INSTITUTE OF TERRESTRIAL ECOLOGY

(NATURAL ENVIRONMENT RESEARCH COUNCIL)

NCC/NERC CONTRACT HF3/08/01

ITE PROJECT 181

Annual report to the Nature Conservancy Council

BIRDS AND POLLUTION

Part 1 Organochlorines and metals in predatory birds

2 Sparrowhawk survey

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1 ORGANOCHLORINES AND METALS IN PREDATORY BIRDS

1.1 Recent findings

The main objective of this work was to analyse the carcasses of predatory birds, supplied by members of the public, in order to continue the monitoring of organochlorine and metal residues in livers. The chemicals of interest included DDE (from the insecticide DDT), HEOD (from the insecticides aldrin and dieldrin), PCBs (polychlorinated biphenyls from industrial products) and Hg (mercury from agricultural and industrial sources).

The main species involved included the sparrowhawk and kestrel, representing the terrestrial environment, and the fish-eating heron, kingfisher and great-crested grebe, representing the aquatic environment. The last major analysis of long-term data was by Cooke et al. (1982), on specimens obtained to 1977.

During 1985, the livers from 184 birds were analysed, including those from 50 kestrels, 67 sparrowhawks, 28 herons, 11 kingfishers, 15 great-crested grebe and 13 others. These totals included some birds which had died in earlier years, but which were analysed in 1985. The results from all these birds are listed in Table 1, and the geometric means for each chemical from the main species (1985 specimens only) are given in Table 2.

Seven significant differences in geometric mean values were found between the 1985 and 1984 results, out of 20 comparisons (Table 3). These included an increase in the mean DDE value for herons, a decline in the mean HEOD value for sparrowhawk, declines in mean PCB values for sparrowhawk, kestrel and kingfisher, and increases in mean Hg values for heron and kingfisher. It is impossible to say whether these differences reflected real changes in exposure.

1.2 Long-term trends

In order to assess the recent results for each species in the context of long-term trends, the individual values of all chemicals are given in Figures 1-20 nationwide for the whole monitoring period. Trends are indicated by 3-year moving averages. Analyses for DDE and HEOD were started in 1963-64, analyses for PCB in 1967-69, and for Hg in 1969-80, depending on species.

In each case the significance of the long-term trend was assessed by regression analyses of residue levels on years (Table 4), covering the whole analytical period for each chemical. During the periods concerned, various restrictions were imposed on particular agricultural uses of DDT, aldrin/dieldrin and organo-mercury compounds, so the total amounts of these chemicals applied each year to the land surface of Britain should have declined. Separate regression analyses covered the period 1975-85 for HEOD because in 1975 the last major use of aldrin/dieldrin in British agriculture (as an autumn seed treatment) was curtailed. Further analyses covered the period in 1981-85, for DDT and aldrin/dieldrin, because in 1981 Britain came under EEC regulations banning practically all agricultural uses of these chemicals.

Over the whole analytical period (1963-85), DDE levels declined significantly in all species, though the decline was only slight in the sparrowhawk (Table 4). In the fish-eating species, the decline was evident more or less throughout the period of study, but in the raptors chiefly since the late 1970s (Figures 1-5).

The general level of residues differed between species. In the fish-eaters, geometric mean values were mostly in the range 5-10 ppm fresh weight in the early years, declining to 1-2 ppm later. In the raptors, geometric mean levels were generally higher in sparrowhawks (5 ppm declining to around 3 ppm) than in kestrels (1-2 ppm declining to around 0.6 ppm). After 1970 kestrels showed the greatest range of DDE values, and even in the 1980s, 2 birds (from Kent) had levels exceeding 1000 ppm.

In the period 1981-85, significant change in DDE levels was apparent only in herons, in this case a fairly substantial increase in geometric means, from around 1 ppm to around 2 ppm. Over the whole period 1963-85, significant declines in HEOD levels were evident in sparrowhawk, kestrel and heron (Table 4). In both raptors, levels were similar, declining from a geometric mean of around 1 ppm initially to 0.5 ppm later, but in the heron the decline was steeper, from 1-4 ppm initially to less than 1 ppm later (Figures 6-8). In kingfishers and grebes it was hard to discern any long-term trend in HEOD (Figures 9-10): the higher initial levels in kingfishers could have resulted from the small sample in the early years, after which the geometric mean stayed around 1-2 ppm; in grebes the geometric means stayed below 1 ppm throughout, but fluctuated considerably, often in association with small annual samples.

In the period 1975-85, significant declines were evident in HEOD levels in sparrowhawk and kestrel, and in 1981-85 significant increases were evident in kestrel and heron.

Over the whole period of PCB analysis (1967-85), regression studies suggested very slight declines in levels, but in no species was the trend statistically significant (Table 4). The annual fluctuations in geometric means did not vary in parallel in the different species, and were probably due partly to small or unrepresentative annual samples. In the fish-eaters, annual geometric means were mostly in the range 2-10 ppm, in the sparrowhawk they were mostly in the range 1-3 ppm, and in the kestrel 0.5-2.0 ppm (Figures 11-15).

Over the whole period of Hg analysis (1969/70-85), significant declines in levels were evident in sparrowhawk, kestrel and heron (Table 4). In the remaining species, analyses were started only in 1979-80, and no significant change was apparent by 1985 (Table 4).

The heron was much the most contaminated species, with geometric means of around 40 ppm Hg initially, declining to around 15 ppm latterly (Figure 18). The great-crested grebe had geometric mean levels in 1980-85 mostly around 5-10 ppm, and the kingfisher had mean levels of 1-2 ppm (Figures 19-20).

Of the two raptors, the kestrel had geometric mean levels of almost 5 ppm Hg initially, declining to around 1 ppm later, while the sparrowhawk had levels of 5-6 ppm, declining to around 3 ppm (Figures 16-17).

1.3 Discussion

For any given pollutant, the levels in livers varied between species, as did the extent of change in levels over the study period. This was presumably because of differences in diet between species, and in the ease with which they could metabolise the various chemicals. The fact that the heron accumulated most pollutants to greater levels than the other fish-eaters, could be attributed to the heron taking generally larger (and older) fish, which generally have more residue than do smaller fish. Herons also eat eels, which are known to accumulate fat and organochlorine residues to greater levels than are some other freshwater fish (Holden 1973; Hider et al 1982). To judge from their size, some of the eels eaten by herons could be up to 20 years old (Hussein 1982; Marquiss 1987). Among the raptors, the sparrowhawk had higher levels of most pollutants than the kestrel, and showed less decline in levels during the study period. There were probably three reasons for this difference. The sparrowhawk eats other bird-species (herbivores and carnivores), and hence feeds higher in the food chain than the kestrel, which eats mainly herbivorous voles. Secondly, birds in general are less able to metabolise organochlorines and other pollutants than are mammals (Walker 1983), so for this reason too the bird-eating sparrowhawk would tend to accumulate higher levels than the mammal-eating kestrel. Thirdly, sparrowhawks are less able than kestrels to metabolise organochlorines within their own bodies (Walker et al 1987).

In contrast to the other chemicals, HEOD levels did not differ greatly between the sparrowhawk and kestrel. This was possibly because HEOD is much more toxic than the other residues examined, and accumulation at the upper levels observed is likely to cause death. In this case, more heavily contaminated individuals would not normally be represented in the samples. For the other organochlorines, most of the values recorded were well below the level expected to kill (Cooke et al 1982).

The general declines recorded in the levels of pesticide residues would be expected from declines in agricultural usage, resulting from various restrictions imposed from time to time during the study period. It is surprising, however, that the declines in DDE residues were as slight as they were. This may be due partly to the greater persistence of this chemical in soil and in animal bodies, compared to HEOD. Calculated half-lives of DDE in soil have ranged between 12 and 57 years (Buck et al 1983; Cooke & Stringer 1982), compared with only 4-7 years for HEOD (Anon 1964; Edwards 1966). In the bodies of pigeons, DDE had a half-life of 240 days, compared with 47 days for HEOD (Walker 1983).

The increase in the period 1981-85, in residues of DDE and HEOD in herons and of HEOD in kestrels, was disconcerting and inexplicable. These increases did not result from a changed geographical spread in the sources of specimens, and presumably reflected increased exposures. If they were due to attempts to use up stocks before the EEC regulations came in, then this should have been reflected in the other species, which it was not. It must therefore have been due to some changed exposure which affected only these species.

The fish-eaters were likely to obtain their HEOD residues, not only from agricultural sources, but also from industrial ones, as factory effluent in rivers. Indeed, in some regions factory effluent was probably the major source of residues for herons and kingishers, and improved water quality control is likely to have reduced the input of HEOD from industrial sources over the last 30 years, thus contributing to the decline in overall contamination levels.

The greater range of DDE levels found in kestrels, compared to other species, may occur because a substantial part of the population winters outside Britain. Some individuals reach Spain and North Africa, where recent DDT use has been heavier than in Britain. On the other hand, some of the most heavily contaminated kestrels (>500 ppm in liver) have come from Kent, where much DDT has been used in orchards. In this county, sparrowhawks have only recently begun to recolonize (Newton & Haas 1984), and too few specimens have been received from there to properly assess the DDE levels in this more sensitive species.

It is hard to predict what trend would be expected in PCB levels. In 1970, Monsanto (the main manufacturer for Britain) banned the use of PCBs in all but 'closed systems'. However, no system is completely closed and much chemical must still be reaching the environment from materials made in earlier years. Taking this into account, together with the extreme persistence of PCBs, it is not surprising that no significant decline in residues could be detected in any of the species studied. The negative regression coefficients were encouraging, however.

Levels of PCBs were generally higher in the fish-eaters than in the raptors. This would probably be expected considering the wholly industrial source of PCBs. The somewhat higher levels in sparrowhawk than kestrel could be attributed to the same factors that influence DDE levels, namely feeding habits and differing ability to metabolise organochlorines.

Much more mercury has been used in industrial processes in Britain than in agriculture (DoE 1976), and industrial processes are likely to have provided the main source of residues for at least the fish-eaters. The use and disposal of mercury has been much more rigorously controlled in recent years, and agricultural uses have also been reduced (ARC 1964), so it was not unexpected that residue levels had declined in certain species .

1.4 Conclusions

The 5 species examined have continued to show contamination with organochlorine and mercury compounds. All have shown declines in DDE levels over the last 24 years, and three have shown significant declines in HEOD levels. The decline in DDE levels is perhaps less than would be expected from trends in agricultural usage, and may be due to high persistence. No significant declines have occurred in PCB levels. Hg has declined in both raptors and the heron, the only species for which long-term results were obtained. The heron continues to be the most contaminated of the three fish-eaters examined, and the sparrowhawk the most contaminated of the two raptors.

In view of these various findings, it seems prudent to continue the monitoring programme for some further years. For the pesticides, it is especially important to check the effect of the 1981-83 EEC regulations on residue levels.

1.5 Acknowledgments

Thanks are due to all the contributors who sent in specimens during the past year, too numerous for individual mention.

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Table 1. Levels of organochlorines (ppm in wet weight) and mercury (ppm in dry weight) in the livers of predatory birds analysed between April 1985 and March 1986. ND = not detected.

Specimen number	Month of death	pp'DDE	HEOD	PCBs	Hg
Kestrel (<u>Falco tinnunculus</u>)					
8373	Sep 80	0.10	0.21	ND	0.34
8425	Nov 83	ND	0.23	ND	0.50
8228	84	206.89	1.33	0.38	2.31
8229	84	3.05	1.14	1.00	2.32
8423	Dec 84	0.67	0.50	0.07	1.51
8191	Jan 85	5.47	0.35	6.63	8.29
8140	Jan 85	0.20	0.27	0.57	0.44
8141	Jan 85	0.67	0.61	0.98	0.61
8149	Jan 85	0.33	0.57	0.47	0.69
8158	Feb 85	0.11	0.27	0.90	0.08
8177	Feb 85	0.72	0.15	1.05	4.14
8180	Feb 85	2.49	0.86	0.08	0.65
8184	Feb 85	5.22	0.26	1.97	5.02
8198	Feb 85	2.71	0.20	1.93	2.30
8200	Feb 85	5.94	0.83	1.26	2.19
8225	Mar 85	14.24	1.10	0.45	2.69
8239	Mar 85	2.60	19.29	3.46	1.29
8255	Mar 85	2.01	1.75	0.19	0.44
8392	Mar 85	50.53	0.41	4.89	3.13
8284	Apr 85	0.58	0.83	0.08	1.11
8288	Apr 85	0.71	0.39	0.13	0.76
8287	May 85	5.25	0.94	2.16	9.20
8289	May 85	3.64	1.69	0.45	2.00
8311	Jun 85	1.35	1.71	2.66	0.74
8314	Jun 85	0.97	0.69	0.34	1.21
8356	Jun 85	0.08	0.33	ND	0.60
8319	Jul 85	0.65	1.80	0.80	0.44
8333	Jul 85	0.03	0.37	0.06	0.96
8374	Jul 85	1.22	0.27	0.22	2.75
8397	Jul 85	1.30	0.61	0.82	2.35
8338	Aug 85	0.22	0.13	0.58	6.43
8340	Aug 85	0.06	0.52	0.12	1.68
8347	Aug 85	3.23	0.80	0.27	2.13
8350	Aug 85	0.40	0.72	0.51	0.10
8351	Aug 85	ND	0.16	0.06	0.59
8355	Aug 85	ND	0.12	ND	2.13
8360	Aug 85	3.75	0.96	0.36	2.94
8391	Aug 85	0.28	0.26	0.12	0.59
8426	Aug 85	1.27	0.78	1.61	0.39
8359	Sep 85	0.46	2.01	0.06	0.28
8380	Sep 85	0.97	1.39	0.92	0.36
8381	Sep 85	8.77	0.21	0.39	ND
8393	Oct 85	0.45	0.17	0.19	0.46
8394	Oct 85	0.13	0.65	0.23	4.01
8402	Oct 85	0.16	0.69	0.30	0.91
8450	Nov 85	0.84	0.56	2.19	1.42
8455	Nov 85	1.17	0.28	ND	0.88
8461	Nov 85	0.15	0.18	0.09	1.12
8463	Dec 85	0.74	0.35	0.48	1.70
8465	Dec 85	1.02	0.55	1.90	1.12

Table 1 (contd)

Specimen number	Month of death	pp'DDE	HEOD	PCBs	Hg
Sparrowhawk (Accipiter nisus)					
8275		51.17	1.96	22.26	6.71
8416	Nov 78	1.24	ND	0.77	1.26
8415	Aug 80	0.38	0.10	ND	3.38
8405	Sep 80	0.42	0.12	0.28	2.06
8406	Jul 81	0.11	0.03	ND	2.02
8278	82	152.82	ND	6.08	13.35
8279	Apr 82	0.29	0.05	0.53	2.27
8354	Oct 84	0.86	1.16	0.07	2.42
8240	Nov 84	0.37	0.11	0.54	1.90
8172	Jan 85	36.13	0.07	ND	ND
8157	Feb 85	7.70	0.92	5.52	5.53
8160	Feb 85	0.45	0.19	ND	1.79
8168	Feb 85	0.74	0.08	1.03	3.42
8173	Feb 85	0.37	0.07	0.23	0.70
8182	Feb 85	1.05	0.12	0.19	5.28
8187	Feb 85	67.30	2.21	8.22	4.77
8188	Feb 85	0.48	0.31	0.12	1.34
8194	Mar 85	0.95	ND	0.57	1.71
8195	Mar 85	1.32	0.17	1.33	2.68
8199	Mar 85	10.89	0.70	5.16	1.07
8201	Mar 85	3.79	0.16	0.56	8.99
8231	Mar 85	21.47	2.76	12.00	9.05
8243	Mar 85	10.05	0.87	32.11	5.71
8246	Mar 85	2.91	1.37	14.67	1.15
8247	Mar 85	2.95	0.20	1.61	2.60
8249	Mar 85	8.28	0.52	2.37	3.68
8253	Mar 85	0.91	0.37	0.44	3.22
8254	Mar 85	21.91	1.55	9.54	19.02
8263	Mar 85	82.75	0.70	15.63	4.83
8315	Mar 85	0.38	0.12	ND	4.24
8427	Mar 85	0.70	0.26	0.50	1.32
8257	Apr 85	3.31	0.38	0.85	3.22
8258	Apr 85	1.94	0.24	0.60	0.51
8262	Apr 85	17.24	1.41	15.24	2.12
8266	Apr 85	0.67	0.07	0.24	8.80
8273	Apr 85	1.29	0.14	1.02	2.24
8283	Apr 85	7.82	0.34	0.81	2.56
8300	Apr 85	26.68	9.48	3.06	5.76
8316	Apr 85	2.10	0.25	ND	6.69
8407	Apr 85	34.60	0.86	4.60	2.55
8286	May 85	14.98	0.67	7.99	9.72
8295	May 85	1.10	0.35	0.18	4.13
8310	Jun 85	1.37	0.17	0.35	0.60
8334	Jul 85	3.42	0.12	0.32	1.32
8339	Aug 85	4.47	0.24	0.73	3.37
8341	Aug 85	0.31	0.13	0.43	1.01
8343	Aug 85	3.05	0.75	1.54	1.16
8348	Aug 85	5.32	0.09	0.64	0.73
8349	Aug 85	2.20	0.53	0.51	3.86
8353	Aug 85	4.56	0.09	0.11	2.17
8371	Aug 85	1.51	0.24	1.05	2.71

Table 1 (contd)

Specimen number	Month of death	pp'DDE	HEOD	PCBs	Hg
Sparrowhawk (contd)					
8390	Aug 85	0.77	0.10	ND	0.32
8408	Aug 85	0.92	0.07	ND	0.61
8361	Sep 85	0.27	0.08	0.23	0.94
8369	Sep 85	0.68	1.04	0.69	1.36
8395	Oct 85	6.31	0.29	0.41	2.58
8409	Oct 85	0.45	0.21	0.19	2.57
8412	Oct 85	6.38	0.85	1.62	3.76
8413	Oct 85	0.39	0.08	0.21	0.50
8443	Oct 85	13.12	7.11	6.50	2.83
8448	Oct 85	ND	ND	0.19	1.47
8417	Nov 85	2.59	0.25	0.64	2.52
8446	Nov 85	1.33	0.15	0.63	0.17
8456	Nov 85	34.00	0.65	3.81	ND
8458	Nov 85	0.20	0.03	ND	0.57
8460	Nov 85	1.26	0.74	0.21	ND
8462	Nov 85	16.05	0.12	0.70	5.68
Peregrine (*Falco peregrinus*)					
8292	Apr 85	0.86	0.55	0.69	3.26
Merlin (*Falco columbarius*)					
8372	Oct 83	0.10	0.21	ND	0.34
Long-eared owl (*Asio otus*)					
8375	Mar 81	2.80	ND	1.21	ND
8280	Jan 83	23.35	0.26	1.85	2.00
8438	Mar 84	0.25	0.71	ND	0.12
8439	Mar 84	0.53	ND	0.29	0.59
8385	Nov 84	0.27	ND	ND	ND
8223	Mar 85	0.06	0.05	ND	0.20
8236	Mar 85	132.30	1.11	2.07	2.00
8242	Mar 85	4.17	0.15	ND	0.08
8261	Apr 85	2.05	0.06	1.12	0.55
8437	Apr 85	3.66	0.35	1.81	8.88
8467	Dec 85	0.12	ND	0.40	1.39
Heron (*Ardea cinerea*)					
8147	Jan 85	2.13	0.43	8.57	30.18
8150	Jan 85	12.16	0.71	39.78	93.51
8151	Jan 85	12.87	1.19	12.70	49.83
8154	Jan 85	10.34	13.14	5.27	38.37
8159	Feb 85	1.08	0.44	ND	17.76
8162	Feb 85	1.67	1.48	1.82	29.89
8167	Feb 85	16.16	0.33	9.42	57.62
8170	Feb 85	4.21	1.23	16.57	35.91
8171	Feb 85	40.83	ND	9.79	21.99
8175	Feb 85	8.12	ND	0.80	76.15

Table 1 (contd)

Specimen number	Month of death	pp'DDE	HEOD	PCBs	Hg
Heron (contd)					
8186	Feb 85	5.71	2.24	2.67	21.63
8226	Feb 85	2.17	0.54	0.38	8.51
8245	Mar 85	6.47	1.01	8.12	13.47
8259	Apr 85	41.83	22.59	189.26	17.66
8260	Apr 85	79.31	41.31	254.89	23.53
8270	Apr 85	0.81	1.08	5.11	22.77
8290	May 85	27.23	17.35	81.48	21.49
8296	May 85	22.19	13.18	45.78	29.82
8299	Jun 85	0.75	0.14	2.38	4.06
8308	Jun 85	6.65	26.37	9.49	27.42
8335	Jul 85	2.33	0.50	1.13	10.61
8346	Aug 85	0.08	0.09	0.08	4.97
8388	Sep 85	2.63	2.34	4.41	22.84
8389	Sep 85	0.20	0.05	0.16	2.62
8414	Oct 85	0.31	0.52	0.52	5.16
8419	Nov 85	20.40	ND	21.22	26.95
8451	Nov 85	20.17	1.17	16.10	44.06
8464	Dec 85	0.10	ND	0.25	20.66
Great-crested grebe (Podiceps cristatus)					
8145	Jan 85	7.91	ND	10.34	8.26
8153	Jan 85	2.72	ND	5.03	14.59
8163	Jan 85	9.91	ND	16.65	21.80
8174	Feb 85	0.91	0.08	2.63	17.02
8178	Feb 85	7.59	0.43	2.53	18.12
8185	Feb 85	ND	ND	ND	10.85
8189	Feb 85	0.77	1.03	0.28	7.56
8192	Feb 85	1.24	0.14	2.15	9.60
8232	Feb 85	18.23	3.84	147.86	3.94
8221	Mar 85	0.49	ND	1.23	12.64
8224	Mar 85	0.29	0.08	0.50	14.72
8251	Mar 85	14.08	ND	12.33	17.96
8277	Mar 85	0.13	0.04	0.28	4.34
8309	May 85	ND	ND	3.37	5.01
8379	Sep 85	18.45	ND	39.64	16.28
Kingfisher (Alcedo atthis)					
8143	Jan 85	31.12	10.82	6.89	4.35
8148	Jan 85	3.25	1.65	64.13	5.52
8256	Apr 85	22.80	4.80	6.17	2.01
8312	Jun 85	0.36	1.11	1.62	2.38
8320	Jul 85	0.16	0.76	ND	3.60
8323	Jul 85	0.25	0.80	0.14	4.69
8336	Jul 85	0.80	0.95	ND	1.15
8344	Aug 85	0.33	0.76	0.07	1.14
8400	Aug 85	0.54	1.16	0.43	1.56
8362	Sep 85	0.33	1.00	ND	0.88
8399	Sep 85	0.52	0.63	ND	2.05

Table 2. Geometric mean levels of pollutants in the various species in Table 1, but for 1985 specimens only.

	pp'DDE	HEOD	PCBs	Hg
Kestrel				
Mean	0.68	0.53	0.38	1.05
SD	0.90	0.41	0.68	0.54
Range within 1 SE	0.50-0.93	0.46-0.62	0.30-0.48	0.87-1.26
Sparrowhawk				
Mean	2.49	0.26	0.61	1.70
SD	0.80	0.69	0.90	0.66
Range within 1 SE	1.95-3.17	0.21-0.32	0.46-0.80	1.39-2.07
Long-eared owl				
Mean	1.47	0.08	0.23	0.78
SD	1.01	1.05	1.09	0.54
Range within 1 SE	0.73-2.96	0.03-0.20	0.08-0.65	0.39-1.55
Heron				
Mean	4.07	0.50	4.18	20.66
SD	0.80	1.34	1.02	0.37
Range within 1 SE	2.87-5.76	0.28-0.90	2.68-6.51	17.56-24.31
Great-crested grebe				
Mean	0.87	0.013	2.58	10.75
SD	1.37	1.32	1.01	0.24
Range within 1 SE	0.38-1.97	0.006-0.029	1.41-4.70	9.33-12.40
Kingfisher				
Mean	0.98	1.36	0.24	2.24
SD	0.78	0.38	1.37	0.27
Range within 1 SE	0.57-1.69	1.05-1.78	0.09-0.63	1.85-2.71

Table 3. Comparison of geometric mean residue levels (log values) from birds collected in 1985 and 1984; t values are shown. Minus values indicate a decrease from 1984.

	Sparrowhawk	Kestrel	Heron	Kingfisher	Great-crested grebe
DDE	t_{97} = 0.89	t_{82} = 0.01	t_{18} = 2.47*	t_{15} = -0.81	t_{17} = -0.28
HEOD	t_{97} = -2.22*	t_{64} = 0.34	t_{40} = 0.27	t_{15} = 0.38	t_{17} = -1.66
PCBs	t_{97} = -3.84***	t_{82} = -5.65***	t_{40} = -0.66	t_{19} = -2.10*	t_{17} = -0.68
Hg	t_{97} = -0.51	t_{82} = 1.96	t_{39} = 2.14*	t_{19} = 2.10*	t_{17} = 0.80

<u>Notes</u>: Zero values for DDE and HEOD were taken as 0.001, for PCBs and Hg as 0.01

* significance of difference P<0.05; *** P<0.001

Table 4. Trends in pollutant levels in livers of predatory birds during 1963-85 and 1981-85. Figures show regression coefficients, with significance levels.

		1963-85	1981-85
DDE	Sparrowhawk	-0.016 **	-0.049 ns
	Kestrel	-0.025 ***	0.075 ns
	Heron	-0.026 ***	0.128 *
	Kingfisher	-0.034 **	0.018 ns
	Great-crested grebe	-0.029 *	-0.076 ns
PCBs	Sparrowhawk	-0.010 ns	
	Kestrel	-0.002 ns	
	Heron	-0.005 ns	
	Kingfisher	-0.019 ns	
	Great-crested grebe	-0.032 ns	
HEOD	Sparrowhawk	-0.012 *	-0.033 ns
	Kestrel	-0.023 ***	0.051 *
	Heron	-0.051 ***	0.229 **
	Kingfisher	-0.013 ns	0.024 ns
	Great-crested grebe	-0.010 ns	-0.335 ns
Hg	Sparrowhawk	-0.041 ***	
	Kestrel	-0.069 ***	
	Heron	-0.040 ***	
	Kingfisher		0.016 ns
	Great-crested grebe		0.032 ns

<u>Notes</u>: Analyses for Hg in sparrowhawk, kestrel and heron were started in 1970, in kingfisher in 1980, and in great-crested grebe in 1979.

Analyses for PCBs in sparrowhawk, kestrel and heron were started in 1967, and in kingfisher and great-crested grebe in 1968.

ns = not significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

For HEOD, regression coefficients for 1975-85 were: 0.030** in sparrowhawk, -0.022* in kestrel, -0.010 (ns) in heron, -0.019 (ns) in kingfisher, and -0.028 (ns) in great-crested grebe.

Figure 1. Levels of DDE in livers of individual sparrowhawks, 1963-85.
Lines show 3-year moving geometric means.

