bcc: E. Wheeler
R. Keller

FF

November 13, 1968 [illegible]

Dr. Robert W. Risebrough
Institute of Marine Resources
University of California
Berkley, California 94720

Dear Dr. Risebrough:

Thank you for the opportunity of reviewing your manuscripts concerning polychlorinated biphenyls in the global environment.

I have forwarded your papers to the appropriate research groups in our Organic Research Department and have asked for their comments.

My interests are, for the moment, somewhat advisory in nature. Since the source of these suspected PCB residues is not known, Monsanto's interests are being directed by our Medical Department. Mr. Elmer Wheeler, Industrial Toxicologist, is currently coordinating the program with Dr. Robert E. Keller of our Organic Research Department in charge of the analytical phase of the activities.

I cannot agree that a tolerance for PCB in fish would be required anymore than countless other "contaminates" that might be found in our environment. Until more of the fundamental questions are answered, especially the source, it would be difficult to assume a regulatory stand on this problem. Meanwhile, our Medical and Research personnel will probably be in touch with you sometime in the near future.

Sincerely yours,

Robert A. Conklin,
Research Group Leader
Pesticide Residue Group

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Polychlorinated Biphenyls in the Global Ecosystem

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Polychlorinated biphenyls are widely dispersed in the global ecosystem, and are powerful inducers of hepatic enzymes which degrade oestradiol. Together with other chlorinated biocides, such as DDT, they could account for a large part of the aberration in calcium metabolism which has been observed in many species of birds since the Second World War.

DECLINING populations of raptorial and fish-eating birds in Great Britain[1] and North America[2] have produced thin-shelled eggs since the period after the Second World War. A widespread change in the chemical environment which affected the calcium physiology of these species evidently occurred at that time. The chlorinated hydrocarbons, which came into general use in the 1940s, may now be the most abundant synthetic pollutants present in the global environment[3]. Thin eggshells have been found only in species which accumulate high concentrations of these compounds: relatively uncontaminated populations of these species continue to produce normal eggs[1,2].

Calcium metabolism in birds is intimately related to reproductive metabolism and is to a large extent regulated by steroids such as oestrogen and vitamin D[4]. The deposition of medullary bone, the chief source of calcium during egg and eggshell formation, is controlled by the steroid sex hormones[4-7], and hens deficient in vitamin D lay eggs with lower eggshell weights[8]. Steroids are hydroxylated and thereby degraded in vivo and in vitro by hepatic enzymes induced by exogenous, lipid-soluble substances, including the chlorinated hydrocarbons[9-11]. The relatively small amounts of chlorinated hydrocarbons required to produce this effect[9,11,12-14], and the discovery that small amounts of some of the DDT compounds are oestrogenic[15,16,17], have made irrelevant much of the parts per million approach to pollutant ecology based on toxicity data alone.

In both Great Britain[18-20] and North America[21] it was the decline of the peregrine falcon which initiated concern about the extent of the harmful effects of environmental contamination. In the United States the eastern population was extinct before competent observers were aware of a general, widespread decline[21]. Breeding peregrines persist in apparently normal numbers in British Columbia[22] and in the Arctic[23,24].

In 1967 we collected an unhatched, abandoned egg of a peregrine falcon in south-western North America, where a small remnant population remains (unpublished work of M. N. K., R. W. R. and S. G. H.). Analysis of this egg (Table 1) showed that it contained almost 5 mg of p,p'-DDE (dichloro-2,2-bis(p-chlorophenyl) ethylene). Unknown peaks present in the chromatograms of the extract of the egg were unidentified until polychlorinated biphenyls (PCBs) were detected in European wildlife[25-27]. Positive confirmation of the identification was accomplished by mass spectrometry in Sweden[28]. The retention times of the unknown peaks in the peregrine extracts [illegible] identical with those of several PCB components [illegible] DC 200 and QF-1 columns[3] and on a mixed [illegible] column. Other species of birds and fish [illegible] analysed for PCB. The chlorine [illegible] extracts and standards was determined [illegible] titration and a method [illegible] was devised based [illegible] electron capture detector [illegible] p,p'-DDE. The DDT compounds [illegible] and p,p'-DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane), DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane) and toxaphene are dehydrochlorinated by saponification with alcoholic KOH. PCB is not degraded by either procedure.

