Institute of Terrestrial Ecology

WILDLIFE AND POLLUTION:
1991/92 Annual Report

Natural Environment Research Council

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- improving productivity in forestry
- controlling pests
- managing and conserving wildlife
- assessing the causes and effects of pollution
- rehabilitating disturbed sites

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This report should be cited as:
Newton, I., Asher, A., Freestone, P., French, M.C., Malcolm, H., Osborn, D., Wright, J., Wyatt, C., & Wyllie, I. 1992. Wildlife and Pollution: 1991/92 Annual Report, Joint Nature Conservation Committee Report No. 109. (Institute of Terrestrial Ecology)

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INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)
JNCC PROJECT 018 (Contract HF3/08/01)
ITE PROJECT T07061f5

Annual report to Joint Nature Conservation Committee

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

August 1992

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Part 1 Organochlorines and mercury in predatory birds

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1 ORGANOCHLORINES AND MERCURY IN PREDATORY BIRDS

1.1 Introduction

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). Throughout this section the levels of organochlorines are given as ppm in wet weight and of mercury as ppm in dry weight.

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 findings from various other species received during the year are also included.

1.2 Results from 1991

During the past year, the livers from 219 birds were analysed, including those from 66 kestrels, 107 sparrowhawks, 6 herons, 8 kingfishers, 1 great-crested grebe and 31 others. These totals included some birds which had died in earlier years, but which were analysed in 1991. The results from all these birds are listed in Table 1, and the geometric means for each chemical from the main species (1991 specimens only) are given in Table 2.

Several birds from 1991 contained unexpectedly high levels of pollutants. They include two kestrels (from Jersey and Essex) with 11 and 28 ppm DDE, one kestrel (from Norfolk) with 13 ppm Hg; two sparrowhawks (from Lincs and Essex) with 45 and 50 ppm DDE; one sparrowhawk (from Lincs) with 14 ppm HEOD; one sparrowhawk (from Yorks) with 33 ppm PCB, three sparrowhawks (one from Lincs, two from Argyll) with 25, 28 and 24 ppm Hg; and one merlin (from the North Sea, 1990) with 33 ppm Hg. Hence, although pollutant levels have generally declined since the 1970s (see later), occasional heavily contaminated birds continue to appear.

Out of 16 comparisons, five significant differences in geometric mean values were found between the 1990 and 1991 results. These included an increase in HEOD levels in kestrel, a decrease in DDE levels in kestrel, decreases in PCB levels in kestrel and sparrowhawks, and an increase in the Hg levels in kingfisher (Table 3). It is impossible to say whether these differences reflected real changes in exposure, especially as levels were generally low. Because only one grebe was received in 1991, no comparisons were made for this species.

1.3 Long-term trends

An earlier analysis of long-term trends in residue levels in the five main species to 1988 was included in the 1989 report. The analysis has been repeated here, incorporating the extra data from 1989-91. The nationwide trends for each species are shown in Figures 1-5 by 3-year moving geometric means. 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 ase the significance of the long-term trend was assessed by regression analyses of individual residue levels on years (Table 4), covering the whole analytical period for each chemical. Separate regression analyses covered the period 1986-91 in order to examine the most recent trends, independently of earlier results.

Among the terrestrial-feeders, the bird-eating sparrowhawk had generally higher levels of most residues than the mammal-eating kestrel (Figures 1 & 2). Among the fish-eaters, the heron contained the highest levels of all residues (Figure 3), while the great-crested grebe contained the lowest.

Over the whole monitoring period, the overall data for most species revealed significant downward trends in residues (Figures 1-5, Table 4). The only exceptions were kestrel which showed no long-term decline in PCB levels, and kingfisher and grebe in which the downward trends in DDE (grebe) and mercury (both species) were not statistically significant. However, samples for these species were much smaller than for the others.

Over the shorter period (1986-91), the continuing downward trends in residues emerged as significant in most species. Four exceptions concerned kingfisher (DDE, PCB, Hg and sparrowhawk (Hg), in which downward trends were not significant. In the kestrel, the short-term data revealed a significant decline in PCB levels, in contrast to the long-term data, which showed no change.

1.4 Conclusions

The general picture is of long-term declines in residue levels. This would be expected from the progressive restrictions placed on the use and release over the years of the parent chemicals. In view of the continuing occurrence of occasional high levels of chemicals, however, it seems prudent to maintain the monitoring for some further years.

Table 1. Levels of organochlorines (ppm in wet weight and mercury (ppm in dry weight) in the livers of predatory birds analysed between April 1991 and March, 1992. ND=none detected.

Spec. no.	Date found	County	Age	Sex	DDE	HEOD	PCB	Hg
Kestrel (<u>Falco tinnunculus</u>)								
10393	Dec 86	Bedfords	J	F	0.10	0.08	0.14	0.87
10354	Jul 88	Scotland	-	F	0.12	0.26	0.12	2.41
10558	90	N. Sussex	J	M	0.22	0.49	2.03	1.56
10614	Dec 90	Argyll	J	M	0.27	0.67	4.68	7.64
10321	91	Jersey	J	F	11.30	0.52	0.54	0.83
10629	91	Lincs	A	M	0.06	0.01	0.71	2.59
10618	Jan 91	Argyll	J	F	0.12	0.11	3.71	4.81
10300	Feb 91	Worcs	A	M	1.46	0.06	0.06	0.46
10297	Mar 91	Suffolk	A	M	0.21	0.06	0.31	0.74
10298	Mar 91	Suffolk	A	F	0.04	0.04	0.04	0.47
10299	Mar 91	Suffolk	J	F	0.08	0.11	0.06	0.44
10305	Mar 91	Worcs	A	M	0.05	0.03	ND	0.44
10333	Apr 91	Derbyshire	J	F	0.07	0.05	0.04	0.68
10410	Apr 91	Cheshire	J	F	0.02	0.13	0.03	0.61
10429	Apr 91	Cambs	A	M	ND	ND	0.04	1.20
10371	May 91	Grampian	A	M	2.37	3.05	0.19	0.26
10375	Jun 91	Ayr	A	F	ND	0.06	0.05	0.93
10384	Jul 91	Bedfords	J	M	0.51	0.20	0.16	0.86
10403	Jul 91	Ayr	J	F	0.02	0.04	ND	1.47
10420	Jul 91	Norfolk	-	-	0.11	0.09	0.29	1.06
10433	Jul 91	Dyfed	J	F	0.02	0.04	0.08	1.01
10475	Jul 91	Dumfries	J	F	0.03	0.14	0.54	1.26
10508	Jul 91	Moray	J	M	0.32	0.20	1.19	2.26
10616	Jul 91	Tyne & Wear	J	F	0.01	0.12	0.42	1.22
10405	Aug 91	Lincs.	J	F	0.03	0.05	10.24	0.69
10428	Aug 91	Lincs	J	M	0.02	0.08	0.03	0.39
10431	Aug 91	S. Yorks	J	F	0.10	0.28	0.03	0.64
10432	Aug 91	Cambs	A	F	0.07	0.15	0.01	0.25
10471	Aug 91	Glams	J	F	0.11	0.26	6.09	1.43
10476	Aug 91	Dumfries	A	M	0.03	0 25	0.64	0.63
10477	Aug 91	Dumfries	J	F	0.01	0.12	12.43	0.65
10488	Aug 91	Hants	J	M	0.56	0.27	2.27	0.54
10457	Sep 91	N'umberland	A	M	0.02	0.07	0.14	1.21
10481	Sep 91	London	J	M	0.11	0.22	4.18	0.52
10483	Sep 91	Essex	A	M	28.04	0.69	6.04	0.94
10492	Sep 91	Ayr	J	M	0.03	0.07	1.47	5.79
10496	Sep 91	Strathclyde	J	F	0.08	0.33	4.92	0.65
10713	Sep 91	Aberdeens	J	F	0.23	0.25	1.62	0.94
10714	Sep 91	Aberdeens	J	F	0.21	0.41	0.80	0.54
10514	Oct 91	Derbys	J	F	0.01	0.11	0.19	0.65
10515	Oct 91	Cambs	J	F	0.27	0.29	0.94	2.92
10517	Oct 91	Norfolk	.	F	0.04	0.08	0.67	0.72
10520	Oct 91	Essex	J	F	0.09	0.10	0.82	0.98

10521	Oct	91	Northants	J	F	0.03	0.71	0.31	0.57
10524	Oct	91	Lanarks	J	F	0.04	0.19	1.03	1.57
10536	Oct	91	Leics	J	F	0.01	0.07	0.31	0.39
10537	Oct	91	Suffolk	J	M	1.60	0.24	0.47	0.63
10538	Oct	91	Cambs	A	M	0.03	0.19	0.57	0.47
10539	Oct	91	Suffolk	J	M	0.04	0.07	0.21	0.40
10543	Oct	91	S. Humberside	J	M	0.03	0.68	0.79	0.72
10569	Nov	91	Pembroke	J	F	0.04	0.30	0.95	3.61
10574	Nov	91	Humberside	J	F	0.79	0.64	0.95	1.01
10578	Nov	91	Orkney	J	F	0.16	0.10	2.94	4.35
10598	Nov	91	Essex	J	F	0.02	0.49	0.26	5.97
10599	Nov	91	Norfolk	J	F	0.01	0.02	0.07	13.44
10603	Nov	91	S. Devon	J	F	0.04	0.14	1.72	1.36
10615	Nov	91	Argyll	J	F	0.02	0.08	0.97	1.34
10697	Nov	91	Northants	J	F	0.92	0.40	5.51	1.45
10623	Dec	91	N. Devon	J	F	0.21	0.32	1.14	1.25
10634	Dec	91	Cambs	A	M	0.34	0.01	0.69	0.20
10638	Dec	91	Stirling	J	M	4.30	0.29	0.90	1.63
10639	Dec	91	Cambs	J	F	0.11	0.16	1.25	1.14
10658	Dec	91	Devon	-	-	0.20	0.11	1.80	1.48
10673	Dec	91	Norfolk	J	M	0.07	0.31	1.67	0.68
10674	Dec	91	Norfolk	J	M	0.09	0.29	2.98	0.92
10675	Dec	91	Norfolk	J	M	0.10	0.41	2.83	1.20

Sparrowhawk (Accipiter nisus)

10392	Nov	86	Beds	J	M	0.88	0.07	0.55	1.65
10391	Feb	87	Herefords	A	M	0.32	0.04	0.26	2.12
10358	Apr	88	Scotland	A	F	6.57	20.80	4.42	3.97
10356	Aug	88	Scotland	J	F	0.76	0.11	1.09	10.83
10361	Aug	88	Scotland	A	F	0.10	0.34	0.04	0.90
10544	Aug	89	Scotland	J	F	0.28	0.03	0.37	8.32
10360	Mar	90	Scotland	J	M	11.10	0.61	3.10	15.26
10359	Aug	90	Scotland	J	F	0.05	ND	0.03	2.17
10545	Nov	90	Argyll	J	F	0.05	0.01	0.15	5.05
10546	Nov	90	Argyll	J	F	0.56	0.34	1.30	5.23
10395	-	91	-	J	F	0.15	ND	ND	ND
10630	-	91	Lincs	J	F	2.54	0.48	4.19	4.35
10355	Feb	91	Scotland	-	M	1.36	0.10	0.55	4.94
10288	Mar	91	N. Yorks	J	M	10.25	0.99	32.74	9.52
10293	Mar	91	Bedfords	J	M	0.64	ND	ND	1.04
10294	Mar	91	Sussex	J	M	2.29	0.42	1.36	2.06
10301	Mar	91	Yorks	J	F	0.56	0.42	3.11	3.41
10302	Mar	91	Midlothian	A	F	1.00	0.29	2.75	1.86
10303	Mar	91	Wilts	J	M	0.85	0.09	0.24	1.87
10304	Mar	91	Lincs	J	F	44.72	14.10	18.69	24.58
10306	Mar	91	-	-	M	0.26	ND	0.26	2.67
10307	Mar	91	Worcs	J	F	1.11	0.06	0.03	3.09
10308	Mar	91	Worcs	J	F	0.51	0.11	0.17	2.12
10311	Mar	91	Essex	A	F	49.98	1.27	7.21	5.88
10312	Mar	91	Cambs	J	F	8.04	0.56	1.53	9.90
10323	Mar	91	Suffolk	-	M	2.22	0.28	0.76	1.23
10324	Mar	91	Warwicks	J	M	0.49	0.05	0.79	3.91
10402	Mar	91	N'hants	A	F	0.25	0.03	0.28	1.11
10498	Mar	91	D & G	J	M	0.30	0.10	1.18	3.47