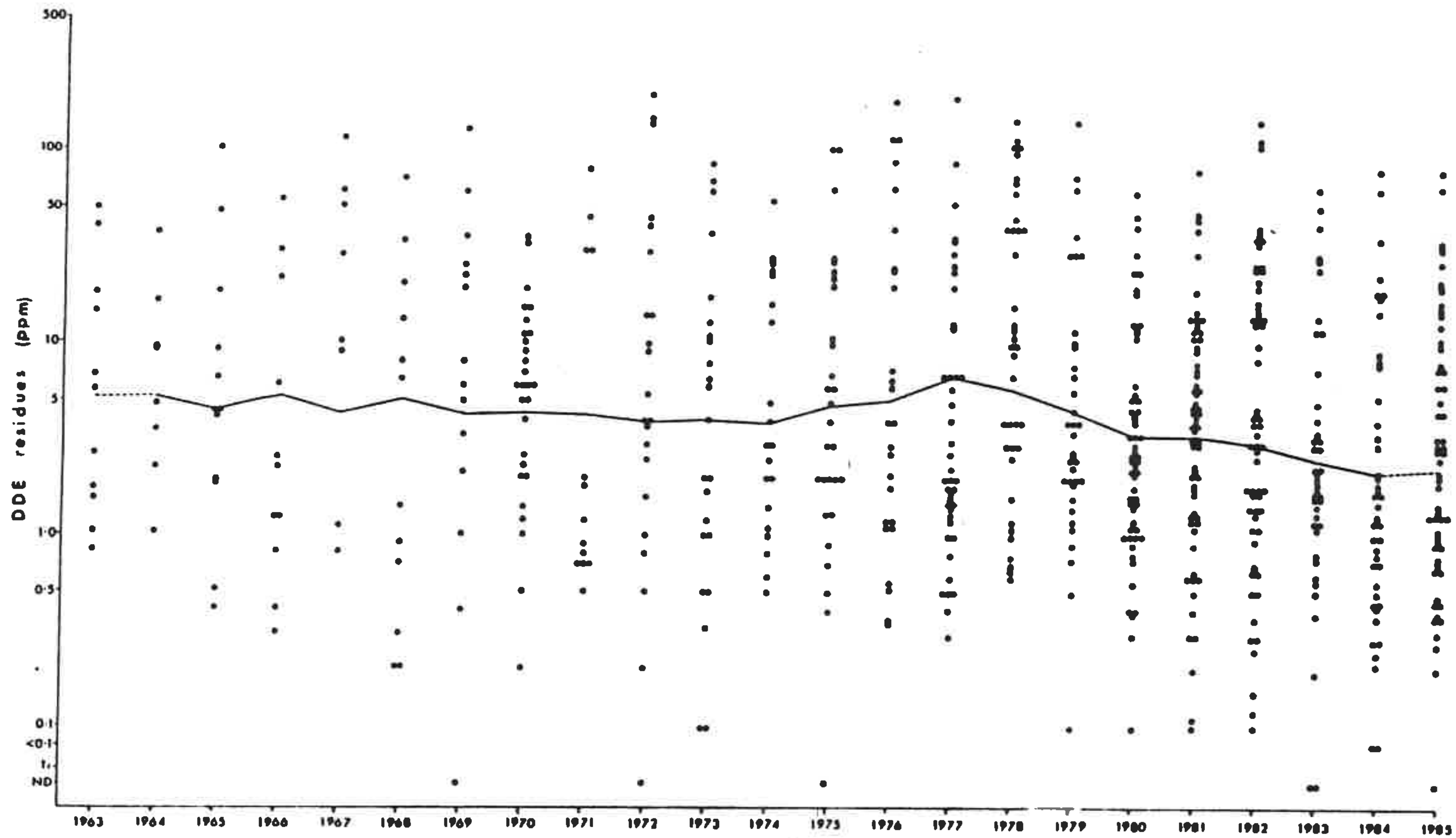


Figure 2. Levels of DDE in livers of individual kestrels, 1963-85.
Lines show 3-year moving geometric means.

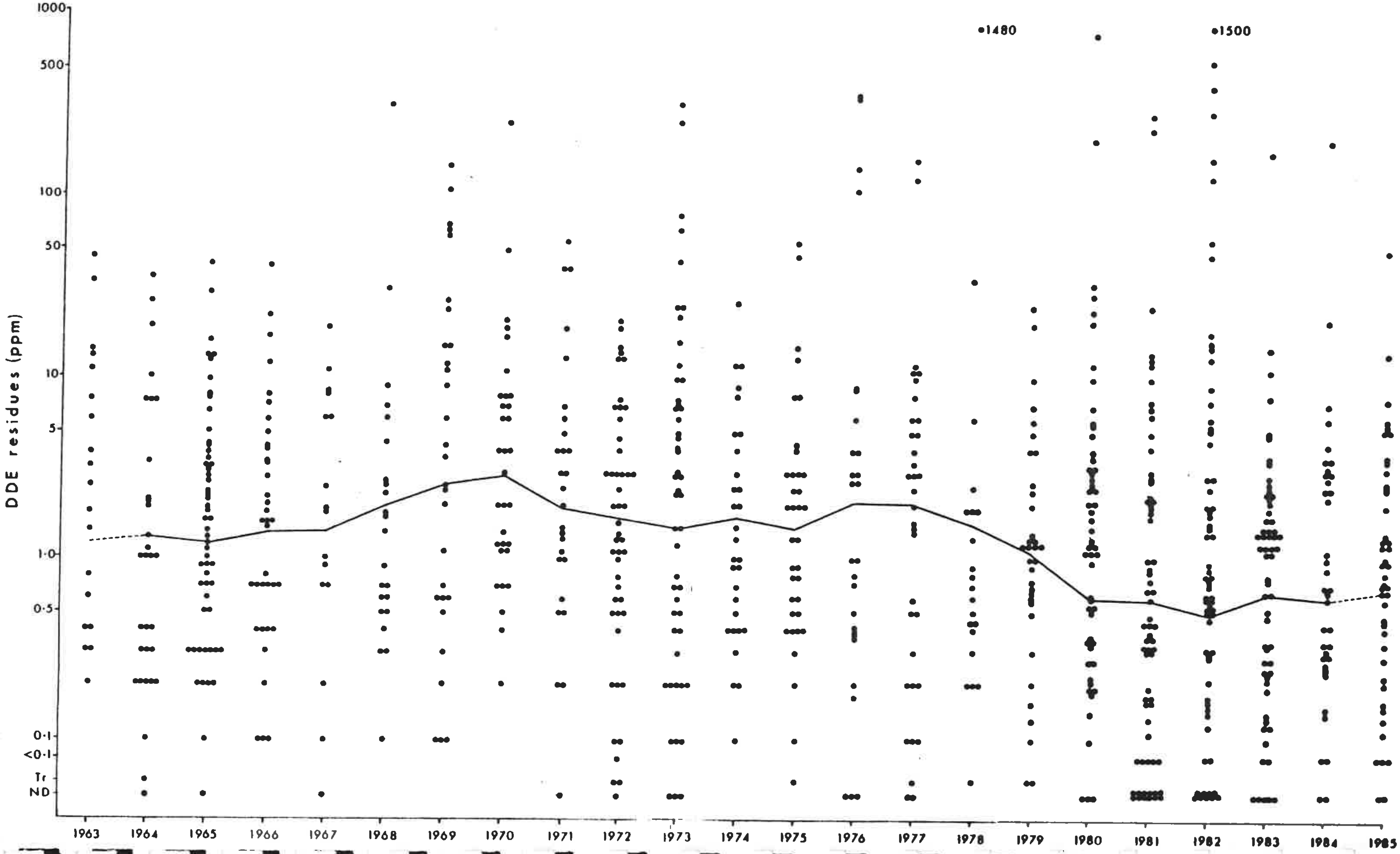


Figure 3. Levels of DDE in livers of individual herons, 1963-85.
Lines show 3-year moving geometric means.

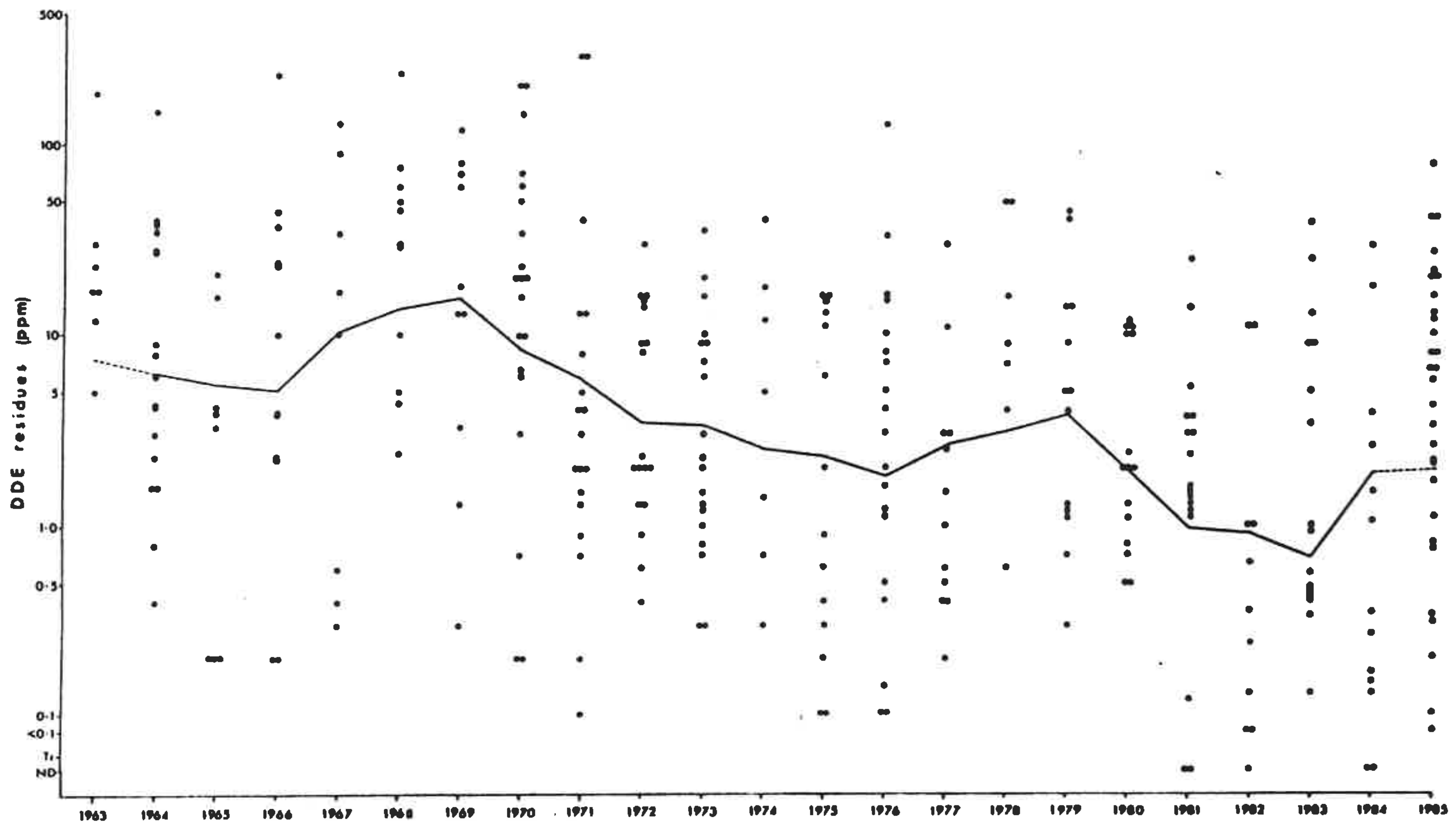


Figure 4. Levels of DDE in livers of individual kingfishers, 1964-85. Lines show 3-year moving geometric means.

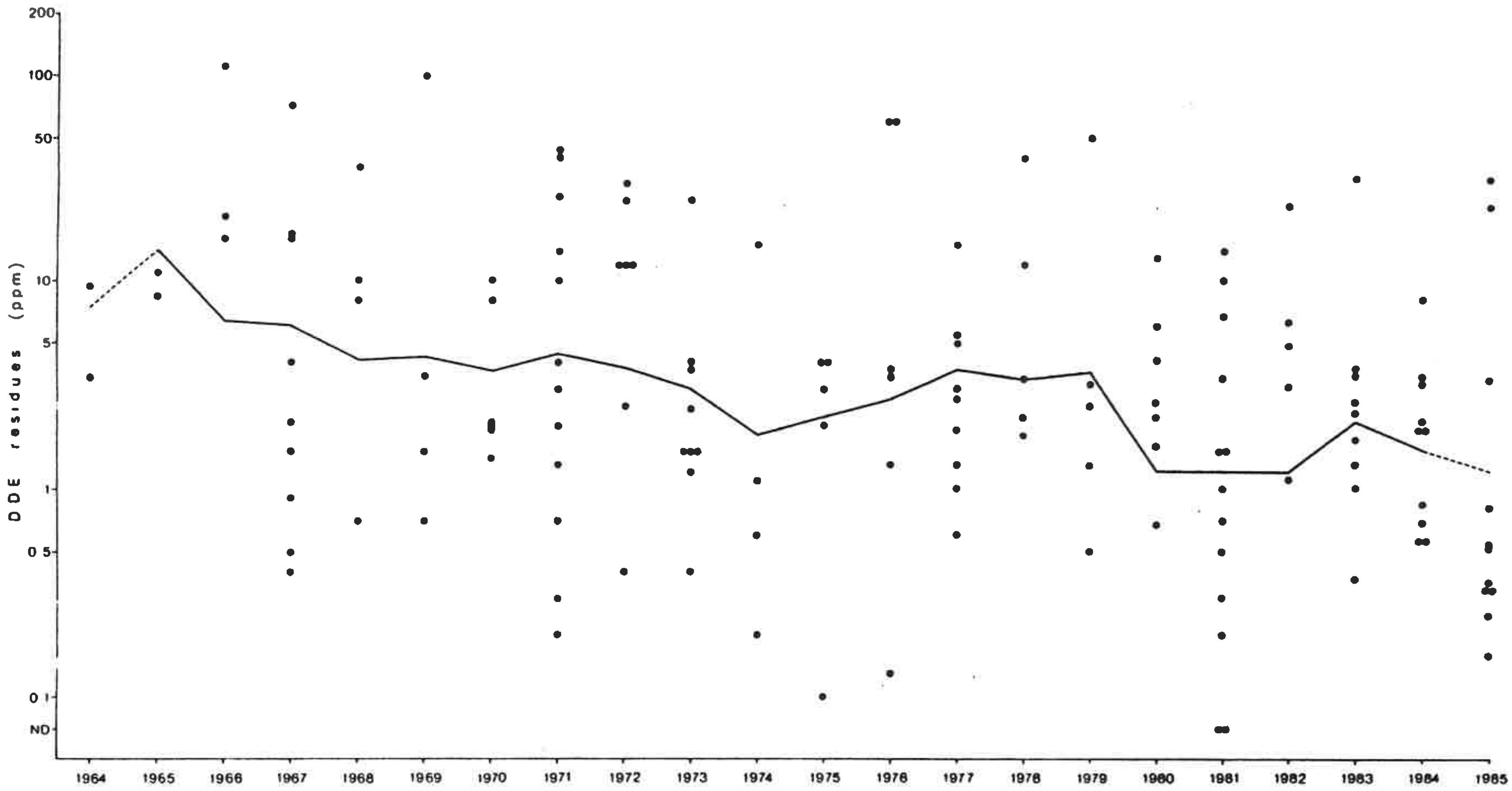


Figure 5. Levels of DDE in livers of individual great-crested grebes, 1963-85.
Lines show 3-year moving geometric means.

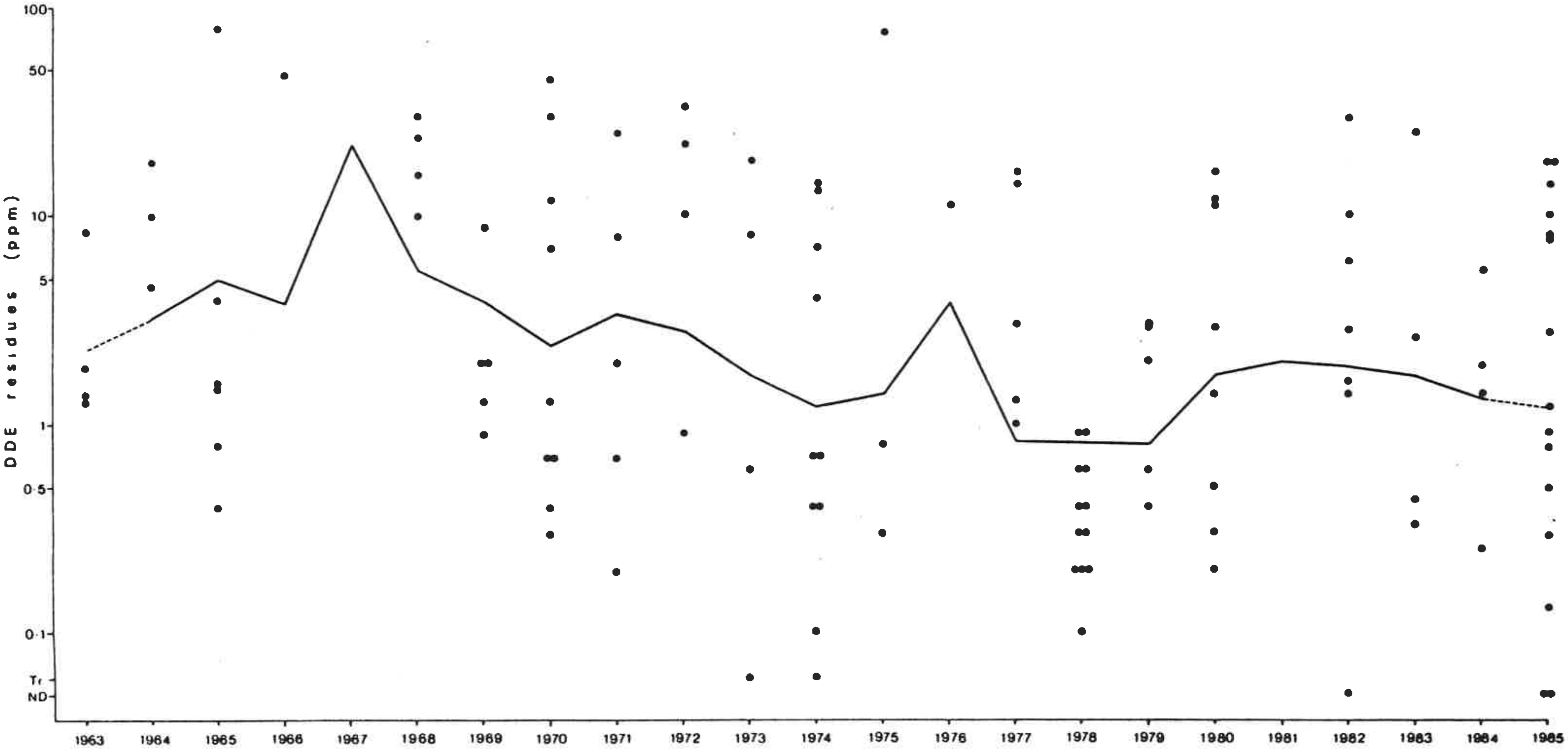


Figure 6. Levels of HEOD in livers of individual sparrowhawks, 1963-85. Lines show 3-year moving geometric means.

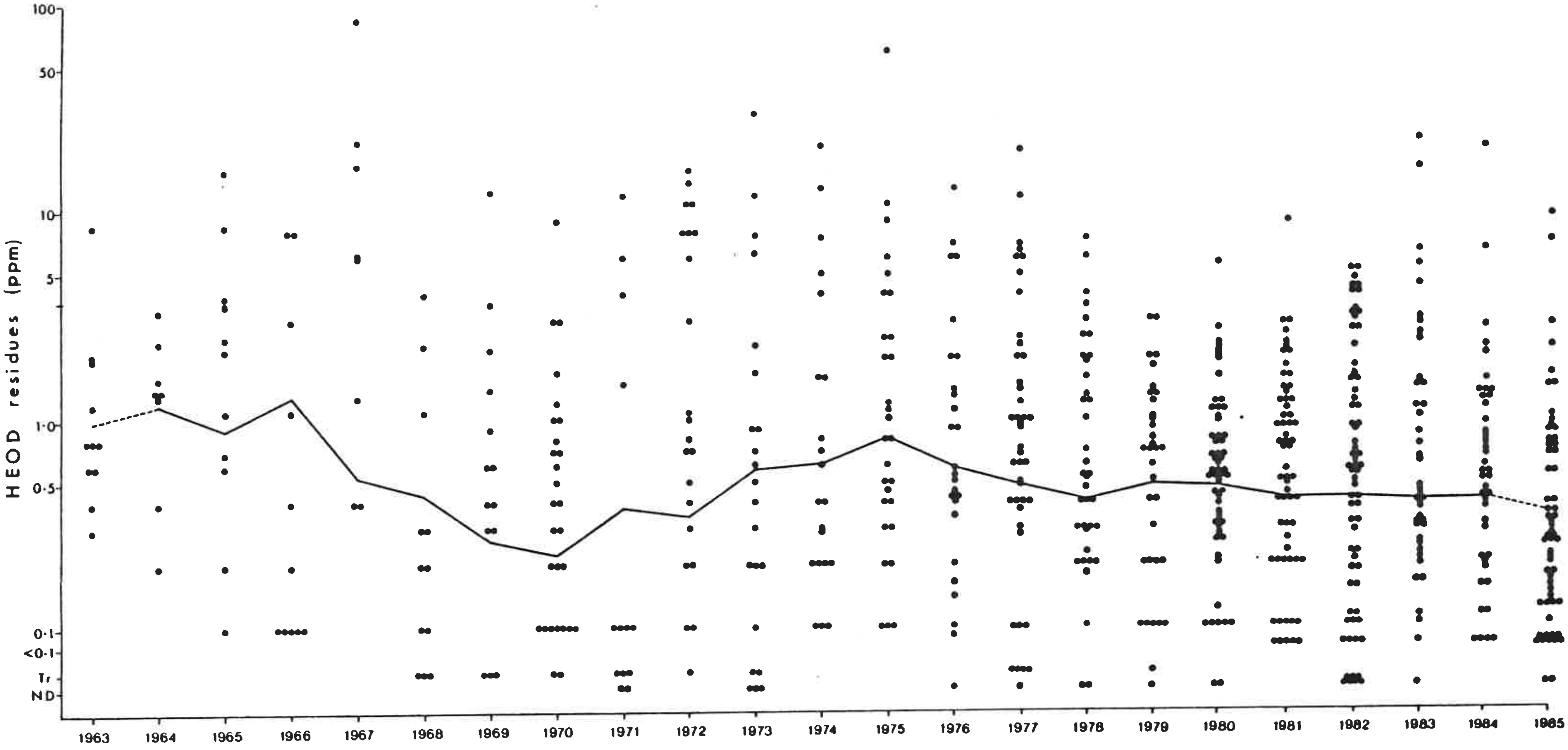


Figure 7. Levels of HEOD in livers of individual kestrels, 1963-85.
Lines show 3-year moving geometric means.

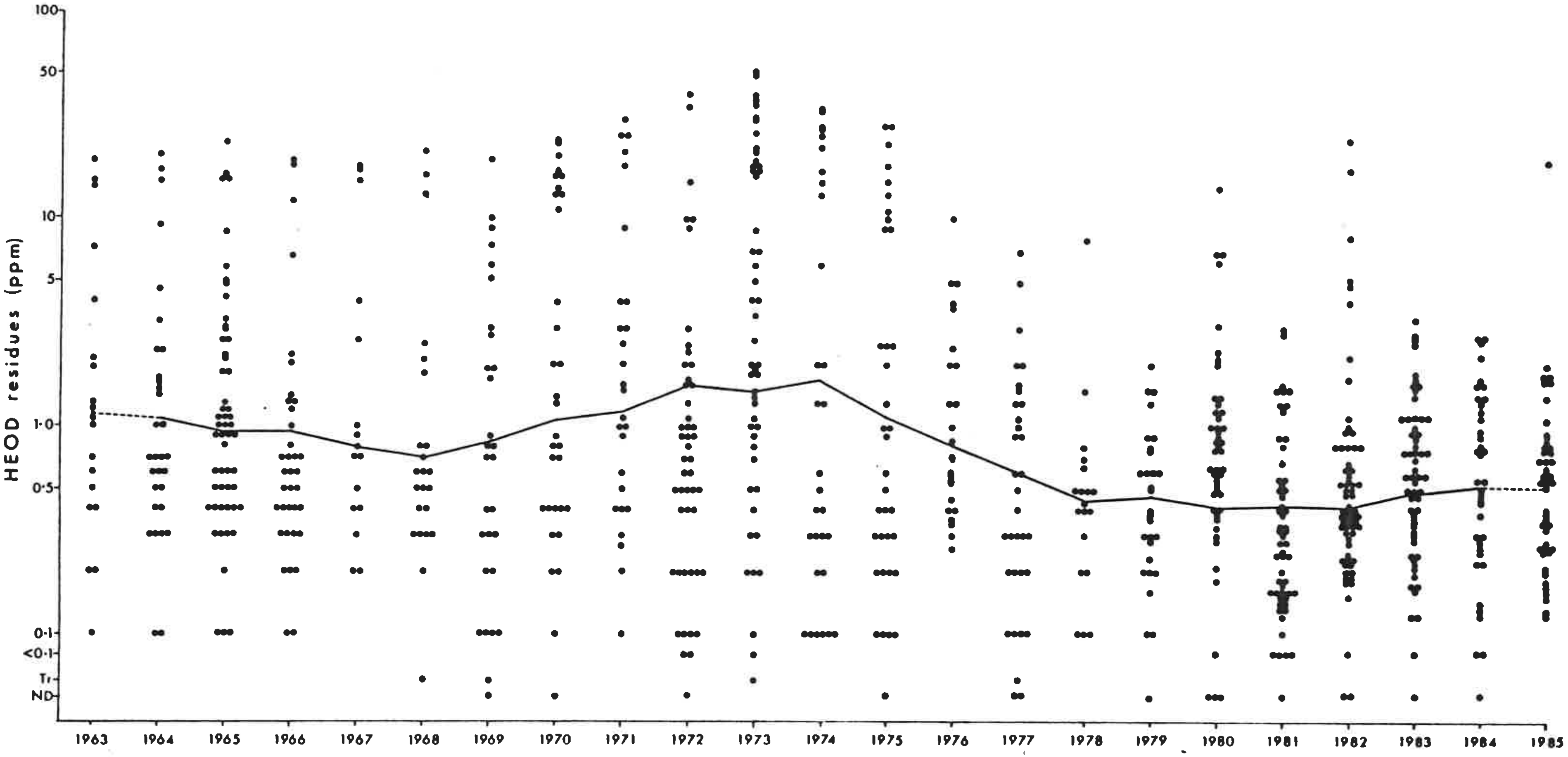


Figure 8. Levels of HEOD in livers of individual herons, 1963-85.
Lines show 3-year moving geometric means.