Table 1. CHLORINATED HYDROCARBONS IN NORTH AMERICAN PEREGRINE FALCONS

Sample	Dieldrin	Total DDT*	Percentage DDE	PCB	DDT/PCB
1. Unhatched egg†					
Baja California (wet)	0·11	103	97	10·2	10
2. Second year‡ migrant from Arctic					
Breast muscle (wet)	NM	92	94	28	3·3
Breast muscle (dry)		296		84	
Brain (wet)	NM	85	95	21	4·0
Carcass (wet)	0·87	70	93	19·7	3·6
Carcass (lipid)	62·5	5,030		1,420	
3. Immature, California§					
Breast muscle (wet)	NM	14·4	90	8·4	1·7
Liver (wet)	NM	7·7	92	4·6	1·7
Brain (wet)	0·04	2·8	80	1·5	1·9
Brain (lipid)	0·30	20		10·3	
Carcass (wet)	0·11	20·2	92	10·6	1·9
Carcass (lipid)	1·0	200		100	
4. Adult, California¶					
Breast muscle (wet)	NM	127	87	93	1·3
Liver (wet)	NM	77	86	67	1·1
Brain (wet)	0·31	47·5	80	34·6	1·4
Brain (lipid)	3·7	395		415	
Carcass (wet)	1·7	83	87	65	1·3
Carcass (lipid)	50	2,600		1,960	
5. Immature** migrant from Arctic					
Breast muscle (wet)	NM	2·8	81	0·20	14
Breast muscle (dry)		7·9		0·54	
Liver (wet)	NM	1·0	93	0·10	10
Brain (wet)	NM	0·45	83	0·037	12
Body fat (wet)	NM	50·5	83	3·2	16
Carcass (wet)	0·07	9·3	82	0·60	15
Carcass (lipid)	0·44	83·7		5·5	
6. Immature Arctic migrant††					
Breast muscle (wet)	NM	1·9	80	0·6	3·2
Breast muscle (dry)		6·0		1·9	

Concentrations in parts per million wet weight, dry weight or lipid weight.

* DDT residues include: p,p'-DDT, p,p'-DDE, p,p'-DDD (p,p'-TDE), p,p'-DDMU, o,p'-DDT and o,p'-DDD. NM, Not measured.

† Chlorinated hydrocarbon contents of the egg were: 4,700 µg p,p'-DDE; 40 µg o,p'-DDE; 23 µg p,p'-DDT; 7·1 µg p,p'-DDD; 37 µg p,p'-DDMU; 5 µg dieldrin; 12 µg heptachlor epoxide. Concentrations were calculated by assuming a volume of 47·3 ml., the average value obtained by measuring eleven clutches of peregrine eggs from California in the Museum of Vertebrate Zoology, University of California, Berkeley, and by assuming a density of 1·0.

‡ Second year female, captured in October on the Texas coast during migration. Died in captivity shortly afterwards, no apparent cause of death. No body fat. Total body content of chlorinated hydrocarbons: 35 mg DDT, 10 mg PCB, 0·44 mg dieldrin, 0·14 mg heptachlor epoxide. Total body lipid, 7 g.

§ Plumage characteristics of both 3 and 4 were intermediate between those of typically resident California birds and the Arctic race F.p. tundrius, as described by White[29]. No. 3 was an immature female of the year trapped in the southern San Francisco Bay area in the winter of 1966. Observed feeding in the area for a week before capture. Died suddenly after eating a dead gull. Moderate body fat. Total body chlorinated hydrocarbon content: 13 mg DDT, 6·9 mg PCB, 0·06 mg dieldrin, 0·09 mg heptachlor epoxide. Total body lipid, 43 g.

¶ Adult female. Trapped in the southern San Francisco Bay area in the winter of 1966. Observed feeding in the area for a month before capture. Died shortly afterwards with no apparent cause of death and no body fat. Total body chlorinated hydrocarbon content: 52 mg DDT, 42 mg PCB, 1·1 mg dieldrin, 1·0 mg heptachlor epoxide. Total body lipid, 20 g.

** First year female trapped on the Texas coast in October. Lost at [illegible], California, [illegible] and was shot by a [illegible] [illegible] body content: 7 mg DDT, [illegible] PCB [illegible] total body lipid, [illegible]

†† [illegible] year female [illegible] on the Texas coast in October. [illegible] all [illegible] of heat prostration.

In Table 1 are presented the results of analyses of peregrine falcons which died from a variety of causes after being trapped for falconry. Significant amounts of PCB were present in Arctic peregrines only a few months old (Nos. 5 and 6), but higher residues were present in a second year Arctic bird (No. 2) and exceptionally high residues were present in an adult trapped in California (No. 4). In birds 2 and 4 the total lipid reserves were very low, and in both the brain concentrations of DDE and PCB were high, perhaps at toxic levels. Fat mobilization during reproduction or in times of starvation or stress could be expected to cause significant changes in the internal distribution of chlorinated hydrocarbons. Steroid hydroxylase activity in the liver might increase at this time. Dieldrin concentrations were lower than in the peregrines analysed in Britain, but DDE concentrations were approximately comparable[21].