10505	Mar	91	Ross	A	M	1.97	0.26	2.83	5.49
10547	Mar	91	Argyll	J	M	6.07	0.33	9.82	28.03
10608	Mar	91	Oxford	J	F	0.36	0.17	0.55	3.62
10314	Apr	91	Ayr	A	F	24.82	1.42	5.70	9.69
10315	Apr	91	Ayr	A	M	2.08	0.19	1.75	2.00
10317	Apr	91	Clwyd	A	F	13.04	0.40	4.10	8.38
10325	Apr	91	W. Midlands	A	M	0.12	0.05	0.43	0.86
10329	Apr	91	Dyfed	J	M	0.45	0.23	0.41	6.13
10334	Apr	91	Anglesey	A	M	14.37	0.40	6.76	7.52
10335	Apr	91	Somerset	A	M	0.63	0.13	0.66	3.42
10336	Apr	91	Cambs	J	M	2.64	0.20	0.71	6.30
10338	Apr	91	Argyll	A	F	11.57	0.20	4.11	24.38
10349	Apr	91	Warwicks	J	F	1.12	0.07	0.39	3.70
10364	Apr	91	Norfolk	A	M	6.92	0.34	1.82	2.76
10367	Apr	91	Norfolk	J	F	15 22	0.26	1.09	5.44
10450	Apr	91	Norfolk	J	F	13.59	0.66	0.53	3.10
10362	May	91	Berks	A	F	1.80	0.17	3.98	6.52
10363	May	91	Warwicks	A	M	0.66	0.02	0.43	2.64
10366	May	91	Beds	J	M	0.17	ND	0.05	2.50
10368	May	91	W. Yorks	A	M	0.31	0.32	0.12	1.38
10374	May	91	Kent	A	F	15.25	1.75	2.65	8.06
10387	Jul	91	N'hants	J	-	0.07	ND	0.05	0.52
10397	Jul	91	N'hants	J	F	ND	ND	ND	0.59
10398	Jul	91	Warwicks	J	M	0.29	0.15	0.35	0.92
10399	Jul	91	Middx	J	M	ND	ND	ND	0.33
10400	Jul	91	Avon	A	M	2.38	0.10	5.14	2.86
10485	Jul	91	N'Hants	J	M	0.17	0.02	0.20	1.99
10406	Aug	91	London	J	F	ND	ND	ND	1.01
10409	Aug	91	Lincs	J	M	0.21	0.05	ND	0.54
10411	Aug	91	Durham	J	M	ND	ND	ND	0.55
10412	Aug	91	Cornwall	J	F	0.04	0.03	0.11	0.53
10414	Aug	91	Lancs	J	F	ND	ND	ND	0.44
10415	Aug	91	Cambs	J	F	ND	ND	ND	0.37
10416	Aug	91	S. Devon	J	F	0.06	ND	ND	0.98
10419	Aug	91	Tyne & Wear	J	M	0.82	0.24	1.37	ND
10421	Aug	91	Cambs	J	M	2.93	0.22	0.69	1.07
10423	Aug	91	Devon	J	F	0.19	0.06	0.08	1.43
10425	Aug	91	Somerset	A	F	0.18	0.02	0.02	0.85
10434	Aug	91	Herefords	J	F	0.12	0.30	0.06	0.93
10435	Aug	91	Inverness	J	F	0.03	ND	0.47	3.46
10437	Aug	91	Sussex	J	F	0.08	ND	ND	0.64
10439	Aug	91	Moray	J	F	0.19	0.06	2.02	2.71
10440	Aug	91	N. London	J	F	16.12	0.43	0.47	0.70
10444	Aug	91	Dorset	J	M	0.18	0.06	0.11	0.59
10445	Aug	91	Highland	J	F	0.79	0.15	0.73	2.87
10446	Aug	91	Humberside	J	F	0.70	0.10	0.60	1.83
10465	Aug	91	Salop	J	M	0.09	0.02	0.13	1.08
10506	Aug	91	Highland	J	M	1.37	0.47	3.66	3.34
10518	Aug	91	Berks	J	M	0.19	0.19	1.43	0.87
10555	Aug	91	Gwynedd	J	M	0.09	0.10	0.19	ND
10584	Aug	91	N'umberland	J	M	0.50	0.13	1.91	1.80
10619	Aug	91	N'umberland	J	M	0.08	0.06	0.70	4.28
10449	Sep	91	Oxford	J	F	0.05	ND	0.01	0.79
10452	Sep	91	Cambs	J	M	0.52	ND	0.09	2.09

10460	Sep 91	Central	A	F	0.15	0.03	0.41	1.06
10473	Sep 91	Avon	A	M	0.24	0.03	0.37	0.85
10482	Sep 91	E. Lothian	J	F	1.38	0.12	0.35	3.42
10486	Sep 91	N'hants	J	M	0.07	0.03	0.12	0.67
10500	Sep 91	Oxford	A	M	2.71	0.13	16.63	0.95
10554	Sep 91	Devon	J	M	0.14	0.04	0.07	1.53
10519	Oct 91	Kent	J	M	0.88	0.13	1.54	1.05
10526	Oct 91	Leics	J	M	0.20	0.10	1.53	0.68
10533	Oct 91	S. Devon	J	F	0.13	0.14	6.50	0.71
10535	Oct 91	Lincs	J	F	1.77	0.06	0.44	1.63
10549	Oct 91	Cambs	J	F	0.08	0.03	0.06	0.70
10552	Oct 91	Inverness	J	F	0.82	0.02	0.25	1.83
10725	Oct 91	Dorset	J	M	4.18	0.36	6.53	3.89
10568	Nov 91	Herts	A	F	0.52	0.15	1.30	0.57
10572	Nov 91	N'hants	J	M	0.18	0.09	1.06	0.95
10585	Nov 91	N'umberland	A	F	2.50	0.38	3.46	0.46
10592	Nov 91	Bucks	A	M	0.76	0.13	3.10	1.24
10593	Nov 91	Berks	J	F	0.04	0.01	0.17	ND
10596	Nov 91	Surrey	A	F	0.16	0.04	0.21	0.32
10610	Dec 91	Lincs	J	F	0.37	0.38	4.80	0.42
10620	Dec 91	Staffs	J	M	1.10	0.41	6.21	1.36
10636	Dec 91		J	F	0.84	0.10	0.89	5.22
10637	Dec 91		A	M	6.75	0.28	0.56	0.44
10654	Dec 91	Lincs	J	M	7.18	0.45	4.44	1.22

Peregrine Falcon (*Falco peregrinus*)

10507	Mar 91	Inverness	A	M	0.09	0.02	0.30	0.24
10378	May 91	Cumbria	A	M	0.50	0.09	0.27	1.83
10382	Jun 91	Dorset	-	-	0.66	0.04	0.67	0.61

Merlin (*Falco columbarius*)

10345	Jan 82	Angus	-	M	27.36	1.04	3.42	2.01
10346	Aug 84	Lewis	J	M	6.29	0.05	1.58	8.21
10342	May 88	Grampian	A	F	0.44	0.05	0.53	1.58
10344	May 90	Kincardines	A	F	0.56	0.08	0.32	2.30
10339	Jun 90	Aberdeens	J	F	0.06	0.01	0.05	0.40
10340	Jun 90	Aberdeens	J	F	0.06	0.03	0.12	0.58
10343	Dec 90	North Sea	J	M	1.54	0.06	3.37	33.09
10347	- 91	-	J	F	5.23	0.69	0.68	1.36
10373	May 91	Yorks	A	F	0.26	0.05	0.31	2.06
10424	Aug 91	N'umberland	J	F	0.33	0.09	0.41	2.32
10451	Aug 91	Berwicks	A	F	7.48	0.11	1.24	5.25
10678	May 91	Kincardines	A	F	3.27	0.41	3.35	2.91
10677	Jun 91	Angus	A	F	2.14	0.36	3.38	3.02
10680	Jun 91	Aberdeens	J	F	0.14	0.06	0.25	0.78

Hobby (*Falco subbuteo*)

10484	Aug 91	Northants	J	F	0.01	0.03	0.05	0.39

Golden Eagle (Aquila chrysaetos)

10503	June 90	E. Ross	J	F	0.03	0.01	0.17	0.19

Buzzard (Buteo buteo)

10388	Jun 87	D & G	A	M	ND	ND	ND	2.14
10174	Oct 90	Argyll	J	F	0.16	0.19	0.17	1.38
10192	Dec 90	Dumfries	J	M	0.03	4.18	0.67	0.85
10474	Mar 91	Cumbria	A	F	0.01	0.04	0.07	1.04
10612	Mar 91	Argyll	J	F	0.03	0.52	1.11	1.24
10396	Jul 91	Dyfed	J	M	ND	ND	ND	0.59
10441	Aug 91	Hants	J	M	0.67	0.04	0.08	0.56
10613	Sep 91	Argyll	J	F	0.04	0.70	0.37	1.67
10595	Nov 91	Glams	J	F	0.01	0.04	0.21	0.30
10602	Nov 91	Dyfed	J	F	0.50	0.07	0.40	0.53

Red Kite (Milvus milvus)

10386	Jul 91	.	.	.	ND	ND	ND	0.49

Long-eared Owl (Asio otus)

10470	Oct 90	Norfolk	J	F	0.05	0.03	0.04	ND
10369	May 91	Beds	A	M	13.23	0.41	0.95	0.98
10575	Nov 91	Central	A	F	0.02	0.01	0.05	0.25

Little Owl (Athene noctua)

10383	Jun 91	Essex	A	F	0.04	0.02	0.10	0.55
10463	Jul 91	Cambs	J	M	0.15	0.02	0.10	0.67
10464	Jul 91	Cambs	J	-	0.04	0.03	0.09	ND
10443	Aug 91	Cambs	J	M	6.60	0.04	0.95	0.64
10501	Oct 91	Lincs	J	F	0.10	0.05	0.32	0.19
10516	Oct 91	Cambs	J	M	0.04	0.04	0.18	0.21
10542	Oct 91	N. Yorks	J	M	0.01	0.01	0.36	ND
10571	Nov 91	IOW	A	F	0.05	0.07	0.50	0.43
10632	Dec 91	Berks	A	M	0.02	0.06	0.52	0.33

Short-eared Owl (Asio flammeus)

10586	Nov 91	Lincs	J	M	0.31	0.03	0.51	2.19

Heron (Ardea cinerea)

10337	Apr 91	Herts	A	F	0.27	0.03	0.14	22.04
10564	May 91	Norfolk	A	M	0.04	0.04	0.38	2.90
10381	Jul 91	Cambs	J	F	0.26	0.15	0.27	8.93
10418	Aug 91	Yorks	J	M	0.02	0.02	0.03	5.37
10436	Aug 91	Dyfed	J	M	0.04	0.03	0.41	3.16
10502	Sep 91	Ross	J	F	0.03	0.04	0.62	2.54
10529	Oct 91	Devon	J	M	0.33	0.08	2.23	5.25
10532	Oct 91	Ayrshire	J	F	1.80	0.20	16.49	21.34

Heron (cont.)

10551	Oct 91	London	J	F	10.14	6.02	79.98	1.52
10580	Nov 91	Ayrshire	J	M	3.51	0.21	18.25	22.95
10604	Nov 91	Derbyshire	A	M	0.10	0.04	0.90	18.86
10605	Nov 91	Lincoln	J	F	0.03	0.04	0.15	4.00
10611	Dec 91	Argyll	J	F	0.08	0.08	1.83	2.04
10633	Dec 91	Ayrs	J	M	0.09	0.03	0.22	11.45

Bittern (Botaurus stellaris)

10322	Mar 90	Lancs	A	M	ND	ND	0.02	9.84
10665	Jan 91	Essex	.	M	5.66	0.10	2.78	33.88

Kingfisher (Alcedo atthis)

10490	Feb 91	Northants	J	M	1.59	0.95	6.66	5.34
10377	May 91	Cambs	J	M	0.07	0.18	0.23	1.73
10404	Jul 91	Herts	J	F	0.46	1.41	2.18	1.54
10509	Jul 91	Ross	J	M	0.13	0.09	0.60	2.15
10427	Aug 91	Kent	J	M	0.57	9.29	0.31	2.08
10448	Aug 91	Essex	J	M	0.15	0.19	0.04	2.07
10472	Aug 91	Co. Durham	A	M	0.24	0.77	4.19	0.87
10565	Nov 91	Berks	A	F	0.09	0.13	1.22	1.60

Great-crested Grebe (Podiceps cristatus)

10309	Apr 91	Lincs	A	F	0.06	ND	0.09	3.48

Table 2. Geometric mean levels of pollutants in the various species in Table 1, but for 1991 specimens only. Great-crested Grebe has been omitted because only one bird was received in 1991.

