's Correlation Coefficient), consistent with the results of earlier studies (Cade *et al.* 1971; Peakall & Kiff 1988; Gilroy & Barclay 1988). The geometric mean thickness over the time period 1981-1988 did not change significantly (Anova, $P > 0.05$). The geometric mean of all eggs was 0.32 mm, or 11% thinner than the historical pre-1947 mean thickness of 0.36 mm (Anderson & Hickey 1972). Only seven shells collected between 1981 and 1988 were thicker than the historical mean level (Figure 2a). The amount of eggshell thinning found in this study is well below the 17% threshold level above which population declines in Peregrines are expected (Peakall & Kiff 1988).

Organochlorines: Trends over Time

DDE and PCB concentrations were compared to data from an earlier study of eastern Peregrine eggs collected between 1981 and 1984, reported as clutch means (Gilroy & Barclay 1988). No change in DDE and PCB levels over the period 1981-1988 could be detected (Anova, ($P > 0.05$) (Figures 2b, 2c). The PCB values of samples collected between 1981 and 1984 were quantified as Aroclor® mixtures; this method may produce estimates of total PCBs that are higher by a factor of two or more than the values generated using individual PCB congeners (Turtle *et al.* 1991). This bias, however, while affecting any conclusion about whether levels have increased, would not affect our conclusion that there was no detectable decrease in PCB contamination levels over the decade.

Several data sets have indicated that DDE levels dropped sharply in eastern North America during the 1970s, i.e. the data from the monitoring program using wing muscles of Mallards, *Anas*

Figure 1. Location of egg collection sites for organochlorine analysis.