Table 2 presents the results of analyses of peregrine prey species, remains of which were collected at eyries in Baja California, Mexico. With the exception of the remains of one mourning dove (*Zenaidura macroura*) and of three fish bats (*Pizonyx vivesi*), prey material found at four eyries consisted of sea birds. Of these, the eared grebe (*Podiceps caspicus*) and the black petrel (*Loomelania melania*) constituted 32 and 25 per cent, respectively, of the remains.

Black petrels, like other petrels and shearwaters (Table 3), contained especially high concentrations of both DDT and PCB. Reproductive success in this population of peregrines seems to be subnormal. In 1968 no pairs were observed to hatch or fledge more than a single young. In the past, two to four young, the number normally produced by healthy peregrines[22,23], were raised by each pair (L. W. Walker, personal communication). The thickness of fragments of a peregrine eggshell, with its membrane, collected in 1968 below an eyrie where one young hatched, was 0·24 mm, a decrease of 24 per cent from the mean thickness of 0·31 mm ± 0·015 mm (95 per cent confidence level) in twenty-three eggs collected in the area before 1947. The region is wilderness, with little or no human interference, and is remote from sources of pollution.

In California, numbers of breeding peregrines have been reduced by at least 80 per cent in recent years. The remaining few pairs, however, seem to be reproducing normally and rear, when undisturbed, between two and four young each year. They are found, like most of the surviving pairs in Great Britain[23-25], in a relatively uncontaminated region and seem to be feeding on birds which contain low concentrations of chlorinated hydrocarbons. A pair which fledged three young in 1965 fed chiefly on passerines and columbiformes during the breeding season. Both prey groups are relatively uncontaminated (M. N. K., R. W. R. and S. G. H., in preparation). A clutch of eggs collected in this region weighed as much as the eggs obtained in pre-war years, whereas other peregrine eggs from California collected since the Second World War have been thin-shelled (ref. 2, and D. W. Anderson, D. Hickey and R. F. Christensen, in preparation). Despite official protection, the surviving birds are still subjected to shooting by sportsmen and to harassment at the eyries. If these could be effectively reduced the population might yet survive.

In Table 3 are presented the results of analyses of marine and terrestrial birds and of three species of freshwater fishes for PCB and DDT content and concentration. From the ratio of total DDT to PCB, it is apparent that *regional fallout patterns* exist. In most of the birds from San Francisco Bay which have been analysed, including peregrine falcons (Table 1) and eggs of the western gull, the Caspian tern and the black-crowned night heron (Table 3), the ratio was between one and two. Another black-crowned night heron egg had a typically "ocean" profile, suggesting that the adult female had wintered along the coast. In most of the birds from the Farallon Islands, which are 27 miles west of the Golden Gate Bridge, this ratio was between 2 and 5. In the Gulf of Panama, where PCB contamination might come from the Canal Zone and industrial areas in Panama City, the ratio is between 1 and 2 (Table 3).

In the Gulf of California, a region relatively remote from the sources of either DDT or PCB contamination, the ratio was in most cases approximately 9 or 10. This was true in the egg of the peregrine falcon (Table 1), in all of the black petrels and least petrels analysed, in the Craveri's murrelets (Table 2), in five of six osprey eggs and in six of seven western gull eggs (Table 3). Among the exceptions the fish bat, with low concentrations of both DDT and PCB, was the most divergent, with a ratio of 43 (Table 2). It is not clear whether this reflects differences between avian and mammalian physiology or a fundamental difference in feeding habits. The other exceptions include species which are present in the area only during the breeding season (Table 2).

In sea birds from the Pacific the ratio was usually between 5 and 10 (Table 3). PCB was not found in eggs of the Adelie penguin from Cape Crozier, Antarctica.