	HEOD	p,p'-DDE	PCBs	Hg
Kestrel				
Mean	0.12	0.14	0.78	1.03
N	100	100	100	100
Range within 1 SE	0.10 - 0.13	0.12 - 0.17	0.66 - 0.92	0.93 - 1.15
Sparrowhawk				
Mean	0.10	0.70	0.61	1.50
N	108	108	108	108
Range within 1 SE	0.09 - 0.12	0.57 - 0.84	0.50 - 0.75	1.31 - 1.72
Merlin				
Mean	0.16	1.19	0.84	2.18
N	7	7	7	7
Range within 1 SE	0.11 - 0.24	0.65 - 2.18	0.56 - 1.27	1.72 - 2.74
Heron				
Mean	0.10	0.30	0.92	8.62
N	28	28	28	28
Range within 1 SE	0.08 - 0.14	0.21 - 0.45	0.59 - 1.43	7.16 - 10.37
Kingfisher				
Mean	0.42	0.52	1.31	2.26
N	11	11	11	11
Range within 1 SE	0.30 - 0.60	0.32 - 0.85	0.77 - 2.24	1.90 - 2.69

Table 3. Comparison of geometric mean residue levels (log values) from birds collected in 1990 and 1991; t-values are shown. Minus values indicate a decrease and plus values indicate and increase from 1990.

	HEOD	p,p'-DDE	PCBs	Hg
Kestrel	t_{98}=+2.6143*	t_{98}=-3.0490**	$t_{93.6}$=-4.1228***	$t_{44.3}$=+0.1755
Sparrowhawk	t_{187}=+0.3706	t_{187}=-1.1381	$t_{186.9}$=-3.4518***	t_{187}=-0.9924
Kingfisher	t_{16}=+0.8603	t_{16}=+1.3279	t_{16}=+2.2448*	t_{16}=+2.6947*
Heron	t_{48}=+0.9715	t_{48}=-0.0013	t_{48}=+0.6196	t_{48}=-0.8743

Great-crested Grebes were omitted because there were only two birds in 1990 and one bird in 1991.

Notes: Zero values were taken as 0.01 for all residues.

Significance of difference * $p<0.05$; ** $P<0.01$; *** $P<0.001$

Table 4. Trends in pollutant levels in livers of predatory birds during 1963 - 1991 and 1986 - 1991. Figures show sample sizes (N) and linear regression coefficients (b), based on log_{10} values with significance levels. ns=not significant; *P<0.05; **P<0.01; ***P0.001

		1963 - 1991		1986 - 1991	
		N	b	N	b
DDE	Sparrowhawk	1195	-0.0345***	482	-0.1129***
	Kestrel	1182	-0.0378***	276	-0.1539***
	Heron	735	-0.0423***	193	-0.1260***
	Kingfisher	180	-0.0469***	41	-0.0553 ns
	Great-crested Grebe	167	-0.0177 ns	46	-0.4242***
PCBs	Sparrowhawk	1150	-0.0138***	482	-0.1568***
	Kestrel	1040	0.0028 ns	276	-0.0699**
	Heron	601	-0.0272***	193	-0.1216**
	Kingfisher	175	-0.0252*	41	-0.0740 ns
	Great-crested Grebe	154	-0.0365**	46	-0.2207*
HEOD	Sparrowhawk	1195	-0.0298***	482	-0.1759***
	Kestrel	1182	-0.0341***	276	-0.1035***
	Heron	735	-0.0513***	193	-0.1102**
	Kingfisher	180	-0.0246***	41	-0.1182*
	Great-crested Grebe	167	-0.0199*	46	-0.2396**
Hg	Sparrowhawk	970	-0.0425***	482	-0.0154 ns
	Kestrel	849	-0.0574***	276	0.0652*
	Heron	438	-0.0228***	193	-0.0428*
	Kingfisher	102	-0.0123 ns	41	0.0387 ns
	Great-crested Grebe	86	-0.0043 ns	46	-0.1364***

Notes: 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.

Figure 1. Trends in pollutant residues in livers of Sparrowhawks, 1963 - 1991. 3-year geometric mean and one geometric standard error.

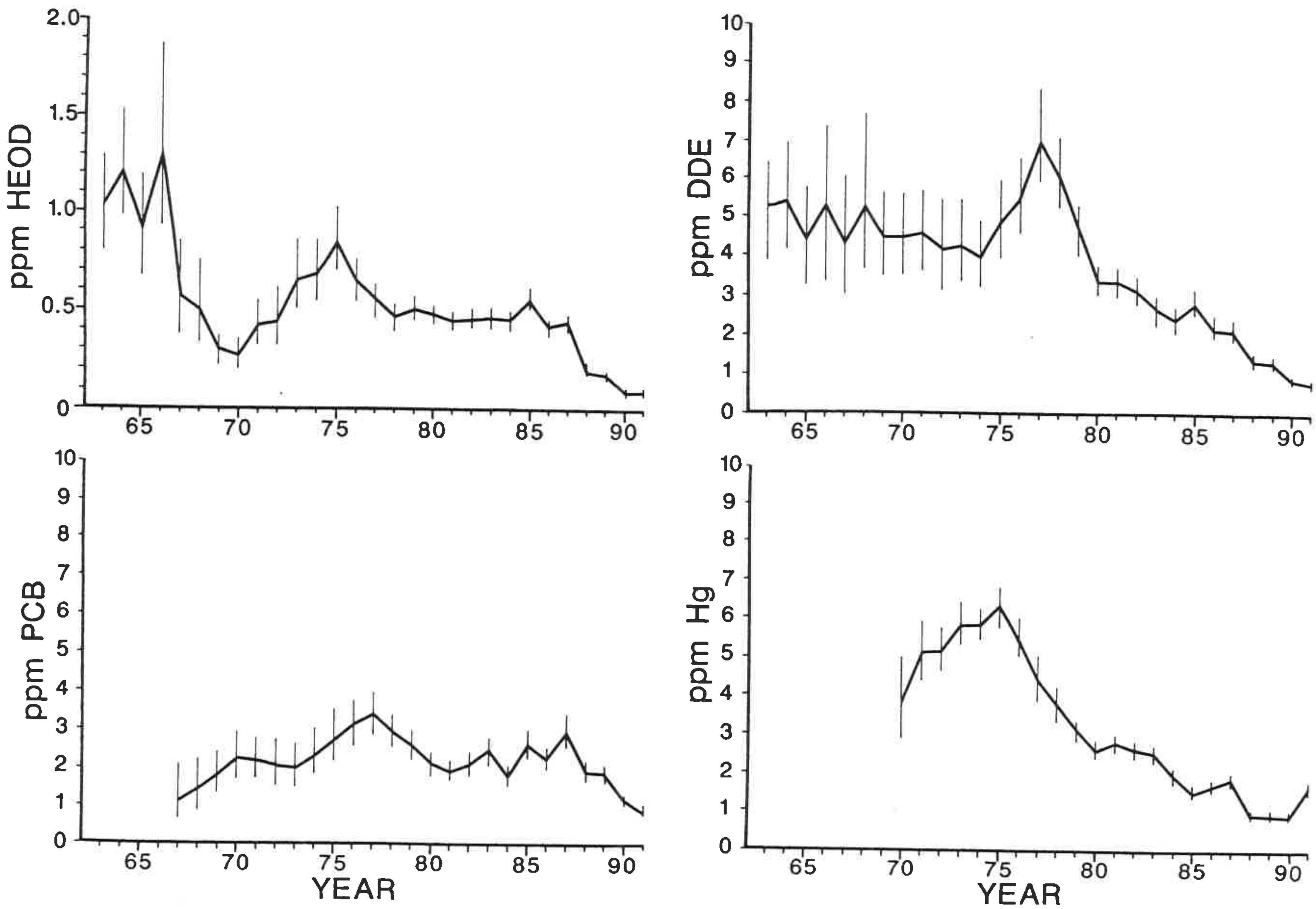


Figure 2. Trends in pollutant residues in livers of Kestrels, 1963 - 1991. 3-year geometric mean and one geometric standard error

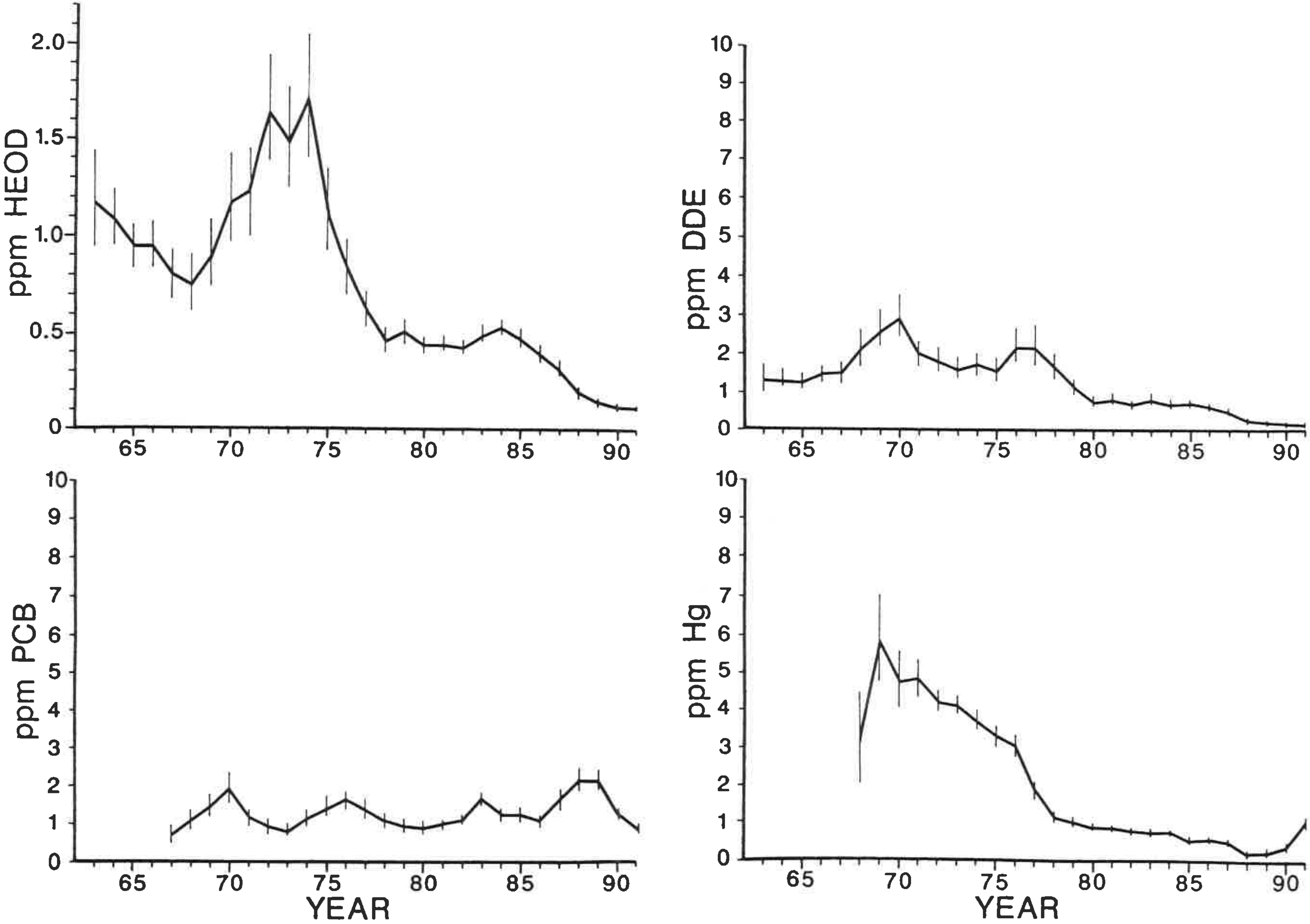


Figure 3. Trends in pollutant residues in livers of Herons, 1963 - 1991.
3-year geometric mean and one geometric standard error