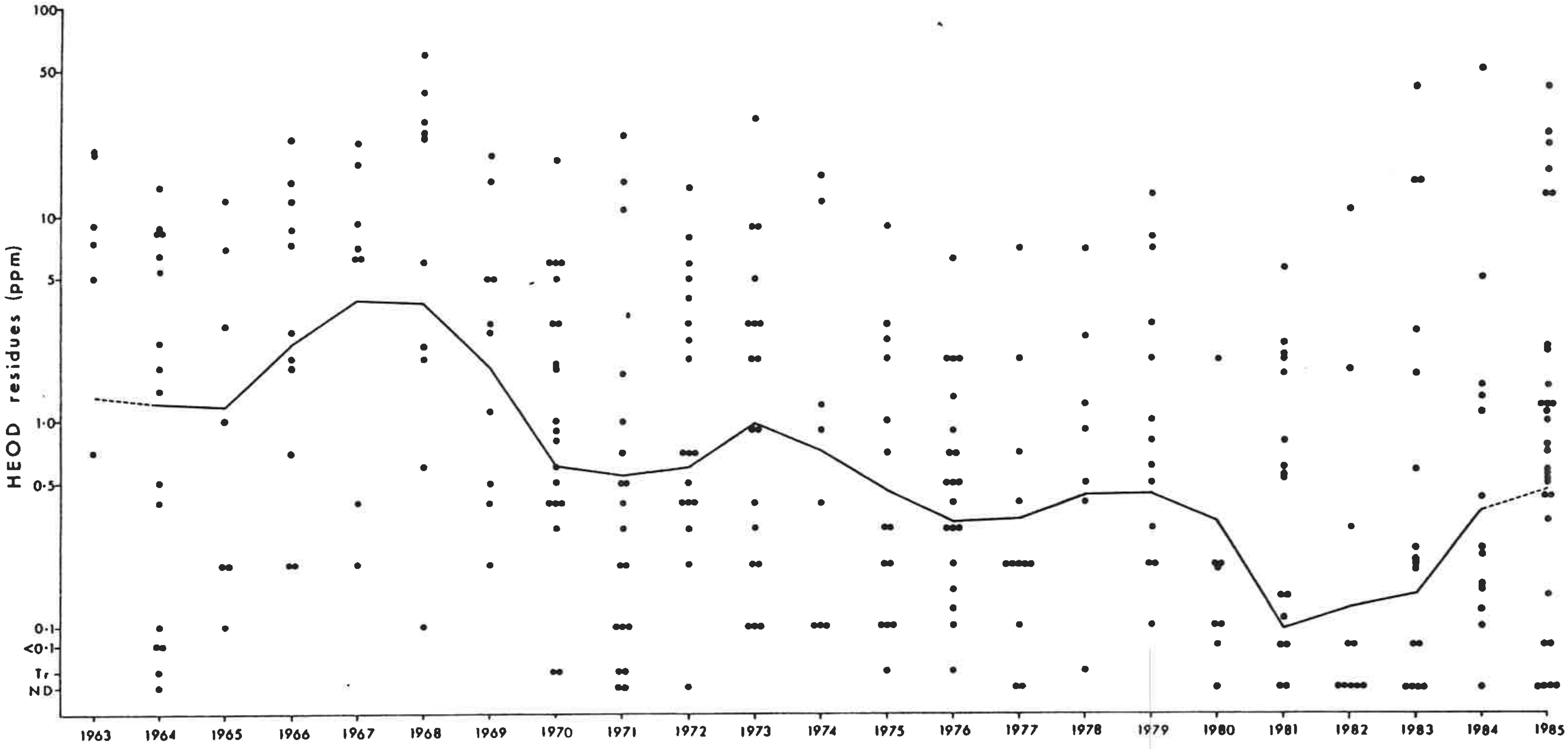


Figure 9. Levels of HEOD in livers of individual kingfishers, 1964-85. Lines show 3-year moving geometric means.

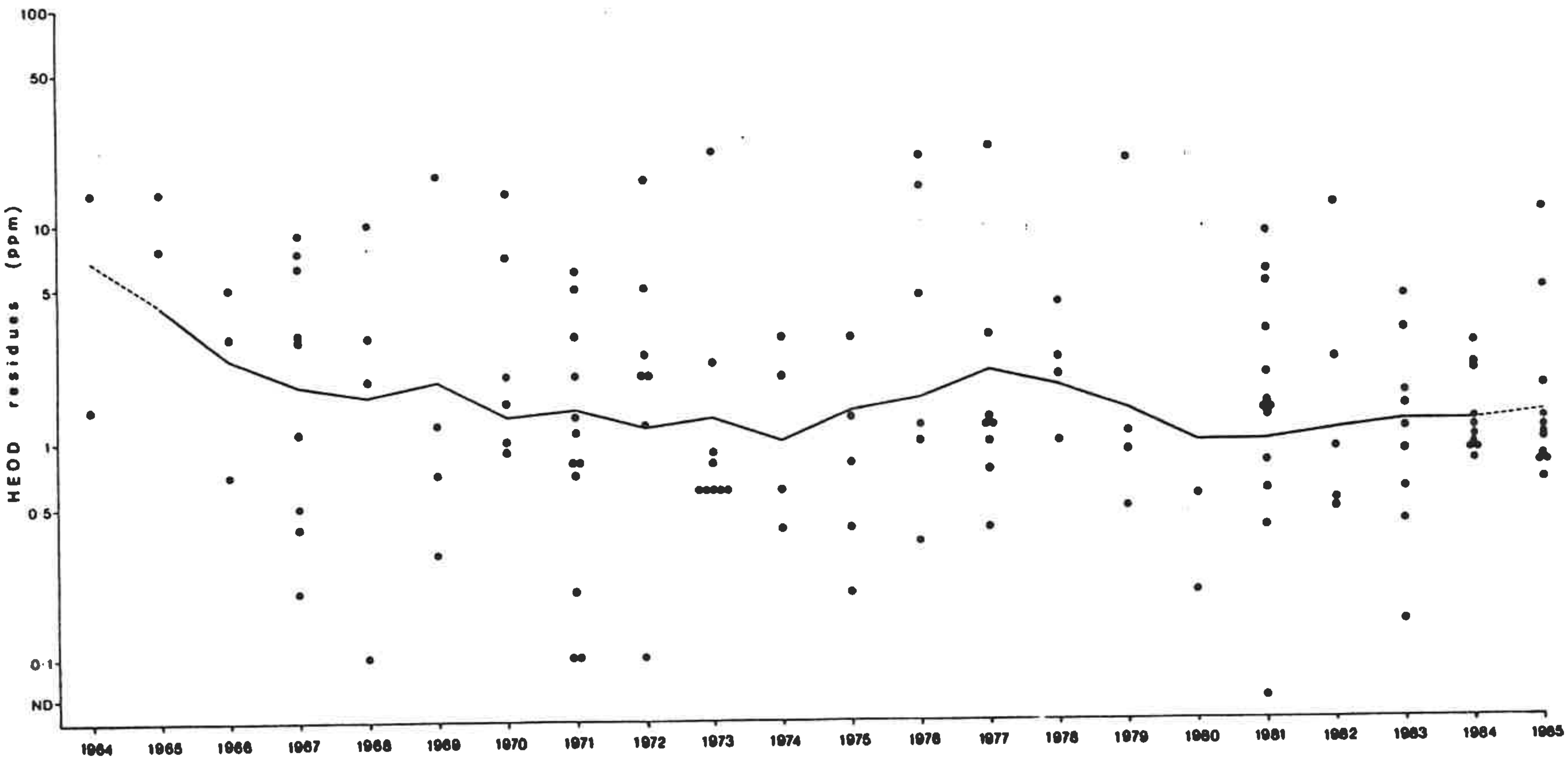


Figure 10. Levels of HEOD in livers of individual great-crested grebes, 1963-85.
Lines show 3-year moving geometric means.

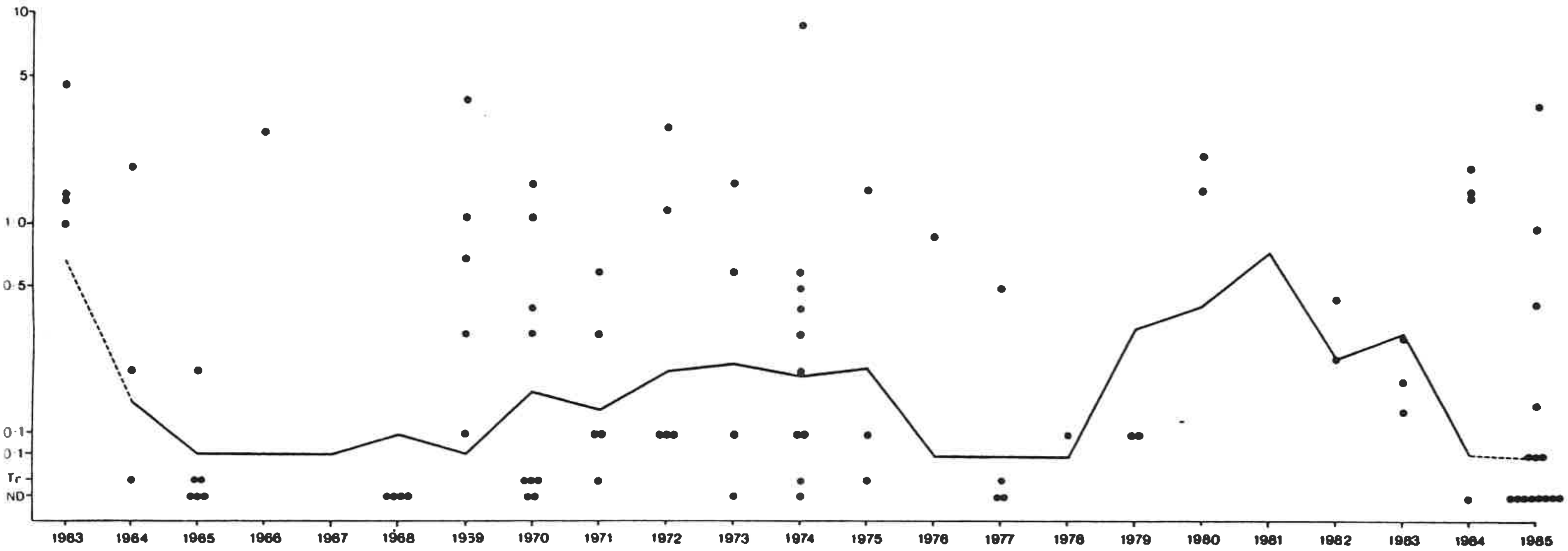


Figure 11. Levels of PCBs in livers of individual sparrowhawks, 1967-85. Lines show 3-year moving geometric means.

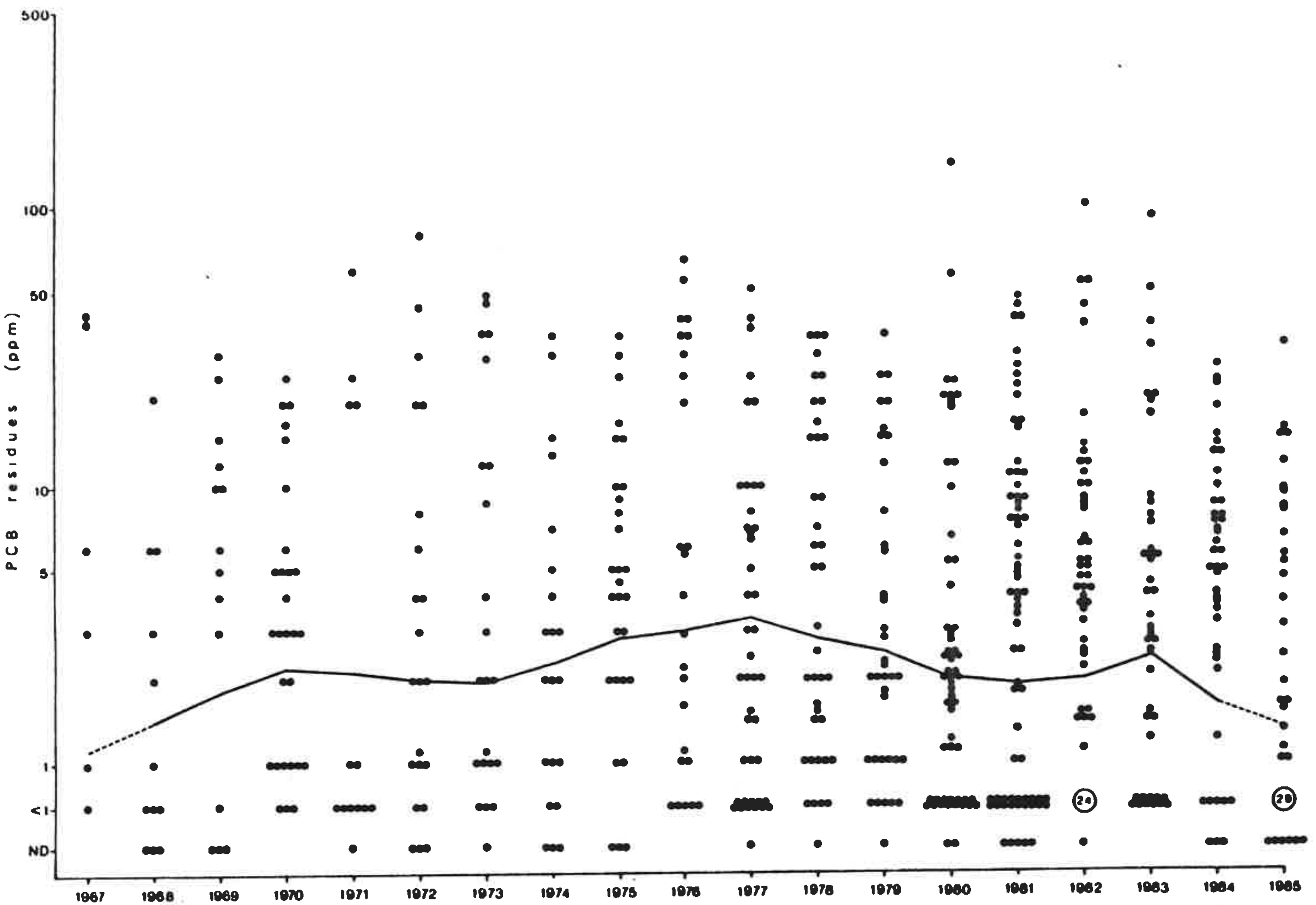


Figure 12. Levels of PCBs in livers of individual kestrels, 1967-85. Lines show 3-year moving geometric means.

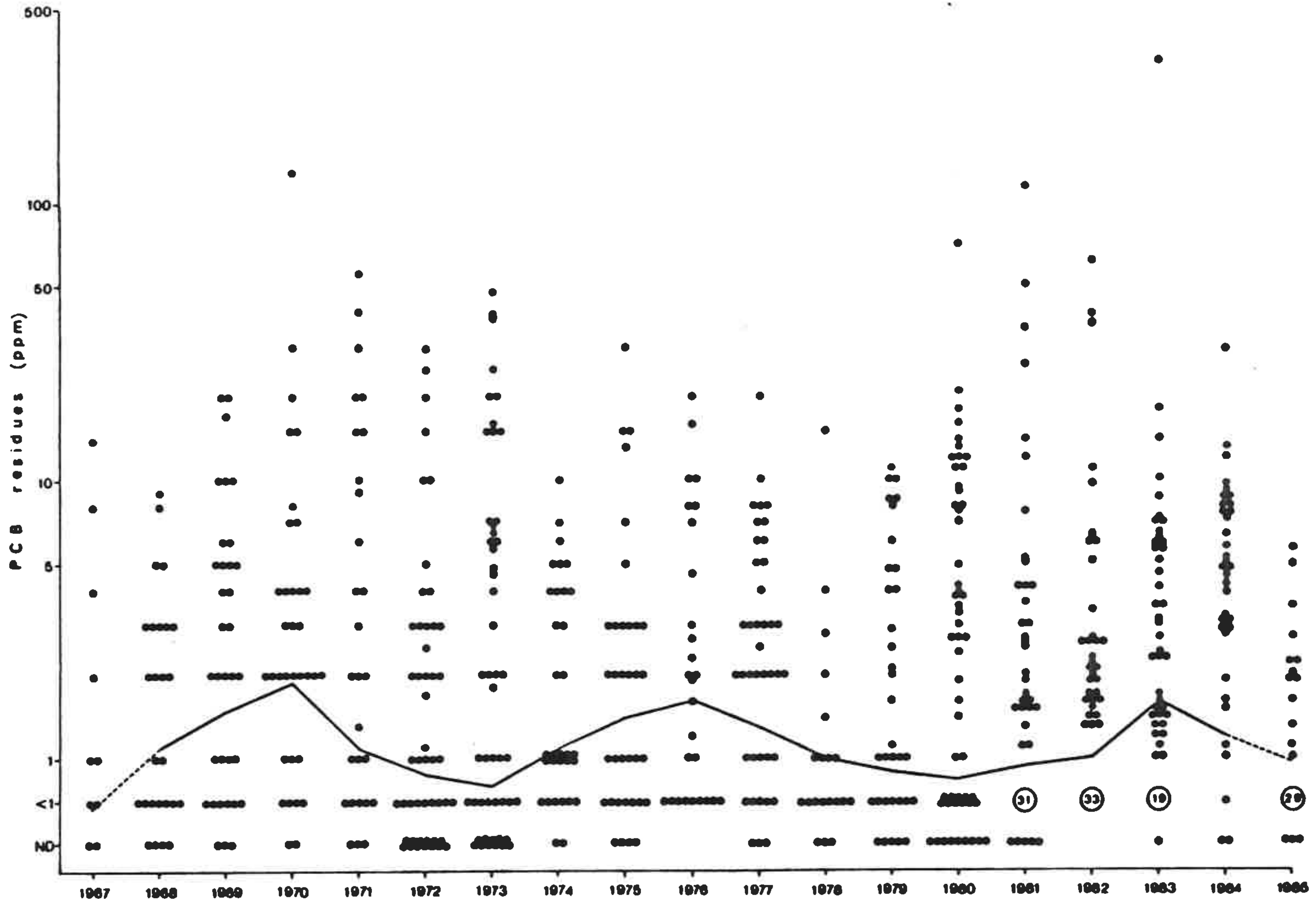


Figure 13. Levels of PCBs in livers of individual herons, 1967-85. Lines show 3-year moving geometric means.

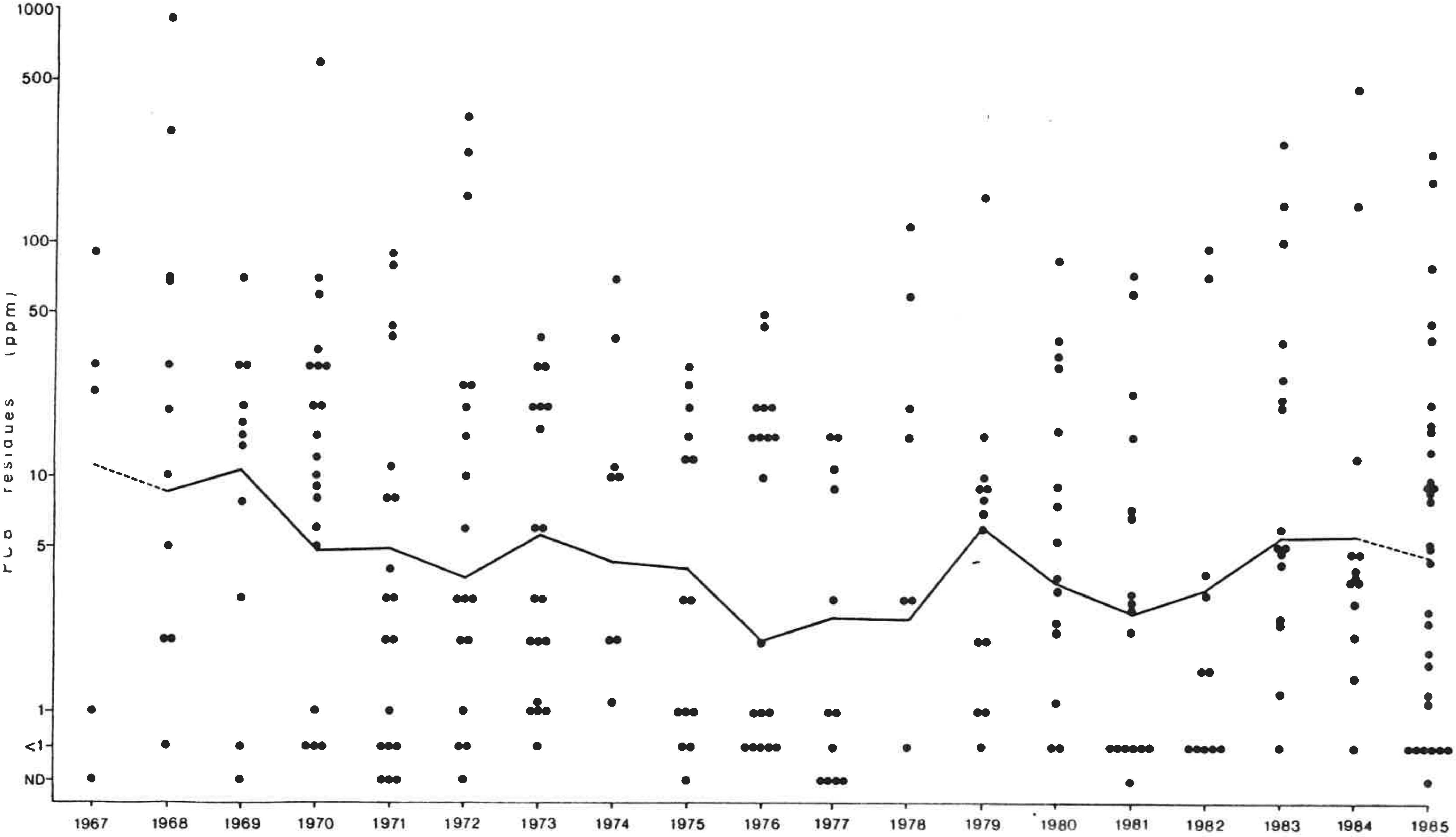


Figure 14. Levels of PCBs in livers of individual kingfishers, 1967-85. Lines show 3-year moving geometric means.

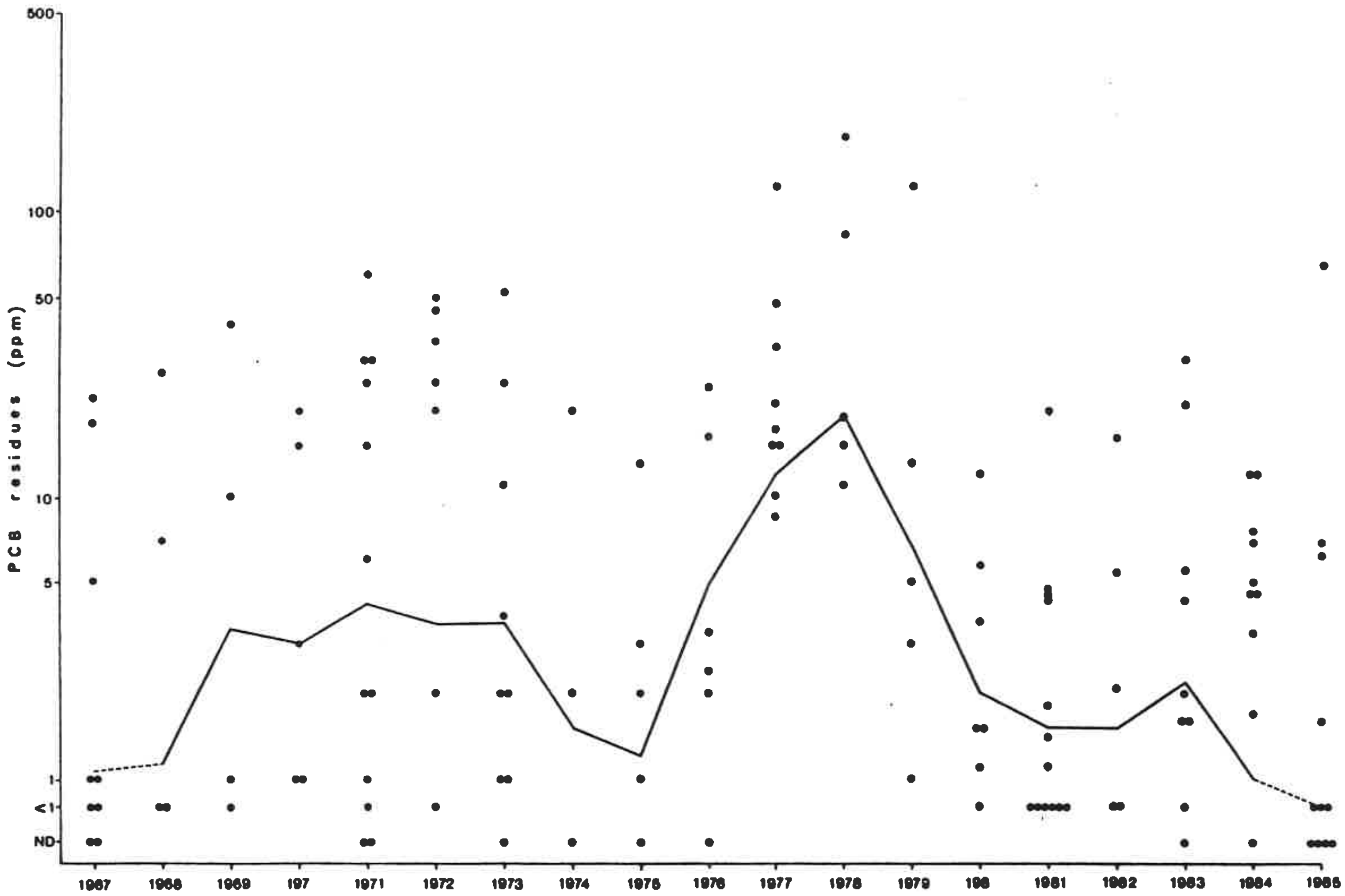


Figure 15. Levels of PCBs in livers of individual great-crested grebes, 1968-85. Lines show 3-year moving geometric means.

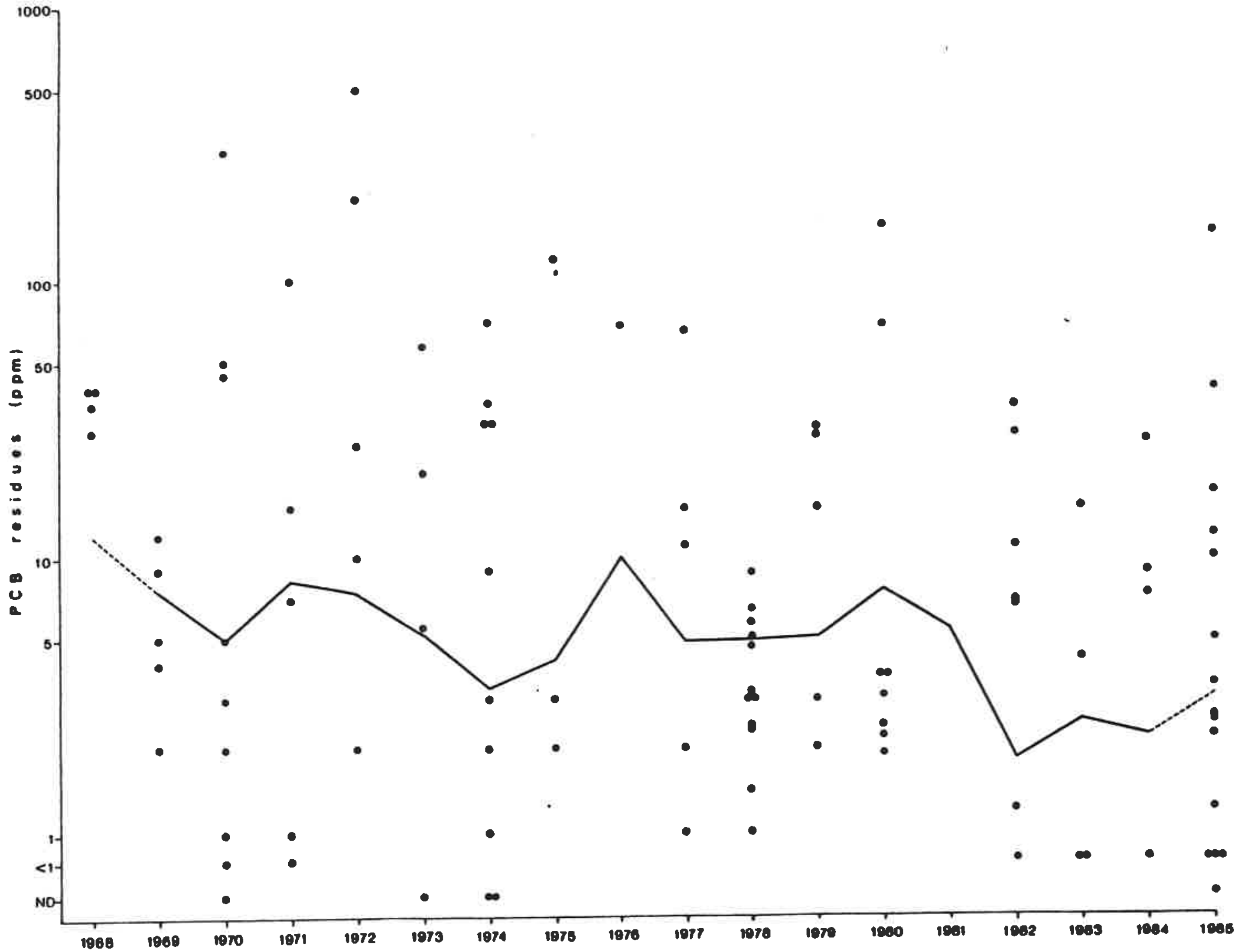


Figure 16. Levels of mercury (Hg) in livers of individual sparrowhawks, 1970-85.
Lines show 3-year moving geometric means.