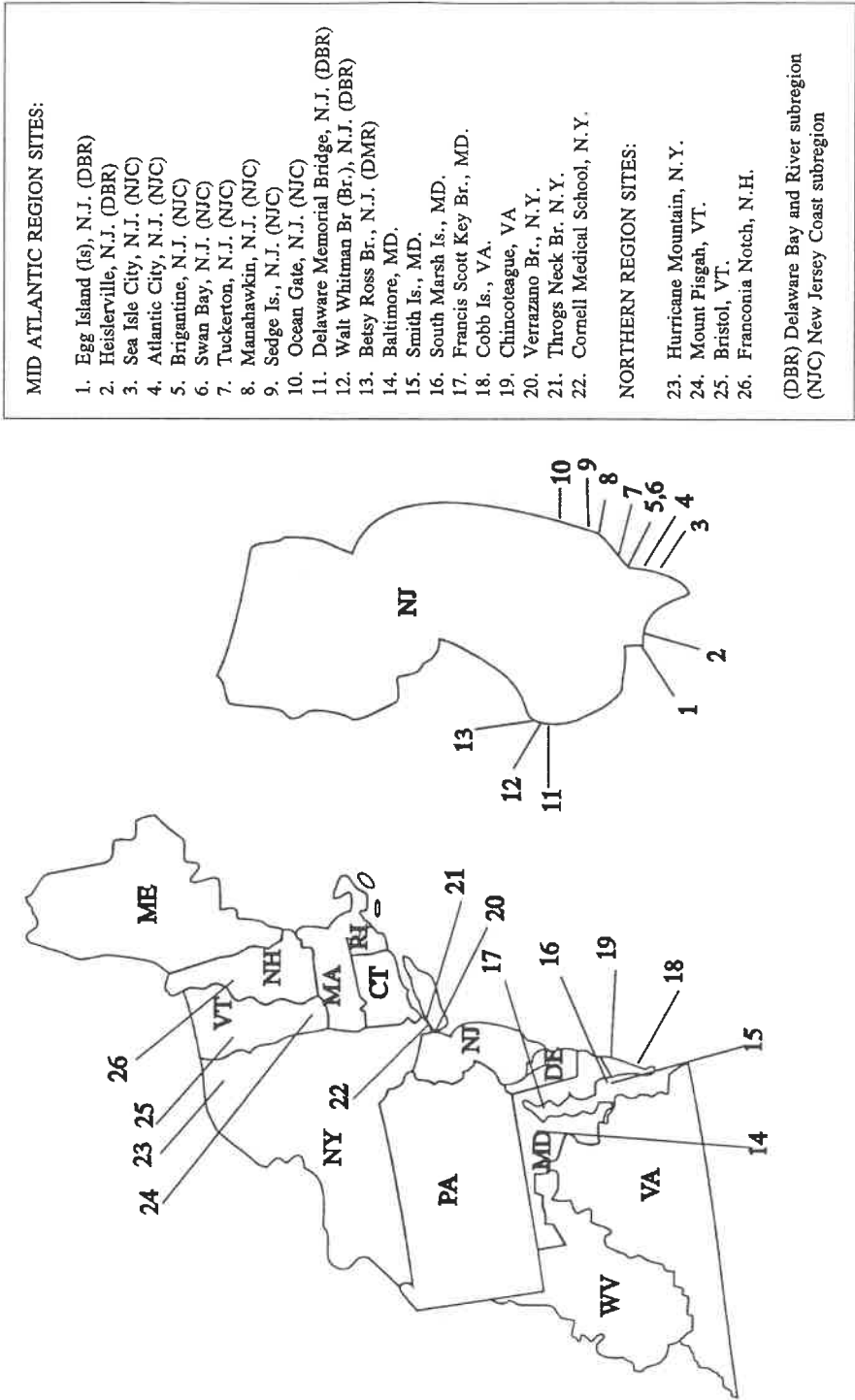
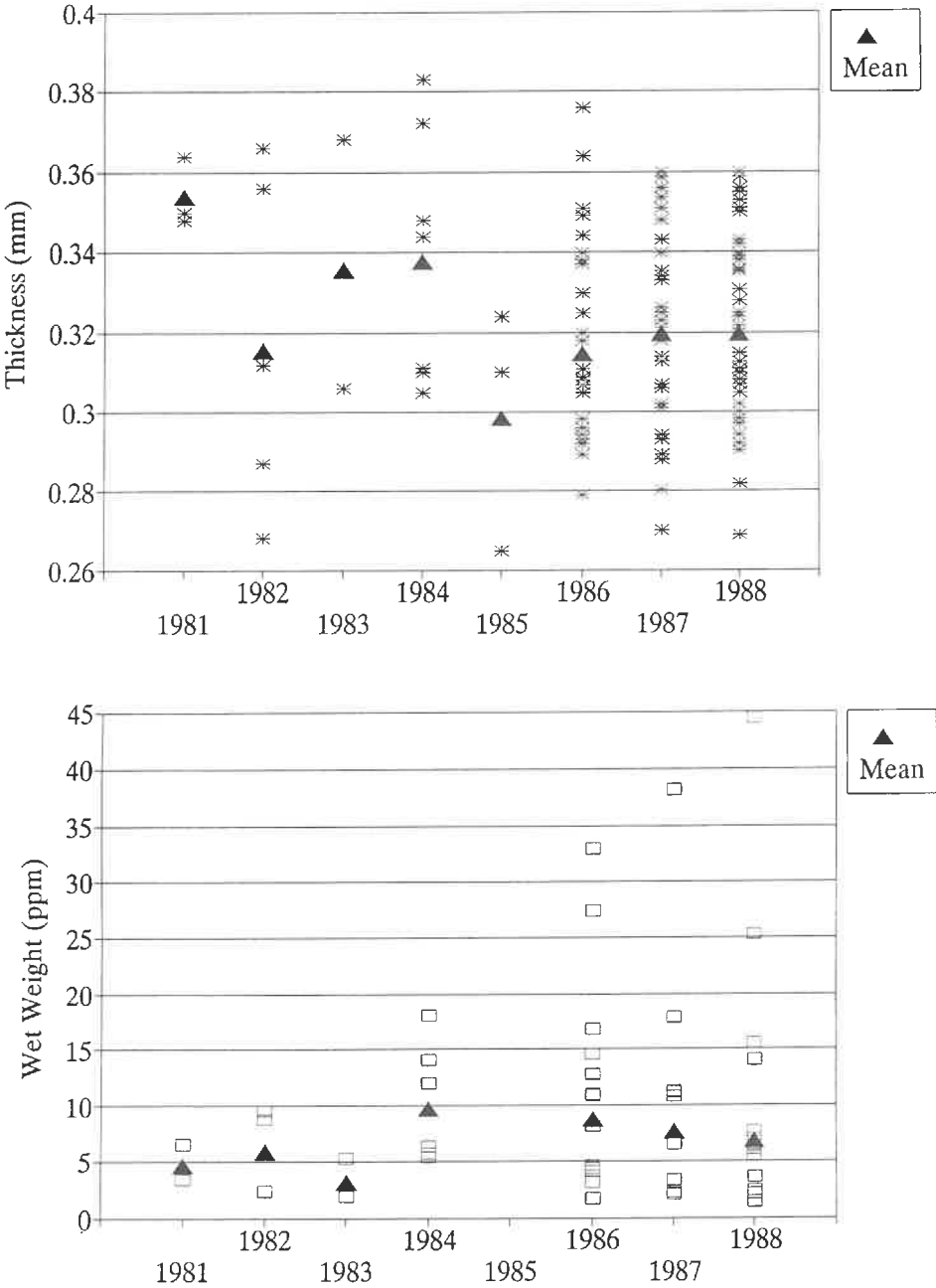