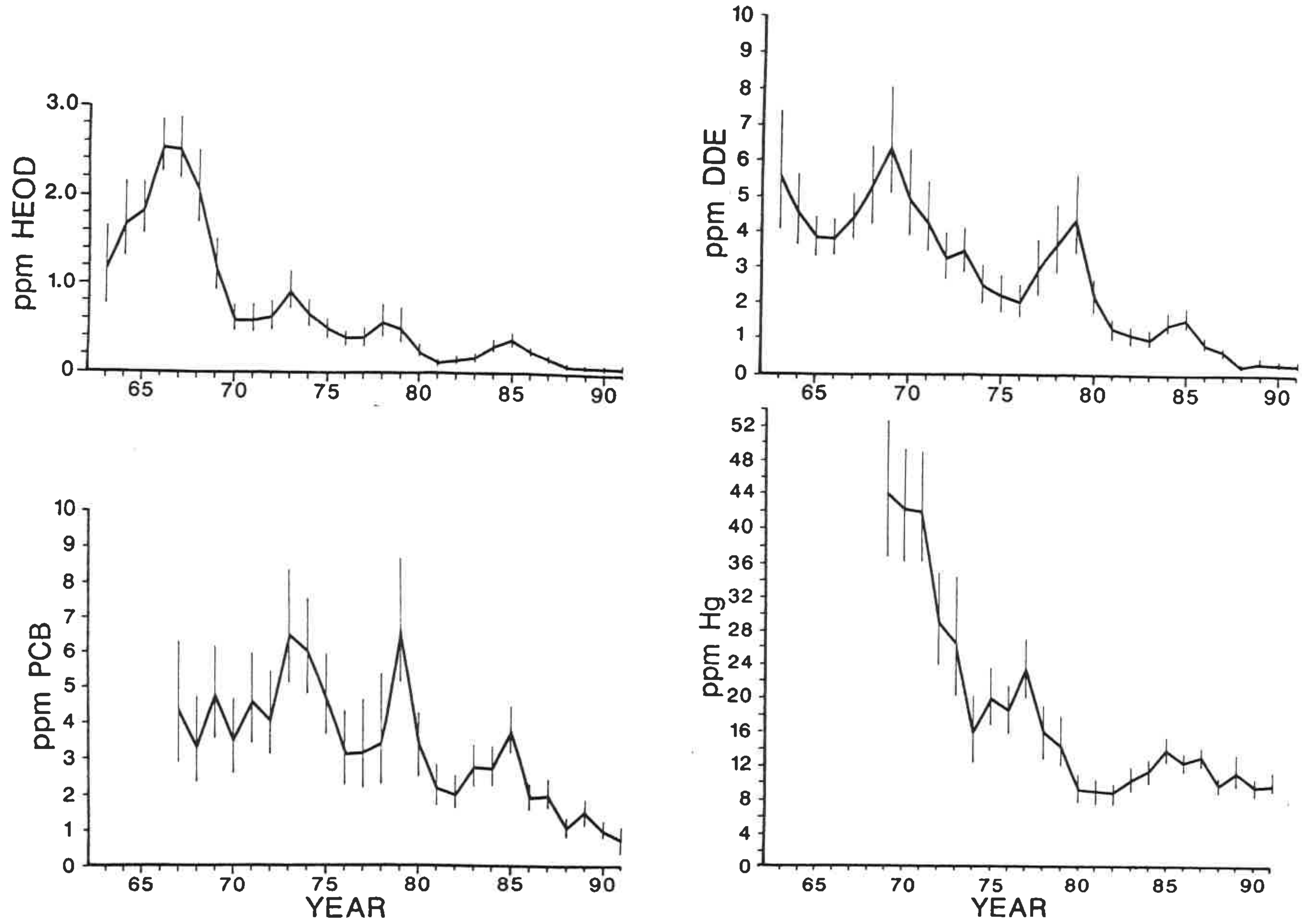


Figure 4. Trends in pollutant residues in livers of Kingfishers, 1963 - 1991. 3-year geometric mean and one geometric standard error.

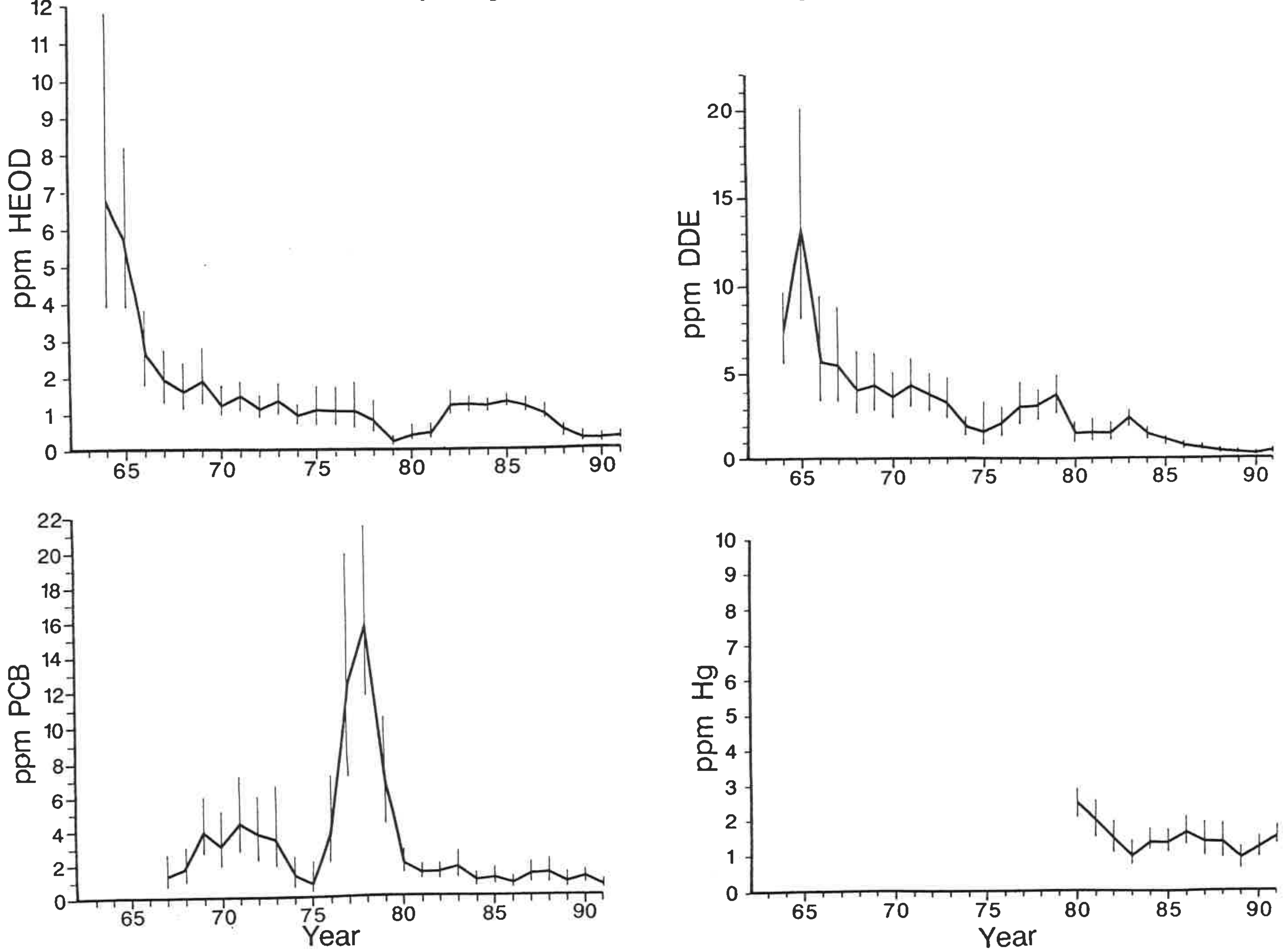
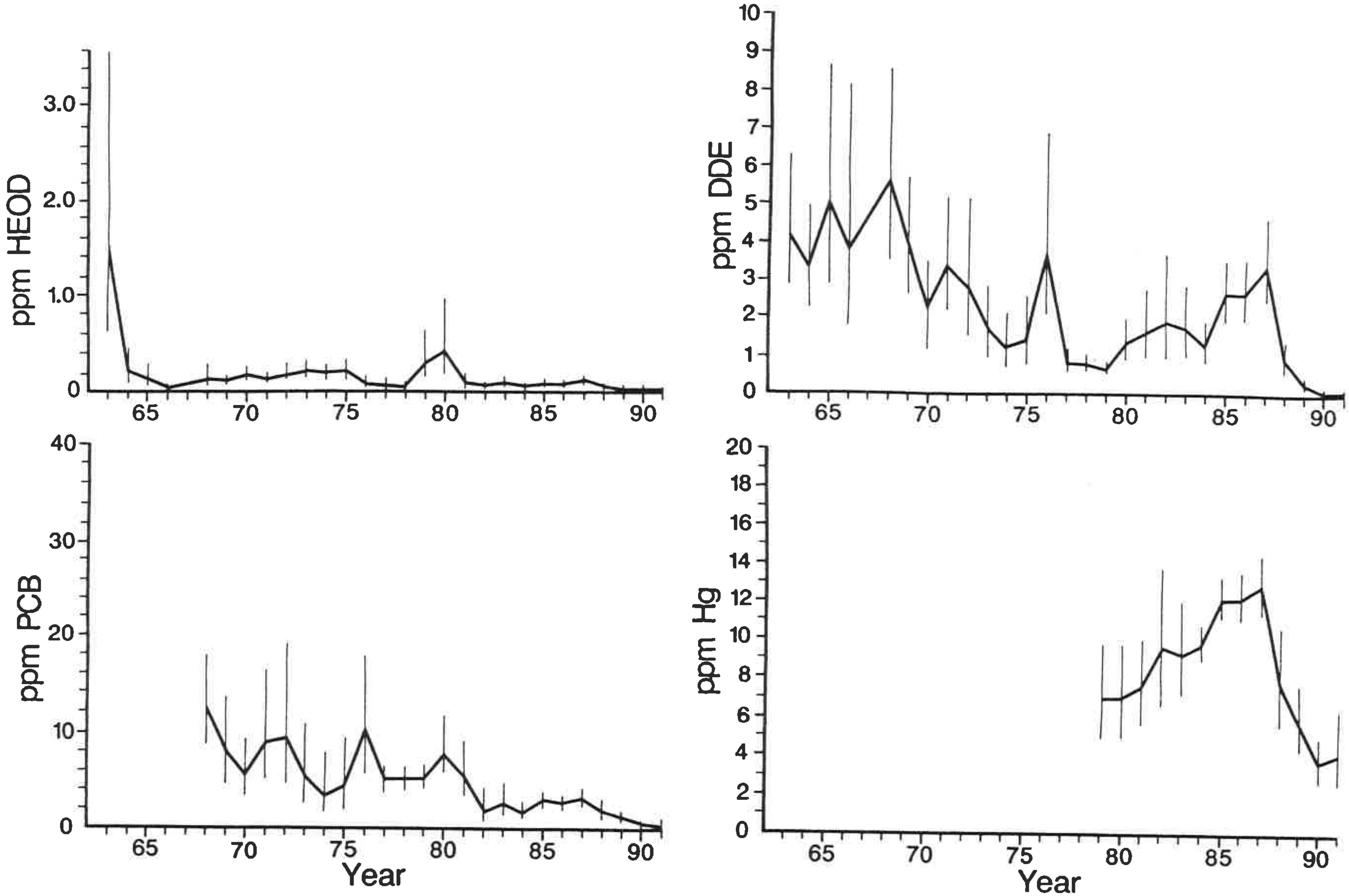


Figure 5. Trends in pollutant residues in livers of Great-crested Grebes, 1963 - 1991. 3-year geometric mean and one geometric standard error. Note that no birds were received in 1967.



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(NATURAL ENVIRONMENT RESEARCH COUNCIL)

JNCC/NERC CONTRACT HF3/08/01
ITE PROJECT T07061f5
Annual report to Joint Nature Conservation Committee

BIRDS AND POLLUTION

Part 2 Organochlorines and mercury in peregrine eggs, 1991

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August 1992

2 ORGANOCHLORINES AND MERCURY IN PEREGRINE EGGS, 1991

2.1 Introduction

The findings from all peregrine eggs analysed between 1961 and 1986 were summarised in Newton *et al.* (1989); those from eggs analysed during 1987-90 are given in previous reports in this series, and those from eggs analysed in 1991 are given in Table 5. The table includes eggs given to Glasgow University Veterinary School, which were analysed as part of our programme. This gave at least one egg from a total of 47 clutches. Unfortunately no coastal eggs were represented.

2.2 Results

The findings add little to those of previous years; they confirm continuing widespread contamination of British peregrine eggs with organochlorines and mercury. However, most of the residues were present at relatively low level. The highest DDE level recorded in 1991 was 6.4 ppm wet weight (in an egg from Strathclyde), the highest HEOD level was 0.5 ppm (also Strathclyde), the highest PCB level 10.7 ppm (in an egg from Gwynedd) and the highest mercury level 3.0 ppm dry weight (also Gwynedd).

There seems little doubt that organochlorine levels in British peregrines are continuing to decline.