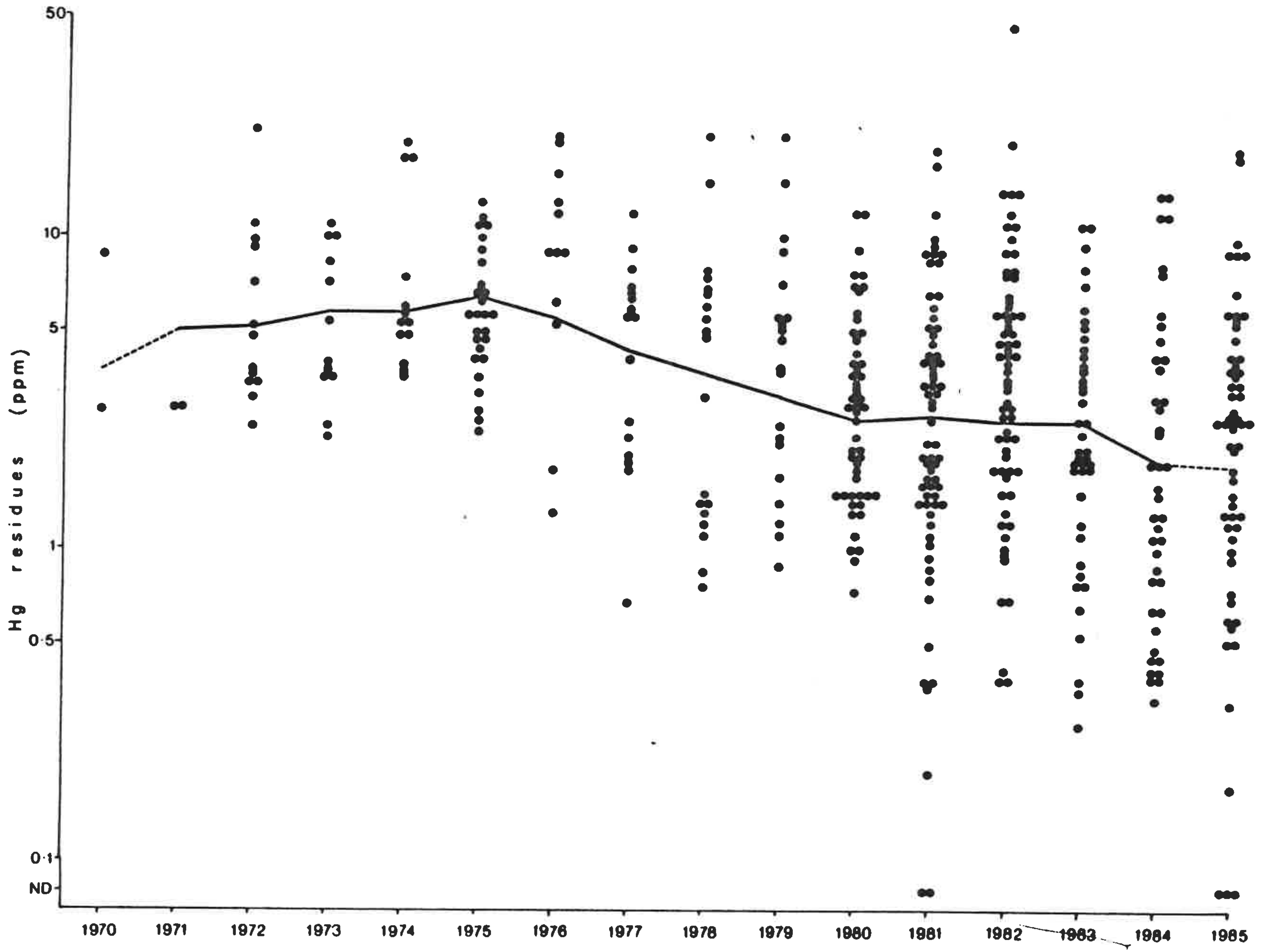


Figure 17. Levels of mercury (Hg) in livers of individual kestrels, 1970-85. Lines show 3-year moving geometric means.

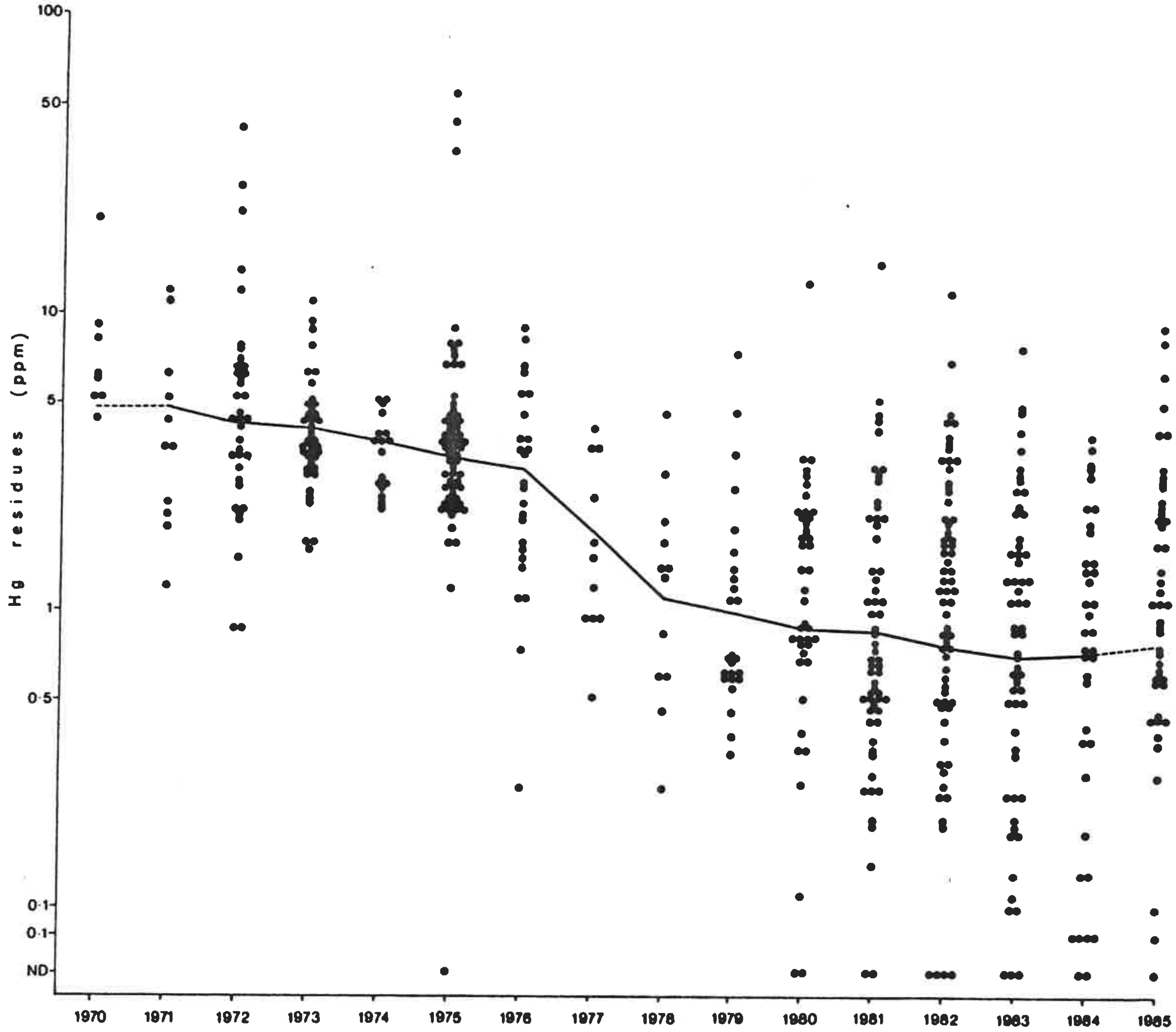


Figure 18. Levels of mercury (Hg) in livers of individual herons, 1969-85.
Lines show 3-year moving geometric means.

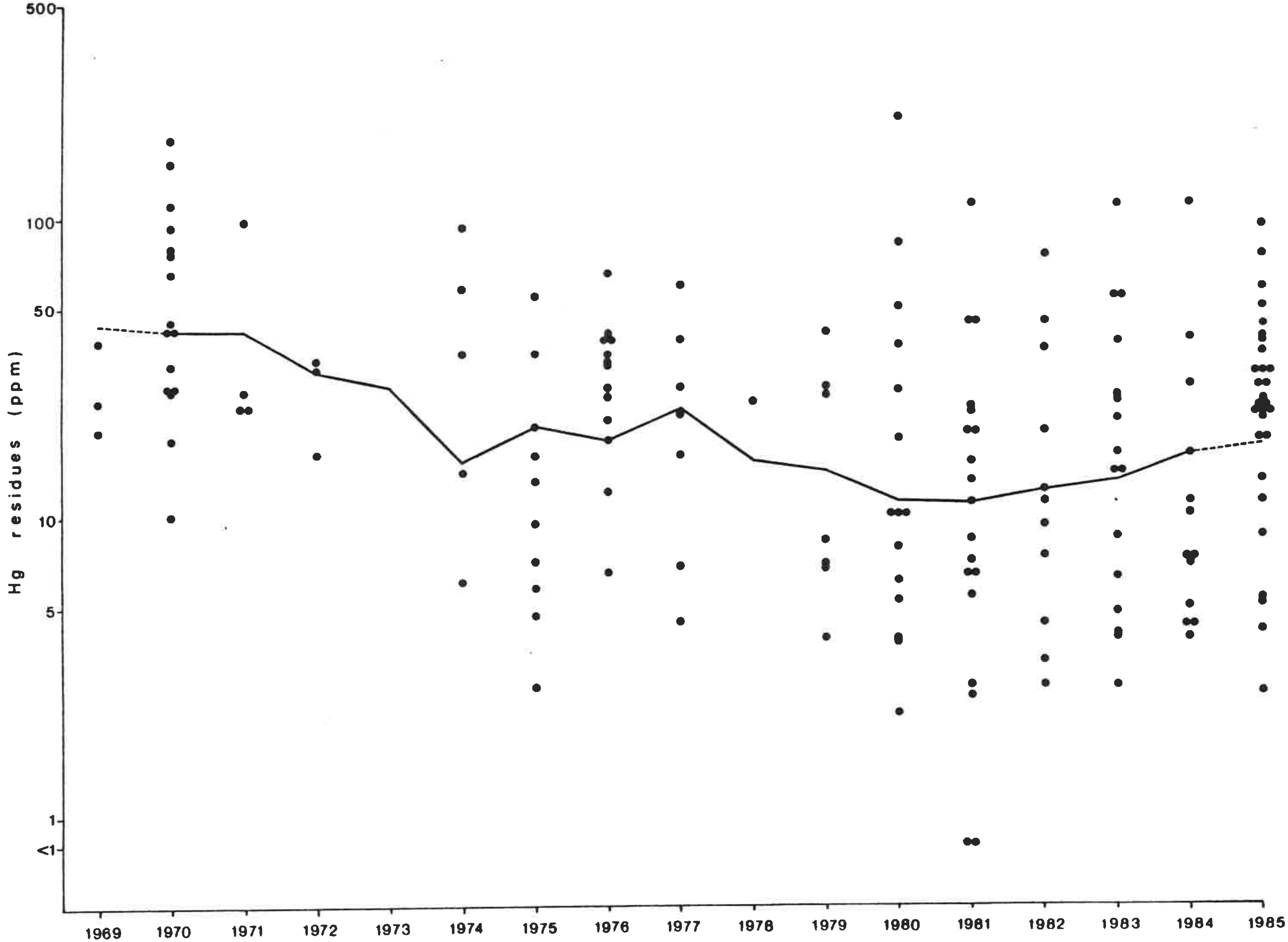


Figure 19. Levels of mercury (Hg) in livers of individual kingfishers, 1980-85. Lines show 3-year moving geometric means.

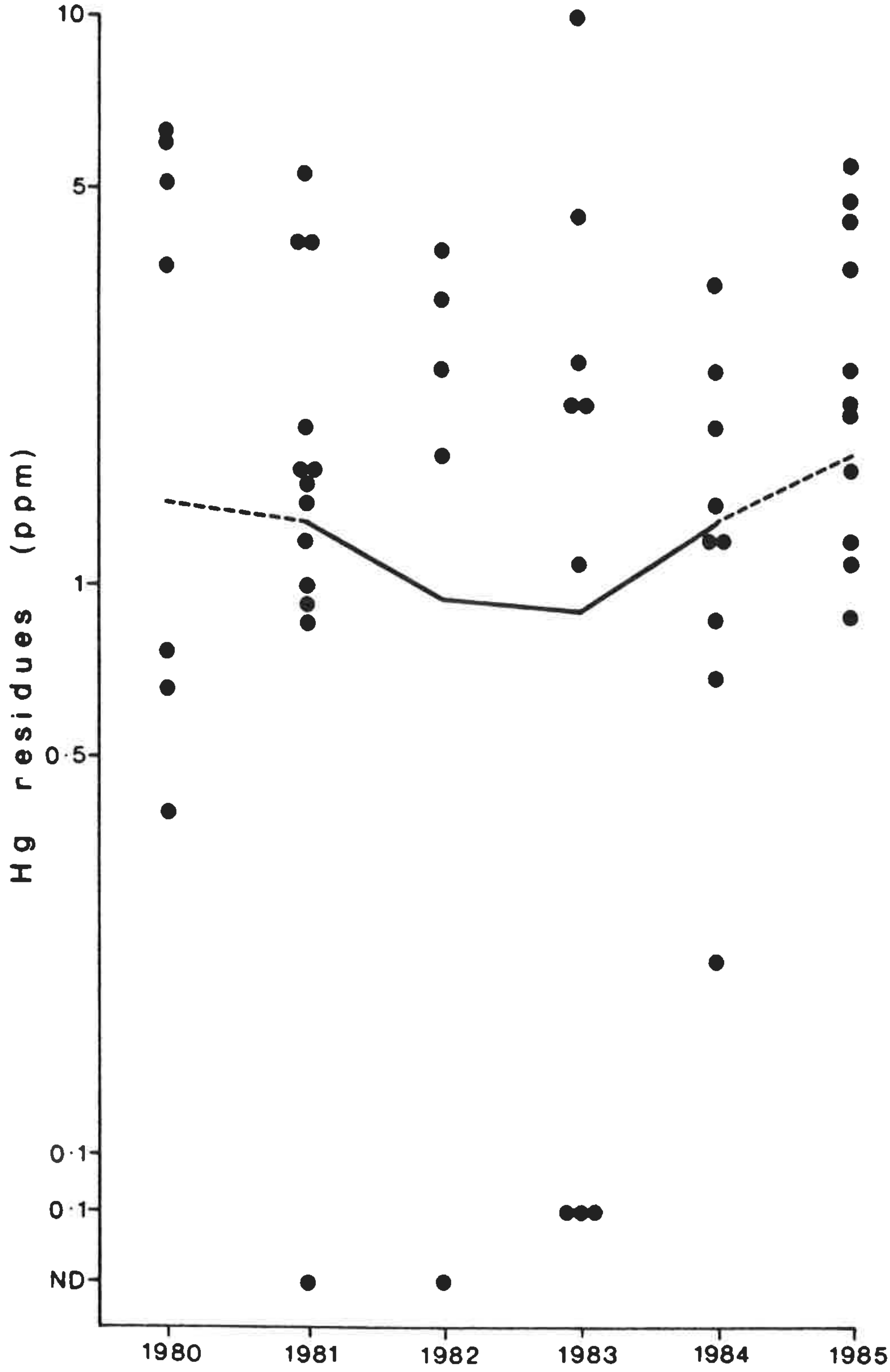
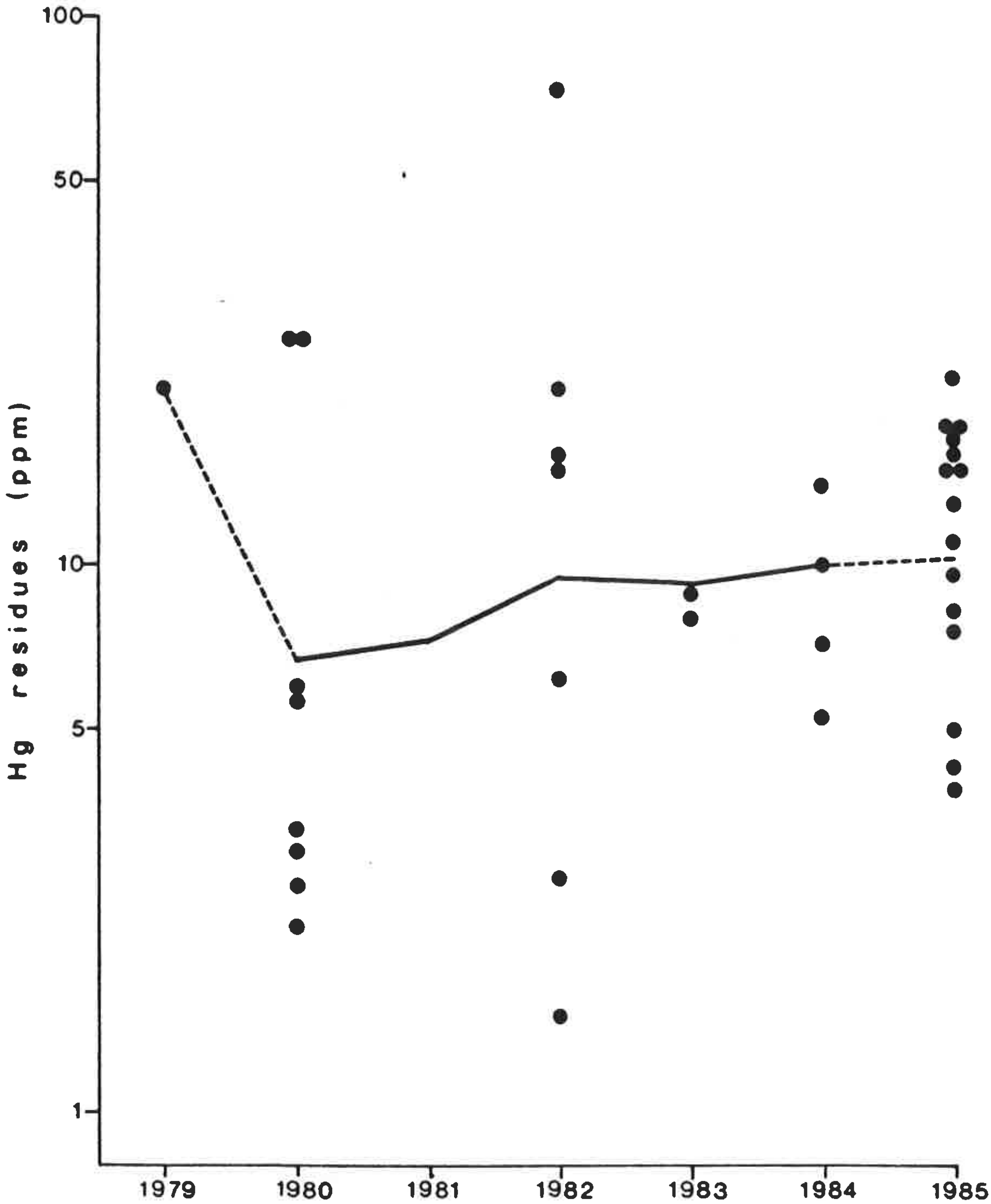


Figure 20. Levels of mercury (Hg) in livers of individual great-crested grebes, 1979-85. Lines show 3-year moving geometric means.



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Annual report to Nature Conservancy Council

BIRDS AND POLLUTION

Part 2 Sparrowhawk Survey

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August 1986

2 SPARROWHAWK SURVEY

2.1 Introduction

The sparrowhawk suffered a marked population decline in the late 1950s, following the widespread introduction of cyclodiene pesticides in agriculture. Since 1964, in each of 7 study areas, potential territories have been checked periodically for occupation and breeding success. In this way it was hoped to find whether sparrowhawks were recovering in numbers, following successive restrictions in cyclodiene use. In 1985, the survey was again concentrated on the East Midlands area where increasing numbers of hawks have been seen in recent years. The findings are summarized in Table 5.

2.2 Results

Woods judged capable of holding 30 territories were searched between mid-April and late July. This was the greatest number surveyed in one season in this study area, and included some large woods, mostly difficult to access and search, and some small woods, shelterbelts and copses, which were more easily covered. A further increase in sparrowhawk presence was evident, with nests or other signs at 8 sites. Both territories where breeding was first recorded, successfully, in 1984, were re-occupied, although one pair had moved some distance to an adjacent compartment. This territory was again successful, fledging at least 4 young from a clutch of 5. Repeated searching of the other site, prompted by the presence of secondary evidence, confirmed only a partly-constructed nest, close to the original. A third nest was found late, in one of the isolated woods; only one large young was then observed, but evidence around the nest indicated more.

Only one of the 5 territories showing other signs had done so previously. Its proximity to one of the breeding sites suggests that the signs were probably the work of birds hunting from there in both years. The other 4 sites had no previous evidence of sparrowhawks, and were presumably within the hunting ranges of birds from other areas or were occupied by non-breeders.

Although spring sightings of sparrowhawks have recently been reported from one large block of prime territories, the continuing failure to find either new or old nests there, or in other suitable sites, indicates that recolonization is still incomplete.

Table 5. Occupation of sparrowhawk territories in the East Midlands study area, 1985

Total potential territories checked	30
Number with successful nests	2
Number with failed nests	1
Number with no nest, but other signs	5
Number of territories with old nests	2

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BIRDS AND POLLUTION

Part 3 Heron Survey

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August 1986

3 HERON SURVEY

3.1 Introduction

Since 1964, observations have been made annually at the 2 Lincolnshire heronries of Willoughby Wood and Troy Wood in order to assess the numbers of heron pairs breeding in each and the proportions breaking eggs. Periodically, a sample of fresh eggs has been taken for chemical analysis and determination of eggshell index; dead young birds have also been collected for analysis whenever available. The herons in these colonies had exhibited shell-thinning, apparently caused by DDE, but, unlike some birds of prey, had not suffered a marked population decline.

In 1985, the final year of the present study, the opportunity was taken to collect a further sample of eggs from Troy, together with a small number of dead young, and to maintain observations, on various dates between early March and mid-July. The number breeding at Willoughby was confirmed by Mr R B Wilkinson, of the Lincolnshire Naturalists' Trust, but data on egg breakage and other aspects were not obtained.

3.2 The Troy heronry

Despite two periods of severe weather in January and February, 102 nests were occupied at some time during the ensuing season compared with 72 in 1984. The unexpected increase was accounted for by an unusually large number of 30 new nests, and a 63% increase over the 1984 increment (Figure 21). Some of these nests were started, exceptionally, in March, even though, as usual, many of the existing nests still remained vacant. Although there were some aborted breeding attempts in both old and new nests, this was the largest number of pairs recorded in this colony in the 22 years of observations, well exceeding the previous peak of 88, in 1965.

The average size of 11 clutches completed in the period mid-March to late-April was unusually low, at 3.7 (4 of c/3, 6 of c/4, 1 of c/5). This compares with an average 4.2 for 20 clutches monitored over a slightly longer period in 1983, when 80 pairs bred, although in neither instance was account taken of the age of the breeding birds. The level of parental egg destruction had fallen from its sudden new peak of 33% in 1984 (the highest for 11 seasons), but still remained high, occurring at 27% of 41 nests checked.

Single eggs were removed from each of 10 clutches for chemical analysis and determination of shell-index (Table 6). The residue levels were not significantly different from those found in the last samples, obtained in 1983, except for PCBs, which were lower (t_{23} = -5.85, $P<0.001$). Mean shell-index did not differ from that in 1983.

Fledging success was not monitored, but as usual, small numbers of young were found dead beneath some of the nests. Most were decomposed but 5 were still suitable for examination and chemical analysis (Table 6). One of these had died early, probably in poor condition without body-fat, whereas another single and a brood of 3 had all died in good condition, with ample body-fat. These were all medium-aged birds bearing head- and foot-injuries similar to those seen on young in 1983, and then attributed to sibling-attack (Bell et al 1984). Intra-brood aggression, usually associated with feeding times and sometimes sufficient to cause death, has been observed in grey herons over many years (Milstein et al 1970), but the prime condition of these Troy casualties would seem to exclude food shortage as the initial cause. More extensive injuries on these birds, together with the loss of an entire brood, suggest sustained attack by an adult, possibly a parent; attack by a predator is unlikely, as any predator would be kept at bay by unattended young of this age.

To assess the long-term trend in pollutant levels in birds from this colony, a regression analysis was performed of residue values for individual eggs or chicks against year, for the period 1966-85. Levels of DDE and HEOD had declined significantly in eggs over this period, and so had levels of DDE, HEOD and PCBs in chicks (Table 7). Mercury analyses on Troy samples were not started untl 1981, and then only on chicks. In the years since then, no significant change in levels was detected.

3.3 Willoughby

In marked contrast to events at Troy, a count on 10 May showed no corresponding increase at Willoughby, which remained at the 1984 level of 20 occupied nests. Here, only one nest was new; built in isolation from both the main colony and from the recently formed 'splinter group'. This continued the fragmentation which has been a feature of this heronry in recent years. No data on breeding success were obtained, but no undue loss of eggs or chicks was evident.

3.4 Discussion

The contrasting fortunes of these 2 heronries are surprising, in view of the proximity and similarity of their locations, only 22 km apart on the edge of the Lincolnshire Wolds. Willoughby is situated on their south-eastern extremity, in a large area of unmanaged woodland, free from disturbance, and apparently largely dependent on feeding areas afforded by the drains of the coastal plain, one km distant, but extending almost 11 km to the coast. After a long decline, beginning in 1968, the colony seems to have stabilized over the past 9 seasons at about half its former numbers. No eggs have been collected since 1977, and so it is not known whether their former appreciable DDE burdens persist. The former central part of the colony is now largely abandoned, with the few new nests now usually appearing in peripheral sites, often in isolation, and seldom persisting for long. The decline and recent erratic nature of this heronry, and some possible reasons, were discussed in the 1984 report.

