

Organochlorine Pesticides, Chlorinated Dioxins and Furans, and PCBs in Peregrine Falcon *Falco peregrinus* Eggs from the Kola Peninsula, Russia

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ABSTRACT

Nesting of a bog-associated population of migratory Peregrine Falcons, *Falco peregrinus*, along the Ponoy River depression, Kola Peninsula, Russia, has been studied since 1977. In 1987-91 production rates averaged 1.94 young per active nest and the number of breeding pairs increased from 4 to 10. In 1991, most eyrie sites were visited during the egg stage and a "sample" egg was collected for contaminant analysis. Eight Peregrine Falcon eggs contained relatively low concentrations of *p,p'*-DDE (DDE) (geometric mean 3.5 µg/g) and of other organochlorine pesticides. These DDE concentrations are similar to those reported in Peregrine Falcon eggs from an Alaskan population that had also showed a recent population increase. Eggshell thinning (11.4%) was similar to that found in Alaska. Concentrations of polychlorinated biphenyls (PCBs) were higher than DDE concentrations, comparable to the contamination profile shown by Peregrine Falcon populations in Fennoscandia, and were higher than those found in Alaskan birds. Before this study, no Peregrine Falcon eggs from Russia had been analyzed for PCB congeners, polychlorinated dibenzo-*p*-dioxins (PCDDs), or polychlorinated dibenzofurans (PCDFs). Conversions of analytical concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), other PCDDs, PCDFs and PCB congeners based on relative aryl hydrocarbon hydroxylase induction potencies allowed the estimation of total 2,3,7,8-TCDD equivalents (TEQs). The TEQs are in the range that is associated with embryonic mortality in other species. Even though the Peregrine Falcon population now seems to be released from decades of a DDT problem, exposure to other contaminants continues. There is an obvious need to assess further the sources and longer-term trends of the PCBs. We also report residue concentrations from one White-tailed Eagle, *Haliaeetus albicilla*, egg.

INTRODUCTION

At the First World Conference on Birds of Prey, Galushin (1977) noted a rapid and continuous decline of the Peregrine Falcon in the Soviet Union. Unfortunately chemical residue levels were unavailable for pesticides or other poisons in eggs or carcasses, but taking into consideration some indirect evidence, he suggested pesticides were at least partly responsible for the decline. Peakall and Kiff (1979) measured eggshells at the Zoological Museum, Moscow, and reported significant shell thinning (25%) in eggs of Peregrine Falcons from Siberia in 1961-66. They also reported the presence of DDE in shell membranes of the eggs measured. Because of this background and the general understanding that DDE residues in Peregrine Falcon eggs decreased widely following DDT bans in the early 1970s (Cade *et al.* 1988), Henny and Ward travelled to the study area of Ganusevich on the Kola Peninsula in 1991 to collect Peregrine Falcon eggs. The eggs were brought to the United States for analyses of eggshell thickness and chemical residues.

STUDY AREA

Ganusevich (1988) provided a review of raptors nesting on the Kola Peninsula of extreme northwestern Russia (near the Finland border), including Osprey, *Pandion haliaetus*, White-tailed Eagle, *Haliaeetus albicilla*, Northern Goshawk, *Accipiter gentilis*, Eurasian Sparrowhawk, *Accipiter nisus*, Rough-legged Buzzard, *Buteo lagopus*, Golden Eagle, *Aquila chrysaetos*, Hen Harrier, *Circus cyaneus*, Merlin, *Falco columbarius*, Gyrfalcon, *Falco rusticolus*, and Peregrine Falcon. Ganusevich began studying the Peregrine Falcon population on the Kola Peninsula in 1977. Its known territories have been monitored annually with additional searches for new territories. Aerial, boat, and foot surveys of selected areas of the peninsula suggest a local distribution of the Peregrine Falcon population in the basin of the upper and middle course of the Ponoy River. The Ponoy depression is characterized by large bogs, many small and large lakes, rivers, and hills with parcels of land elevated (above the bogs) with forests, rocks, and cliffs. An abundance of prey (primarily shorebirds associated with the bogs and lakes), suitable nesting sites, and the absence of human activities define optimum conditions for breeding of the Peregrine Falcon. The territories are constant from year to year, although the actual eyrie site may change annually. An easy access to many eyries by predatory animals sometimes causes nest failure.