Table 2. PCB AND DDT IN PREY SPECIES OF PEREGRINE FALCONS IN THE GULF OF CALIFORNIA

Species*	N	DDT (µg)	DDT (p.p.m.)	Percentage DDE	PCB (µg)	PCB (p.p.m.)	DDT/PCB
Eared grebe (12) Whole body	3	—	0·23, 0·20, 12·3	97	NM†		—
Black petrel (10) Whole body	6	810 (655–1,341)	9·2 (W)	81	—	1·0 (W) (0·90–1·14)	9·2
Least petrel (6) Whole body	2	92	8·2 (W)	83	—	0·85 (W)	9·8
Eggs	2	30 (23–37)	—	84	3·1 (1·2–5·0)	—	10
Fish bat (3) Whole body	7	23 (16–31)	0·71 (W)	62	0·53 (0·45–1·08)	0·02 (W)	43
Craveri's murrelet (9) Eggs (one clutch)	2	230‡ (227–233)	39 (L)	80	—	4·5 (L)	8·7
Whole body, adult	1	37·1	0·31 (W)	83	—	0·040 (W)	7·8
Whole body, adult	1	235	2·4 (W)	85	—	0·26 (W)	9·3
Elegant tern (1) Eggs	6	15·5 (0·3–21·3)	6·0 (L)	90	—	1·5 (L) (0·5–2·6)	8·9
Heermann's gull (1) Eggs	3	195 (91–278)	48 (L)	95	—	6·1 (L) (3·5–11·3)	8·0

Contents in µg of whole bodies and eggs; concentrations in p.p.m. wet weight (W) or lipid weight (L).

* [illegible] were collected in the vicinity of four peregrine eyries in Baja California. Numbers in parentheses are the number of remains of [illegible] at the eyries. Also found were remains of one cormorant (*Phalacrocorax* sp.), one red phalarope (*Phalaropus fulicarius*), [illegible] one mourning dove (*Zenaidura macroura*), but body contents of these species were not analysed. Eggs of [illegible] Eared grebe: *Podiceps caspicus*; black petrel: *Loomelania melania*; least [illegible] Craveri's murrelet: *Endomychura craveri*; elegant tern: *Thalasseus elegans*; Heermann's gull: [illegible]

† [illegible] Interfering peaks on chromatograms.

‡ [illegible] p.p.m. dieldrin (lipid weight) and 0·17 p.p.m. endrin (lipid weight).

Table 3. PCB AND DDT IN THE GLOBAL ECOSYSTEM

Species	N	Total DDT (µg)	Total DDT (p.p.m.)	Percentage DDE	PCB (µg)	PCB (p.p.m.)	DDT:PCB
[illegible] (1)	1	—	1·83 (W)	8	—	0·0[illegible] (W)	475
[illegible] (2)	1	—	2·1[illegible] (W)	6	—	0·0[illegible]	[illegible]
[illegible]	1	—	5·5 (W)	4	—	0·0[illegible]	1,[illegible]
[illegible] (4) [illegible]	5	0·78 (0·50–1·01)	0·126 (L)	74	<0·011 µg/egg		>16
[illegible] (5) [illegible] muscle	1	—	20·4 (W)	5	—	0·0[illegible] (W)	270
[illegible] (6)							
A	1	—	0·11 (W)	76	—	0·04 (W)	3
B	1	—	3·4 (W)	80	—	0·31 (W)	11
C	1	10,476	17·5 (W)	98	8,000	0·5 (W)	3·7
Pink-footed shearwater (7)	1	2,090	3·0 (W)	97	277	0·42 (W)	7·2
Sooty shearwater (8)							
A	1	—	12·3 (W)	91	—	1·2 (W)	10
B	1	—	10·3 (W)	60	—	0·9 (W)	12
C	1	1,286	2·3 (W)	85	NM		
Slender-billed shearwater (9)	1	—	82·0 (W)	93	—	2·1 (W)	35
Ashy petrel (10)	8	2,158 (1,611–2,820)	59·3 (W)	95	330 (205–462)	9·5 (W)	6·5
Brown pelican (11)							
Eggs, Panama	6	83 (18–183)	11·6 (L)	61 (47–78)	23·7 (14–30)		1·55 (0·97–3·2)
Eggs, Baja California	2	53 (47–59)	10·0 (L)	81	10·4 (9·0–11·7)	—	0·5, 4·0
[illegible] (12) eggs, Panama	3	9·6, 5·7, 30·0	—	88	8·4, 6·7, 24·0	—	1·1, 1·5, 0·4
[illegible] (13) eggs, Panama	4	20·8 (16·4–24·6)	8·2 (L)	80	12·2 (8·6–18·0)	4·6 (L)	1·7
Brandt's cormorant (14) eggs	17	326	—	91	115	—	2·9
Pelagic cormorant (15) eggs	2	124 (125–150)	—	90	63 (48–75)	—	2·1
[illegible] (16)	1	4,340	10·0 (W)	70	—	0·92	12
White-tailed kite (17)							
Eggs, clutch A	4	11·4 (9·8–12·9)	0·76 (W)	77	6·4 (5·5–7·8)	—	1·8
[illegible] egg B	1	5·1	0·34 (W)	83	0·84	—	6·0
Unhatched egg C	1	6·3	0·35 (W)	73	3·9	—	1·5
Clutch D	2	8·8/egg	—	82	4·3/egg	—	2·0
Clutch E	3	10·2/egg	9·0 (L)	57	4·0/egg	—	2·6
Clutch F	4	31·2/egg	—	80	9·8/egg	—	3·5
[illegible] (18)	1	6,200	23·2 (W)	90	—	6·3	4·0
[illegible] (19)	1	150	2·0 (W)	98	17·5	0·23 (W)	8·5
[illegible] Baja California	6	127 (80–241)	55 (L)	85	(7·3, 3·0, 103) (21, 7·1, 13)	—	8·5, 10·1, 1·3, 11·2, 9·7, 11·1
[illegible] (21)	1	435	2·0 (W)	94	65·4	0·29 (W)	12·3
[illegible] (22)							
[illegible] adults	7	5·1	0·014	39	3·7	0·031	1·4
[illegible]	6	2·4/egg	0·20 (W)	65	1·6/egg	0·00 (W)	2·2
[illegible]							
[illegible]	1	641	—	80	330	—	1·4
[illegible]	1	100	—	99	23	—	30
[illegible]							
[illegible] San Francisco [illegible]	4	868 (632–1,123)	—	85	862 (680–1,310)	—	1·0
[illegible]	10	412 ± 102	—	89	130 ± 35	—	3·0
[illegible] Calif. [illegible]	7	355 ± 230	—	97	46 ± 30	—	9·1, 10·5, 3·0, 12·3, 10·6, 10·7, 10·5
[illegible] eggs	2	645 (595–732)	—	89	114 (91–137)	—	5·6
[illegible]							
[illegible] San Francisco	2	1,200 (1,210–1,352)	—	89	805 (610–930)	—	1·5
[illegible] San Diego Bay	5	1,430 (691–2,420)	—	88	1,010 (650–1,600)	—	1·4
[illegible] (25)	1	—	0·78 (W)	79	—	0·10	8
[illegible] eggs	6	1,015 (632–3,621)	151 (L)	90	858 (204–1,010)	46 (L)	3·3
[illegible]	1	—	8·8 (W)	98	—	0·10	30
[illegible]	1	—	0·75	90	—	0·15	5
[illegible] (31)	1	—	2·7	97	—	0·35	8
[illegible]	2	12·0, 83·1	0·10 (W)	77, 89	Not detected	—	—
[illegible]	3	27·7/egg	1·25 (W)	95	10·4/egg	0·47 (W)	2·7
[illegible]	2	143/egg	6·0 (W)	60	14·4/egg	0·08 (W)	30
[illegible]	2	21·2, 418	0·16, 9·3 (W)	77, 93	2·5, 24·1	—	8·4, 15·9