From its position at the foot of the Wolds, the Troy heronry gives access to a large area of drains within the catchment of the River Witham, rising in the East Midlands, as well as to its adjacent tributary, the Bain, draining from the Wolds. The large tract of woodland in which the colony is situated enjoys SSSI status and is also completely secluded from public disturbance. Although active management in the form of forestry operations has recently commenced, both this and the winter shooting are regulated seasonally so as not to impinge on the herons' breeding activities. The only potential disturbance arises from the immediate proximity of a flight-path of RAF Coningsby, which a proportion of the birds have to cross as they commute to feeding areas to the south.

At a record 102 occupied nests, preliminary results of the 1985 national census of heronries (Marquiss & Reynolds 1986) show Troy to be one of only 2 colonies exceeding 100 pairs. This is despite a continuing high frequency of egg breakage, with shell-thickness index partially recovered in the early 1970s, but now stabilized at about 5% below the general pre-DDT index. HEOD and DDE residues in collected egg samples also remain steady after initially declining in the late 1960s and early 1970s, following successive reductions in organochlorine use. Chick mortality, apparently resulting from sibling or parental attack, is too infrequent to affect the population, and food shortages seem unlikely to be implicated.

3.5 Acknowledgments

We are grateful to Major Sir David Hawley, Bt, and to Mr J L Roughton, JP, the respective owners of the Troy and Willoughby Woods, for kindly allowing our continued access to their properties to carry out these long-term studies.

3.6 References

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MARQUISS, M. & REYNOLDS, C. 1986. How many Herons? BTO News, **143**, 12.

MILSTEIN, P. le S., PRESTT, I. & BELL, A.A. 1970. The breeding cycle of the Grey Heron. Ardea, **58**, 171-257.

Table 6. Residues of organochlorine insecticides (ppm wet weight) and heavy metals (ppm dry weight) in the eggs and chick livers of herons from Troy, 1985

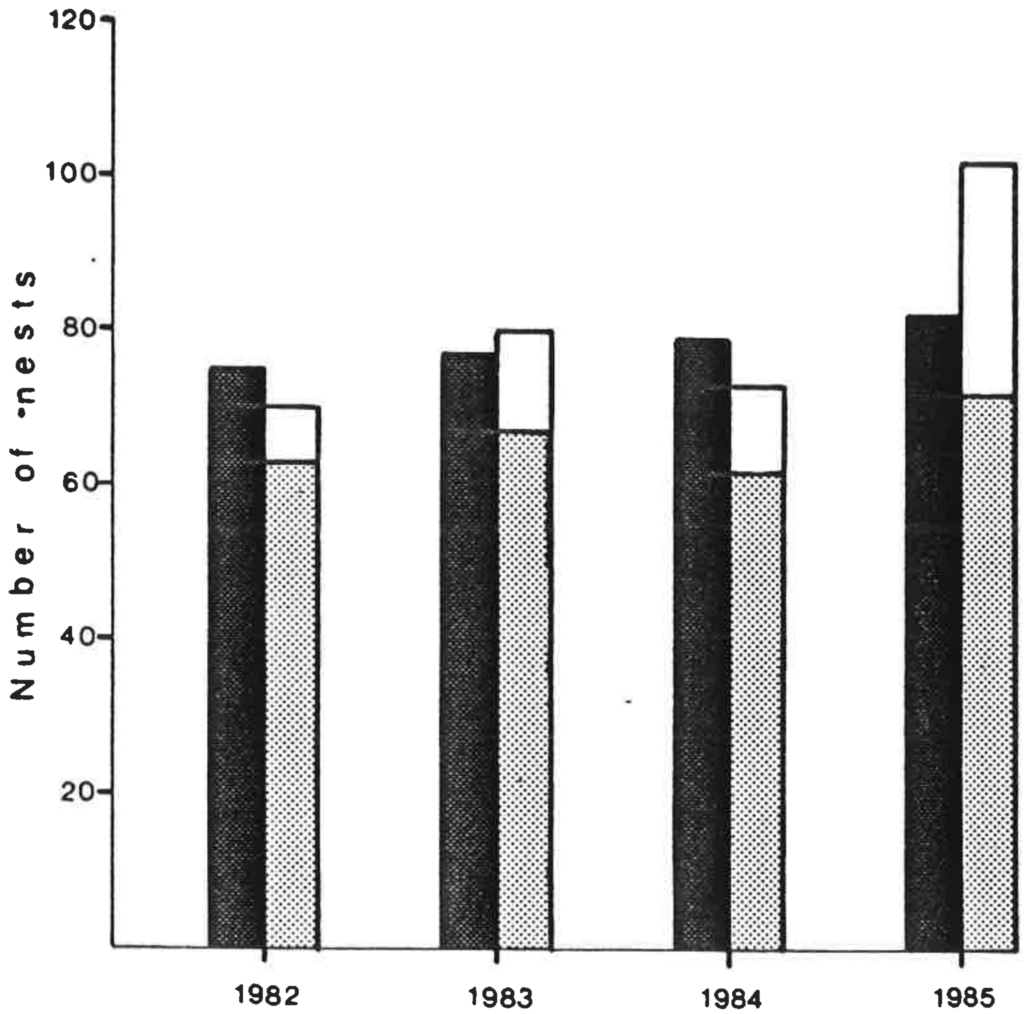
Sample	Shell-index	pp'DDE	HEOD	PCBs	Hg
Egg 1	1.87	0.54	0.42	0.57	0.99
2	1.51	2.36	0.93	ND	1.07
3	1.63	3.18	1.23	0.83	1.07
4	1.76	0.69	ND	0.56	0.74
5	1.64	4.20	ND	0.70	1.41
6	1.86	3.07	0.40	0.47	0.99
7	1.59	2.08	1.05	0.63	0.93
8	1.34	11.07	0.66	0.69	0.49
9	1.66	0.28	ND	ND	0.43
10	1.74	1.51	0.35	ND	0.79
Mean*	1.66	1.80	0.09	0.18	0.84
SD	0.16	0.47	1.40	0.87	0.16
Range within 1 SE	1.61-1.71	1.28-2.53	0.30-0.25	0.10-0.34	1.75-0.95
Chick 1	-	0.10	0.11	0.36	1.32
2	-	0.19	0.12	0.73	1.26
3	-	0.24	0.17	0.65	1.52
4	-	0.22	0.12	0.24	0.76
5	-	0.21	0.09	0.09	1.24
Mean*	-	0.18	0.12	0.33	1.19
SD	-	0.15	0.10	0.37	0.11
Range within 1 SE	-	0.16-0.22	0.11-0.13	0.22-0.48	1.06-1.34

<u>Note</u>: *geometric means for residues, arithmetic for shell-indices.

Table 7. Trends in pollutant levels in eggs and chick livers from Troy heronry, 1966-85, as revealed by regression analysis. Figures show regression coefficients and significance levels (**P<0.01, ***P<0.001).

Sample	DDE (1966-85)	HEOD (1966-85)	PCBs (1968-85)	Hg (1981-85)
Eggs	-0.018**	-0.051***	0.081	-
Chicks	-0.023**	-0.073***	-0.051**	0.007

Figure 21. Nest numbers at Troy, 1982-85. Black - numbers of nests surviving the winter; grey - numbers re-occupied; white - numbers newly built.



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BIRDS AND POLLUTION

Part 4 Pollutants in gannet eggs

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August 1986

Table 8. Residues of organochlorines (ppm wet weight) and heavy metals (ppm dry weight) in the eggs of gannets, 1985

Specimen number	Shell-index	pp'DDE	HEOD	PCBs	Hg
Ailsa Craig					
1	2.84	0.37	0.26	1.99	1.71
2	2.71	0.51	0.47	15.02	1.90
3	2.66	0.31	0.27	1.13	2.67
4	3.04	0.16	0.20	1.84	2.31
5	3.24	0.55	0.39	3.22	2.07
6	2.60	0.57	0.54	5.81	1.19
7	2.65	0.38	0.28	2.84	1.69
8	2.99	1.06	0.17	3.53	2.49
9	2.65	0.35	0.32	4.38	2.19
10	2.67	0.20	0.21	2.20	2.71
Mean*	2.81	0.39	0.29	2.87	2.08
SD	0.22	0.24	0.16	0.22	0.14
Range within 1 SE	2.74-2.87	0.33-0.46	0.26-0.33	2.44-3.37	1.88-2.31
Bass Rock					
1	3.02	0.53	0.34	4.27	1.65
2	3.04	0.63	0.33	6.00	2.52
3	2.91	0.56	0.27	2.83	2.01
4	3.26	0.51	0.30	2.80	1.28
5	3.28	0.26	0.18	2.36	1.27
6	3.38	0.21	0.12	0.99	1.21
7	3.23	0.42	0.32	3.46	1.92
8	2.92	0.32	0.25	3.14	1.43
9	3.26	0.27	0.16	2.93	2.82
10	3.18	0.19	0.06	2.25	2.29
11	2.67	0.30	0.21	1.37	1.85
12	3.48	0.25	0.19	2.40	1.55
Mean*	3.14	0.34	0.21	2.70	1.75
SD	0.23	0.18	0.22	0.21	0.12
Range within 1 SE	3.07-3.27	0.31-0.39	0.18-0.24	2.35-3.11	1.62-1.90
St Kilda					
1	2.61	0.19	0.13	2.61	2.66
2	2.92	0.53	0.17	2.57	2.64
3	2.90	0.14	0.09	1.43	1.39
4	3.07	0.12	0.09	1.49	1.51
5	3.20	0.37	0.20	3.23	2.01
6	2.76	0.73	0.24	4.04	5.06
Mean*	2.91	0.28	0.14	2.39	2.30
SD	0.21	0.32	0.18	0.18	0.20
Range within 1 SE	2.82-3.00	0.12-0.17	0.21-0.38	2.02-2.83	1.90-2.79

Note: * Geometric means for residues, arithmetic for shell-indices.

Table 9. Changes in mean residue levels in 1985 eggs from previous eggs at the same sites. Figures show t values, with significance levels (*P<0.05, **P<0.02, ***P<0.001).

	DDE	HEOD	PCB	Hg	Shell-index
Ailsa Craig	t_{18} = +2.76**	t_{18} = +5.62***	t_{18} = +2.76**	t_{18} = -2.66**	t_{18} = -1.08
Bass Rock	t_{20} = +4.08***	t_{9} = +0.004	t_{10} = 5.62***	t_{10} = -1.21	t_{20} = +0.71
St Kilda	t_{14} = +0.29	t_{6} = +2.70*	t_{10} = -1.69	t_{6} = -8.20***	t_{13} = +1.00

Note: As variances were unequal, degrees of freedom were calculated.

4 POLLUTANTS IN GANNET EGGS

4.1 Results

In 1985, samples of eggs were obtained from both main study colonies, Ailsa Craig and Bass Rock, and also from St Kilda. Residues and shell -indices are listed in Table 8.

The previous eggs from Ailsa Craig and Bass Rock were obtained in 1983, and from St Kilda in 1979. Compared to these previous eggs, those from 1985 showed some significant changes in mean residue levels (Table 9). At Ailsa Craig, DDE, HEOD, PCB and Hg levels had all increased; at Bass Rock, DDE and PCB levels had increased; and at St Kilda, HEOD levels had increased, while Hg levels had declined.

The causes of these changes were not known, but as most of them involved increases, it might be worthwhile taking further samples in 1987 or 1988, at least from the 2 main colonies.

4.2 Acknowledgments

Thanks are due to Dr Cameron Easton (Bass Rock), Barry Pendlebury and Andrew Laing (Ailsa Craig), and Dr Mike Harris, for collecting the eggs.

5 ORGANOCHLORINES IN PEREGRINE EGGS

5.1 Introduction

The aim was to pull together in one place the results of analyses of Peregrine eggs done in Britain since the previous compilation by Ratcliffe (1980), who tabulated results for 1963-78 inclusive. Like previous analyses, some were undertaken at the Laboratory of the Government Chemist, others at Monks Wood Experimental Station and yet others at Glasgow University Veterinary School (by J.A. Bogan). In the past, consistency in results from these 3 laboratories has been checked on the same samples. Usually no more than one egg per clutch was analysed, but where larger numbers were involved, mean clutch values were calculated. All eggs were either addled or deserted. The results of analyses (together with shell-indices) for all clutches are given in Table 10, arranged by region in the same way as Ratcliffe (1980). The 1978 values include some given by Ratcliffe (marked *), and others obtained subsequently. A total of 188 clutches is represented.

5.2 Results

Regional means for organochlorine values and shell-indices during 1978-85 are given in Table 11. Significant regional variation was found: (1) for DDE, where the highest regional mean recorded (Wales) was higher than the lowest (central and eastern highlands); (2) for PCBs, where the mean for the southern highland fringe was higher than those for the central and eastern highlands, northern England and southern Scotland respectively; and (3) for HEOD, where the mean for Wales was higher than that for the central and eastern highlands. Eggs from the southern highland fringe included a large proportion from coastal sites (Table 10), which accounted for the high mean level of PCBs. No significant regional variation in shell-index was apparent, but the regions with the highest mean DDE levels (Wales and the southern highland fringe) also had the lowest mean shell-indices (Table 11).

To investigate any trends in residue levels over time, regression analyses were done for 4 regions (with large samples), with the individual residue values as the dependent variable and year as the independent variable. One analysis covered the whole period of the study 1963-85, and included results in Ratcliffe (1980), and the second analysis covered the recent period 1978-85 (Table 12).

Over the longer period, for DDE declines were indicated in all regions, and emerged as statistically significant in northern England, southern Scotland and the central and eastern highlands. For HEOD, significant declines were indicated in all areas. For PCBs, no significant change was noted in any region.

Over the shorter period (1978-85), only the decline in HEOD levels in southern Scotland emerged as significant, but regression slopes were negative in almost all regions. Similarly for DDE, regression slopes were negative in all regions. In assessing these time trends, eggs from known coastal sites were omitted, because they occurred sporadically through the sample; they often had high levels which would have greatly influenced regression slopes.

In conclusion, for inland areas, trends in pesticide residues were as expected from known trends in usage, with general declines in both DDE and HEOD. In contrast, PCB levels showed no obvious change.

5.3 References

RATCLIFFE, D.A. 1980. The Peregrine. Calton: Poyser.

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BIRDS AND POLLUTION

Part 5 Organochlorines in peregrine eggs

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August 1986

Table 10. Organochlorine levels and shell-indices for peregrine eggs collected in 1978-85. Each clutch represented only once by mean values. GC = Government Chemist; MW = Monks Wood Experimental Station; UG = University of Glasgow Veterinary School; C = coastal sites; ND = not detected: Tr = trace.

Year	Analyst	Location	HEOD	DDE	PCBs	Shell-index
SOUTH-WEST ENGLAND						
1985	MW	Cornwall	0.38	2.48	1.33	1.96
WALES						
1978	UG	Merioneth	0.08	7.00	12.00	1.90
1979	GC	Merioneth	0.40	3.00	2.00	1.57
1980	MW	Merioneth	0.98	4.44	3.63	1.55
	MW	Pembrokeshire (C)	0.61	1.02	5.01	1.72
1984	MW	Powys	0.19	2.57	0.31	1.82
NORTHERN ENGLAND						
1978	UG	Cumberland	0.20	2.00	1.80	1.43*
	UG	"	0.30	6.70	4.30	1.67*
	UG	"	1.20	6.30	2.30	2.01*
	GC	"	0.20	4.00	4.00	1.60
	GC	"	0.30	6.00	2.00	1.77
	GC	Durham	0.10	2.00	<1.00	1.69
1979	GC	Cumberland	Tr	1.10	1.00	1.99
	GC	"	0.10	1.10	1.00	2.06
1980	MW	Cumberland	1.04	1.99	2.15	1.96
1982	UG	Cumberland	ND	0.88	0.31	2.23
	MW	"	0.67	2.04	0.59	1.98
	MW	"	0.63	4.32	1.29	1.70
	MW	"	0.18	3.46	1.75	1.61
	MW	"	0.21	0.91	0.41	2.17
	MW	"	0.31	1.62	0.99	1.81
	MW	"	0.09	1.70	0.71	1.96
1983	UG	Cumberland	0.02	0.76	1.28	1.89
	MW	"	0.30	1.33	0.76	2.19
	MW	"	ND	1.28	Tr	2.10
	MW	Northumberland	0.48	2.53	2.26	2.08
	MW	Northumberland	ND	2.23	0.30	1.40
1984	UG	Cumberland	0.07	1.76	2.04	1.65
	UG	"	0.30	2.40	15.65	1.60
	UG	"	0.21	3.15	5.88	1.38

Table 10 (contd)

Year	Analyst	Location	HEOD	DDE	PCBs	Shell-index
1984	UG	Cumberland	0.11	2.46	2.24	1.69
	UG	"	0.10	3.34	3.92	1.90
	UG	"	0.07	4.57	2.64	1.56
	UG	"	0.02	0.56	0.89	-
	MW	"	0.71	4.30	0.76	1.68
	MW	Northumberland	0.19	0.86	6.40	1.88
	MW	"	0.16	0.69	3.83	1.78
	MW	"	0.45	1.34	7.49	1.92
	MW	"	0.12	0.52	2.84	1.86
	MW	"	0.24	0.67	3.25	1.74
1985	MW	Cumberland	0.79	3.71	5.46	1.72
	MW	"	0.63	4.30	6.52	1.65
	MW	"	0.55	5.04	0.59	1.65
	MW	"	0.33	5.46	0.73	1.65
	UG	Northumberland	0.08	3.36	5.80	1.69
	UG	Isle of Man	0.43	2.32	3.36	1.65
SOUTHERN SCOTLAND						
1978	UG	Ayrshire	0.10	1.90	2.10	1.94*
	UG	Wigtownshire (C)	0.50	12.00	71.90	1.63*
	UG	Dumfriesshire	0.30	6.80	3.60	1.70*
	UG	"	0.20	2.00	1.10	1.90*
	UG	"	0.16	7.40	9.00	1.62*
	UG	"	0.60	1.90	1.70	1.73*
	UG	"	0.01	0.10	0.30	-*
1979	UG	Galloway	0.02	1.40	1.00	1.86
	UG	"	0.04	1.30	0.90	2.20
	UG	"	0.06	1.50	3.38	1.96
	UG	"	0.17	1.43	2.07	2.06
	UG	"	0.19	3.10	2.40	1.73
	UG	Dumfriesshire	0.04	1.10	2.50	1.60
	UG	"	0.03	0.57	0.54	1.88
	UG	"	0.04	2.40	3.40	1.80
	UG	"	0.15	0.80	0.40	2.00
	UG	"	0.18	3.30	3.40	1.72
	UG	Galloway	0.16	0.60	1.50	1.86
	UG	"	0.18	9.10	7.40	-
	UG	"	0.05	0.70	2.30	-
	UG	"	0.46	14.60	15.50	-
	UG	" (C)	0.06	3.80	4.70	1.80
	UG	" (C)	0.57	4.60	16.80	1.47
	UG	"	0.44	13.50	9.80	1.70
	UG	"	0.57	11.50	8.40	1.69
1980	UG	Galloway	0.03	1.30	1.10	1.71
	UG	"	0.20	1.70	1.80	-
	UG	"	0.04	2.00	1.40	1.84
	MW	"	1.09	6.96	7.99	1.43

Table 10 (contd)

Year	Analyst	Location	HEOD	DDE	PCBs	Shell-index
1980	MW	Kircudbrightshire	0.50	2.20	3.34	2.00
	MW	"	0.35	4.44	1.74	1.85
	MW	Wigtownshire (C)	0.28	3.39	4.65	1.76
1982	UG	Galloway	0.24	1.81	2.82	1.60
	UG	"	0.03	1.52	1.29	1.78
	UG	"	0.03	0.86	0.63	1.62
	UG	"	0.22	4.58	7.17	1.56
	UG	"	0.06	2.00	5.91	1.81
	UG	"	0.85	6.94	7.27	-
	UG	"	0.04	1.38	2.15	1.54
	UG	"	0.04	2.26	4.50	1.92
	UG	"	0.16	1.54	4.39	1.69
	UG	"	0.05	2.80	0.71	1.78
	UG	"	0.07	1.38	0.78	1.74
	UG	"	0.20	3.05	4.47	1.88
	UG	Dumfriesshire	0.14	2.11	1.40	1.76
	UG	Midlothian	0.60	2.02	1.65	1.65
1983	UG	Dumfriesshire	0.15	2.00	2.23	1.87
	UG	"	0.60	0.35	2.00	1.69
	UG	Galloway	0.02	0.78	0.97	1.65
	UG	"	0.02	0.72	0.17	1.99
1984	UG	Lanarkshire	0.01	0.84	0.79	2.03
	UG	Dumfriesshire	0.05	1.43	2.34	1.75
	UG	Galloway	0.26	2.39	5.77	1.78
	UG	"	0.07	2.00	1.70	1.69
	UG	"	0.35	2.22	1.32	1.90
	UG	"	0.27	2.92	1.81	-
	MW	Roxburghshire	0.09	1.25	0.72	1.82
	MW	"	ND	ND	ND	-
1985	MW	Dumfriesshire	0.06	1.48	1.37	1.72
	UG	Peebles	0.01	1.10	1.47	1.84
	UG	"	0.02	1.50	1.13	1.57
	UG	Ayrshire	0.52	3.79	10.50	-
	UG	Dumfriesshire	0.04	1.05	1.33	1.65
	UG	Galloway	0.04	3.67	4.92	1.42
	UG	Ayrshire	0.05	2.11	8.68	1.62

SOUTHERN HIGHLAND FRINGE

Year	Analyst	Location	HEOD	DDE	PCBs	Shell-index
1978	UG	Perthshire	0.03	0.40	0.80	1.84*
	UG	"	0.20	5.20	4.70	-*
	UG	Argyll (C)	0.43	5.35	28.93	1.37*
1979	UG	Stirlingshire	0.09	0.80	1.30	1.82
	UG	"	0.04	2.50	2.40	2.05
	UG	"	0.02	0.20	0.40	1.91

Table 10 (contd)

Year	Analyst	Location	HEOD	DDE	PCBs	Shell-index
1979	UG	Buteshire	0.30	2.90	2.00	1.93
	UG	"	0.45	14.60	3.90	1.45
	UG	Argyll	1.60	24.60	4.00	1.86
	UG	"	0.02	2.20	5.30	-
	UG	Renfrewshire	0.15	2.60	2.60	-
1980	MW	Buteshire	0.50	9.50	57.70	1.36
	MW	"	0.40	5.60	20.10	1.74
	MW	Dunbartonshire	0.20	1.70	24.80	-
	UG	Perthshire	0.20	5.50	6.30	2.06
	UG	Stirlingshire	0.30	1.20	1.20	1.61
1982	UG	Argyll	0.49	2.09	12.34	-
	UG	"	0.35	5.10	14.41	-
	UG	"	0.06	1.48	5.47	1.47
1983	UG	Buteshire	0.54	7.68	9.49	-
	UG	"	0.17	3.21	9.43	1.60
	UG	"	0.34	5.46	12.98	1.56
	UG	Argyll	1.20	6.29	44.50	1.81
	UG	"	1.45	8.21	64.12	1.47
	UG	Perthshire	0.05	1.25	1.71	1.88
1984	UG	Stirlingshire	0.20	5.83	14.94	1.58
	UG	Kintyre	0.60	5.33	8.99	1.52
	UG	Argyll	0.20	6.40	27.16	-
	UG	"	0.04	1.02	7.80	1.69
	UG	"	0.01	2.87	1.81	1.65
	UG	"	0.06	3.50	8.68	1.66
	UG	"	0.21	2.51	9.54	1.95
	UG	Perthshire	0.17	4.24	3.85	1.58
	UG	"	0.04	0.74	0.99	2.00
	UG	"	0.02	0.52	1.17	1.75
	UG	"	0.01	0.62	0.60	2.02
	UG	"	<0.004	0.28	0.53	1.97
	UG	"	0.04	1.83	1.15	1.60
	UG	"	0.11	0.20	0.18	1.77
	UG	"	<0.003	1.00	1.10	1.82
	UG	Buteshire	0.24	6.23	13.54	-
	UG	"	0.08	6.24	1.44	1.82
1985	UG	Argyll	0.52	4.89	37.22	1.51
	UG	"	0.02	1.31	0.91	1.67
	UG	"	0.03	2.47	12.72	1.73
	UG	"	0.01	0.13	0.68	2.30

Table 10 (contd)

Year	Analyst	Location	HEOD	DDE	PCBs	Shell-index
CENTRAL AND EASTERN HIGHLANDS						
1978	UG	Inverness-shire	0.20	5.20	4.70	1.80
	UG	Perthshire	0.01	0.90	3.00	1.91
1980	UG	Inverness-shire	0.10	1.30	3.20	1.92
1981	MW	Angus	0.10	0.84	0.13	1.61
1982	UG	Inverness-shire	0.07	1.38	0.78	1.74
	UG	Perthshire	0.01	0.15	0.61	1.33
	UG	"	0.02	0.63	1.08	1.83
	UG	Fifeshire	0.10	3.53	4.43	1.54
	MW	Inverness-shire	0.06	0.77	3.29	-
	UG	Aberdeenshire	0.01	0.35	0.64	-
	UG	Banffshire	0.01	0.48	1.11	1.63
	UG	"	<0.003	0.15	0.43	1.76
	UG	Fifeshire	0.06	3.27	1.86	1.96
1984	UG	Kincardineshire	0.02	0.80	0.99	1.65
	UG	"	0.02	0.65	0.39	1.42
	UG	"	0.15	5.60	4.65	1.92
NORTHERN AND WESTERN HIGHLANDS						
1978	GC	Wester Ross	0.50	9.00	25.00	1.53
1982	UG	Orkney (C)	0.10	4.14	20.64	1.62
1984	UG	Wester Ross	0.01	2.00	8.32	1.94
IRELAND						
1983	MW	Antrim	0.25	2.76	2.33	1.48
1984	MW	Waterford (C)	2.03	1.31	8.47	1.68
	MW	" (C)	ND	ND	5.45	1.58
1985	MW	Waterford (C)	0.21	2.32	0.72	1.60
	MW	" (C)	0.13	2.10	0.37	1.54
	MW	" (C)	0.44	1.41	0.19	1.88
	MW	" (C)	0.12	0.99	0.31	1.80
	MW	" (C)	0.48	1.68	1.04	1.54

*Reported in Ratcliffe (1980).

Table 11. Regional means of organochlorine levels and shell-indices for peregrine eggs collected in 1978-85. Only regions with eggs from more than 5 clutches are included; residue levels are expressed as geometric means and shell-indices as arithmetic means.