As part of a general survey for environmental contaminants from the Kola Peninsula, we elected to evaluate chemical residue levels of organochlorine (OC) pesticides and selected chlorinated aromatic compounds in the eggs of Peregrine Falcons. Our concern about DDT, other OC pesticides, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) centers on their toxicity, persistent nature, and propensity for bioaccumulation. Our analysis of PCB congeners focused on those congeners with zero or one chlorine substituted in the ortho position of the phenyl rings. They are particularly toxic to sensitive species and are potent inducers of hepatic aryl hydrocarbon hydroxylase (AHH) (Safe 1987). These planar non-ortho-C1 PCB congeners are approximate isostereomers of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and their ability to induce AHH activity is similar to that of TCDD (Safe 1990). The group of PCBs, PCDDs, and PCDFs that induce AHH activity will be collectively referred to as planar halogenated hydrocarbons (PHHs).

ANALYTICAL METHODS

Sample extraction, lipid determination, cleanup and fractionation procedures have been described in detail (Schmitt *et al.* 1985; Schmitt *et al.* 1990). The fraction of the sample extract containing PCBs and PHHs was quantitatively divided into 2 portions, one for determination of specific congeners by the method of Schwartz and Stalling (1991), and one for enrichment and determination of PHHs by the method of Smith *et al.* (1990).

Organochlorine residues were determined by gas chromatographic separation using DB-1 and OV-17 fused silica capillary columns with electron-capture detection as described previously (Schmitt *et al.* 1985, 1990; Smith *et al.* 1990; Schwartz and Stalling 1991). Extracts containing

dioxins and furans were separated by gas chromatography in a DB-5 capillary column and quantified with a Finnigan mass spectrometer. Calibration provided the relative response factors of the native (analytes) and C¹³-labelled congeners (recovery standards) within each homologue series, from which concentrations of the dioxin and furan analytes were calculated. The non-ortho-Cl PCB congener concentrations were determined with a DB-1 capillary column in a HP 5890A gas chromatograph interfaced to a VG70-250S high-resolution mass spectrometer. Calibration provided the relative response factors of the native and C¹³-labelled PCB congeners, from which concentrations of the non-ortho-Cl PCB analytes were calculated. For all analytes, extraction efficiencies (recoveries) were measured using the relative responses of internal reference (added to extracts before gas chromatography) and recovery standards.

Method and procedure blanks were processed with the samples to verify that solvents, reagents, apparatuses and instrumentation did not add detectable positive biases to the residue concentrations. For statistical treatment, the method lower limits of detection (MLLDs) and method lower limits of quantitation (MLLQs) for each contaminant were determined according to the method of Keith *et al.* (1983). In general the MLLDs and MLLQs were similar to those reported previously (Schmitt *et al.* 1990). Residue concentrations in eggs were corrected to an approximate fresh wet weight (Stickel *et al.* 1973) and expressed on a wet-weight basis.

RESULTS

Peregrine Population

The number of known Peregrine Falcon nesting territories has increased during the early years of investigations by Ganusevich (1988) because of increased detection from better understanding of the region and habitat requirements. A complete annual survey of all 15 known nesting territories has been made since 1987 in the 1,000 km² study area (Table 1).

Table 1. The breeding success of Peregrine Falcons on the Kola Peninsula in Russia, 1987-91 (Ganusevich, unpublished data).

Category	1987	1988	1989	1990	1991	TOTAL
Active Nests	4	5	5	8	10	32
No. of Nestlings	9	10	12	12	19	62
Young/Active Nest	2.25	2.00	2.40	1.50	1.90	1.94

Prey Species

Food remains from the eyries and vicinity were used to evaluate prey species eaten by the Peregrine Falcons. Ganusevich collected 269 prey items over the years, all but 1 of which were birds, including 30 prey species: Ruff, *Philomachus pygmaeus*, 52.0%, Common Snipe, *Gallinago gallinago*, 8.6%, Jack Snipe, *Lymnocyrtus minima*, 4.8%, Wood Sandpiper, *Tringa glareola*, 4.5%, and Arctic Tern, *Sterna paradisaea*, 3.4%; other species comprised not more than 3% of prey items.