[illegible] in µg and concentrations in p.p.m. wet weight (W) or lipid weight (L).

[illegible] spectral analyses were of whole bodies. Endrin and dieldrin were identified on the basis of retention times on both QF-1 and DC 200

1. [illegible], 24 g, Clear Lake, Lake Co., Calif., May 1968.
2. [illegible], 212 g, Clear Lake, Lake Co., Calif., May 1968.
3. [illegible], Clear Lake, Lake Co., Calif., May 1968.
4. [illegible], Antarctica, October 1967.
5. [illegible], Clear Lake, Lake Co., Calif., May 1968.
6. [illegible] B: Monterey Bay, Calif., November 1, 1966. C: Point Reyes, Calif., December 1967. Fulmars breed in Alaska.
7. [illegible] Collected in May 1968, in the Gulf of California.
8. [illegible] New Zealand and Chile. A and B: Monterey Bay, November 1, 1966. C: Gulf of California, May 1968. NM, Not [illegible]
9. [illegible] Australia. Monterey Bay, December 1966.
10. [illegible] Islands, Calif., May 1968.
11. [illegible] collected on Isla Pacheca and Isla Pachequilla, Gulf of Panama, February 1968. One egg contained [illegible] endrin, another contained [illegible] p.p.m. dieldrin and 0·07 p.p.m. endrin (lipid weight). Baja California [illegible] [illegible] March 1968. One egg contained 0·24 p.p.m. dieldrin and 1·12 p.p.m. endrin (lipid weight).
12. [illegible] 1968.
13. [illegible] Panama. February 1968. Two eggs were analysed for dieldrin and endrin. Dieldrin: 0·05, [illegible]
14. [illegible] May 1968.
15. [illegible] Calif.
16. [illegible] Adult male.
17. [illegible] May 1968. B and C: Contra Costa Co., May 1968, two and three young raised, respectively. D: [illegible] May 1968. E and F: Destroyed nests, Contra Costa Co., March 1968.