Region	DDE	HEOD	PCBs	Shell-index
NORTHERN ENGLAND (40)				
Mean	2.08	0.14	1.67	1.79
SD	0.31	0.78	0.48	0.22
Range within 1 SE	1.86-2.33	0.13-0.14	1.41-2.00	1.68-1.75
WALES (5)				
Mean	3.00	0.33	2.67	1.71
SD	0.31	0.43	0.59	0.15
Range within 1 SE	2.18-4.14	0.21-0.51	1.45-4.92	1.64-1.78
SOUTHERN SCOTLAND (66)				
Mean	1.73	0.10	1.97	1.77
SD	0.56	0.58	0.50	0.16
Range within 1 SE	1.47-2.04	0.08-0.11	1.71-2.29	1.75-1.79
SOUTHERN HIGHLAND FRINGE (43)				
Mean	2.52	0.14	5.01	1.72
SD	0.51	0.60	0.64	0.21
Range within 1 SE	2.08-3.05	0.11-0.18	3.94-6.37	1.69-1.76
CENTRAL & EASTERN HIGHLANDS (23)				
Mean	1.03	0.02	1.36	1.77
SD	0.48	0.02	0.43	0.20
Range within 1 SE	0.81-1.30	0.02-0.02	1.10-1.68	1.72-1.81

Notes:

For DDE, the mean level for Wales was higher than that for the central and eastern highlands ($t_{25} = 2.05$, $P<0.06$).

For HEOD, the mean level for Wales was higher than that for the central and eastern highlands ($t_{25} = 5.87$, $P<0.01$).

For PCBs, the mean level for the southern highland fringe was higher than those for the central and eastern highlands ($t_{25} = 3.68$, $P<0.001$), northern England ($t_{76} = 3.71$, $P<0.001$) and southern Scotland ($t_{98} = 3.52$, $P<0.001$).

Table 12. Trends in organochlorine levels in peregrine eggs from different regions. Figures show regression coefficients, with significance levels.

Region	Period	HEOD	DDE	PCBs
NORTHERN ENGLAND	1963-85	-0.044 **	-0.041 ***	0.005 ns
	1978-85	0.003 ns	-0.019 ns	0.034 ns
SOUTHERN SCOTLAND	1963-85	-0.045 ***	-0.049 ***	0.009 ns
	1978-85	-0.061 *	-0.047 ns	-0.028 ns
SOUTHERN HIGHLAND FRINGE	1963-85	-0.046 **	-0.005 ns	0.031 ns
	1978-85	-0.039 ns	-0.009 ns	0.051 ns
CENTRAL & EASTERN HIGHLANDS	1963-85	-0.052 ***	-0.023 **	-0.006 ns
	1978-85	-0.079 ns	-0.041 ns	-0.085 ns

Notes:

ns = not significant; * = $P<0.05$; ** = $P<0.01$: *** = $P<0.001$.

Analyses for PCBs began in 1967, except for northern England where they began in 1969.

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BIRDS AND POLLUTION

Part 6 Puffins and PCBs

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August 1986

6 PUFFINS & PCBs

In 1985, 2 dosed and 2 control puffins were found and collected. The small sample reflected the difficulty of locating the few puffins still remaining from the experiment, which started in 1977. As a supplement to the controls, 3 other puffins were collected.

PCB residues were similar in both pairs of the experimental birds (Table 13), and the results were considered to be similar to those obtained in recent years. PCB residues in the fat of control puffins from the Isle of May may have declined since the first samples were collected in the late 1970s, but regression analysis gave a non-significant result. Residues in the 3 other puffins that were collected in 1985 were similar to those found in the 4 experimental birds (Table 14).

In addition to residues of PCBs, a number of other organochlorines were detected. For example, for fat, DDE and HEOD occurred in all 6 samples (ranges - DDE 2.1-4.5 ppm; HEOD 0.9-1.6 ppm), heptachlor epoxide in 5 (range - 0.4-0.6), and HCB was present in at least 5 (range - 0.5-0.9 ppm.).

No further analysis of the data was done as the study continues under the new contract.

Table 13. Levels (ppm wet weight) of PCB in tissues of puffins killed at various times after implantation of PCB (dosed) or sucrose (control)

	Months after implantation	Fat	Liver	Kidney	Muscle	Brain
Dosed	1	301	43.1	ND	6.9	ND
	1	299	24.5	2.6	3.9	ND
	1.5	251	9.9	ND	7.3	ND
	3.5	280	ND	ND	ND	ND
	3.5	347	48.4	ND	21.1	50.9
	3.5	612	16.4	9.9	20.4	4.0
	3.5	610	21.5	12.5	20.1	ND
	3.5	516	24.0	11.3	25.2	ND
	3.5	451	23.1	11.6	17.8	13.0
	9	654	6.3	4.7	2.3	<1.0
	9	371	2.1	<1.0	2.6	<1.0
	9	429	14.0	<1.0	6.3	<1.2
	12	284	10.0	4.5	8.1	ND
	12	105	3.5	2.6	4.0	ND
	12	294	17.3	2.8	10.2	4.5
	12	141	9.8	2.7	3.4	1.0
	12	457	10.5	8.2	14.8	6.0
	16	341	ND	ND	ND	ND
	16	200	ND	ND	ND	ND
	16	128	<1.0	ND	ND	ND
	16	211	30.3	14.1	12.4	8.2
	16	214	ND	ND	ND	ND
	16	118	1.2	1.0	7.7	2.7
	34	-	7.7	1.6	3.2	7.6
	34	93.5	2.4	ND	ND	ND
	34	124	3.2	ND	2.0	ND
	34	82.2	ND	ND	ND	ND
	34	97.1	2.6	ND	ND	ND
	34	97.1	1.0	ND	ND	ND
	48	7.8	ND	ND	ND	ND
	48	12.2	ND	ND	ND	ND
	48	8.6	ND	ND	ND	ND
	48	0.6	ND	ND	ND	ND
	48	1.3	ND	ND	ND	ND
	48	9.9	ND	ND	ND	ND
	48	32.0	ND	ND	ND	ND
	57	0.6	ND	ND	ND	ND
	58	6.9	ND	ND	ND	ND
	58	6.2	ND	ND	ND	ND
	58	8.6	ND	ND	ND	ND
	58	11.1	ND	ND	ND	ND
	58	28.0	ND	ND	ND	ND
	60	11.8	ND	ND	ND	ND
	60	89.6	2.5	ND	1.0	4.6
	60	-	1.2	1.6	0.8	1.2
	60	40.7	2.5	ND	0.5	0.6
	60	23.0	2.4	ND	ND	0.5

Table 13 (contd)

	Months after implantation	Fat	Liver	Kidney	Muscle	Brain
Dosed	65	47.0	0.9	2.6	0.9	0.7
	65	-	1.1	1.1	0.8	ND
	65	25.4	1.0	0.6	1.1	0.6
	72	9.4	3.1	3.3	0.4	6.4
	73	12.6	0.6	3.4	0.8	0.3
	73	17.8	1.3	1.0	0.6	1.0
	73	18.1	3.7	0.7	2.9	1.5
	73	22.5	17.3	1.4	3.1	10.8
	77	84.1	3.6	0.8	0.7	0.2
	77	-	0.6	0.8	0.8	0.2
	85*	10.8	0.7	ND	ND	ND
	94*	9.7	ND	ND	ND	ND
Control	3	ND	ND	ND	ND	ND
	24	25.7	ND	ND	ND	ND
	24	69.9	1.3	1.9	1.0	1.4
	24	34.5	ND	ND	ND	ND
	26	49.4	ND	ND	ND	ND
	28	38.5	ND	ND	ND	ND
	34	57.0	ND	ND	ND	ND
	34	73.6	ND	ND	ND	ND
	34	28.7	ND	ND	ND	ND
	34	28.1	ND	ND	ND	ND
	48	0.4	ND	ND	ND	ND
	48	0.6	ND	ND	ND	ND
	48	0.3	ND	ND	ND	ND
	48	3.0	ND	ND	ND	ND
	60	14.1	ND	ND	ND	ND
	60	8.2	ND	ND	ND	ND
	82	1.0	3.5	1.8	0.5	ND
	82	-	2.3	0.6	ND	0.8
	97*	16.4	2.4	ND	0.7	ND
	97*	9.1	ND	1.3	0.8	ND

<u>Notes</u>: *Birds collected in 1985

ND = no PCB detected (limit of detection c. 0.5 ppm)

- = no sample possible

Table 14. PCB concentrations (ppm wet wt) in other puffins collected in 1985

Bird description	Fat	Liver	Kidney	Muscle	Brain
Normal	-	1.3	ND	ND	ND
Killed in collision	14.8	0.5	ND	ND	ND
Found dying (in convulsions)	18.0	1.0	ND	ND	ND

Notes: ND = no PCB detected (limit of detection c. 0.5 ppm).

- = no sample possible.

INSTITUTE OF TERRESTRIAL ECOLOGY
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BIRDS AND POLLUTION

Part 7 Aluminium in dipper eggs

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7 ALUMINIUM IN DIPPER EGGS

7.1 Introduction

Nyholm and Myhrberg (1977) have reported impaired reproduction in insectivorous birds living near freshwaters in Sweden; this was subsequently linked to aluminium interference with calcium and phosphorus metabolism in the female bird, resulting in eggshell thinning (Nyholm, 1981). In Canada, recent work has shown that a small, but significant, part of the variance in the reproductive parameters of insectivorous birds was due to water chemistry influenced by lake acidification (Ormerod, pers comm). In Britain, the decline of dipper (Cinclus cinclus) populations in some upland rivers in southern Scotland was noted by Fry and Cooke (1984). Dipper territories have increased in area in acid rivers over the last 20 years. This coincides with a decrease in the invertebrate populations on which dippers feed (Fry, unpublished). Recent work too (Ormerod, 1985; Ormerod et al, 1985) has shown a positive correlation between the abundance of breeding dippers and water pH. The authors suggest this may be because their macro-invertebrate prey is scarce at low pH (Stoner et al, 1984). This report summarizes analytical studies of 31 dipper eggs and 21 invertebrate samples. The samples were collected from Welsh streams by RSPB field workers. The RSPB and Welsh Water Authority are examining the impact of acidification on populations of dippers and grey wagtails. The objectives of the work are:-

a) to find whether aluminium concentrations are elevated in eggs from near acid streams;
b) to determine whether the physical characteristics (eg thickness) of the shell are different near acid streams;
c) to find whether aluminium concentrations in typical invertebrate prey are higher in samples from acid streams.

A similar study is in progress at the Edward Grey Institute, Oxford, using eggs from dipper nests in southern Scotland collected under licence from NCC (Vickery, pers comm).

7.2 Methods - egg and invertebrate samples and sampling site chemistry

The egg and invertebrate samples were supplied by RSPB together with details of the collection sites. Eggs collected were either addled or deserted. Before chemical analysis physical measurements and detailed notes were made on each of the eggs, and on the invertebrate samples.

7.2.1 Egg descriptions

Upon receipt each egg was allocated two reference numbers, an analytical reference number and a number 1-31 which is used throughout this report. A brief description of the eggs was provided by the RSPB (Table 15), this includes the grid reference of the nest site, the name of the adjacent river and the egg reference number. Additional measurements by us are summarized in Table 16. These include shell length, breadth and thickness, the condition of each egg on arrival and the condition of the contents and shell after "blowing", ie cutting open the shell with a scalpel and scraping out the contents. Eggshell thickness was measured mechanically using a modified micrometer screw gauge.

7.2.2 Invertebrate sample description

Eight sets of invertebrate samples were supplied by RSPB fieldworkers from 7 sites of various chemistries (Table 17). For most sites separate samples of stonefly, mayfly and caddisfly larvae were available, but for a few sites no caddis or mayfly larvae were collected (Table 18). The samples had been stored in formalin solution. This may have led to leaching of aluminium from the specimens (Ormerod, pers comm). The specimens were measured and counted before chemical analysis (Table 18).

7.2.3 Sampling site chemistry

Chemical data on the stream water at each invertebrate sampling point and adjacent to each nest site were supplied by the Welsh Water Authority (Table 17). Mean pH, Ca and filterable Al are reported together with standard deviations and the number of observations on which these were based. It was noticeable from these values that pH, Ca and Al levels were correlated and that, as would be expected, low pHs were associated with low Ca values and higher Al concentrations. Only one egg collection site had a mean pH <5.5 however (Camddwr, pH 5.26), and this was the only river with significant amounts of Al in solution. Four sites of invertebrate collections were pH <5.5 (Table 17).

7.3 Methods - chemical analysis

Eggshells and egg contents were analysed separately for both Ca and total Al. Ca analyses were done by standard methods using atomic absorption spectrophotometry. Al analysis required development of suitable chemical methods as no standard analytical method has been described in the literature. The methods developed were checked using sub-samples of chicken eggshell and contents, spiked with known amounts of aluminium. Recoveries were close to 100%.

7.3.1. Aluminium analysis of eggshells

Eggshells, together with the membrane adhering to the inner surface, were carefully cleaned and dried to constant weight at room temperature. Weighed samples were digested with concentrated nitric acid, with subsequent treatment with hydrogen peroxide. The dried digest was dissolved in dilute hydrochloric acid and made up to known volume. Samples were analysed using the catechol violet colorimetric method (Bull & Hall, in press). The method of additions with standard solutions of aluminium was used to eliminate any interferences from the digest solutions.

7.3.2 Aluminium analysis of egg contents

The contents from each egg were thoroughly homogenised with glass distilled water. A portion of homogenate was dried to constant weight at 80°C. Samples were digested with a nitric/perchloric acid mixture and analysed using catechol violet as above (Wilson, 1984).

7.3.3 Aluminium analysis of invertebrates

Upon receipt, the invertebrate samples were carefully washed with distilled water, the number of animals counted and measured, and then dried to constant weight at 70°C. The dried samples were digested and analysed in the same way as egg contents.

7.4 Results - physical measurements of eggs

Size, weight and thickness of eggshell were compared with stream pH values. Whilst no apparent changes of egg length or width were observed with changes of stream pH, shell weight seemed, at first sight to be lower at lower pHs (Figure 22). However, notes on the shell condition showed clearly that those from the low pH streams were incomplete shells. Eggshell thickness showed an even more pronounced decrease below pH 6.5 (Figure 23). This apparent clear trend, however, was the result of the shell thickness of eggs from only two egg clutches. In addition, those from the lowest pH stream were eggs which had well developed embryos. The shells seemed more brittle to handle, and, on close observation, were obviously without a membrane adhering to the inner surface of the shell.

7.5 Results - aluminium concentrations

The aluminium concentrations measured were compared with the physical measurements made on the samples and the chemical characteristics of the stream near the sampling site.

7.5.1 Aluminium in eggshells

Al levels in eggshells were low, ranging from 1 to 11 $\mu g\ g^{-1}$. (Table 19). If Al concentrations were plotted against stream pH values (Figure 24) there were no apparent trends across the pH range studied. Even within clutches the variation was as great as that between clutches. There were no obvious correlations of Al levels with any other stream parameter or any of the observations we have made on the eggs themselves.

7.5.2 Aluminium in egg contents

Al concentrations in egg content varied even more than in shells - 0-26 $\mu g\ g^{-1}$ dry weight. (Table 19). Once again within clutch variations were high and no apparent trends with stream pH were discernable (Figures 25). No other correlations with stream or egg measurements were found. The concentrations were within the range reported for dipper egg content by Lachenmayer et al (1985). They have not related their concentrations to stream pH, but have reported higher Al levels in eggs collected in April and early May than in those collected later in the year.

7.5.3 Aluminium in invertebrates

The invertebrates were from sites with a stream pH range of 4.7 to 7.1. (Table 17). There was some variation in the levels of Al found in the 3 taxa of invertebrates, with generally lower levels in the mayfly larvae samples ie 30 - 2200 μg g^{-1} (Table 21). The stonefly and caddisfly larvae samples were in the range 500 - 5600 μg g^{-1}, showing some fluctuations but neither consistently higher or lower than the other. The values obtained were fairly similar to those found by Sadler & Lynam (1985), and those reported by Lachenmayer et al (1985).

The Al levels were plotted against stream pH but revealed no obvious correlation for any of the taxa analysed (Figure 26).

7.6 Results - calcium concentrations

Calcium concentrations in eggshell and egg contents showed opposite trends at the lowest stream pH levels (Figures 27 & 28). Much of this trend, however, was associated with the well developed embryos which were found in several of the eggs from the more acid sites. As would be expected, the calcium content of the developed embryos was higher than the undeveloped egg content, whilst the shell calcium levels were lower for the developed embryos. Some of this change was associated with movement of calcium from the shell to the developing embryo, though some too may have resulted from inclusion of shell membrane and shell fragments with the contents when the eggs were "blown". Loosening of the membrane occurs prior to hatching and these analyses confirm our shell thickness measurements and observations on eggshells with developed embryos (Section 7.4).

7.7 Conclusions and recommendations

There was no evidence to show that aluminium concentrations in egg contents or shells were different for eggs collected from different pH waters. Although there may have been a possibility that some eggshell thinning occurred near acid waters, this effect was confounded, in these samples, with the changes associated with developing embryos. We recommend that further samples of eggs are collected, especially from water with pH <5.5, to find whether shell thinning really occurs.

Any future sampling for invertebrates must be carefully planned. The animals analysed to date showed no clear trends of aluminium content with pH. However, we have no information on how invertebrates accumulate aluminium, and whether differences with size, age or season are likely. The samples analysed had similar levels to those previously reported, so loss of aluminium on storage may not have been the problem at first supposed. Nevertheless, we recommend that samples collected in the future are deep frozen if they are to be analysed for aluminium. There is an obvious need to measure aluminium concentrations in water and invertebrate populations to determine possible relationships. These should include studies on size and seasonal effects, as well as short-term fluctuations in changing water conditions. Ideally such studies should take place near breeding dipper populations. Only one invertebrate sampling site was the same as that from which eggs were collected in this present study.

7.8 Acknowledgements

We are grateful to F Moriarty and H Hanson for advice on the physical measurements of eggs. We are also grateful to S Ormerod (Welsh Water Authority) and S Tyler (RSPB) for supplying the samples and technical information on the sampling sites.

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TABLE 15 Details of dipper eggs supplied by the RSPB

Egg reference number	Nest site	Adjacent river	Grid ref.	Date collected	Egg description
1	Rockfield	Monnow	S0482149	09/06/85	3 pulli 6-7 days
2	Llanfihangel Crucorney	Afon Honddu	S0323211	18/04/85	2 pulli 12 days
3	Nr. Cregrina	Edw	S0110500	28/04/85	deserted, 1 cracked
4					
5					
6					
7	Nr Erwood	Bach Howey	S0118435	13/05/85	pulli 4-5 days.
8	Newbridge	Wye	–	06/05/85	–
9	Llanbadarn Fynydd	Ithon	S0097782	25/04/85	–
10					
11	Glasbury	Llyfri	S0163366	28/04/85	pulli 7 days, broken.
12	Llangurig	R. Wye near mouth of R.Bidno	SN890800	05/05/85	Under bridge on ledge , no nest
13	Nr. Builth Wells	Chewfru	S0032513	06/05/85	unhatched old egg
14	Nr. Rhayader	Elan	SN954669	20/04/85	pulli 1-2 days
15	Cwmhinddu	Duhonw tributary	S0031478	early April 1985	deserted, laid 31 March
16					
17	Cynghordy	Abercrychan	SN793372	10/04/85	addled, pulli C.8 days
18	Nr. Cwmystwyth	Afon Ystwyth	SN758730	01/05/85	deserted
19					
20	top of Tywi Valley	Camddwr	–	05/05/85	deserted, 2 of the eggs frozen in one pot
21					
22					
23					

TABLE 15 Cont

Egg reference number	Nest site	Adjacent river	Grid ref.	Date collected	Egg description
24	-	Afon Groes	SN706610	19/05/85	deserted
25					
26					
27					
28	Carno	Afon Garno	SN994958	05/05/85	unhatched pulli C.15 days
29	New Mills	Afon Rhiw	SJ091014	21/04/85	pulli 9-10 days
30	-	Nant Rhydol	SN76166	19/05/85	cracked
31	Llancillo	Monnow	SO379253	24/04/85	deserted

TABLE 16 Measurements and descriptions of egg samples

Egg reference no.	Shell length (cms)	Shell breadth (cms)	Shell thickness (mm)	Condition of egg upon receipt	Condition of contents after "blowing"	Amount of shell present	Membrane condition
1	2.705	1.885	0.107	some contents lost	Creamy	a	z
2	2.510	1.835	0.088	Cracked, about ⅓ contents lost	Creamy	a	z
3	2.690	1.995	0.094	Cracked, some contents lost, egg grey	Bad	b	z
4	2.660	1.995	0.091	Cracked, some contents lost egg grey	'Fresh' yolk growing mould	a	z
5	2.65	1.940	0.099	Cracked, hole, contents grey, with about ⅔ lost	Dried up	a	z
6	2.625	1.910	0.095	Cracked, hole, most contents lost, egg grey	Dried up	c	y
7	2.640	1.885	0.095	Cracked, some contents lost and still leaking	Creamy	c	x
8	2.740	1.800	0.097 (ii)	Cracked, some contents lost and still leaking, egg grey	–	a	x
9	2.600 (i)	1.925 (i)	0.101	Broken in handling	Addled	a	z
10	2.685	1.960	0.097	Intact, small crack	–	b	z
11	2.495	1.820	0.100 (ii)	Large hole, some shell missing, most contents lost, those remaining gelled	Rotting embryo	c	x
12	2.575	1.880	0.096	Cracked, some contents lost, those remaining black	'Fresh' with mould growing	b	z
13	2.575	1.875	0.097 (ii)	Intact	Addled	c	x
14	2.665	1.885	0.096	Small hole, otherwise intact	'Fresh'	b	z
15	–	1.845	0.099	Cracked, hole, some contents lost and still leaking	Addled	b	z

TABLE 16 Cont

Egg reference no.	Shell length (cms)	Shell breadth (cms)	Shell thickness (mm)	Condition of egg upon receipt	Condition of contents after "blowing"	Amount of shell present	Membrane condition
16	2.540 (i)	1.890 (i)	0.100	Very cracked most contents lost	-	c	y
17	-	1.900	0.111	Cracked, broken in handling	-	a	z
18	2.550	1.880	0.081	Intact, some fine cracks	Dessicated	c	y
19	2.570	1.950	0.090	Small hole, otherwise intact	Drying out	b	y
20	2.680	1.880	0.092 (ii)	Cracked, some contents lost	Embryo with feathers	c	x
21	-	-	0.072 (iv)	Badly broken	Embryo with feathers	c	x
22	-	-	0.074 (iii)	Badly broken	Embryo with feathers	c	x
23	-	-	0.071 (iii)	2 eggs broken and frozen in one pot	Both embryos with feathers	c	x
24	2.700	1.940	0.091	Very cracked, some some contents lost and still leaking	Creamy	c	y
25	2.53	1.975	0.091	Cracked, some contents lost	Dried creamy	b	y
26	2.640 (i)	1.945 (i)	0.105	Cracked, some contents lost, still leaking, egg grey	Rotten embryo	c	y
27	2.580	1.980	0.092	Cracked, large hole, some contents lost, egg grey	Bad	c	y
28	2.635	1.945	0.097	Cracked, some contents lost, still leaking, smelly	Addled	b	y

TABLE 16 Cont

Egg reference no.	Shell length (cms)	Shell breadth (cms)	Shell thickness (mm)	Condition of egg upon receipt	Condition of contents after "blowing"	Amount of shell present	Membrane condition
29	-	-	0.106	Cracked, large holes, some contents lost	Dessicated	c	z
30	2.505	1.840	0.100	Cracked, small hole, some contents lost	Dried up, Embryo?	c	y
31	2.665	1.830	0.088	Cracked, mouldy, some some contents lost	Yolk only, albumen lost	c	y

KEY

i Estimated measurements due to shell damage
ii Summed total of separate shell and membrane measurements
iii No membrane visible
iv Possibly no membrane

a Approximately 100% shell present
b Most of shell present
c Percentage of shell present doubtful

x Membrane wholly separated from shell
y Membrane partially separated from shell
z Membrane not separated from shell

TABLE 17 Water quality at collection sites

Egg site reference no.	pH			$CaCO_3$			Filterable Al ($\mu g\ g^{-1}$)		
	x	SD	n	x	SD	n	x	SD	n
1	8.07	0.40	18	182.4	45.3	16	-		
2	8.18	0.18	18	130.7	20.0	17	-		
3									
4	7.54	0.36	18	84.18	22.8	16	-		
5									
6									
7	7.54	0.33	16	85.28	17.47	14	-		
8	6.80	0.47	28	18.04	9.27	26	-		
9	7.64	0.37	19	68.00	20.9	20	-		
10									
11	No data								
12	5.89	0.68	34	8.45	-	29	0.099	-	26
13	6.80	0.57	6	22.0	-	4	-		
14	6.60	0.63	32	12.3	4.93	33	-		
15	7.27	0.37	19	59.6	16.76	17	-		
16									
17	7.3	-	1	49	-	1	-		
18	5.75	0.90	7	10.2	2.4	7	0.040	-	4
19									
20									
21	5.26	0.92	45	6.43	1.43	41	0.176	0.116	39
22									
23									
24									
25	6.57	0.33	25	13.04	3.35	25	0.032	0.018	25
26									
27									
28	6.98	0.36	7	27.62	2.26	8	-		
29	7.26	0.45	5	53.8	15.4	5	-		
30	6.12	0.64	23	6.87	-	23	0.034	-	23
31	8.07	0.4	18	182.4	45.3	16	-		
Invertebrate sampling sites									
Ystwyth	5.4	-	>30	7.66	-	>30	0.225	-	>30
Gwesyn	5.93	0.55	30	8.61	1.64	28	0.049	0.039	29
Doethie	5.59	0.61	60	7.88	1.42	50	0.123	0.072	47
LI2	4.70	0.23	74	5.26	1.34	76	0.492	0.137	74
LI6	6.84	0.53	50	14.31	7.78	48	0.067	0.067	48
LI7 pre	7.10	0.30	45	20.68	9.23	42	0.040	0.020	40
LI7 episode	5.02	0.10	92	16.20	5.10	20	0.347	0.047	19
CI3	5.33	0.33	161	3.49	1.66	165	0.107	0.043	146

TABLE 18 Description of invertebrate samples

Invertebrate sampling site	Species	No.	Approx. size (mm)	Dry wt (g)
Ystwyth	S	8	13	0.0516
	S	13	8	
	M	1	20	
	M	1	11	0.0123
	M	4	7	
	C	1	9	0.0022
Gwesyn	S	12	13	0.0332
	S	12	7	
	M	1	25	0.0364
	M	8	10-12	
	C	3	10	0.0119
Doethie	S	13	13	0.0049
	C	1	15	0.0083
	C	6	10-12	
LI2	S	8	10-12	0.0166
	S	54	<10	
	M	1	18	0.0176
	M	4	10-12	
LI6	S	7	10	0.0215
	S	6	<10	
	M	2	15-20	0.0241
	M	6	<10	
	C	7	10	0.0215
	C	5	<10	
LI7 pre	S	3	>10	0.0183
	S	10	<10	
	M	3	>10	0.0201
	M	4	10	
	C	17	6-12	0.0277
LI7 ep	S	8	5-10	0.0040
	M	5	15	0.0226
	M	5	5-10	
	C	44	5-10	0.0130
CI3	S	17	5-10	0.0221
	M	4	10-15	0.0192

Key to species:-

S Stonefly
M Mayfly
C Caddis

TABLE 19 Al and Ca in egg shells and contents

Egg reference no.	Eggshell Al $\mu g\ g^{-1}$	Eggshell Ca $\mu g\ g^{-1}$	Egg contents Al $\mu g\ g^{-1}$	Egg contents Ca $\mu g\ g^{-1}$
1	20	340000	-	4700
2	5	350000	5	4200
3	5	360000	-	3400
4	10	360000	-	3800
5	10	340000	20	5300
6	10	380000	-	2900
7	5	340000	-	13000
8	10	370000	5	9700
9	10	350000	5	1600
10	10	360000	10	2600
11	10	350000	10	10000
12	-	350000	10	3300
13	5	350000	-	9300
14	5	350000	-	2900
15	-	350000	-	2900
16	5	340000	25	6700
17	5	350000	5	2200
18	5	320000	-	3800
19	-	320000	-	3700
20	5	340000	15	17000
21	10	360000	15	22000
22	-	300000	10	19000
23	-	300000	10	30000
24	10	300000	-	9200
25	10	350000	-	7500
26	-	280000	15	7400
27	-	330000	10	3700
28	10	360000	10	3000
29	10	350000	5	4500
30	-	360000	20	12000
31	-	360000	-	8400