Egg Contaminant Residues and Eggshell Thickness

Intact eggs were obtained from 6 different clutches in 1991, and large eggshells were obtained from 2 additional clutches. At Trophim Hill where a 3-day-old young was present, we collected 3 added eggs. Eyries with eggshells only included 1 destroyed by a predator (probably a fox) and another (2 young produced) where a broken eggshell was found below the nest ledge. Therefore, egg residues were obtained from 6 nest sites and eggshell thicknesses from 8 nest sites (Table 2). Viable eggs were collected at only 3 nests (Devichy Hill, Okunjevy Hill and Palnik Lake); the other 5 eggs were already dead at the time of collection.

Table 2. Clutch size, young produced and eggshell thickness for Peregrine Falcons on the Kola Peninsula, Russia, 1991.

Nest Site	Clutch Size	No. of Young	Eggshell Thickness (mm)
Devichy Hill	4 ^a	3	0.289
Okunjevy Hill	4 ^a	3	0.310
Trophim Hill	4 ^b	1	0.311 ^c
Palnik Lake	3 ^a	2	0.283
Vuljavr Lake	3 ^b	2	0.306
Maloe Vasiljevskoe Lake	NA	0	0.325 ^d
Verhnekamenskoe Lake	3	2	0.323 ^d
Tebek Rus	4 ^b	3	0.333
El River	3	3	--
Veha	NA	0	--
Mean	3.50	1.90	0.310

NA = Not Available.

^a Viable egg was collected from the clutch for residue analyses.

^b Added egg(s) collected from clutch.

^c Mean of 3 added eggs (0.310, 0.311, and 0.312 mm)

^d Large eggshell that was not intact.

Mean clutch size was 3.50 eggs with an equal number of 3-egg and 4-egg clutches. An average of 1.90 young was produced per nesting attempt, and if all 3 viable eggs collected had yielded young, the production rate would have been 2.20 young in 1991. Mean eggshell thickness (and SD) in 1991 was 0.310 (0.017) mm, compared with 0.350 mm for pre-DDT era Swedish Peregrines between 1861 and 1946 (Lindberg 1975); this represents a reduction of 11.4%. The pre-DDT era Swedish shell thickness information was the geographically closest data available. Other indices to thickness, such as those from Finland (Lindén *et al.* 1984), were not directly comparable to our thickness measurements. The 3 eggs from the same clutch (Trophim Hill) showed nearly identical shell thicknesses. The mean for the 3 Trophim Hill eggs was used to calculate the overall mean for the 8 clutches sampled.

The *p,p'*-DDE concentrations were judged low; the geometric mean was 3500 ng/g or 3.5 µg/g (fresh wet weight) with no concentrations above 5 µg/g (Table 3). Total PCBs were higher (geometric mean 7.3 µg/g), with values from some eggs about triple the mean. The Trophim Hill clutch had 3 added eggs (with no development) and contained the highest PCB and PHH levels (Tables 3 - 6). All residues from the 3 eggs are shown to document the remarkable consistency in contaminant concentrations among eggs within the same clutch.

The study area also contained a number of White-tailed Eagle nests. We had the opportunity to sample one of these nests. An added egg was obtained from a nest with a large young nearly ready to fledge. Although one egg is inadequate to reach many conclusions, the eggshell thickness was 0.611 mm, with residue concentrations presented in Tables 3 - 6. Koivusaari *et al.* (1980) reported a pre-DDT era shell thickness [mean (SE)] of 0.620 (0.010) mm from nearby Finland (1884-1935).