Table 2 (continued)

18. *Accipiter cooperii*. Balboa Park, San Diego, February 1968. First year female, died of [illegible].
19. [illegible], Calif., April 1968. Unhatched egg in nest where one young was raised. Egg also contained 0·7 μg of
19. [illegible]
    dieldrin, [illegible], March 1968. One egg also contained 0·10 p.p.m. dieldrin and 0·25 p.p.m. endrin (L).
20. [illegible]
21. [illegible] Adult was killed on road, [illegible] Co., Calif., December 1967. Eggs from Davis, California, 1966.
22. [illegible] San Francisco Bay, May 1967.
23. [illegible] 95 per cent confidence limits.
24. [illegible] San Diego Bay, May 1967.
25. [illegible]
26. [illegible] Monterey Bay, November 1, 1966
27. [illegible] Farallon Islands, May 1967.
28. [illegible] Farallon Islands, April 1968.
29. [illegible] Monterey Bay, November 1, 1966.
30. [illegible] Monterey Bay, November 1, 1966.
31. [illegible] San Diego, [illegible]
32. [illegible] from Contra Costa Co., Calif., March 1968. Clutch *B* from Yolo Co., Calif., April 1968.
33. [illegible] Davis, Calif., December 1967.

In these, however, the amount of DDT was very low; with a DDT : PCB ratio of 15, no PCB would have been detected. A larger amount of fat material from Antarctic organisms, which would contain more DDT, would therefore have to be analysed before concluding that PCB has not yet reached the Antarctic.

Individuals of species resident in industrial areas have, as expected, higher PCB levels than individuals of the same species from more remote regions. Analysis of ten eggs from ten clutches of the western gull from the Farallon Islands showed an average PCB content of 130 ± 55 μg (95 per cent confidence level). PCB content of four eggs from three clutches from an island in San Francisco Bay averaged 805 μg with a range from 580 to 1,310 (Table 3). Seven eggs from seven clutches in the Gulf of California contained 45 ± 30 μg of PCB. The DDT content of the eggs from the Farallons was not significantly different from that of the Baja California eggs.

Birds from the Gulf of California also contain dieldrin and endrin (Tables 2 and 3), but the number of analyses is as yet inadequate to compare their relative abundance with that of DDT and PCB. Despite the inability of the [illegible] Company to find any chlorinated hydrocarbons [illegible] of California and in the mouth of the Colorado River[illegible], which drains into the Gulf, it is likely that some do enter from the Colorado River and from agricultural areas in western Mexico. A significant fraction, however, must come from the atmosphere[illegible], and air transport best explains the presence of PCB in remote areas. In extracts from the Gulf of California one PCB compound was present in relatively small concentrations. This compound is readily degraded by ultraviolet light irradiation in laboratory experiments, and may therefore be selectively degraded in the atmosphere. Although PCB is not soluble in water, it has a low but finite vapour pressure[illegible]. Incineration of material containing PCB would greatly increase the rate of entry into the atmosphere. PCB is used in the manufacture of many industrial products, so the high amounts found in San Francisco Bay, Puget Sound[illegible] and San Diego Bay presumably result from direct discharge of industrial wastes into these waters and from local fallout.

The presence of PCB in the few land birds and freshwater fish analysed indicates that it is also distributed among continental ecosystems in North America. Peregrines would therefore acquire PCB, as well as the other [illegible], over all their global range. [illegible] data are available for prey species from [illegible], but compounds which seem to be PCB [illegible] from [illegible]. A second year male [illegible] winter of 1967–68 on Isla Pechora, [illegible] pelican, booby and frigate-bird eggs of [illegible]. The Cooper's hawk which was [illegible] preys upon birds, contained [illegible] (Table 3). Cooper's [illegible] North America and in [illegible] e.g.[illegible]. Several species of raptors do not accumulate high amounts of the organo-chlorine compounds (Table 3), a result of the very low residue levels usually found in their prey. American kestrels and barn owls are common residents of California cities. The white-tailed kite, which was near extinction 40 years ago in California, is now abundant in areas where insecticide use is intense, yet because it preys primarily upon the short-lived and herbivorous vole, *Microtus*, the species accumulates very little DDT or PCB (Table 3).

Previous work[11] has shown that both DDT and dieldrin induce hepatic enzymes in the pigeon which, in an *in vitro* preparation, increase the metabolism of progesterone and testosterone. This work has now been extended to study the metabolism of oestradiol by enzymes induced by *p,p'*-DDE, technical DDT (Dupont) and PCB ('Aroclor 1262'). The experimental procedure previously described[16] was followed except that the chlorinated hydrocarbons were injected intramuscularly rather than given orally, and in the separation of oestradiol and its metabolites the solvent system used was the upper layer of a mixture of benzene : heptane : methanol : water 7 : 3 : 8 : 2. The strips were monitored with an autographic strip scanner. The profiles obtained for the various inducing agents are shown in Fig. 1. It will be noted that the profiles of the metabolites obtained after enzyme induction using DDE and DDT are identical, but that a different metabolite is produced by the enzyme induced by PCB. The amount of metabolites formed was calculated from the radioactivity of the peaks. The results obtained are given in Table 4.