2.3 Reference

NEWTON, I., BOGAN, J.A. & HAAS, M.B. 1989. Organochlorines and mercury in British Peregrine eggs. Ibis 131; 355-376.

Table 5. Residue levels (organochlorine ppm wet weight; mercury ppm dry weight) and shell-indices for Peregrine eggs analysed in 1990. ND=none detected.

Egg No.	Year	County	Shell Index	pp'-DDE	HEOD	PCBs	Hg
WALES							
E4737	1991	Gwynedd	1.63	5.29	0.14	10.67	2.99
E4748	1991	Gwynedd	1.70	2.20	0.18	4.24	1.87
E5003	1991	Powys	1.76	0.44	0.08	0.19	0.35
E5097	1991	-	1.74	1.10	0.10	0.41	0.42
E5099	1991	-	1.95	2.85	0.06	1.13	0.47
E5100	1991	-	1.87	0.90	0.08	0.80	0.89
E5101	1991	-	2.11	1.21	0.09	0.35	0.68
E5110	1991	-	1.89	0.76	0.06	0.45	0.78
E5112	1991	-	1.76	0.56	0.08	0.24	0.55
E5115	1991	-	1.75	2.36	0.12	1.23	0.63
E5116	1991	-	-	2.73	0.40	1.85	0.60
E5117	1991	-	1.75	0.42	0.03	0.29	0.25
E5118	1991	-	1.85	2.01	0.33	1.48	0.84
E5120	1991	-	2.12	1.00	0.15	0.34	1.12
E5121	1991	-	2.18	1.87	0.17	0.64	1.24
E5122	1991	-	1.54	3.74	0.17	5.34	0.64
NORTHERN ENGLAND							
E4753	1991	Cumbria	1.84	1.17	0.04	0.79	0.49
E4755	1991	Cumbria	1.90	0.97	0.10	3.16	1.22
E4757	1991	Cumbria	-	2.30	0.27	2.41	1.18
E4759	1991	Cumbria	1.93	3.16	0.29	2.85	2.32
E4760	1991	Cumbria	1.50	3.89	0.22	4.50	1.64
E4761	1991	Cumbria	1.55	4.50	0.17	5.95	1.53
E4762	1991	Cumbria	2.05	0.37	0.06	0.30	0.61
E4764	1991	Cumbria	1.94	0.13	0.03	0.09	0.61
CENTRAL AND EASTERN HIGHLANDS							
E4640	1991	S'clyde	-	6.41	0.45	9.26	1.87
E4980	1991	Ross-shire	1.28	0.07	0.01	0.11	0.30
E4983	1991	Ross-shire	1.83	0.02	ND	0.01	ND
E4984	1991	Ross-shire	1.91	0.13	0.01	0.20	0.77
E5019	1991	Grampian	-	0.27	0.05	1.04	ND
E5020	1991	Grampian	1.82	0.89	0.08	0.97	ND
E5022	1991	Grampian	1.74	0.21	0.02	0.12	0.54
E5050	1991	Central	-	0.08	0.02	0.05	0.71
E5051	1991	Central	-	1.02	0.06	1.42	1.83
E5052	1991	Central	-	0.53	0.05	0.77	1.06
E5055	1991	Central	-	0.10	0.02	0.10	1.07
E5056	1991	Central	-	0.44	0.04	1.06	1.34
E5057	1991	Central	-	0.06	0.01	0.06	1.13
E5058	1991	S'clyde	-	0.27	0.02	0.29	0.49
E5059	1991	S'clyde	-	0.46	0.02	0.24	1.09
E5060	1991	S'clyde	-	0.12	0.03	0.22	1.37

E5062	1991	S'clyde	-	0.38	0.21	0.28	0.87
E5063	1991	S'clyde	-	0.38	0.01	0.66	0.57
E5064	1991	S'clyde	-	0.47	0.05	0.24	1.73
E5065	1991	S'clyde	-	0.07	0.01	0.04	2.39
E5066	1991	S'clyde	-	0.09	0.01	0.05	0.49
E5067	1991	S'clyde	-	0.32	0.03	0.12	0.73
E5001	1991	Highland	2.17	0.20	0.02	0.32	0.44

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BIRDS AND POLLUTION

Part 3 Organochlorines and mercury in merlin eggs, 1991

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August 1992

3 ORGANOCHLORINES AND MERCURY IN MERLIN EGGS, 1991

3.1 Introduction

The findings from most previous analyses of merlin eggs were given in Newton & Haas (1988), those from 1987-1990 in previous reports in this series, while those from 1991 are summarised in Table 6.

3.2 Results

The results from these additional 42 merlin eggs add little to the findings from previous years, but serve to confirm the continuing widespread contamination of British merlins with organochlorines and mercury. DDE exceeded 10 ppm (wet weight) in four eggs from the North York moors, and, as in previous years, Hg was present at high level (5.5 - 19.0 ppm in dry weight) in eggs from the Northern Isles. On the other hand, PCB levels were relatively low (highest value 5.8 ppm, wet weight), and HEOD exceeded 1 ppm in only one of the eggs examined.

Together with previous findings, the data indicate a continuing downward trend in organochlorine residues in merlins, but occasional high DDE levels still occur and mercury remains at high level in eggs from the Northern Isles.

3.3 Reference

NEWTON, I. & HAAS, M.B. 1988. Pollutants in Merlin eggs and their effects on breeding. Brit. Birds 81: 258-269.

Table 6. Residue levels and shell indices for Merlin eggs analysed in 1991. Organochlorines expressed as ppm in wet weight (and in lipid); Mercury as ppm in dry weight.

C=clutch size; B=brood size; ND=none detected

County	C	B	Shell Index	DDE	HEOD	PCBs	Hg
WALES							
Dyfed	-	-	1.22	0.80(11.40)	0.04(0.60)	0.14(1.99)	2.11
-	5	3	1.28	0.53(6.70)	0.04(0.45)	0.19(2.35)	0.83
-	5	3	1.22	1.26(18.87)	1.26(18.87)	0.10(1.55)	2.05
-	5	2	1.26	0.54(7.71)	0.03(0.47)	0.10(1.41)	2.51
-	4	-	1.14	2.54(44.96)	0.02(0.41)	0.14(2.49)	3.55
NORTHERN ENGLAND							
N. Yorks	4	3	1.10	5.17(83.09)	0.95(15.33)	2.54(40.87)	3.57
N. Yorks	-	-	-	3.26(57.79)	0.09(1.59)	1.30(23.06)	1.40
N. Yorks	-	-	1.07	14.41(261.86)	0.13(2.42)	4.16(19.05)	2.09
N. Yorks	4	2	1.13	6.45(137.33)	0.14(2.90)	0.86(18.37)	4.46
N. Yorks	-	-	1.32	5.85(103.33)	0.13(2.36)	1.91(33.76)	2.03
N. Yorks	-	-	1.18	3.93(68.36)	0.40(7.02)	0.96(16.77)	1.41
N. Yorks	-	-	1.11	16.99(290.58)	0.10(1.68)	1.73(29.58)	2.43
N. Yorks	-	-	1.24	5.85(90.36)	0.56(8.63)	1.27(19.68)	1.89
N. Yorks	-	-	-	12.06(188.31)	0.45(7.05)	5.75(89.69)	3.19
N. Yorks	-	-	1.28	0.33(6.30)	0.03(0.61)	0.11(2.11)	0.68
N. Yorks	-	-	0.99	18.96(311.10)	0.47(7.65)	1.27(20.86)	2.45
GALLOWAY AND SOUTHERN UPLANDS							
Kincards	-	-	-	0.87(34.30)	0.05(1.82)	0.79(30.98)	4.41
Perths	-	-	1.10	5.92(221.06)	0.13(4.87)	0.76(28.26)	4.05
Aberdeens	-	-	1.17	3.28(88.32)	0.22(5.89)	1.22(32.82)	2.85
Aberdeens	-	-	1.19	4.62(83.26)	0.12(2.11)	0.40(7.18)	0.86
Banffshire	-	-	0.99	4.74(218.74)	0.16(7.35)	1.84(84.90)	2.51
Aberdeens	-	-	1.38	3.98(68.71)	0.10(1.64)	1.01(17.42)	1.78
Strathcl	3	1	1.13	1.03(20.49)	0.03(0.66)	0.77(15.23)	3.25
Strathcl	4	1	1.27	0.28(5.66)	0.02(0.32)	0.21(4.25)	2.36
Argyll	-	-	1.28	1.25(43.31)	0.09(2.96)	0.44(15.29)	5.12
Kincards	-	-	1.13	5.65(122.91)	0.22(4.86)	2.50(54.41)	2.67
Aberdeens	-	-	0.96	6.33(86.64)	0.09(1.24)	3.04(41.66)	2.95
Aberdeens	-	-	1.16	3.05(52.97)	0.15(2.57)	1.82(31.63)	2.08
Aberdeens	-	-	1.06	2.46(79.07)	0.10(3.33)	2.64(84.74)	2.88
Aberdeens	-	-	1.04	3.28(66.84)	0.07(1.46)	3.16(64.41)	2.08
Kincards	-	-	0.96	6.23(111.25)	0.24(4.26)	4.00(71.46)	1.44
Tayside	-	-	1.19	4.57(94.57)	0.81(16.60)	3.86(79.78)	1.59

HIGHLANDS

Sutherland	-	-	1.04	3.81(94.57)	0.16(4.00)	0.33(8.11)	2.63
Moray	-	-	1.30	0.95(16.70)	0.02(0.42)	0.28(5.02)	4.63
Moray	-	-	1.28	0.73(13.28)	0.05(0.88)	0.22(3.95)	2.07
Moray	-	-	1.45	0.60(10.48)	0.02(0.35)	0.15(2.64)	2.56
Ross-shire	-	-	1.19	1.18(21.98)	0.11(2.07)	0.32(6.02)	5.03
Ross-shire	-	-	1.12	1.14(15.88)	0.11(1.57)	0.37(5.18)	6.01

NORTHERN ISLES

Shetland	-	-	-	0.45(11.57)	0.03(0.66)	0.63(15.99)	16.49
Shetland	-	-	-	0.68(18.96)	0.02(0.46)	1.64(45.66)	19.06
Shetland	-	-	-	1.20(23.51)	0.05(1.00)	0.24(4.61)	7.53
Shetland	-	-	-	1.10(26.31)	0.03(0.76)	0.31(7.28)	5.47

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BIRDS AND POLLUTION

Part 4 Organochlorines and mercury in Golden Eagle eggs, 1991

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Monks Wood
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August 1992

4 ORGANOCHLORINES AND MERCURY IN GOLDEN EAGLE EGGS, 1991

4.1 Introduction

The findings from analyses of golden eagle eggs obtained during 1963-86 were given in Newton & Galbraith (1991), and from 1987-90 in previous reports in this series. Eggs from seven clutches were received in 1991, and the results are given in Table 7.

4.2 Results

The new analyses serve to confirm the low levels of contamination found in recent years in Golden Eagle eggs (Table 7). All residue levels were low, including those from three coastal eggs, and well within the range of previous values.

4.3 Reference

Newton I. & Galbraith, A.E. 1991. Organochlorines and mercury in the eggs of Golden Eagles *Aquila chrysaetos* from Scotland. Ibis 133: 115-120.

Table 7. Residue levels (organochlorine ppm wet weighit; Mercury ppm dry weight) and shell-indices for Golden Eagle eggs received in 1991.

Number	SI	DDE	HEOD	PCB	Hg
WESTERN SCOTLAND - COASTAL					
E4988	3.28	0.04	0.01	0.32	ND
E4989	-	0.03	0.01	0.11	ND
E5070	-	0.06	0.02	0.25	1.63
WESTERN SCOTLAND - INLAND					
E4990	3.17	0.04	0.01	0.14	ND
E4991	3.47	0.05	0.01	0.16	ND
EASTERN SCOTLAND - INLAND					
E5016	3.04	0.03	0.02	0.03	ND
E5017	3.30	0.01	0.03	0.14	ND

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BIRDS AND POLLUTION

Part 5 Organochlorines and Mercury in Sea Eagle Eggs

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5 ORGANOCHLORINES AND MERCURY IN SEA EAGLE EGGS

5.1 Introduction

So far, the Sea Eagles *Haliaetus albicilla* introduced to western Scotland in the period 1976-85 have bred with poor success. Most breeding attempts have failed completely. One of the possible problems might be contamination with organochlorine and mercury residues, which the birds could acquire particularly from the marine component of their diet, various fish and seabirds. Some of the nests have been on inaccessible sea-cliffs, and so far only three unhatched eggs have been obtained for analysis, all from the island of Mull. The findings are given in Table .