TABLE 20 Al in invertebrate larvae ($\mu g\ g^{-1}$)

Invertebrate Sampling Site	Stonefly	Mayfly	Caddis
Ystwyth	1600	1900	2400
Gwesyn	2800	2200	5600
Doethie	3600		1400
LI2	4700	790	
LI6	2300	500	590
LI7 pre	640	480	510
LI7 episode	1700	30	3900
CI3	670	770	

Figure 22

Dry shell weights plotted against stream pH

● Approximately 100% shell present

○ Most of the shell present

△ Percentage of shell present uncertain

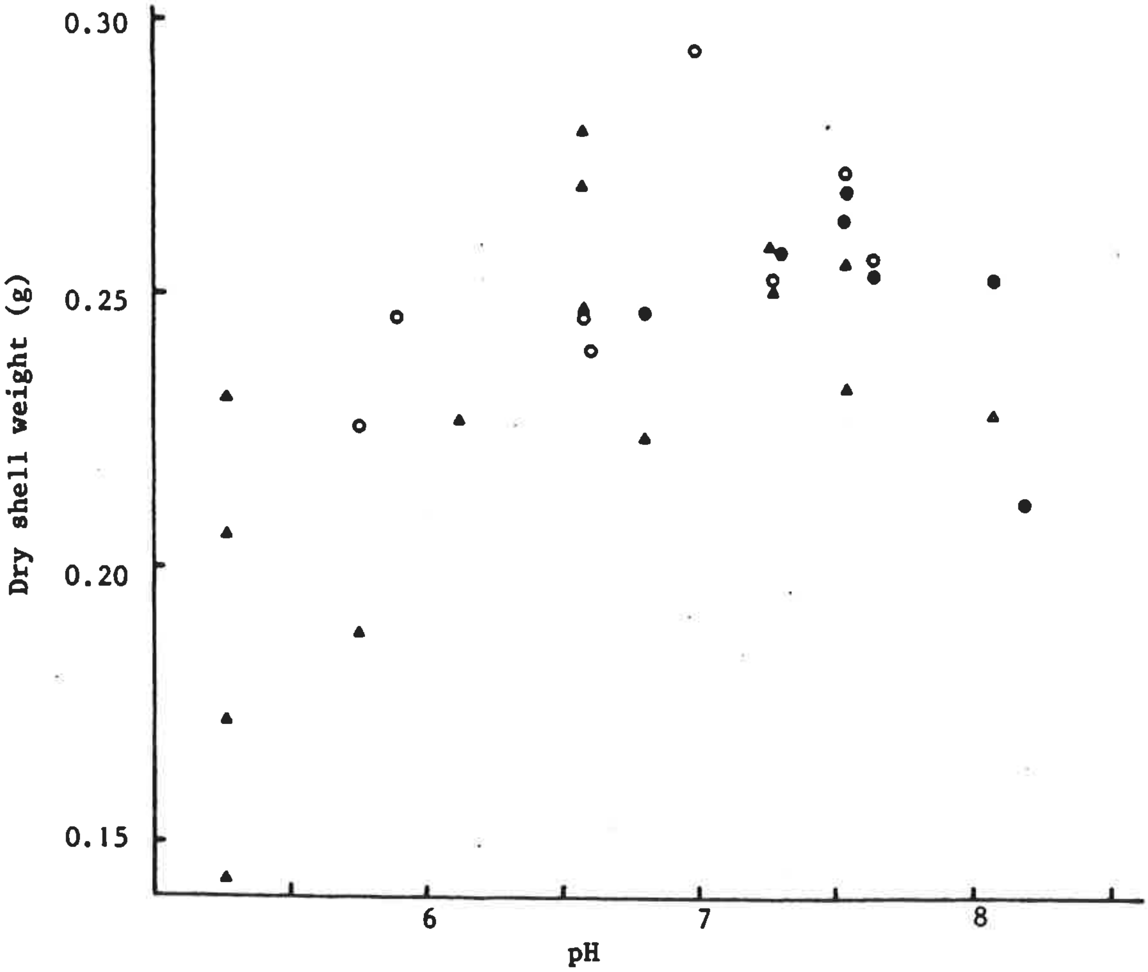


Figure 23

Eggshell thickness (mm) plotted against stream pH

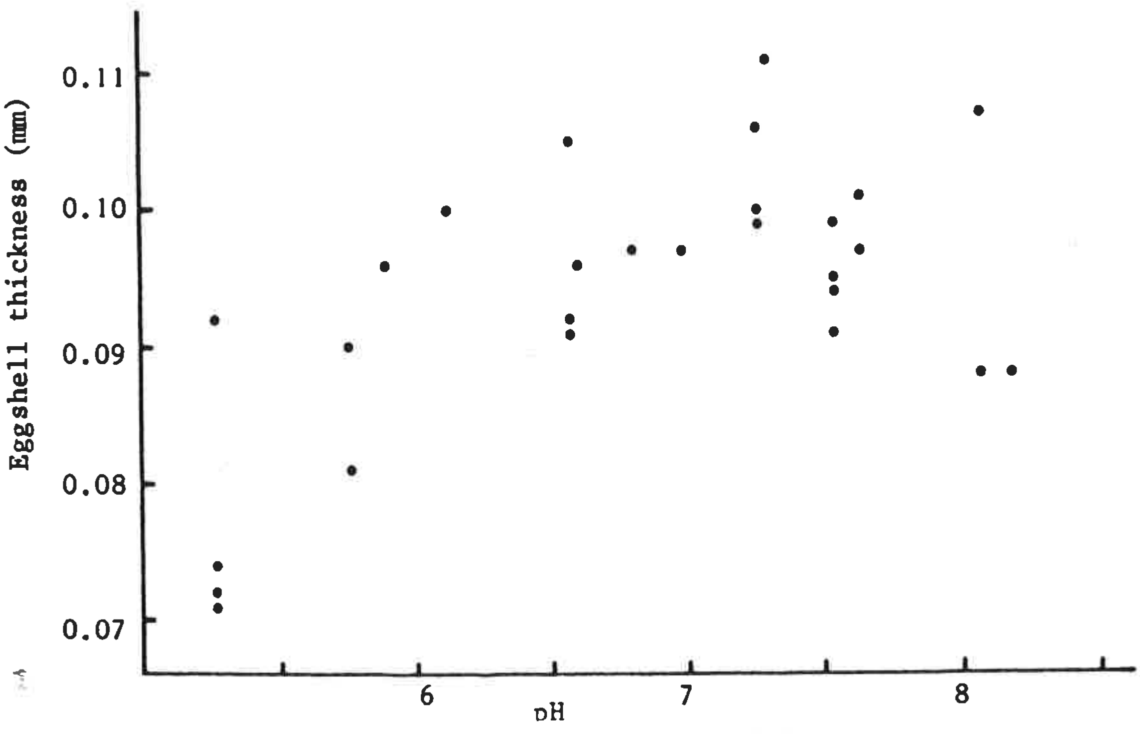


Figure 24

Concentrations of Al ($\mu g\ g^{-1}$) in eggshells plotted against stream pH

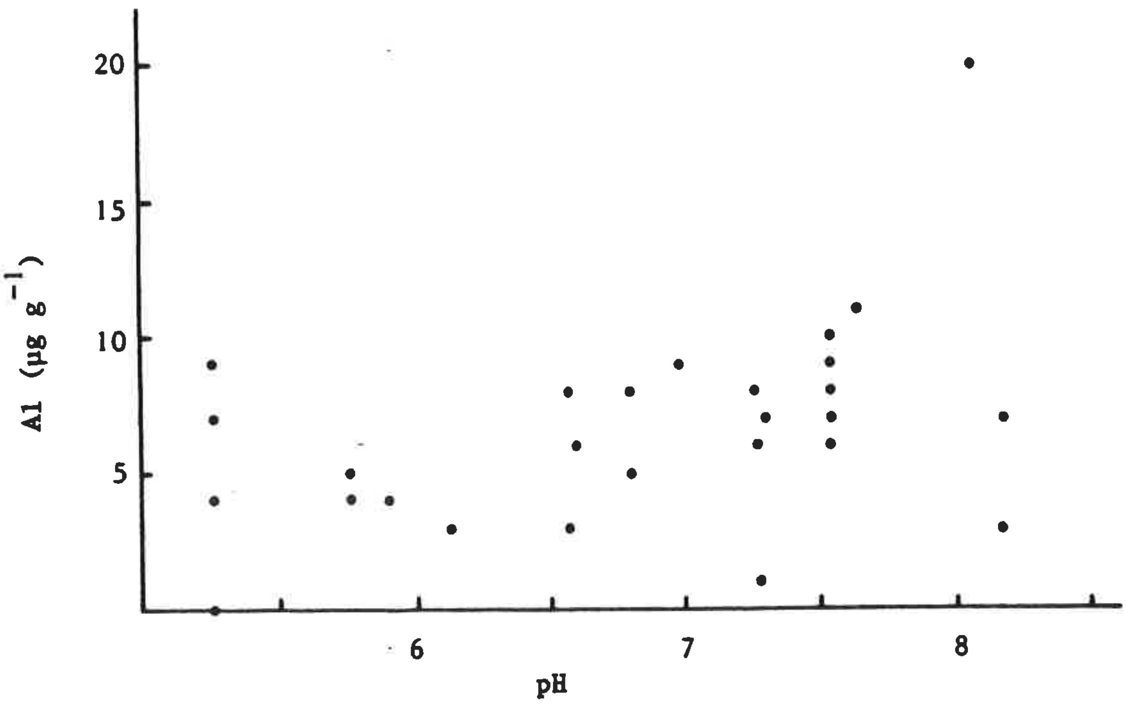
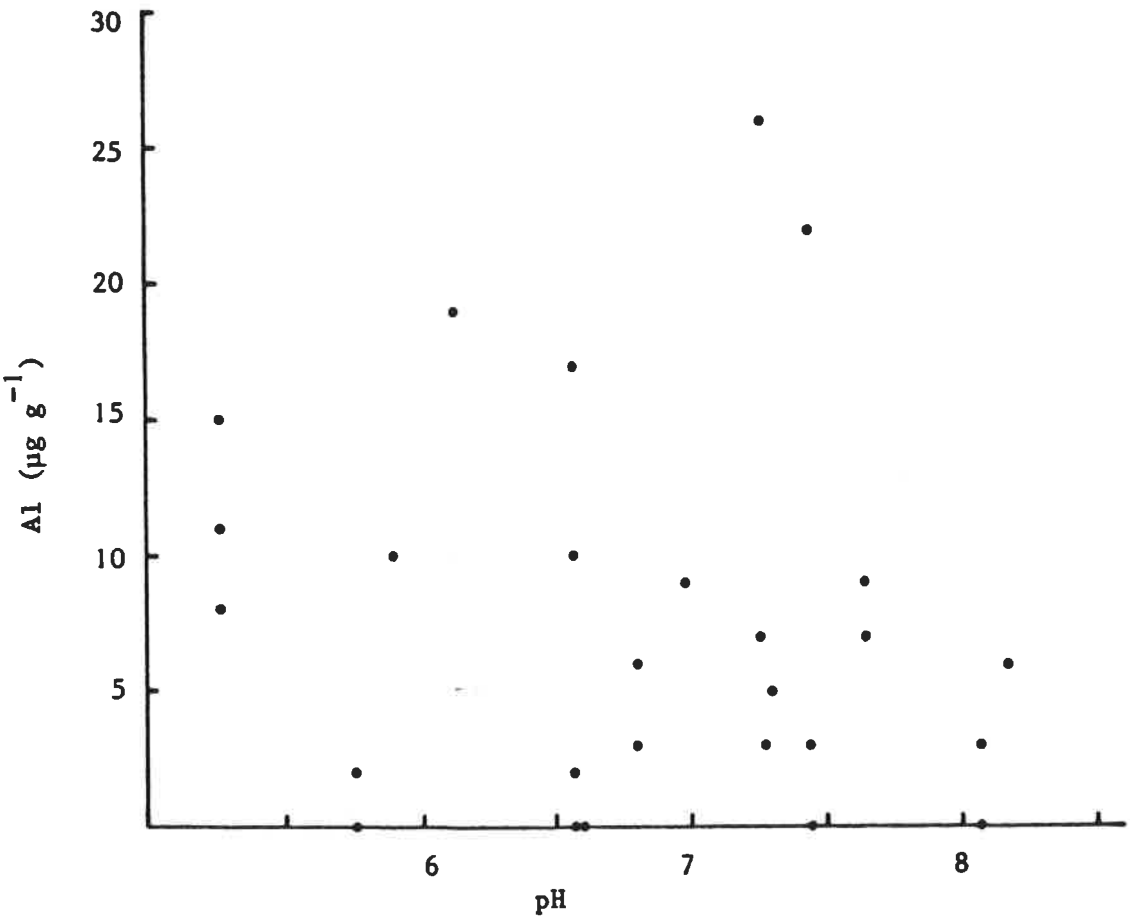


Figure 25

Concentrations of Al ($\mu g\ g^{-1}$) in egg contents plotted against stream pH



INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

NCC/NERC CONTRACT HF3/08/01
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BIRDS AND POLLUTION

Part 8 Aluminium in quail eggs

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August 1986

8 ALUMINIUM IN QUAIL EGGS

8.1 Introduction

The widespread distribution and environmental consequences of "acid" deposition have led to the suggestion that some species of birds are suffering reduced breeding success in areas of high acidic deposition. For example, the breeding success of dippers in Wales may have declined (see Section 7 of this report). One possible cause of the decline is the aluminium released into waterways by acid deposition, which might enter dipper prey species. The main aim of this work was to begin an investigation of the effects of elevated concentrations of dietary aluminium on bird reproduction.

In the first instance it was decided to determine, in a pilot study, whether birds given aluminium in the diet laid fewer eggs, or eggs with thinner shells, than did control birds.

8.2 Dosing levels and choice of test species

8.2.1 Dosing

Aluminium has a complex toxicology. In normal humans, elevated aluminium in the drinking water is no threat to health, as the kidneys rapidly eliminate the metal from the circulation. This means that little of the small proportion of the aluminium in the diet absorbed through the gut is actually retained in the body for any length of time. This is not the case for patients with kidney failure, who, through using tap-water with a high aluminium content, for dialysis, have suffered serious medical problems, presumably because they could not excrete the metal.

The chemistry of aluminium is a complicating factor when considering the amount of aluminium that is likely to be absorbed from the gut. It binds to many dietary elements, and its absorption may be limited by the presence of inorganic anions, such as phosphates, with which aluminium may form relatively insoluble complexes. This implies that the choice of compound used to spike the diet (eg aluminium oxide, sulphate, or phosphate) could affect the complexes formed in the gut, and hence the amount of aluminium absorbed.

After consideration, we decided to apply aluminium to the diet as sulphate, a soluble salt, which enabled us to ensure a consistent dosing regime. Two dietary dose levels were chosen, in addition to the control, 100 ppm and 1000 ppm. Although these concentrations would normally be considered high, they were only just in the range of values found in likely food items of dippers (see section 7 of this report).

8.2.2 Test species

Since aluminium studies were new to us, it was decided to use a species which had a well known egg-laying performance. For this reason, Japanese quail were used. It was appreciated at the outset that the species might not produce a result which could be extrapolated to those species whose breeding success may have been affected by acid deposition in the wild.

8.3 Methods

8.3.1 Experimental design

Birds were kept in groups of 3 per cage: 2 females and 1 male, with 4 cages per treatment. The birds were kept on a light regime of 18L:6D, and given ad libitum access to food and water. The maintenance diet was a commercially-prepared layer crumb. Eggs were collected daily, and stored initially at room temperature in paper envelopes, and later in a cold room maintained between 4°and 10°C. It proved possible to distinguish the eggs laid by each female in each cage, on the basis of egg marking and colouration.

The initial experimental protocol envisaged the following timings for the study:

1. Transfer birds from rearing pens to cages on 18L:6D.

2. Wait for egg-laying to commence and become regular.

3. Collect eggs for up to 4 weeks prior to dosing to ensure adequate collection of control material, as each bird might have to act as its own control (eg if inter-bird variation in eggshell thickness was great).

4. Dose birds with aluminium in a crumb diet, at the following concentrations: 1000 ppm (high dose), 100 ppm (low dose), 0 ppm (controls). Collect eggs for 4-6 weeks.

5. End experiment, determine number of eggs laid, eggshell thickness, in the different treatment groups.

This protocol had to be amended, because on the day before stage 4 commenced, the effects of an incorrectly prepared batch of the commercially-supplied diet became apparent, and many birds began laying thin-shelled eggs.

Ascertaining the cause of the problem, obtaining fresh supplies of food, and stabilizing egg-laying once again took several further weeks. In consequence, it was decided that, since these birds were susceptible to laying thin-shelled eggs in response to variation in diet, the experiment should be conducted using one batch of food. This meant limiting the dosing period to approximately 3 weeks. It was appreciated that this was probably a short period of time in which to detect the effects of aluminium, but it was considered the best option, given the resources available.

It was also decided to take advantage of the inadequate diet, and a small, additional trial was conducted using the same concentrations of aluminium, but this time added to the inadequate diet, which itself induced birds to lay thin-shelled eggs. This dosing trial was run over a similar period to the first, but food was sufficient for only 2 groups of birds (ie 4 females) per dietary aluminium level, plus 2 groups of birds as controls.

The aim of this trial was to see whether aluminium worsened the effects of the inadequate diet.

8.3.2 Measurement and observation of eggs

The original intention was to obtain both a Ratcliffe Index (I) and the actual eggshell thickness in µm. However, Moriarty and Hanson (1986) have raised some questions about I, and as some difficulties were experienced in handling the very thin eggs that were sometimes laid, we measured the length and breadth of eggs, to obtain a measure of size and shape, and then the shell thickness. Length and breadth were measured with an engineering height gauge (equipped with a vernier scale, which enabled measurements to the nearest 0.01 mm to be made), and eggshell thickness was measured with a digital display micrometer (enabling measurements to the nearest 0.001 mm to be made).

Eggshell thickness was determined by cutting the egg longitudinally and removing the contents and membranes manually. Pieces of shell from the waist of the egg were then dried overnight at 60°C and 4 measurements of shell thickness taken with the micrometer. The mean of the 4 values was used as the eggshell thickness.

In addition to these measurements, the number of eggs laid by each female was recorded, and the number of cracked ones noted.

8.3.3 Food consumption

Food consumption was monitored initially. However, since birds in all cages ate the diet consistently, and since it was not possible to determine individual food consumption, this was not monitored during the dosing period.

The birds accepted the aluminium diet, as well as they did the maintenance diet, throughout the experiment.

8.3.4 Chemical analysis

No chemical analysis of eggs, eggshells, food, or birds was conducted, except for the analysis done to establish the deficiency in the inadequate diet.

8.3.5 Water loss from intact eggs, measured as weight loss

In the normal diet experiment, 8 eggs collected from both the control and high dose groups on one day were placed in a desiccator with silica gell for 48 h. The differences in the weight of the eggs before and after their treatments were recorded.

8.4 Results

8.4.1 Number of eggs laid and number of abnormal eggs

a. Experiment 1 : normal diet

The results given in this report have mainly been obtained for the 5-day period before dosing started and the 5-day period at the end of dosing.

Table 21 shows numbers of total eggs laid during the 2 periods, and the number of these that were cracked, or abnormal in some other way.

The results show that aluminium had no clear effect on the number of eggs laid; it may have caused a small increase in the proportion of abnormal eggs, but on the sample available, this was not significant.

b. Experiment 2 : inadequate diet

Because this was a small trial, all the data for the dosing period were pooled. Aluminium had a small effect on the number of eggs laid, and a larger effect on the number of abnormal eggs (Table 22). Both effects were dose-related.

From this small trial, it appeared that aluminium dosing of birds on an inadequate diet increased the proportion of abnormal eggs laid.

8.4.2 Egg size and shape

No differences in egg size and shape were noted in either experiment.

8.4.3 Eggshell thickness

For both experiments data were collected for 4-5 eggs laid prior to dosing and for 4-5 eggs laid at the end of dosing. To date, only the eggshells from control and high dose birds have been examined.

a. Experiment 1 : normal diet

For all 8 control females, no significant differences were found between eggs laid during the pre-dosing and end of dosing periods (Table 23). It thus appeared that birds laid eggs of a typical thickness and this did not change during the course of dosing. There was a considerable amount of inter-female variation; the thinnest mean value recorded was 171 ± 3 µm and the thickest 202 ± 5 µm (mean values ± 1 SE).

For all 8 high-dosed females, no significant differences were found between eggs laid pre-dosing and those laid at the end of dosing. Once again the inter-female variation was great, the smallest mean value for shell thickness being 171 ± 4 µm and the largest 212 ± 3 µm (Table 23).

The overall eggshell thickness for control birds before the dosing period was 187 ± 3 µm, and at the end of dosing it was 188 ± 3 µm. The overall eggshell thickness for the dosed birds was 188 ± 3 µm before their exposure to aluminium and 189 ± 4 µm after exposure.

b. Experiment 2 : inadequate diet

Table 24 shows that of the control birds on an inadequate diet, 2 birds (2A and 2B) showed evidence for a decline in shell thickness, whereas 3 birds in the aluminium dosed group showed a decline (5B, 6A and 6B). The decrease in the mean thickness of birds 1A and 5A was not significant. This result suggested that aluminium had little or no effect on thinning over and above that caused by the poor diet. Additional support for this view came from the mean shell thickness of all eggs measured in the various groups. This mean in control birds before aluminium dosing was 141 ± 3 µm (mean ± 1 SE), and after dosing 121 ± 4 µm. In dosed birds the equivalent figures were 142 ± 3 µm and 118 ± 4 µm.

8.4.4 Chemical analysis

Chemical analysis of the inadequate diet revealed that it was deficient in at least 2 minerals, calcium and zinc. An adequate diet contained >40 000 ppm calcium and >100 ppm zinc; the inadequate diet contained only 25 000 ppm calcium and 70 ppm zinc.

8.4.5 Water loss, as indicated by weight loss

Control eggs lost 62.8 ± 3.0 mg (mean ± 1 SE) and high dose eggs 56.2 ± 1.3 mg; n = 8 for both groups. This small, albeit non-significant difference may indicate that, had an experiment been designed specifically to examine water loss from eggs in detail, some effect of aluminium dosing may have become apparent.

8.5 Conclusions

8.5.1 Aluminium at 1000 ppm in the diet had no effect on eggshell thickness in quail on either a normal or an inadequate (mineral deficient) diet.

8.5.2 The combination of the inadequate diet, plus aluminium at 100 ppm and 1000 ppm, appeared to cause a dose-related increase in the number of abnormal eggs laid.

8.5.3 With the inadequate diet, of the 64 normal eggs that could have been laid, the controls laid 40 (63%), the low dose birds 34 (53%), and the high dose birds 28 (44%). This result suggests that high dose birds might have hatched fewer young than control birds.

8.5.4 The porosity of eggs between control and high dose birds may have differed. If so, this could affect hatchability.

8.5.5 Aluminium at dose levels of 100 and 1000 ppm had no obvious adverse effects on the quail themselves.

8.6 Further research

These experiments were conducted over a short time period, with low to moderate doses of aluminium added to the diet. The work produced some evidence that, in birds fed a mineral deficient diet, aluminium might contribute to an increase in the number of abnormal eggs laid and a consequent decrease in the number of young hatched. However, no evidence was obtained that any of the effects observed could be related to eggshell thinning at the doses used. Indeed, no evidence was obtained that aluminium caused eggshell thinning. Given these points, any further work should concentrate on studies of eggshell structure/porosity/strength, and/or on the hatchability and viability of young produced from adults exposed to aluminium. Higher doses of aluminium should be used to match the concentrations found in prey items more closely.

8.7 References

MORIARTY, F., BELL, A.A. & HANSON, H. 1986. Does p,p'-DDE thin eggshells? Environ. Pollut. A, **40**, 257-286.

Table 21. Eggs laid during the pre-dosing period and towards the end of dosing for birds on the adequate diet.

Treatment	Total eggs		Normal eggs		Abnormal eggs	
	Pre-dosing	End dosing	Pre-dosing	End dosing	Pre-dosing	End dosing
Control	36	36	36	36	0	0
Low dose	37	36	37	35	0	1*
High dose	35	33	35	29	0	4*

Notes: The maximum number of eggs that could have been laid was 40.

*These eggs had a smeared surface and had some unusual bright-red/brown markings.

Table 22. Eggs laid during the dosing period by birds on the inadequate diet.

Treatment	Total eggs	Normal eggs	Abnormal eggs*
Control	52	40	12
Low dose	50	34	16
High dose	49	28	21**

Notes: The maximum number of eggs that could have been laid was 64.

* mostly cracked when collected

** includes 5 eggs which dried out internally before eggshell thickness was recorded, 1 egg with an unusual, pale, smeared surface, and 1 very large egg.

Table 23. Thickness of eggshells laid by dosed and control quail before the start of dosing and at the end of dosing.
Values are in µm, means ± 1 SE (n)

Bird No	Controls Before	Controls At end	Bird No	Dosed Before	Dosed At end
1A	184 ± 2 (5)	180 ± 5 (4)	9A	182 ± 4 (4)	183 ± 5 (4)
1B	194 ± 1 (5)	195 ± 2 (5)	9B	186 ± 2 (4)	195 ± 5 (3)
2A	185 ± 7 (4)	202 ± 5 (5)	10A	174 ± 2 (4)	171 ± 4 (4)
2B	190 ± 2 (4)	182 ± 5 (5)	10B	190 ± 2 (4)	188 ± 5 (4)
3A	193 ± 2 (5)	191 ± 1 (5)	11A	202 ± 4 (4)	195 ± 2 (5)
3B	174 ± 1 (4)	171 ± 3 (5)	11B	199 ± 5 (4)	212 ± 3 (4)
4A	199 ± 2 (5)	192 ± 5 (4)	12A	184 ± 4 (4)	184 ± 1 (3)
4B	179 ± 6 (4)	188 ± 6 (5)	12B	190 ± 2 (5)	184 ± 6 (5)

Table 24. Thickness of eggshells of birds on the inadequate diet, before exposure to aluminium and at the end of dosing.
Values are in μm, means ± 1 SE, n = 4.

Bird No	Controls		Bird No	Dosed	
	Before	At end		Before	At end
1A	137 ± 4	128 ± 6	5A	144 ± 6	132 ± 4
1B	128 ± 6	138 ± 7	5B*	142 ± 5	121 ± 5
2A*	153 ± 2	118 ± 6	6A*	144 ± 1	124 + 6
2B*	137 ± 7	100 ± 4	6B*	138 ± 9	96 ± 7

*Significant decline in eggshell thickness between 2 periods of time. ($P<0.05$, t-test).

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BIRDS AND POLLUTION

Part 9 Mersey Birds

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August 1986

9 MERSEY BIRD MORTALITIES

9.1 Introduction

Work again centred on measuring alkyl lead in the livers of teal collected on the Mersey. Co-operation with the North West Water Authority (NWWA) has continued, with NWWA acting as a "clearing house" for the birds, which were collected by members of the British Association for Shooting and Conservation. All the analytical and post-mortem results were described in earlier reports.