Table 4. INCREASE OF OESTRADIOL METABOLISM BY PIGEON LIVER HOMOGENATES FROM BIRDS TREATED WITH VARIOUS CHLORINATED HYDROCARBONS

	Amount of polar metabolites formed in mμmoles
Control	29·3 ± 6·5
DDE (40 mg/kg)	76·2 ± 13·1
DDT (40 mg/kg)	93·1 ± 11·2
PCB (20 mg/kg)	160·0 ± 10·5

Each figure is the average with standard deviation of a group of four birds. In all cases 503 mμmoles of oestradiol-6,7-T (500 μCi/mmole) was present in the incubation mixture. Incubation time 30 min, weight of microsomal fraction used 200 mg. All chlorinated hydrocarbons were injected intramuscularly into the pectoral muscle 7 days before death.

Body concentrations of 40 p.p.m. of *p,p'*-DDE significantly increased the rate of oestradiol degradation by the induced enzymes in the experimental conditions. On a weight basis the PCB preparation had an oestradiol degrading potential approximately five times that of *p,p'*-DDE or technical DDT. Both DDE and PCB, which are apparently the most abundant of the chlorinated hydrocarbon pollutants in the global ecosystem, have therefore the capacity to produce sublethal physiological effects in birds.

Studies on the activity of induced enzymes in the rat at various times after a single injection of DDT or dieldrin have been made by Ghazal *et al.*[20]. He found that it took 76 days for the activity to fall to half its maximum value in the case of DDT and 15 days in the case of dieldrin. Experiments with dieldrin on pigeons

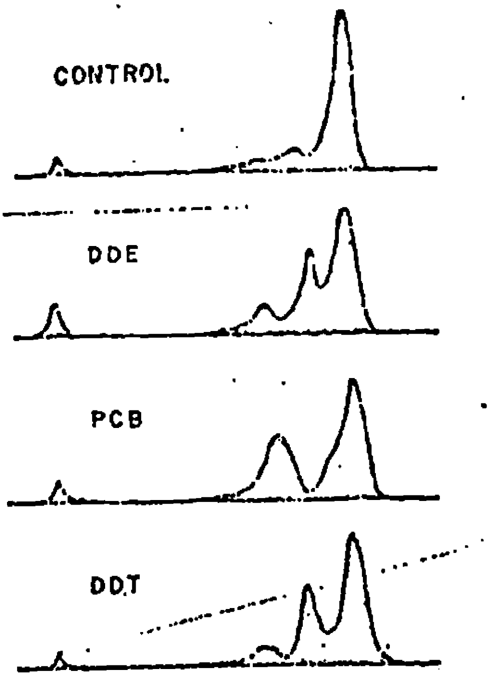

Fig. 1. Chromatographic separation of oestradiol and its metabolites. The large peak is unaltered oestradiol.

show that only a quarter of maximum activity remains after a month. Thus there is evidence that the effects of these induced enzymes can persist over a long period of time although more studies are needed to determine the steroid degrading potentials of livers of those species contaminated with chlorinated hydrocarbons. The [illegible] of the metabolites should be some indication of the [illegible] of exposure to chlorinated hydrocarbons.

The reductions in eggshell thickness and eggshell weight increase the chances of egg breakage[21–24], and water retention, which affects hatching success[40–41], might be impaired. The environment in which birds now exist is therefore no longer the same as that in which they evolved: it is unlikely that any species has the genetic capacity to meet the selection pressures resulting from the abrupt environmental change which has produced the thin eggshells. The peregrine falcon is a species long highly revered and respected. G. H. Thayer[42] has described it as "the embodiment of noble rapacity and lonely freedom". An irony therefore exists in the fact that the peregrine may be the first species to be extirpated by global contamination.