5.2 Results

The egg from 1986 was extremely heavily contaminated with DDE, HEOD and PCBs; and that from 1990 with PCBs. The egg from 1991 had much lower levels of all three types of chemicals. This may have been due to the different diet composition noted in this year, as hares were more abundant than usual and we were told that the eagles took more of these animals and other land-based prey. Mercury levels were not especially high in any of the eggs. Clearly further monitoring of egg residues is desirable.

Table 8. Residue levels (organochlorine ppm wet weight (in lipid); mercury ppm in dry weight), and shell indices for Sea Eagle (*Haliaeetus albicilla*) eggs analysed from 1986 to 1991.

Year	Location	Shell index	pp'-DDE	HEOD	PCBs	Hg
1986	Mull	-	29.27(313.01)	8.07(86.27)	32.19(344.21)	0.56
1990	Mull	-	2.32(73.44)	1.77(56.20)	14.73(467.02)	ND
1991	Mull	4.15	0.31(13,00)	0.02(0.67)	0.15(6.14)	0.46

Eggs without a Shell Index were blown before receipt.

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BIRDS AND POLLUTION

Part 6 Organochlorines and Mercury in Gannet Eggs, 1991

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Monks Wood
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August 1992

6 ORGANOCHLORINES AND MERCURY IN GANNET EGGS, 1991

6.1 Introduction

The findings from all Gannet eggs examined to 1987 were summarised in the report for 1989, and in published form in Newton *et al.* (1990). Subsequent results, based on eggs from Ailsa Craig in 1989 and from Ailsa Craig, Bass Rock and St Kilda in 1990 were given in the reports for 1990 and 1991, while results from some Hermaness eggs obtained in 1991 are given in Table 9.

6.2 Results

Low levels of DDE, HEOD, PCBs and Hg were found in all the eggs from Hermaness. Compared with previous eggs from this colony, obtained in 1983, the recent eggs showed a significant increase in PCB and Hg levels, and a significant improvement in mean shell-index. With such low levels of chemicals, however, little biological significance could be attached to these changes.

Longer term trends in chemical residues at four colonies over the period 1971-91 and 1981-91 were examined by linear regression models, with the annual geometric mean levels as the dependent variables and year as the independent variable (Table 10). At certain colonies linear models may not have given such a good fit to the data as polynomial models, but our objective was merely to find whether there had been a net rise or fall in residue levels during the periods concerned. Over the longer period 1971-91, the six significant changes detected included declines in all chemicals at Ailsa Craig, and in DDE at Bass Rock and an increase in mercury at St Kilda. Over the shorter period 1981-91, the only significant change was a decline in DDE at Ailsa Craig. At all colonies, however, all residues were low and unlikely to have adverse effects on Gannet reproduction or survival.

6.3 Reference

NEWTON, I., HAAS, M.B. & FREESTONE, P. 1990. Trends in organochlorine and mercury levels in Gannet eggs. Environ. Pollut. 63: 1-12.

Table 9. Residues of organochlorines (ppm wet weight) and mercury (ppm dry weight) in the eggs of Gannets (Sula bassana), from Hermaness, 1991.

Colony	Shell Index	DDE	HEOD	PCBs	Hg
HERMANESS	2.80	0.14	0.08	0.35	2.97
	2.95	0.27	0.10	0.69	3.31
	3.23	0.10	0.09	0.41	2.51
	3.18	0.12	0.09	0.43	3.30
	3.30	0.13	0.15	0.84	3.41
	3.23	0.10	0.07	0.31	3.02
	3.36	0.15	0.12	0.83	3.61
	2.89	0.12	0.09	0.71	3.44
	3.29	0.14	0.11	0.65	2.75
	3.14	0.12	0.07	0.38	3.83
Mean	3.14	0.13	0.09	0.53	3.20
SD	0.19	0.12	0.10	0.16	0.05
Range within 1 SE	3.08-3.20	0.12-0.15	0.09-0.10	0.47-0.59	3.07-3.33

*Means: arithmetic for Shell-index; geometric otherwise

Differences in Shell Index, PCB and mercury levels showed a significant increase since 1983.

Shell Index	t_{18}2.34	P>0.05
DDE	t_{18}0.18	ns
HEOD	t_{18}0.72	ns
PCB	t_{18}2.12	P>0.05
Hg	t_{18}21.38	P>0.001

Table 10. Long-term trends of pollutants in Gannet eggs based on regression analysis of annual geometric mean values on year. Linear regression coefficients with probability (* P=<0.05; ** P=<0.01; *** P<0.001; ns=not significant).

	1971 - 1991	1981 - 1991
AILSA CRAIG		
HEOD	-0.0303**	0.0027 ns
DDE	-0.1038**	-0.0468*
PCB	-0.3854*	0.0295 ns
Hg	-0.1001**	-0.0977 ns
BASS ROCK		
HEOD	-0.0188 ns	0.0189 ns
DDE	-0.0638**	-0.0120 ns
PCB	-0.1898 ns	0.4195 ns
Hg	0.0149 ns	-0.1184 ns
ST. KILDA		
HEOD	0.0213 ns	-0.0442 ns
DDE	-0.0125 ns	-0.0526 ns
PCB	0.0827 ns	-0.4997 ns
Hg	0.2252*	0.1511 ns
HERMANESS		
HEOD	-0.0044 ns	-0.0090 ns
DDE	-0.0270 ns	-0.0247 ns
PCB	-0.0242 ns	0.0210 ns
Hg	0.1354 ns	0.0902 ns

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BIRDS AND POLLUTION

Part 7 Rodenticide Residues in Barn Owls

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7 RODENTICIDE RESIDUES IN BARN OWLS

7.1 Introduction

The aims of this study were to find (1) to what extent Barn Owls *Tyto alba* in Britain are contaminated with certain rodenticide residues, and (2) whether such residues are likely to represent a significant source of mortality. As Barn Owl numbers are thought to have declined in Britain during the present century (Bunn et al 1982, Shawyer 1987, Percival 1991), it is important to assess any role that secondary poisoning from rodenticides might have.

It is the so-called 'second-generation' anticoagulant rodenticides which are likely to pose the greatest threat, as these are rapidly replacing warfarin and other 'first generation' rodenticides, to which rats and mice in many areas have become resistant. Four second generation rodenticides are currently in use in Britain. Difenacoum was introduced in 1975, bromadiolone in 1980, brodifacoum in 1982 and flocoumafen in 1986. All these chemicals are more toxic than warfarin (Table 11), and also more persistent, giving the possibility of secondary poisoning in rodent predators. As the Barn Owl often nests and hunts around farm buildings where these chemicals are commonly used, it would seem to be at particular risk.

We began analysing Barn Owls for rodenticide residues in 1983, and the findings from 145 carcasses examined up to March 1989 were summarised in Newton *et al.* (1990). Since then, we have examined a further 218 carcasses, and the results from all 363 birds are brought together here.

7.2 Methods

Carcasses were obtained and analysed as described in Newton *et al.* (1990). A recent complication was that the analytical equipment was changed in 1990 from a Varian Spectrofluorometer to a Shimadzu Spectrofluorophotometer, which lowered the limits of detection. In earlier samples the lowest limit of detection was about 0.005 μg for difenacoum, 0.008 μg for brodifacoum, 0.01 μg for flocoumafen and 0.02 μg for bromadiolone (a mass of 0.01 μg was equivalent to a concentration of 0.01 - 0.02 μg^{-1g}, depending on sample weight). On the new machine, these limits fell to around 0.0025, 0.004, 0.005 and 0.01 μg for the four compounds respectively. In effect, however, this change of equipment meant that only one bird in 1990-91 contained residues (0.01 bromadiolone in 1990) that would have been missed in earlier years, so the findings were not corrected to allow for the change in sensitivity. Results are reported here on a wet weight basis, and refer to all isomers of the chemicals involved.

7.3 Survey results

In the period 1983-91, a total of 363 Barn Owls was received for analysis. They came from all major regions of Britain (Figure 6, Table 12), and from all months of the year (Newton *et al.* 1991). No ecological significance could be attached to the rise in numbers received per year over the study period, as this could have been due to the greater publicity given to the species in more recent years. The sex ratio among 350 birds in which the gonads could be examined was exactly equal, with 175 of each sex. The age ratio among 346 birds was 130 adults to 216 (62%) first-year birds. As an estimate of first-year mortality, this latter figure is the same as calculated by Glue (1971) from 320 ring recoveries in 1909-69, but lower than our previous estimate of 70% based on only 100 birds in 1989-90 (Newton et al 1991).

The numbers of owls in different mortality categories are given in Table 13, along with the number in which rodenticides were detected. The main mortality causes were road accidents (45%), other accidents (6%) and starvation (36%), with various other causes accounting for the remainder. In each of the main categories around 20% of carcasses had detectable rodenticide residues in the liver.

7.4 Proportion containing residues

Of the 363 birds examined, 75 (21%) contained detectable residues of second generation rodenticides in the liver. Most specimens had residues of only one chemical, but 14 birds had residues of 2 or 3 different chemicals. No obvious age or sex bias was apparent: 26% of all adults contained rodenticide compared with 19% of all first-year birds, and 20% of all males compared with 22% of all females. Nor was there much regional variation in the frequency of contaminated birds.

The proportion of owls in which residues were detected, varied considerably from year to year, but was especially high in 1990-91, at over 30% (Table 14). While this might have represented a genuine increase over the years, it also coincided with the change to sensitive equipment. In theory, this should have hardly affected the figures, for only one bird from the later period would have been missed earlier, but it still casts doubt on the validity of the upward trend. None-the-less, the fact that rodenticides were detected in more than one third of all Barn Owls received in these years indicates how widespread the exposure to these chemicals now is.

Overall, difenacoum was found in 49 (13%) birds, bromadiolone in 23 (6%), brodifacoum in 16 (4%) and flocoumafen in five (1%). Interestingly, these figures closely matched the usage frequency of the four chemicals on British farms (Table 15), as revealed by a survey in 1988-89 by the Ministry of Agriculture, Fisheries & Food (Olney *et al* 1991a, 1991b). This survey was based on questionnaires sent to a large sample of farms throughout England and Wales, asking for details of the types of rodenticides used. It seems, therefore, that Barn Owls accumulated a more or less representative cross-section of the second generation rodenticides in use.

Difenacoum was found in liver at concentrations of 0.002-0.135 $\mu g\ g^{-1}$ (mean 0.029 $\mu g\ g^{-1}$), bromadiolone at 0.004-0.319 $\mu g\ g^{-1}$ (mean 0.099. $\mu g\ g^{-1}$), brodifacoum at 0.002-0.515 $\mu g\ g^{-1}$ (mean 0.109 $\mu g\ g^{-1}$), and flocoumafen at 0.003-0.144 $\mu g\ g^{-1}$ (mean 0.045 $\mu g\ g^{-1}$).

In previous studies various experimental owls which were known to have died of rodenticide poisoning contained after death around 0.20-1.25 $\mu g\ g^{-1}$ residue in their liver (Table 11). However, not all owls with residues in this range died of rodenticide poisoning. Only six (1.7%) owls in our sample, or 80% of those in which rodenticide was detected, contained more than 0.2 $\mu g\ g^{-1}$ of residue. But five of these birds had apparently died of causes other than rodenticide poisoning, mostly accidents or starvation. Only two birds were diagnosed on post-mortem as likely rodenticide victims. One bird contained 0.423 $\mu g\ g^{-1}$ brodifacoum in its liver, within the recognised lethal range. The other bird contained 0.002 μg^{-1} brodifacoum plus 0.047 $\mu g\ g^{-1}$ bromadiolone and 0.003 $\mu g\ g^{-1}$ flocoumafen. Both these birds had extensive haemorrhaging of heart, lungs, liver, brain and subcutaneous areas under the wings, and showed no other obvious cause of death. It seems then that, despite the frequent occurrence of rodenticide residues in British Barn Owls, less than 1% of our total sample are likely to have died directly of rodenticide poisoning. Another 20% contained what were probably sublethal levels.

7.5 Discussion

About 21% of the 363 Barn Owls examined in 1983-91 had residues of one or more rodenticide in their bodies, but this sample may not reflect the true exposure of owls to rodenticides in the regions concerned. Almost certainly the owls in our sample did not form a representative cross-section of Barn Owl deaths. They were probably biased towards those forms of mortality most associated with people, accounting for the high proportion of accident victims. On the other hand, the sample may have under-estimated the proportion of deaths due to rodenticides because, some hours before death, affected animals become lethargic. Any affected owls are therefore likely to die on their roost sites, in tree holes or roof cavities, where they are less likely to be found by the casual observer than are birds that die in the open. This statement is entirely conjectural, however, and as yet there is no evidence one way or the other.