The relative biologic potencies of a suite of PCDD, PCDF and PCB congeners to induce microsomal AHH in the H4IIE rat hepatoma cell line have been summarized by Safe (1990). Transforming our Peregrine Falcon egg concentrations (Tables 4-6), on the basis of each PHH's induction capability relative to 2,3,7,8-TCDD, permits the reporting of relative contributions in a common unit of measure, TCDD-equivalents (TEQs, Table 7). The equation used to obtain relative induction potencies is identical to that published by Sawyer *et al.* (1984). Conversion factors were

Table 3. Organochlorine pesticides and total polychlorinated biphenyls (PCBs) (ng/g, fresh wet weight) in Peregrine Falcon eggs and one White-tailed Eagle egg from the Kola Peninsula, Russia, 1991.

Nest Site	%Lipid	TOXA	DDE	DDD	DDT	MIREX	PCBs	HCB	LIND	βHCH	OXY	HE	αNON	cCHL	DIEL	cNON
Devichy Hill	3.5	200	4,100	30	88	25	18,000	43	150	74	36	49	6	0	76	7
Okunjevy Hill	3.3	90	3,900	5	7	11	5,000	30	2	270	47	45	6	0	26	1
Trophim Hill ^a	4.0	200	3,000	18	19	110	18,000	37	22	83	48	62	20	0	160	9
	4.2	200	3,400	17	25	110	21,000	37	19	84	48	66	20	0	170	8
Palmik Lake	3.9	200	3,200	18	17	130	21,000	39	16	88	57	63	15	0	170	8
	2.1	90	4,400	5	18	6	3,000	39	1	61	25	24	4	0	39	1
Vuljavr Lake	4.9	60	4,600	7	30	10	4,000	26	140	99	21	27	2	0	58	1
Tebek Rus	3.3	100	1,900	6	17	26	7,000	24	50	39	29	36	5	0	53	3
Geometric Mean ^b	--	110	3,500	9	22	19	7,300	33	18	86	33	39	5	0	59	2
White-tailed Eagle	4.1	90	700	24	0	2	2,000	4	0	12	4	3	12	8	14	4

Note: TOXA = Toxaphene, PCBs = Total Polychlorinated Biphenyls, HCB = Hexachlorobenzene, LIND = Lindane, OXY = Oxyachlordane, HE = Heptachlor Epoxide, αNON = *trans*-Nonachlor, cCHL = *cis*-Chlordane, DIEL = Dieldrin, DDE = *p,p'*-DDE, cNON = *cis*-Nonachlor, DDD = *p,p'*-DDD, DDT = *p,p'*-DDT, No Dacthal, *o,p'*-DDE, *o,p'*-DDD, *o,p'*-DDT, Endrin or Methoxychlor were detected.

^a Three eggs from the same clutch.

^b Arithmetic mean of 3 eggs from Trophim Hill was used to calculate overall geometric mean for the six Peregrine Falcon clutches sampled.

Table 4. Polychlorinated Dibenzo-*p*-Dioxins (pg/g, wet weight) in Peregrine Falcon eggs and one White-tailed Eagle egg from the Kola Peninsula, 1991, and their Toxic Equivalency Factors (TEFs)^a.

	Tetra	Penta		Hexa			Hepta	Octa
	2,3,7,8	1,2,3,7,8	1,2,4,7,8	1,2,3,4,7,8	1,2,3,6,7,8	1,2,3,7,8,9	1,2,3,4,6,7,8	--
TEF	1.0	0.5	0.005	0.1	0.1	0.1	0.01	--
Nest Site								
Devichy Hill	30	18	<0.4(ND)	5.2	10	0.7	0.8(NO)	1.6
Okunjevyy Hill	5.2	8.0	<0.2(NO)	2.7	3.7	<0.2(NO)	0.6	2.1
Trophim Hill ^b	37	27	<0.1(NO)	7.2	16	1.0	1.6	4.9
	38	28	<0.1(NO)	7.3	17	1.1	1.6	4.8
	37	28	<0.2(NO)	7.8	17	1.0	1.7	5.1
Palnik Lake	5.3	9.6	<0.3(ND)	1.8	9.0	0.3	0.8	1.6
Vuljavr Lake	4.0	3.8	<0.3(NO)	1.4	3.3	<0.3(NO)	0.6	4.6
Tebek Rus	11	14	<0.2(ND)	5.2	7.4	0.4	0.8	2.6
Geometric Mean ^c	11	11	(ND,NO)	3.3	7.2	0.3	0.7	2.6
White-tailed Eagle ^d	1.2	1.6	<0.2(ND)	0.3	0.8	<0.1(ND)	<0.3(NO)	1.8

^a TEFs from Kuiz *et al.* (1990).