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[1] Ratcliffe, D. A., *Nature*, 215, 208 (1967).
[2] Hickey, J. J., and Anderson, D. W., *Science*, 162, 271 (1968).
[3] Risebrough, R. W., in *Chemical Fallout, First Rochester Conference on Toxicity* (in the press, 1968).
[4] Simkiss, K., *Calcium in Reproductive Physiology* (Reinhold, New York, 1967).
[5] Simkiss, K., *Biol. Rev.*, 36, 321 (1961).
[6] Clavert, J., and Benoit, J., *C.R. Soc. Biol., Paris*, 136, 309 (1942).
[7] Kyes, P., and Potter, T. S., *Anat. Rec.*, 60, 377 (1934).
[8] Hart, E. B., Steenbock, H., Lepkovsky, S., Kletzien, S. W. F., Halpin, J. G., and Johnson, O. N., *J. Biol. Chem.*, 65, 579 (1925).
[9] Welch, R. M., Levin, W., and Conney, A. H., *Chemical Fallout, First Rochester Conference on Toxicity* (in the press).
[10] Hart, L. G., Schultice, R. W., and Fouts, J. R., *Toxicol. Appl. Pharmacol.*, 5, 371 (1963).
[11] Hart, L. G., and Fouts, J. R., *Naunyn-Schmiedeberg's Arch. Exp. Path. Pharmakol.*, 249, 486 (1965).
[12] Conney, A. H., Welch, R. M., Kuntzman, R., and Burns, J. J., *Clin. Pharmacol. Therap.*, 8, 2 (1967).
[13] Conney, A. H., *Pharmacol. Rev.*, 19, 317 (1967).
[14] Kupfer, D., *Residue Rev.*, 19, 11 (1967).
[15] Gerboth, G., and Schwabe, U., *Arch. Exp. Pathol. Pharmakol.*, 246, 469 (1964).
[16] Gillett, J. W., *J. Agric. Food Chem.*, 16, 295 (1968).
[17] Schwabe, U., *Arzneimittel-Forsch.*, 14, 1265 (1964).
[18] Peakall, D. B., *Nature*, 216, 505 (1967).
[19] Welch, R. M., Levin, W., and Conney, A. H., *Toxicol. Appl. Pharmacol.* (in the press).
[20] Bitman, J., Cecil, H. C., Harris, S. J., and Fries, G. F., *Science*, 162, 371 (1968).
[21] Ratcliffe, D. A., *Brit. Birds*, 51, 23 (1958).
[22] Ratcliffe, D. A., *Bird Study*, 10, 56 (1963).
[23] Ratcliffe, D. A., *Bird Study*, 12, 66 (1965).
[24] Ratcliffe, D. A., *Bird Study*, 14, 238 (1967).
[25] Hickey, J. J., *Peregrine Falcon Populations: Their Biology and Decline* (University of Wisconsin Press, in the press).
[26] Beebe, F. L., *Condor*, 62, 145 (1960).
[27] Cade, T. J., White, C. M., and Haugh, J. R., *Condor*, 70, 170 (1968).
[28] Enderson, J. H., and Berger, D. D., *Condor*, 70, 149 (1968).
[29] Jensen, S., *New Sci.*, 32, 612 (1966).
[30] Widmark, G., *J. Assoc. Off. Anal. Chem.*, 50, 1069 (1967).
[31] Holmes, D. C., Simmons, J. H., and Tatton, J. O'G., *Nature*, 216, 227 (1967).
[32] Erro, F., Devenue, A., and Beckman, H., *Bull. Environ. Contam. Toxicol.*, 372 (1967).
[33] White, C. M., *Auk*, 85, 179 (1968).
[34] Jefferies, D. J., and Prestt, I., *Brit. Birds*, 59, 49 (1966).
[35] *Aldrin, Dieldrin, Endrin (A Status Report)* (The Shell Chemical Company, 1967).
[36] Risebrough, R. W., Huggett, R. J., Griffin, J. J., and Goldberg, E. D., *Science*, 159, 1233 (1968).
[37] *Tech. Bull. PL-306* (Monsanto Chemical Company).
[38] Holden, A. V., and Marsden, K., *Nature*, 216, 1274 (1967).
[39] Ghazal, A., Koransky, W., Portig, J., Vohland, H. W., and Klempau, I., *Arch. Exp. Pathol. Pharmakol.*, 249, 1 (1964).
[40] Jones, R. E., and Leopold, A. S., *J. Wildl. Management*, 31, 221 (1967).
[41] Mayhew, W. W., *J. Wildl. Management*, 19, 36 (1955).
[42] Thayer, G. H., *Bird Lore*, 6, 47 (1904).

Tsunamis on the Moon?

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The spacing of the five annular mountain rings around Mare Orientale fits a dispersion curve for gravity waves on a 50 km "liquid" layer overlying a rigid basement.

The question whether the multiple ring-like mountain [illegible] surrounding most of the lunar craters larger [illegible] miles in diameter might be "frozen tsunamis", [illegible] by the shock waves caused by impacting planetesimals was first brought to my attention by R. B. Baldwin (personal communication). Baldwin points out that in several cases (including the giant Mare Imbrium) two or more rings can be made out

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