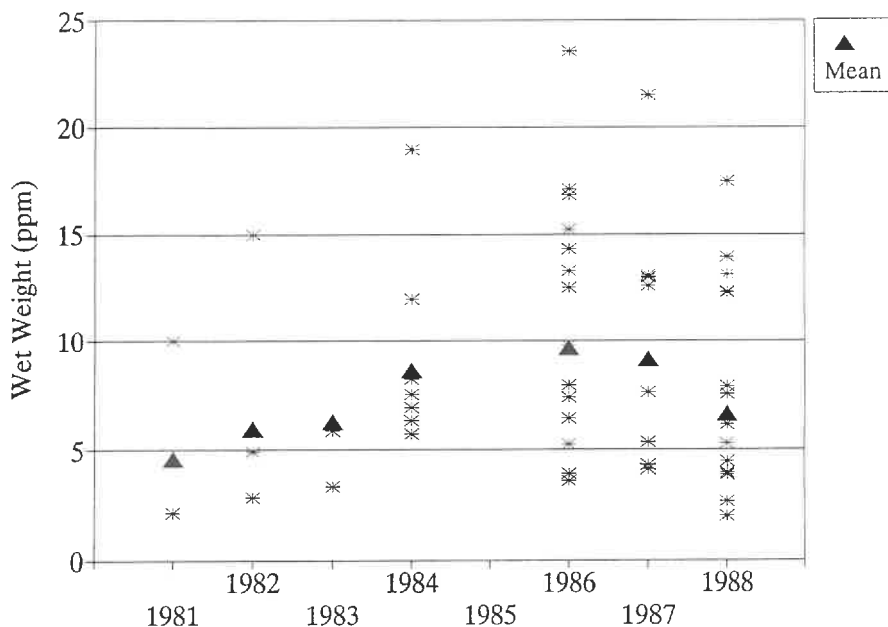