^b Three eggs from the same clutch.

^c Arithmetic mean of 3 eggs from Trophim Hill was used to calculate overall geometric mean for the six Peregrine Falcon clutches sampled.

^d Arithmetic mean of two samples from the same egg.

(ND) Not Detected -- Primary and/or secondary ions for the analyte cluster were not detected.

(NO) Not Quantifiable -- Secondary/Primary ion ratio exceeds QC limit or cluster incomplete.

Table 5. Polychlorinated Dibenzofurans (pg/g, wet weight) in Peregrine Falcon eggs and one White-tailed egg from the Kola Peninsula, 1991, and their Toxic Equivalency Factors (TEFs)^a.

TEF	Tetra		Penta		Hexa			Hepta			Octa
	2,3,7,8	1,2,3,7,8	1,2,3,7,8	2,3,4,7,8	1,2,3,4,7,8	1,2,3,6,7,8	1,2,3,7,8,9	2,3,4,6,7,8	1,2,3,4,6,7,8	1,2,3,4,7,8,9	--
<u>Nest Site</u>											
Devichy Hill	0.1	0.05	0.5	0.1	0.1	0.1	0.1	0.1	0.01	0.01	--
Okunjevy Hill	55	9.2	49	5.5	3.0	0.5	0.5	1.8	<0.3(NQ)	<1(NQ)	3.8
Trophim Hill	31	3.0	15	2.0	0.8	<0.2(NQ)	0.5	0.5	<0.3(NQ)	<0.4(NQ)	1.0
Palnik Lake	49	10	62	14	5.2	0.8	0.8	2.7	1.0	<2(NQ)	4.2
Vuljavr Lake	52	11	65	14	5.8	0.7	0.7	2.8	0.8	1.7	3.4
Tebek Rus	50	11	63	15	5.7	0.8	0.8	2.8	<1(NQ)	<2(NQ)	3.6
Geometric Mean	12	1.3	22	1.9	1.6	<0.3(ND)	0.6	0.6	<0.4(ND)	<0.4(ND)	0.6
White-tailed Eagle	18	1.3	9.9	0.9	0.6	<0.2(NQ)	0.3	0.3	<0.3(NQ)	<0.3(NQ)	0.8
	41	7.7	38	4.3	2.5	<0.2(NQ)	1.2	1.2	<0.3(NQ)	<0.4(NQ)	1.1
	30	4.0	27	3.2	1.8	0.2	0.2	0.9	0.2	0.3	1.4
	1.6	0.6	5.1	0.6	0.4	<0.1(NQ)	0.4	0.4	<0.1(NQ)	<0.1(NQ)	<0.3(NQ)

^a TEFs from Kutz *et al.* (1990).

Table 6. AAH-active PCB congeners (ng/g, wet weight) in Peregrine Falcon eggs and one White-tailed Eagle egg from the Kola Peninsula, Russia, 1991, and their Toxic Equivalency Factors (TEFs)^a

	Tetra		Penta				Hexa				Hepta	
	77	81	105	114	118	123	126	156	157	167	169	189
TEF	0.01	---	0.001	0.001	0.001	0.001	0.1	0.001	0.001	0.001	0.05	0.001
Nest Site												
Devichy Hill	3.0	0.27	180	18	1,300	6.1	2.8	160	24	120	0.44	21
Okunjevy Hill	2.2	0.18	54	4.9	320	1.8	1.2	53	11	37	0.21	7.7
Trophim Hill	2.6	0.28	210	18	1,200	6.0	3.8	230	32	130	1.2	39
	2.7	0.31	210	18	1,300	6.1	3.8	240	33	130	1.3	39
	2.5	0.29	220	19	1,300	7.3	3.6	250	35	140	1.2	42
Palmik Lake	0.51	0.05	39	3.0	200	<0.43 (ND)	0.61	43	6.0	20	0.14	5.0
Vuljavr Lake	0.85	0.07	33	3.2	210	0.9	0.46	43	4.7	26	0.16	6.3
Tebek Rus	1.6	0.13	54	6.1	410	1.7	1.1	78	9.1	59	0.33	14
Geometric Mean	1.5	0.14	72	6.7	450	1.7	1.3	82	12	51	0.31	12
White-tailed Eagle	0.14	0.03	17	2.0	93	<0.43 (ND)	0.19	16	2.0	10	0.05	1.6