9.2 Mortalities in 1985-86

For the second consecutive year, no corpses were received for analysis.

9.3 Alkyl lead levels in Mersey teal

Table 25 shows all the data for teal liver, muscle and kidney obtained during the course of the monitoring study, since it began in 1980. Figure 29 is a plot of the liver data given as an aid to identifying trends and to illustrate the distribution of the data. Table 26 shows the mean values for liver, muscle and kidney, and Figure 30 is a plot of the mean values ($\pm$ 1 SE) for liver.

The data suggest that a general decline in levels has occurred over the period from autumn 1980. Classifying the data by overwintering period gave 6 groups of data (from 1980-81 (period 1) to 1985-86 (period 6)), on which a regression analysis was performed. The data were first transformed to a $\log_{10}$ basis to remove some of the non-normality. The resulting regression equation had the form $y = -0.12x + 1.51$ (y = alkyl lead concentration, x = overwintering period (1-6), significance of regression coefficient $P<0.05$). This suggested alkyl lead levels had declined over the period as a whole. However, the value of r^2, at 8%, indicated that only a small part of the variance had been 'explained'.

To some extent, firm conclusions are difficult to reach because of the sporadic occurrence of higher mean values for some collections amongst the runs of lower means obtained in the past 2 or 3 overwintering periods.

Taking the data as a whole and comparing the mean liver levels with the "environmentally safe" target figure of 0.5 ppm (which was set on the basis of early field observations and experimental studies), the following results emerge:

1. For the period from 1980-81 to 1982-83, 10 collections were made. Of these, only one mean value was below 0.5 ppm.

2. For the 7 collections made in 1983-84, the mean for one collection was below 0.5 ppm.

3. For the 7 collections made during 1984-85 and 1985-86, the mean values for 6 were below 0.5 ppm.

Thus, it appears that alkyl lead levels in teal are gradually approaching the environmentally safe limit, below which large-scale mortalities would not be expected.

However, the sporadic higher values recorded in March 1984 and October 1985 suggest that some caution is still required. Possibly the tidal and hydrological conditions that contributed to the 1979 mortality incident may recur from time to time, causing birds to be exposed to higher levels of alkyl lead than usual.

9.4 Post-mortem findings on Mersey teal collected in 1985-86

Once again no marked abnormalities were seen and the birds were generally in good condition. Those collected in October 1985 had a little less visible fat than the birds collected between November 1985 and January 1986. This could be due to seasonal effects, but it is interesting that the March 1984 birds, which also had relatively high alkyl lead levels, were also in a relatively poor condition. Further work on the relationship of teal body condition to alkyl lead levels is desirable.

9.5 Conclusions and recommendations

9.5.1 No birds were known to have died of alkyl lead poisoning on the Mersey estuary during the 1985-86 overwintering period.

9.5.2 Alkyl lead levels may have now declined to "environmentally safe" levels, but sporadically, higher values have occurred.

9.5.3 The collection of teal for alkyl lead analysis is now no longer required on a routine basis. However, regional NCC officers, and other parties with an interest in the bird populations on the estuary, should remain aware of the possibility of future mortalities.

9.6 Acknowledgement

Again we thank Mr D Jones of the Frodsham & District Wildfowlers' Club (BASC) for collecting the samples and Dr K Wilson (NWW) for storing and transporting the birds to Monks Wood.

Table 25. Alkyl lead in Mersey teal, ppm wet wt: all data collected during the monitoring with teal.

Shooting season	Month & year of collection	Collection number	No. of birds examined	Alkyl lead Muscle	Liver	Kidney
1980-81	Sept 1980	1	1	0.7	1.2	2.5
	Oct 1980	2	9	0.3	0.6	1.3
				0.1	0.2	0.4
				0.8	2.1	3.0
				<0.1	<0.1	<0.1
				<0.1	<0.1	<0.1
				1.3	4.3	4.2
				1.1	3.3	3.3
				2.2	5.3	7.6
				1.1	2.8	4.4
	Jan/Feb 1981	3	6	1.0	1.9	2.9
				0.4	1.0	2.1
				0.7	1.1	2.2
				0.4	1.6	2.4
				0.4	1.6	2.4
				0.8	2.0	3.1
1981-82	Sept 1981	4	8	1.7	4.2	8.0
				1.0	3.0	-
				1.0	1.9	2.9
				0.4	1.0	2.1
				0.7	1.2	2.2
				0.4	1.6	2.4
				0.4	0.6	1.6
				0.8	2.0	3.1
	*Nov 1981	5	10		<0.1	
					<0.1	
					0.3	
					0.2	
					0.2	
					0.3	
					2.2	
					2.8	
					<0.1	
					0.3	
	*Dec 1981	6	4		<0.1	
					0.9	
					<0.1	
					<0.1	
	Feb 1982	7	10	1.2	5.5	6.9
				<0.1	0.2	0.5
				0.1	0.6	1.3
				1.1	2.5	4.1
				0.2	0.5	0.6
				0.2	0.2	0.7
				-	0.1	0.1
				0.9	4.2	6.8
				-	<0.1	<0.1
				0.2	0.7	1.5

Table 25 (contd)

Shooting season	Month & year of collection	Collection number	No. of birds examined	Alkyl lead Muscle	Alkyl lead Liver	Alkyl lead Kidney
	*Mar 1982	8	9		5.3	
					2.8	
					<0.1	
					4.3	
					4.3	
					0.2	
					0.2	
					2.2	
					3.3	
	*Apr 1982	9	8		2.5	
					0.7	
					2.1	
					4.9	
					0.8	
					4.0	
					4.0	
					3.1	
1982-83	Nov 1982	10	7	2.6	2.8	5.4
				0.6	1.0	3.0
				1.8	2.1	4.0
				0.7	1.6	3.6
				0.3	0.5	1.0
				0.5	0.7	1.9
				0.2	0.5	1.0
1983-84	*Sept 1983	11	10		2.3	
					0.8	
					2.5	
					3.7	
					6.0	
					1.3	
					1.0	
					1.9	
					0.2	
					5.1	
	*Oct 1983	12	10		0.7	
					0.6	
					<0.1	
					0.3	
					1.9	
					1.2	
					2.2	
					2.6	
					1.7	
					1.7	
	*Nov 1983	13	8		0.1	
					<0.1	
					0.9	
					2.4	
					0.3	
					4.4	
					3.3	

Table 25 (contd)

Shooting season	Month & year of collection	Collection number	No. of birds examined	Alkyl lead		
				Muscle	Liver	Kidney
	*Dec 1983	14	12		0.4	
					1.1	
					<0.1	
					0.2	
					<0.1	
					0.3	
					<0.1	
					0.3	
					1.0	
					<0.1	
					0.5	
					0.2	
	*Jan 1984	15	10		0.2	
					1.0	
					0.6	
					0.9	
					0.8	
					0.6	
					1.6	
					1.0	
					0.1	
					3.5	
	*Mar 1984	16	10		0.3	
					2.0	
					0.9	
					1.9	
					2.5	
					3.8	
					2.9	
					5.1	
					0.1	
					3.1	
	*Apr 1984	17	5		1.7	
					0.3	
					1.8	
					0.7	
					0.8	
1984-85	*Sept 1984	18	2		0.1	
					<0.1	
	*Oct 1984	19	6		1.0	
					<0.1	
					0.2	
					<0.1	
					0.4	
					0.2	
	*Nov 1984	20	5		<0.1	
					<0.1	
					0.5	
					<0.1	
					<0.1	

Table 25 (contd)

Shooting season	Month & year of collection	Collection number	No. of birds examined	Alkyl lead		
				Muscle	Liver	Kidney
1985-86	*Oct 1985	21	8		3.2	
					2.6	
					1.5	
					3.1	
					0.8	
					4.0	
					0.2	
					0.4	
	*Nov 1985	22	5		0.2	
					<0.1	
					<0.1	
					0.9	
					0.2	
	*Dec 1985	23	10		0.4	
					<0.1	
					0.1	
					0.1	
					<0.1	
					0.1	
					<0.1	
					<0.1	
					0.1	
					0.1	
	*Jan 1986	24	6		0.5	
					0.6	
					<0.1	
					0.9	
					0.2	
					0.2	

<u>Note</u>: * = only liver samples analysed this month.

Table 26. Alkyl lead in Mersey teal, ppm wet wt.

Shooting season	Month & year of collection	SubCollection number	No. of birds examined	Alkyl lead Muscle	Liver	Kidney
1980-81	Sept 1980	1	1	0.7	1.2	2.5
	Oct 1980	2	9	0.8 ±0.3	2.1 ±0.7	2.7 ±0.8
	Jan/Feb 1981	3	6	0.6 ±0.1	0.2 ±0.2	2.4 ±0.2
1981-82	Sept 1981	4	8	0.8 ±0.4	1.9 ±0.4	3.2 ±0.8
	Nov 1981	5	10	na	0.7 ±0.3	na
	Dec 1981	6	4	na	0.05* ±0.01	na
	Feb 1982	7	10	0.5 ±0.2(8)	1.5 ±0.6	2.3 ±0.9
	Mar 1982	8	9	na	2.5 ±0.7	na
	Apr 1982	9	8	na	2.8 ±0.6	na
1982-83	Nov 1982	10	7	1.0 ±0.4	1.3 ±0.3	2.8 ±0.6
1983-84	Sept 1983	11	10	na	2.5 ±0.6	na
	Oct 1983	12	10	na	1.3 ±0.3	na
	Nov 1983	13	8	na	1.6 ±0.6	na
	Dec 1983	14	12	na	0.4 ±0.1	na
	Jan 1984	15	10	na	1.0 ±0.3	na
	Mar 1984	16	10	na	2.3 ±0.5	na
	Apr 1984	17	5	na	1.1 ±0.3	na

Table 26 (contd)

Shooting season	Month & year of collection	SubCollection number	No. of birds examined	Alkyl lead Muscle	Liver	Kidney
1984-85	Sept 1984	18	2	na	0.05*	na
	Oct 1984	19	6	na	0.3 ±0.2	na
	Nov 1984	20	5	na	0.1 ±0.09	na
1985-86	Oct 1985	21	8	na	2.0 ±0.5	na
	Nov 1985	22	5	na	0.3 ±0.2	na
	Dec 1985	23	10	na	0.1 ±0.03	na
	Jan 1986	24	6	na	0.4 ±0.1	na

Notes: Values given in the table are means +SE, calculated as Pb in trimethyl lead.

na = tissue not analysed.

* = samples where the calculated mean was <0.1, ie below the usually quoted limit of detection for this work.

() = figures in parentheses indicate the number of samples actually analysed.

Figure 29 Individual data points for alkyl lead in livers of teal.

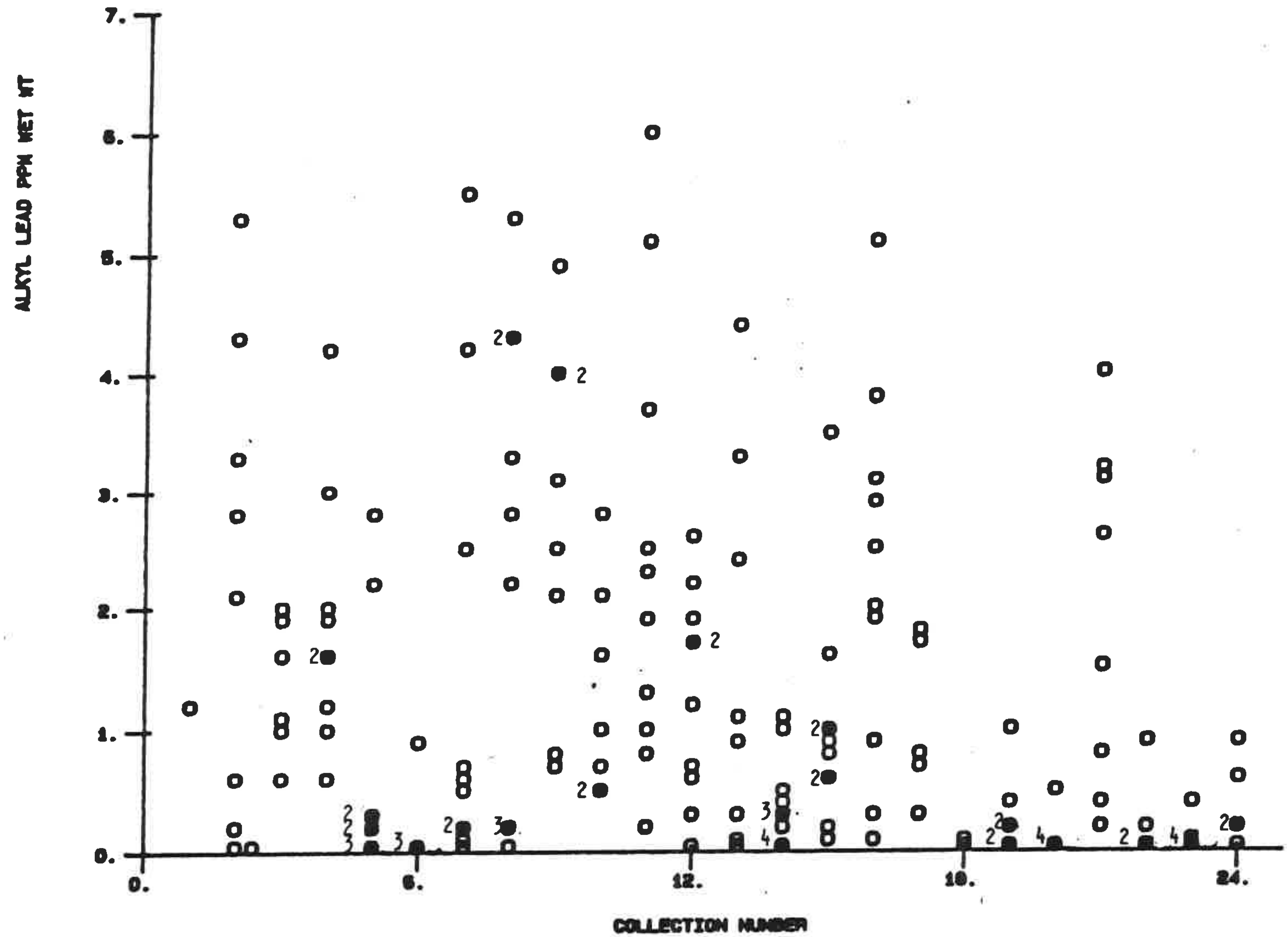
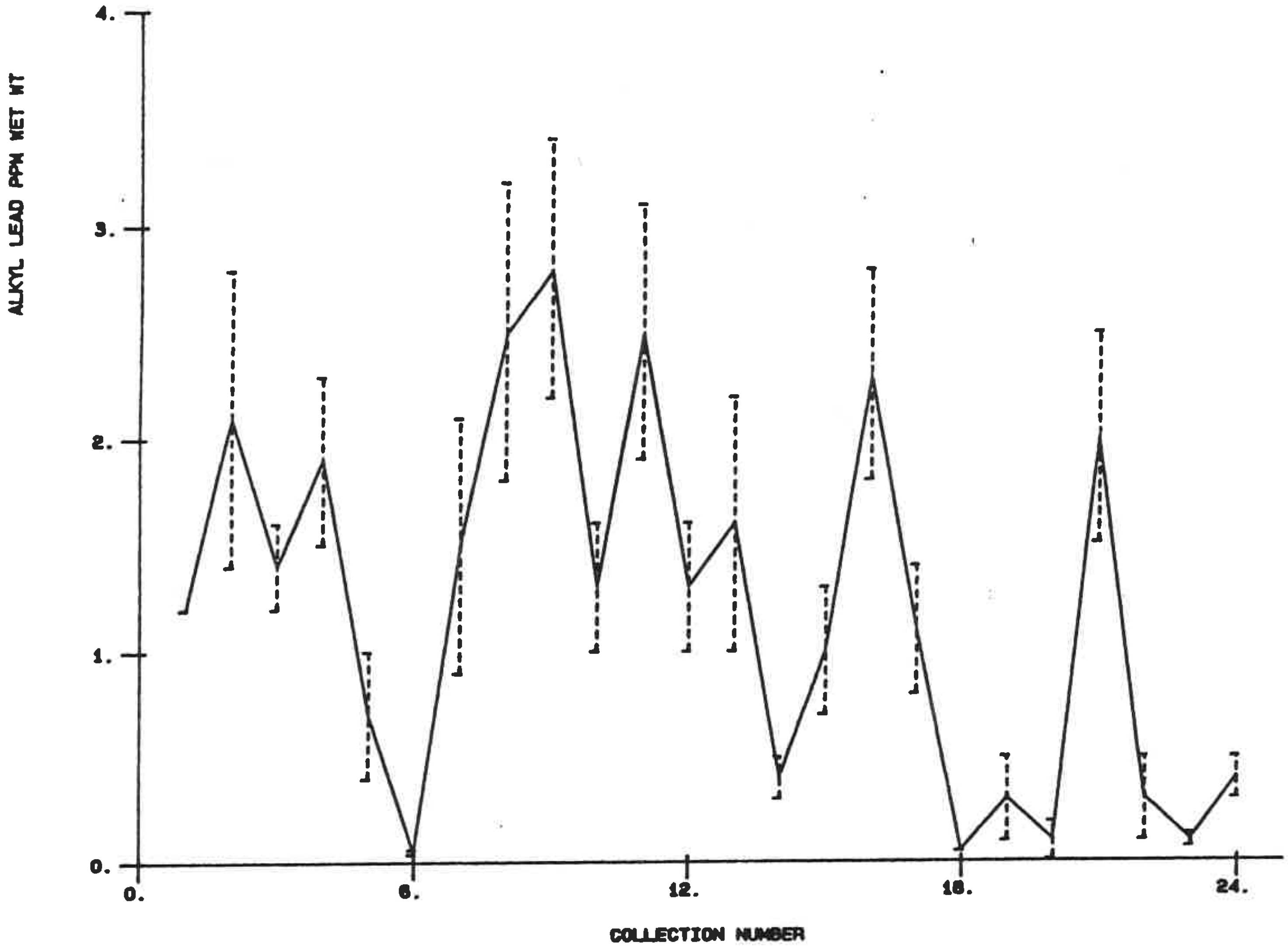


Figure 30. Mean levels (±SE) of alkyl lead in livers for each collection of teal.



10 INCIDENT INVESTIGATIONS

10.1 Introduction

During the year, numerous requests to investigate wildlife mortality incidents were received. Several which were likely to have some agricultural cause were passed on to MAFF Laboratories at Tolworth. The following refer mainly to incidents for which some analytical work was done at Monks Wood.

10.2 Essex Brent geese

Following the findings from earlier years, where some Brent geese were diagnosed as having lethal levels of lead in their tissues, Mr R Hamilton of NCC Colchester office, asked for further analyses to find whether the Brent wintering in Essex were sublethally affected.

So far, 8 carcasses have been received for analysis, all birds shot under licence. The results of lead analysis of the livers of 7 of these birds are given in Table 27 (in the eighth the liver had been damaged by lead shot).

Birds from the Foulness area had higher concentrations of lead in the liver than did birds from other areas. Levels of lead in the geese from Hadleigh and Hamford could be regarded as "elevated". The 3 birds from Foulness also had lower fat reserves than the birds from elsewhere. At present, we cannot say if the poorer fat reserves were the result of lead contamination.

We recommend that some further work should be done on this topic as the levels of lead in Foulness birds are in the range that might be expected to have some deleterious sublethal effect, and reduced fat reserves could be one symptom.

10.3 Essex gulls

There have been no further reports of unusual mortalities of gulls in the Thames estuary area.

10.4 Worcestershire herons

Last year's report referred to an unusual heron mortality incident near Evesham which had occurred during March-April 1985. Soon after the incident we received 5 corpses for analysis. Results of organochlorine analysis of livers are given in Table 28.

Four of the birds probably died of HEOD poisoning, as they contained >10 ppm HEOD in the liver. However, the deaths of these birds may not have been entirely due to HEOD. The residues of DDE are certainly in the range known to have sublethal effects on birds, and one residue is not far from the 'lethal' level of 100 ppm. Further, 2 of the PCB residues exceed 100 ppm, the value at which sublethal effects of these compounds might reasonably be expected. Mercury residues were also relatively high.

It was not possible to discern whether the birds were exposed suddenly to a large dose of organochlorines, or whether some other factor caused the birds to mobilize an exceptional proportion of body fat and thus release into circulation a large proportion of the organochlorines they had accumulated over a longer period of time.

Since the residues were so high, compared to other findings from this area, the birds had probably been exposed to exceptional levels. The relevant Water Authority and MAFF staff are continuing to investigate this incident in the hope of identifying the source of HEOD. We would hope this work would also throw light on the source of some of the other chemicals found in these herons.

10.5 Ferry Meadows wildfowl

The Warden of Ferry Meadows, Peterborough, contacted us between 7-10 December 1985 about mortalities and sickness amongst the duck at this park. Several species were affected, with mallard and tufted duck featuring prominently. It was estimated that about 30 birds were involved in all.

MAFF at Tolworth Laboratory, and the Animal Health Laboratories at the Royal College of Surgeons, have also examined samples from these ducks. No cause of death has been identified. However, the birds examined had "congested" lungs and, unusually, fluid was escaping from the nostrils. The faeces were also very fluid. The birds were unable to fly and were clearly suffering some respiratory distress.

Gizzard contents included debris from fishing activities, including lead shot, line and hooks, maggots and an amorphous material that may have been ground bait.

On a visit to the site soon after the mortality, a large area of ground was found which was covered with ground bait dyed pink, and dead maggots. A fishing competition had taken place at the weekend before the deaths and sickness in the ducks was noted.

Although the sickness may have been associated with material left over from the fishing competition, no proof was obtained. Interestingly, a similar incident occurred at Monks Wood, with birds fed fishing bait maggots. Again, no cause of the problem was identified.

10.6 Corby gulls

In March 1985, an unusual mortality of gulls occurred on a municipal waste disposal site in Corby, Northamptonshire. About 200 gulls (mostly black-headed with some common gulls) died within a period of about 4 h. No detectable residues of organochlorines were found, nor were there any detectable residues of mercury, lead, or cadmium (limit of detection 1 ppm) that could account for such a sudden mass mortality.

Post-mortem examination of the gulls revealed congestion of the aorta and the vessels in the heart, suggesting that the birds had died of some acute cardiac problem. Further investigation of the incident was conducted by MAFF staff.

INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

NCC/NERC CONTRACT HF3/08/01
ITE PROJECT 181
Annual report to Nature Conservancy Council

BIRDS AND POLLUTION

Part 10 Incident investigations

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10.7 East coast shorebirds

Dr I Keymer sent several batches of tissues for analysis during March 1986. These were from birds found dead after the low mid-winter temperatures. The tissues came from shelduck, redshank and some other species. Analysis was performed only for organochlorines (Table 29). The presence of heptachlor epoxide in these samples was unusual, as this pesticide has 'officially' not been used in Britain for 20 years. Perhaps the birds had accumulated their residues elsewhere in Europe. No cause of death could be established.

We concluded that these birds had probably died when their feeding grounds became frozen over, and their carcasses remained undiscovered for some time. Several reports of small groups of birds dead on the shore were received at about this time, but no exact figures of the total numbers involved were obtained. Thirteen shelducks were found on one occasion in one place.

10.8 St Kilda puffin chicks

A relatively high mortality of puffin chicks occurred on St Kilda in the 1985 breeding season. Four chicks and one sample of food were received for analysis, and results for organochlorine, PCB, mercury and cadmium analyses are in Table 30; the levels were of little toxicological significance.

No chemical cause of the deaths of the chicks was identified, although the detected residues seemed rather high for young chicks.

The 0.4 ppm cadmium recorded for the fish sample was not surprising. Analysis of gut contents of puffins from St Kilda has been conducted at Monks Wood in the past, and levels of up to 2 ppm were recorded.

10.9 Hebridean golden eagle

The RSPCA Inspector on the Hebrides sent a corpse of a golden eagle to us in April 1986. On first examination the bird appeared to have been shot (to judge from marks on the breast muscle), but an X-ray revealed no shotgun pellets.

Internal examination showed that the bird had a ruptured liver, which could have been caused by a collision or a fall. Organochlorine levels in the liver were low (DDE - 3.9, HEOD - 0.3, PCB - 14.9 ppm in wet weight), but the mercury residue (23.9 ppm in dry weight) may have been high enough to have contributed to death.

10.10 Incidents involving industrial spills

Two reports were received, which concerned spills of wood preservative into waterways. Both involved a mixture of dieldrin and tin compounds. One incident resulted in contamination of the River Rother in Sussex, the other in contamination of waterways near the Farnsdown Industrial Estate in south-west England. Advice was given to the relevant NCC regional staff, along with an undertaking to analyse carcasses. The manufacturers of the parent chemicals involved have also sought information and advice.

No carcasses were received for analysis, nor any further details of the incidents.

Table 27. Levels of lead (ppm dry wt) in the livers of Brent geese from Essex.

Specimen number	Date shot	Area	Lead
1	28.1.86	Hadleigh Marsh	6.1
2	16.12.85	Foulness	11.9
3	"	"	10.6
4	"	"	20.3
5	20.1.86	Hamford Water	6.7
6	"	"	4.1
7	"	"	5.9

Notes: Mean (± 1 SE) for Foulness birds = 14.3 ± 3.0

Mean (± 1 SE) for other birds = 5.7 ± 0.6

Table 28. Organochlorine, PCB, and mercury (Hg) residues in heron livers from Evesham area. Organochlorines expressed as ppm fresh weight, and mercury as ppm dry weight.

Specimen number	Heptachlor epoxide	HEOD	DDE	PCB	Hg
1*	0.6	22.6	41.9	189.0	17.7
2*	0.9	41.9	79.3	254.0	23.5
3	ND	1.1	0.8	5.1	22.8
4*	0.3	17.4	27.2	81.5	21.5
5*	0.2	13.2	22.2	45.8	29.8

Notes: *These birds were probably killed by the organochlorine residues they contained.

HEOD residues confirmed by capillary GC and a chemical confirmation method.

The birds also contained small amounts of other materials not thought likely to have contributed to death (eg HCH or HCB).

Table 29. Organochlorine and PCB residues in livers of birds found dead on the east coast (ppm wet wt).

Species and number		Heptachlor epoxide	HEOD	DDE	PCB
Shelduck	1	0.2	0.2	0.5	1.3
"	2	0.6	0.1	0.8	1.8
"	3	0.2	0.1	1.7	13.3
"	4	0.3	ND	2.3	24.9
Redshank	1	0.5	1.0	1.5	18.2
"	2	0.2	0.9	0.8	2.2
Curlew	1	1.3	2.4	4.0	3.4

<u>Note</u>: Limit of detection HEOD <0.1 ppm.

Table 30. Residues of toxic chemicals in puffin chicks and a sample of food. Levels in ppm dry wt for metals and ppm wet wt of organochlorines.

Sample and number	Mercury	Cadmium	HEOD	DDE	PCB
Food (fish)	0.1	0.4	ND	ND	ND
Puffin chick liver 1	2.2	ND	ND	2.9	10.1
" " " 2	0.5	ND	ND	1.4	ND
" " " 3	0.3	ND	ND	ND	ND

Notes: One puffin chick was too decomposed to analyse.

ND = none detected; limits of detection: cadmium, DDE and HEOD 0.1 ppm, PCB 0.5 ppm.