Despite any possible bias in the sampling procedure, it is clear that contamination of Barn Owls with second generation rodenticides is both widespread and increasing. Contaminated specimens came from all major regions of Britain, and were not restricted to the warfarin-resistance areas, as depicted by Shawyer (1987). Nevertheless, the residues in most specimens were well below lethal levels, and less than 1% of all owls examined appeared from their symptoms to have died directly from rodenticide poisoning. As five owls which died of other causes had rodenticide levels within the known lethal range (above 0.2 $\mu g\ g^{-1}$), rodenticide may have pre-disposed their deaths or reduced the chance of recovery from accidents. Alternatively if they had not died of some other cause, they may have later succumbed to rodenticide. Either way, the likely maximum proportion of deaths to rodenticide is still small (at most 2% of all specimens). As yet, therefore, we have no evidence that second-generation rodenticides contribute appreciably to the overall mortality in British Barn Owls, and hence no evidence that they are affecting population levels.

Recent work on mammals and birds has shown that rodenticide residues may persist in liver for up to several months after a single oral dose (Parmar *et al.* 1987, Huckle *et al* 1989a, b). This means that owls in which residues were detected could have been exposed up to several months previously or on more than one occasion. On the other hand, it is unlikely that rodent prey species would remain contaminated so long, because in these animals a single oral dose would normally be lethal. Trials have shown that mice and rats die some 2-14 days (mostly 3-8) after a single feed of any of the chemicals involved (Bajomi 1984, Hoppe & Krambias 1984, Newton *et al* 1991 & unpublished).

The main prey of Barn Owls in Britain is the Field Vole *Microtus agrestis* (Glue 1974, Taylor 1989), which has not yet been subject to extensive control operations. Clearly, if the new rodenticides were ever used away from buildings (and contrary to regulations), the potential for secondary poisoning of owls would greatly increase. A study of the foraging behaviour of Barn Owls on farmland in the United States (Hegdal & Blaskewicz 1984, Hegdal & Colvin 1984) showed that owls seldom hunted close to farm buildings and would therefore be unlikely to ingest high levels of rodenticide when usage is restricted to those sites. In our sample, two out of two birds from the Isle of Man were contaminated, as were six out of eight from the Channel Islands. On these islands, Field Voles are lacking, and Barn Owls feed much more heavily on commensal Rats *Rattus norvegicus* and House Mice *Mus musculus*, together with Wood Mice *Apodemus sylvaticus*. It would not be surprising, therefore, if a high proportion of owls on these islands were contaminated. The different diet of Barn Owls on the Isle of Man also led them to be more affected by dieldrin than mainland birds (Newton et al 1991).

7.6 Summary

Of 363 Barn Owls examined during 1983-91, the deaths of 51% were attributed to accidents, of 36% to starvation, and the rest to various minor causes. The residues of one or more rodenticides were found in the liver of 75 (21%) of these birds, but only two birds were thought to have died directly of rodenticide poisoning. As yet, we have no evidence that these chemicals cause any appreciable mortality or have had any appreciable impact on Barn Owl numbers in Britain.

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Table 11. Toxicity and other details of four second general rodenticides and warfarin.

Chemical	Year of Introduction to UK	LD_{50} (mg kg^{-1})		Liver levels (ug g^{-1}) detected in poisoned non-target species	
		Rat	Mouse		
Warfarin	1952	185	374	-	
Difenacoum	1975	1.80	0.80	Tawny Owl[1]	<0.2
Bromadiolone	1980	0.55	0.99	None reported	
Brodifacoum	1982	0.26	0.40	Barn Owl[2]	0.63-1.25
				Barn Owl[3]	0.29-0.61
				Screech Owl[4]	0.4-0.8
Flocoumafen	1986	0.25	1.13	Barn Owl[5]	0.93

1 Anon 1982
2 Newton *et al* 1990
3 Greig-Smith *et al* 1989
4 Hegdal & Colvin 1988
5 Newton *et al* 1992

Table 12. Levels of rodenticides (ppm in wet weight corrected for moisture loss) in the livers of Barn Owls (Tyto alba) analysed in 1991.

ND=None detected; J=juvenile in first year; A=adult, other than first year; M=male; F=female; brod=brodifacoum; difen=difenacoum; brom=bromadialone; floc=flocoumafen.

No.	Date	County	Age	Sex	brod	difen	brom	floc
10062	Dec 88	Somerset	A	M	ND	ND	ND	ND
10150	- 90	Norfolk	J	F	ND	0.083	ND	ND
10136	Jan 90	Cambs	A	F	ND	ND	ND	ND
10379	Feb 90	Devon	-	-	ND	0.013	ND	ND
9952	Mar 90	Devon	J	F	ND	ND	ND	ND
9980	Mar 90	Anglesey	J	F	ND	ND	0.189	ND
10135	Mar 90	Norfolk	A	M	ND	ND	ND	ND
9949	Apr 90	Yorkshire	J	M	ND	0.046	ND	ND
9961	Apr 90	Gwynedd	J	F	ND	ND	ND	ND
9981	Apr 90	Essex	A	M	ND	ND	ND	ND
9982	Apr 90	Kirkcuds	A	M	0.009	ND	ND	ND
10080	Apr 90	Norfolk	A	M	ND	0.011	ND	ND
9993	May 90	Hampshire	A	M	ND	ND	ND	ND
9998	Jun 90	Guernsey	J	F	0.072	ND	ND	ND
10033	Aug 90	Surrey	J	M	ND	ND	ND	ND
10048	Aug 90	Devon	J	M	ND	ND	ND	ND
10054	Aug 90	Warwicks	J	F	ND	ND	ND	ND
10081	Aug 90	Norfolk	J	F	ND	ND	ND	ND
10064	Sep 90	Surrey	A	M	ND	ND	ND	ND
10093	Sep 90	Hereford	J	M	ND	ND	ND	ND
10101	Sep 90	Dyfed	A	F	ND	0.008	0.084	ND
10132	Sep 90	Norfolk	J	F	ND	ND	0.158	ND
10133	Sep 90	Norfolk	J	F	ND	ND	ND	ND
10134	Sep 90	Norfolk	J	M	ND	ND	ND	ND
10099	Oct 90	Somerset	J	M	ND	ND	ND	ND
10104	Oct 90	Lincs	J	M	0.002	ND	0.047	0.003
10105	Oct 90	Lincs	J	-	ND	ND	ND	ND
10106	Oct 90	Sussex	A	F	ND	ND	ND	ND
10119	Oct 90	Suffolk	J	F	ND	0.020	ND	ND
10121	Oct 90	D & G	A	F	ND	ND	ND	ND
10122	Oct 90	Suffolk	J	F	ND	ND	ND	ND
10125	Oct 90	D & G	J	F	ND	ND	ND	ND
10126	Oct 90	Norfolk	A	M	ND	ND	ND	ND
10127	Oct 90	Sussex	J	F	ND	ND	ND	ND
10131	Oct 90	Norfolk	A	F	ND	ND	ND	ND
10149	Oct 90	Norfolk	J	F	ND	ND	ND	ND
10232	Oct 90	Nairns	A	F	ND	0.012	ND	ND
10151	Nov 90	Wilts	J	F	ND	ND	ND	ND
10157	Nov 90	Northants	J	F	ND	ND	ND	ND
10159	Nov 90	Bucks	A	-	ND	ND	ND	ND
10164	Nov 90	Northants	J	M	ND	ND	ND	ND
10180	Nov 90	Oxon	J	M	ND	ND	ND	ND
10197	Nov 90	Jersey	A	F	ND	ND	ND	ND
10187	Dec 90	Devon	J	M	0.012	ND	ND	ND

10189	Dec 90	Cambs	J	F	ND	ND	ND	ND
10191	Dec 90	Jersey	J	M	ND	0.037	ND	ND
10194	Dec 90	Lincs	J	M	ND	ND	ND	ND
10723	Dec 90	Clwyd	J	M	ND	0.005	ND	ND
10380	- 91	-	A	F	ND	ND	ND	0.023
10590	- 91	-	J	M	ND	0.081	ND	ND
10202	Jan 91	Norfolk	J	M	ND	ND	ND	ND
10204	Jan 91	Lincs	J	M	ND	ND	ND	ND
10206	Jan 91	Anglsey	A	F	ND	ND	ND	ND
10233	Jan 91	Ross-shire	J	M	ND	ND	ND	ND
10244	Jan 91	Yorks	A	F	ND	ND	ND	ND
10246	Jan 91	Cambs	J	M	ND	0.007	ND	ND
10251	Jan 91	Glos	A	M	ND	0.055	ND	ND
10468	Jan 91	Anglesey	J	M	ND	ND	ND	ND
10504	Jan 91	Ross-shire	J	M	ND	ND	ND	ND
10271	Feb 91	Essex	J	F	ND	ND	ND	ND
10280	Feb 91	Lincs	A	F	ND	0.004	ND	ND
10289	Feb 91	-	J	F	ND	ND	ND	0.039
10320	Feb 91	Alderney	J	F	ND	0.060	ND	0.018
10292	Mar 91	Lincs	A	F	ND	ND	ND	ND
10296	Mar 91	Lincs	A	M	ND	ND	0.080	NF
10318	Mar 91	Jersey	J	M	ND	ND	ND	0.144
10319	Mar 91	Jersey	A	M	ND	ND	ND	ND
10326	Mar 91	Carnarvons	A	M	ND	0.016	ND	ND
10365	Mar 91	Worcs	J	F	ND	0.020	ND	ND
10489	Mar 91	Lincs	A	M	0.012	0.023	0.026	ND
10587	Mar 91	Norfolk	J	M	ND	ND	ND	ND
10588	Mar 91	-	J	F	ND	ND	ND	ND
10328	Apr 91	Notts	J	M	ND	ND	ND	ND
10332	Apr 91	Cambs	J	M	ND	ND	ND	ND
10350	Apr 91	Oxon	J	M	ND	ND	ND	ND
10559	Apr 91	Sussex	A	M	ND	ND	ND	ND
10351	May 91	Northants	J	M	ND	ND	ND	ND
10372	May 91	Anglesey	A	M	ND	0.135	ND	ND
10376	Jun 91	Northants	J	M	ND	ND	ND	ND
10385	Jul 91	Sussex	J	F	ND	ND	ND	ND
10487	Jul 91	Glos	A	M	ND	ND	ND	ND
10513	Jul 91	Dyfed	A	M	ND	0.036	ND	ND
10407	Aug 91	Berks	J	M	ND	ND	ND	ND
10413	Aug 91	Dorset	J	F	ND	0.027	ND	ND
10442	Aug 91	Northants	J	M	ND	ND	0.188	ND
10469	Aug 91	Anglesey	J	M	ND	ND	ND	ND
10550	Aug 91	Hampshire	J	M	ND	ND	ND	ND
10560	Aug 91	Gwynedd	J	F	ND	ND	ND	ND
10561	Aug 91	Gwynedd	J	M	ND	ND	ND	ND
10562	Aug 91	Gwynedd	J	-	ND	ND	ND	ND
10454	Sep 91	Suffolk	J	M	ND	ND	ND	ND
10455	Sep 91	Berks	J	M	ND	ND	ND	ND
10458	Sep 91	D & G	J	M	ND	ND	ND	ND
10479	Sep 91	Anglesey	J	M	ND	ND	0.090	ND
10480	Sep 91	Cumbria	J	M	ND	ND	ND	ND
10494	Sep 91	Yorks	A	F	ND	0.003	ND	ND
10495	Sep 91	Lincs	J	F	ND	0.020	ND	ND
10497	Sep 91	Wilts	J	F	ND	ND	ND	ND
10531	Sep 91	Sussex	J	M	ND	ND	ND	ND
10589	Sep 91	Norfolk	J	F	ND	ND	ND	ND
10511	Oct 91	Cambs	J	M	ND	ND	ND	ND
10512	Oct 91	Hunts	J	F	ND	ND	ND	ND

10522	Oct 91	Powys	J	M	ND	ND	ND	ND
10523	Oct 91	Essex	J	F	ND	0.019	ND	ND
10530	Oct 91	Strathclyde	J	F	ND	ND	ND	ND
10534	Oct 91	Inverness	J	F	ND	ND	ND	ND
10540	Oct 91	Glamorgan	J	F	ND	ND	ND	ND
10541	Oct 91	Warwicks	J	.	ND	ND	ND	ND
10548	Oct 91	Wilts	A	M	ND	ND	ND	ND
10553	Oct 91	Leics	J	F	ND	ND	ND	ND
10573	Nov 91	Suffolk	J	F	ND	ND	ND	ND
10576	Nov 91	Sussex	J	M	ND	0.007	ND	ND
10581	Nov 91	Berks	J	F	ND	ND	0.319	ND
10582	Nov 91	Northants	J	M	ND	ND	ND	ND
10591	Nov 91	Lancs	J	F	ND	ND	ND	ND
10594	Nov 91	Cambs	J	F	ND	ND	ND	ND
10600	Nov 91	Dorset	J	F	ND	ND	ND	ND
10601	Nov 91	Banffs	J	F	ND	ND	0.243	ND
10606	Nov 91	Cambs	J	F	ND	ND	0.153	ND
10609	Nov 91	Lincs	J	F	ND	ND	ND	ND
10624	Nov 91	Berks	J	F	ND	ND	0.179	ND
10621	Dec 91	Hampshire	A	F	ND	0.004	ND	ND
10625	Dec 91	Essex	J	F	ND	ND	ND	ND
10628	Dec 91	Lincs	J	F	ND	ND	ND	ND
10640	Dec 91	Yorks	J	F	ND	ND	0.076	ND
10641	Dec 91	Yorks	J	F	ND	ND	0.032	ND
10642	Dec 91	Suffolk	J	F	ND	0.013	ND	ND
10644	Dec 91	Gwynedd	J	F	ND	ND	ND	ND
10651	Dec 91	Cheshire	J	M	ND	0.053	ND	ND
10682	Dec 91	Yorks	J	M	ND	0.119	0.050	ND
10723	Dec 91	Clwyd	J	M	ND	0.005	ND	ND

Table 13. Recorded causes of death and rodenticide contamination for 363 Barn Owls, 1983-91.