Figure 2. Scatterplots and geometric mean concentrations of eggshell thickness (mm, top) *p,p'*-DDE (middle), and PCBs (bottom, both mg/kg, wet weight) in East Coast Peregrine Falcon eggs, 1981-1988. DDE and PCB data from eggs collected between 1981-1984 are from Gilroy & Barclay (1988).





platyrhynchos, and Black Ducks, *A. rubripes* (Heath 1969; Heath & Hill 1974; Prouty & Bunck 1986). DDE and other DDT contamination also declined in coastal marine waters (Elliott *et al.* 1988). In the Great Lakes, levels of DDE, PCBs and several other organochlorines dropped sharply in the mid-1970s, but levelled off during the 1980s with few detectable trends (Weseloh *et al.* 1979; Mineau *et al.* 1984; Environment Canada *et al.* 1991b). Our data suggest a comparable pattern for DDE and PCBs in the northeastern states during the 1980s.

Organochlorines: A Regional Contamination Pattern

No differences in levels of any of the contaminants among the regions (Table 1) could be detected (Northern vs. Mid-Atlantic; among Northern, Chesapeake, New Jersey coast and Delaware Bay; New Jersey coast vs. Delaware Bay; Anova, $P > 0.05$). Moreover, with the exception of HCB which shows variable recoveries in the analyses, and of a barely non-significant correlation between PCBs and Heptachlor epoxide ($r_s = 0.34$, $df = 30$, $P = 0.05$) all contaminants were significantly correlated with each other ($r_s > 0.39$, $df = 30$, $P < 0.05$; Spearman's Rank Correlation Analysis). A region-wide contamination pattern is indicated. Visual examination indicated that the profiles of the individual PCB congeners were similar between the northern and mid-Atlantic regions.

Dieldrin levels in the eggs ranged from 91 to 810 $\mu\text{g/kg}$ (ppb), with a geometric mean value of 270 $\mu\text{g/kg}$ ($n=33$). The geometric mean value of dieldrin in Peregrine eggs collected from Great Britain between 1961 - 1977 was calculated to be 200 $\mu\text{g/kg}$ ($n=146$) by Nisbet (1988) from data of Ratcliffe (1980) and Cooke *et al.* (1982).

Local Variation

New Jersey Atlantic Coast sites

There were a total of eight Peregrine sites along the New Jersey coast. Although these sites are close geographically, the levels of organochlorine residues in eggs vary greatly. An example of this is the difference between the Brigantine and Atlantic City sites, which are less than 8 km

apart. Brigantine is approximately 5 km inland in a coastal marsh, and the Atlantic City site is located on a casino overlooking a marsh directly on the coast. The Brigantine site had the highest ratio of DDE:PCB, 3.1, whereas the Atlantic City site had the lowest DDE:PCB ratio of all the sites, 0.36. The contaminant levels between these sites also varied between 1986 and 1988. The mean of the Brigantine DDE levels ($n=3$) was higher than the mean of the Atlantic City levels ($n=2$) by a factor of 5.8 (38 mg/kg versus 6.5 mg/kg). The PCB residue levels of the Atlantic City site were higher than the Brigantine site by a factor of 1.5 (18 vs 12 mg/kg). The fact that these two nests are geographically close and yet have different levels of organochlorines indicates that these females may be feeding on different prey sources. The birds from the Atlantic City site have been observed taking rails as their primary prey.

The productivity of active nests on the New Jersey coast was higher than the Delaware Bay and River sites from 1979-1988 (Steidl *et al.* 1991). The means of the New Jersey PCB and DDE residue levels during 1986-1988 are approximately 1.5 times higher than those from the Delaware Bay region (Table 1). This suggests that the low productivity of the Delaware region may be due to causes other than the organochlorine residues reported in this study.

Bridge sites

Seven collection sites were from Peregrine nests located on bridges. Four of the bridge sites are on the Delaware River, two of these on the same bridge, east and west Delaware Memorial Bridge (DMB). These four sites are located within 50 km of each other. The largest difference in residue levels is between DMB west and DMB east: the DDE level of the first clutch DMB west was five times higher than the DMB east level (17 vs 3.4 mg/kg) and the PCB value was six times higher (18 vs 2.8 mg/kg). Second clutch DMB west DDE value was 1.8 times higher (6.1 vs. 3.4 mg/kg), and the PCB value was 2.9 times higher (8.3 vs 2.8 mg/kg). The levels in the egg from Betsy Ross Bridge were approximately three times lower than those from the Walt Whitman Bridge for both DDE and PCB (5.3 vs 18, and 4.3 vs 14 mg/kg respectively). These differences indicate either that the females are feeding on different prey sources, or that the ingestion of occasional "hot" prey items results in a different contaminant profile in the eggs.