^a TEFs from Safe (1990).

Table 7. Calculated 2,3,7,8-TCDD equivalences (TEQs) for Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, and AHH-active PCB congeners (pg/g) in Peregrine Falcon eggs, and one White-tailed Eagle egg from the Kola Peninsula, Russia, 1991.

Nest Site	Dioxins		Furans				PCBs			TEQs	
	2,3,7,8	Total	2,3,7,8	2,3,4,7,8	Total	77	105	118	126	169	Total
Devichy Hill	30	41	5.5	25	32	30	180	1,300	280	22	2,100
Okunjevy Hill	5.2	9.8	3.1	8	26	22	54	320	120	11	640
Trophim Hill	37	53	4.9	31	39	26	210	1,200	380	61	2,400
	38	55	5.2	32	40	27	210	1,300	380	64	2,400
	37	54	5	32	40	25	220	1,300	360	62	2,500
Palmik Lake	5.3	11	1.2	11	13	5.1	39	200	61	7	390
Vuljavr Lake	4.0	6.4	1.8	5	7.1	8.5	33	210	46	8	390
Tebek Rus	11	19	4.1	19	24	16	54	410	110	17	770
White-tailed Eagle	1.2	2.1	0.16	2.6	2.9	1.4	17	93	19	2.5	170

Note: Total TEQs for dioxins, furans, and PCBs are the summation of all calculated values (see all concentrations used and TEFs in Tables 4-6).

obtained from literature values by Safe (1990). Certain PHHs were not included because of their low computed TEQs (<0.01 pg/g in any egg), as noted in Table 7.

As can be readily seen, the AHH-active PCB congeners dominate the biological potency and thus the estimated toxic potency of the chlorinated PHH isosteres that we report. In all samples, PCB congeners account for more than 94% of the estimated TEQs. The marked difference in total estimated TEQs between the White-tailed Eagle egg and falcon eggs from the clutch with 3 added eggs (170 TEQ/g egg for eagle egg compared with about 2,500 TEQ/g egg for falcon eggs) is striking. These differences most likely reflect variation in dietary contamination of the two species.

DISCUSSION AND CONCLUSIONS

The limited region of the Ponoy River depression that is surrounded by bogs now supports an increasing population of nesting Peregrine Falcons. Earlier population estimates are not available, but the adjacent Fennoscandian Peregrine Falcon population declined during the 1950s and 1960s and probably reached its lowest level at the beginning of the 1970s (Lindberg 1985). During the late 1970s both productivity and the number of breeding pairs increased in Finland and Norway, but not in Sweden. The 1975-81 production in northern Finland (above 66° N. Latitude) was much better (1.91 young/pair) than in southern Finland (1.16 young/pair) (Wikman 1985). Thinner-shelled eggs were also reported in southern Finland (Lindén *et al.* 1984).

Reproductive success in northern Finland increased to 2.1 young per breeding attempt in 1981-85 (Lindberg *et al.* 1988). Although the data from Finland were collected about 6 years before ours, the production rates from northern Finland and the recent rates from the Kola Peninsula (study area is above 66° N. Latitude) were similar. The eggshells from the Kola Peninsula still show thinning, but the relationship of DDE to eggshell thickness, as discussed by Blus *et al.* (1972) is typically manifested by a much more rapid improvement in shell thickness as DDE concentrations decrease below those observed in these eggs. In Alaska, in 1979-84, DDE egg residues were higher (geometric mean 10.1 $\mu\text{g/g}$) and eggshell thinning was more severe (13.1 to 13.6% , depending on subspecies), but the DDE apparently had a minimal effect on productivity as the population at that time was increasing (Ambrose *et al.* 1988a, 1988b). The populations have continued to increase in recent years and DDE residues have continued to decline (Ambrose and Henny, unpublished data). Reported PCB concentrations are now much lower in Alaska (geometric mean, 2.0 to 2.7 $\mu\text{g/g}$, depending on subspecies; Ambrose *et al.* 1988a) than in western Russia.

Prey species have not been analyzed for contaminants in the Kola Peninsula; prey species, however, have been identified. We found that 5 key species, all associated with bogs, accounted for 73.3% of the diet. Lindén *et al.* (1984), in their earlier work in Finland, noted large variation in DDE levels in Peregrine Falcon eggs and suggested that chemical contamination in the population was not uniform. The relatively low DDE contamination in Kola Peninsula Peregrine Falcon eggs now appears quite uniform; higher PCB concentrations are more variable. Lindberg *et al.* (1983) noted that chemical residue concentrations in some important prey species on the breeding grounds in Sweden were not high enough to account for the levels found in Peregrine Falcons, suggesting either that residues were accumulated outside the breeding grounds or that bioaccumulation factors for Peregrine Falcons were higher than expected. Wintering-grounds accumulation of DDE was documented for Arctic Peregrine Falcons in North America (Henny *et al.* 1982), and may occur in the Kola Peninsula population. This may explain the higher variability in PCB concentrations. Unfortunately, little is known about the wintering localities of Peregrine Falcons that nest in the Kola Peninsula. Young have been ringed in recent years, but no recoveries have been recorded. The Ruff (52% of the prey on the breeding grounds) rests and molts along the coast of western Europe, the Mediterranean Sea, the Black Sea, the Caspian Sea, and the Nile Valley; most winter in Africa (Van Rhijn 1991).

We were surprised by the relative concentrations of PCBs and TEQs in these Peregrine Falcon eggs compared with those reported in studies of other species. Forster's Terns, *Sterna forsteri*, with about the same concentrations of PHHs experienced reduced reproductive success (Kubiak *et al.* 1989). An unhatched Bald Eagle, *Haliaeetus leucocephalus*, egg, with concentrations approximately twice that of Peregrine Falcon eggs in this study, died at day 19 or 20 and exhibited beak deformity (Schwartz *et al.* pers. comm.). The high PCB and PHH concentrations in the 3 added

eggs at Trophim Hill are of special concern. Hatchability was reduced when PCB residues in chicken eggs ranged from 3 to 14 $\mu\text{g/g}$ (wet weight) (Cecil *et al.* 1974) and 16 $\mu\text{g/g}$ in Ringed Turtle-Dove, *Streptopelia risoria*, eggs (Peakall & Peakall 1973). When Forster's Tern eggs from Green Bay, Wisconsin, USA contained a median concentration of 22.5 $\mu\text{g/g}$ PCBs, hatching success was 52% of that of controls (Hoffman *et al.* 1987). However, at Green Bay the eggs also contained a number of other potentially critical contaminants (Kubiak *et al.* 1989). Although no toxicological data exist for Peregrine Falcon sensitivity to these PHHs, there is cause for concern based on similar PHH concentrations in other species.

The TEQ approach needs to be interpreted with some caution. We do not suggest that the TEQs estimated by our procedure are in fact the actual equivalents that could be present in each egg. Unknown compounds which are AHH active could increase equivalents; others may even reduce the estimated equivalents by antagonism. Regardless, subsequent studies could achieve a more realistic biologically-determined estimate, based on the work of Tillitt *et al.* (1991a). Tillitt *et al.* (1991b) measured the relative biological activity of colonial fish-eating water bird egg extracts by an AHH induction *in vitro* bioassay using the same rat hepatoma H4IIE cell line that was the basis of our equivalents calculations. The bioassay-derived TEQs in the waterbird eggs concurred with residue analyses and biological data from other studies, although the absolute values measured in the bioassay were less than the calculated TEQs.

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