Two bridge sites are in the New York City area, Verrazano Narrows Bridge and Throgs Neck Bridge, and have almost identical levels of DDE and PCB (2.0 vs 2.1, and 4.4 vs 4.7 mg/kg respectively).

Building Sites

Eggs were collected from three Peregrine nests located on buildings in metropolitan cities: Atlantic City, New Jersey (Atlantic); Cornell Medical School, New York (Cornell); and Baltimore, Maryland (Balt). In the eggs collected in 1988, all three sites had similar DDE levels but the Atlantic City site had three times the PCB level of Baltimore and two times more than the Cornell site.

CONCLUSION

The levels of organochlorine compounds and of eggshell thinning measured in this study were generally below those associated with population declines (Peakall & Kiff 1988); there are, however, areas of concern (*i.e.* the New Jersey coast and the Delaware River and Bay area) where the combined DDE and PCB levels are possibly high enough to affect reproduction. According to Steidl *et al.* (1991), the Delaware River and Bay area has lower productivity than the New Jersey coast region, but we found that the DDE and PCB values were similar between the regions. Therefore, there may be a factor in addition to DDE or PCB that might account for the depressed productivity in the Delaware River and Bay area.

The overall levels of DDE were similar to levels found in both Rocky Mountain and California Peregrine eggs, but the PCB levels were higher in the East Coast eggs (Jarman *et al.* 1992a). The possibility that the higher PCB levels could have a negative effect warrants further research.

Table 1. Organochlorine levels (geometric means, $\pm$ 1 std. dev., $\mu\text{g/kg}$, wet weight) in unhatched Peregrine Falcon eggs collected from the eastern United States, 1986-1988.

Parameter	All Sites	North	Mid Atlantic			
	n=37	n=4	All Mid At. n=33	Chesapeake Bay n=5	New Jersey Coast n=14	Delaware River & Bay n=7
% Lipid	6.5 (4.9-8.6)	6.4 (5.3-7.9)	6.5 (4.8-8.6)	7.3 (6.1-8.6)	6.3 (4.7-8.4)	6.9 (4.9-9.7)
% H ₂ O	83 (78-88)	83 (81-86)	83 (78-88)	79 (75-83)	84 (80-88)	81 (75-88)
<i>p,p'</i> -DDE	7,800 (3,200-19,000)	5,000 (2,500-10,000)	8,200 (3,000-20,000)	4,900 (2,600-9,000)	12,000 (5,500-25,000)	9,900 (5,200-19,000)
HCB	23 (11-47)	26 (12-53)	22 (11-46)	29 (14-59)	25 (15-42)	22 (11-42)
<i>trans</i> -nonachlor	200 (86-470)	190 (120-290)	200 (84-490)	160 (65-410)	280 (150-550)	210 (90-480)
Hept epox	170 (72-400)	94 (37-240)	170 (76-400)	200 (120-320)	190 (120-300)	170 (61-490)
Oxychlor	400 (150-1,100)	140 (16-1,200)	460 (260-820)	370 (259-530)	460 (230-910)	580 (360-930)
Mirex	190 (77-460)	170 (81-380)	190 (77-470)	180 (69-470)	230 (150-350)	200 (89-440)
β-HCH	7.8 (2.9-21)	3.6 (0.70-19)	8.6 (3.7-20)	5.9 (3.0-11)	10 (3.5-29)	11 (5.4-22)
Dieldrin	270 (91-810)	100 (21-500)	270 (96-780)	170 (30-950)	340 (133-650)	340 (170-680)
Σ PCB	8,900 (4,800-17,000)	6,100 (3,000-12,000)	9,400 (5,200-17,000)	6,800 (3,900-12,000)	14,000 (10,000-18,000)	9,100 (4,900-17,000)
DDE/PCB	0.87 (0.47-1.6)	0.83 (0.80-0.87)	1.0 (0.45-1.7)	0.7 (0.51-1.0)	0.73 (0.36-1.4)	1.1 (0.40-0.81)

HCB, hexachlorobenzene; Hept epox, heptachlor epoxide; Oxychlor, oxychlordane

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