	Number (% of total)	Number (%) with rodenticide residues
Trauma		
Road casualties	163 (45)	31 (19)
Other collisions	14 (4)	2 (14)
Drowned	5 (1)	2 (40)
Electrocuted	2 (<1)	0 (0)
Other human-related causes		
Shot	5 (1)	0 (0)
Poisoned	2 (<1)	2 (100)
Natural causes		
Starvation	130 (36)	26 (20)
Disease	4 (1)	0 (0)
Predation	1 (<1)	0 (0)
Unknown causes	37 (10)	12 (36)

Table 14. Number of Barn Owls received 1983-91, with the numbers in which rodenticide residues were detected.

Year	Number of owls analysed	Number of owls with detectable residues of: Brodifacoum	Difenacoum	Bromadiolone	Flocoumafen	Number (%) of birds with one or more rodenticides*	
1983	3	0	0	0	0	0	(0)
1984	15	1	0	0	0	1	(7)
1985	33	2	2	1	0	4	(12)
1986	42	2	5	0	0	5	(12)
1987	30	0	2	0	0	2	(7)
1988	31	3	4	2	0	6	(19)
1989	65	2	6	1	0	7	(11)
1990	68	5	14	11	1	24	(35)
1991	76	1	16	8	4	26	(34)
Total	363	16	49	23	5	75	

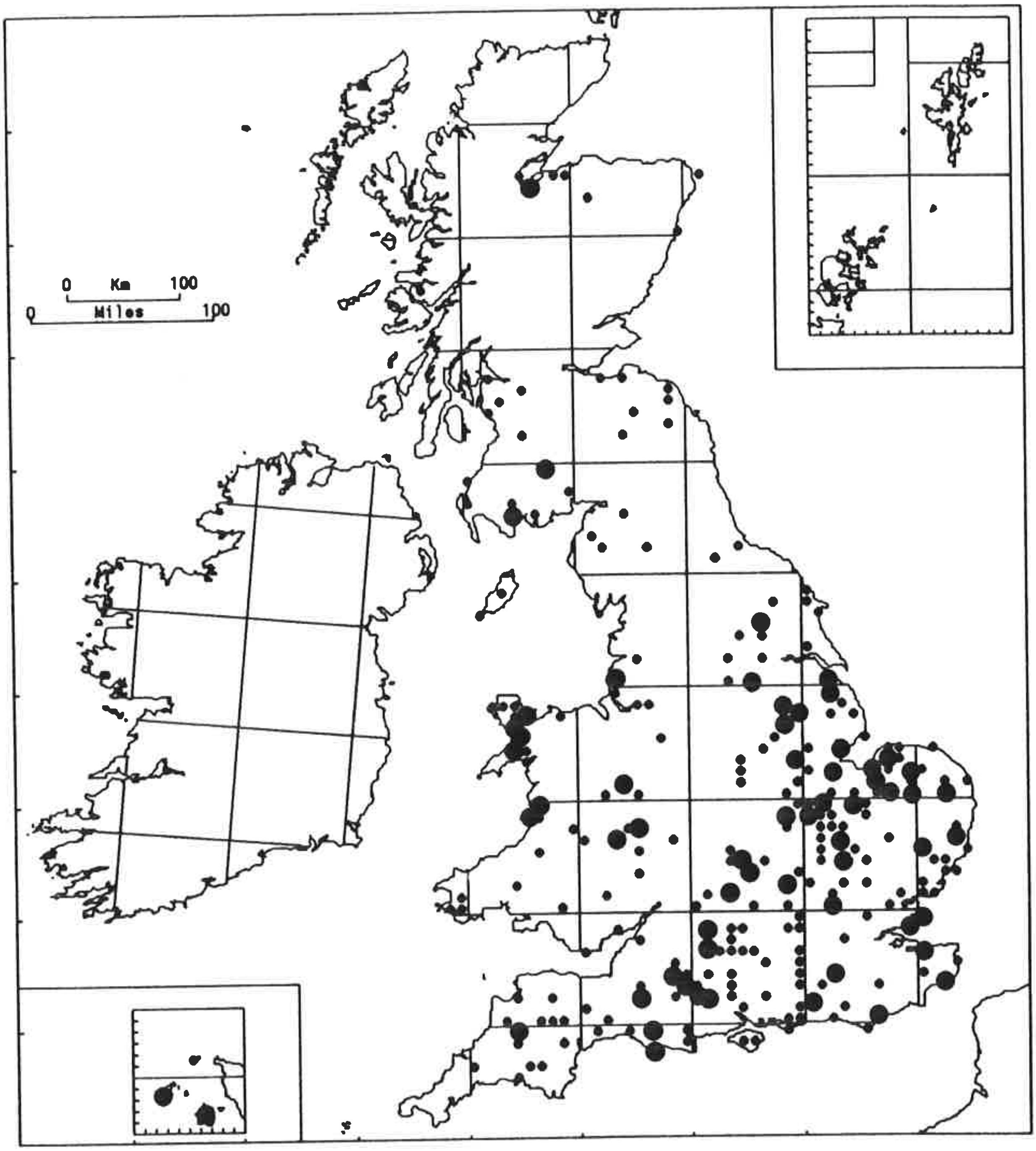
Table 15. Incidence of rodenticide residues in Barn Owl carcasses in relation to usage on farms.

	Farms growing arable crops (1988)*	Farms growing grass & fodder crops (1989)*	Barn Owls containing residues
Number of farms (owls) in sample	565	459	363
Number of occurrences of any second generation rodenticide	431	404	75
Difenacoum	269 (62.4)	217 (53.7)	49 (65.3)
Bromadiolone	138 (32.0)	151 (37.4)	23 (30.7)
Brodifacoum	22 (5.1)	30 (7.4)	16 (21.3)
Flocoumafen	2 (0.5)	6 (1.5)	5 (1.4)

* From Olney *et al* 1991a, b.

Figure 6a

Distribution of Barn Owl carcases sent to Monks Wood, 1983-91

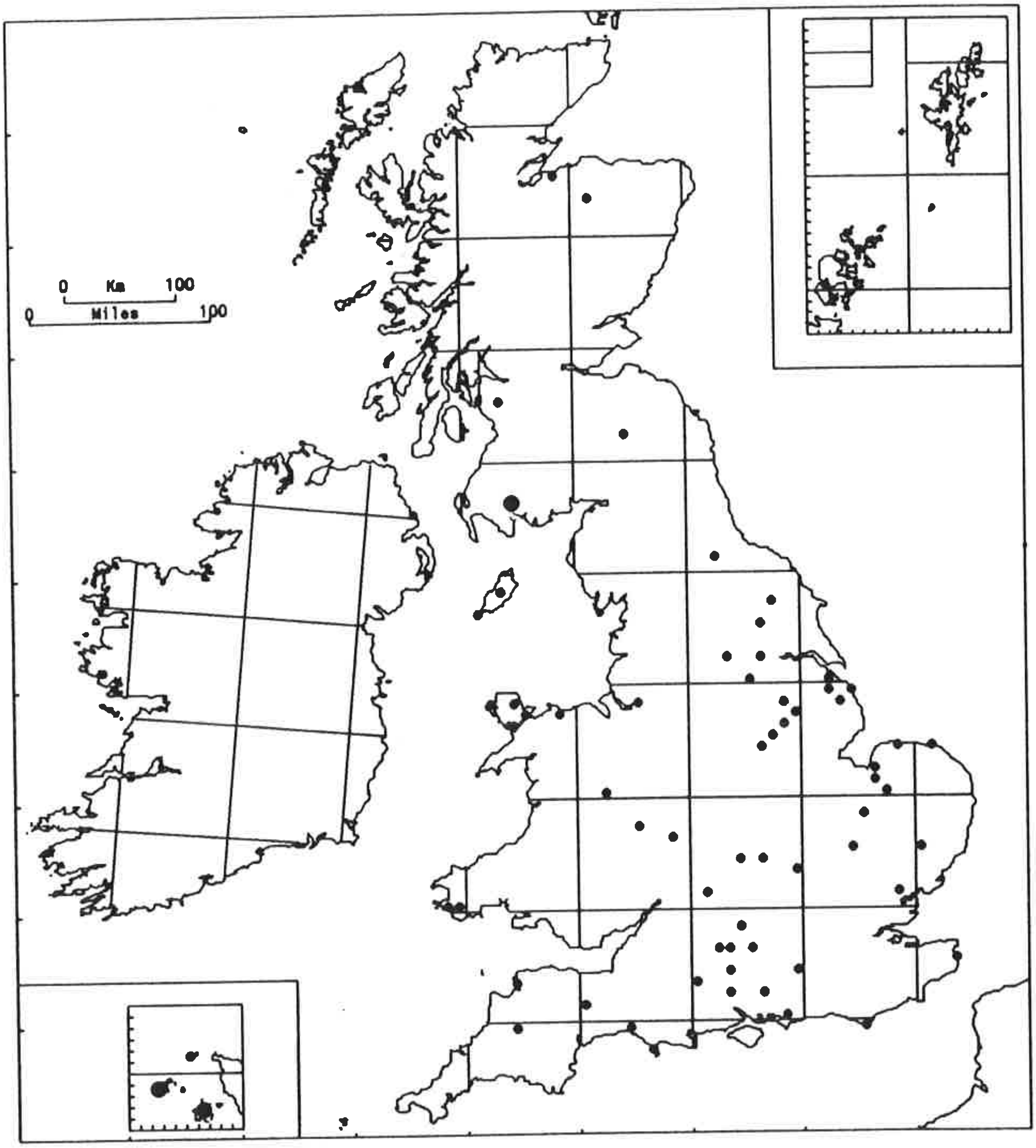


● Places with one record (GB-356, Ir-0, Ch.Is-8)

⬤ Places with more than one record (GB-0, Ir-0, Ch.Is-0)

Figure 6b

Distribution of Barn Owls in which rodenticides were detected, 1983–1991



● Places with one record (GB-68, Ir-0, Ch.Is-6)

● Places with more than one record (GB-0, Ir-0, Ch.Is-0)

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JNCC/NERC CONTRACT HF3/08/01
ITE PROJECT T07061f5
Annual report to Joint Nature Conservation Committee

BIRDS AND POLLUTION

Part 8 Toxicity trials on the rodenticide bromadiolone

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8 TOXICITY TRIALS ON THE RODENTICIDE BROMADIOLONE

8.1 Introduction

In this section we report the effects of feeding Barn Owls on mice killed by the anticoagulant rodenticide, bromadiolone. The chemical was introduced in Britain in 1980, and has now become the most widely-used of the second-generation rodenticides. The work is an extension of earlier trials with difenacoum and brodifacoum, reported in the Annual Report for 1989 and subsequently published by Newton *et al.* (1990).

The methodology was similar to that used in the earlier study, and involved: (1) feeding laboratory mice for one day on bromadiolone bait (commercially available 'Slaymore' with bromadiolone at 0.005%); (2) feeding the dead mice to six Barn Owls in 1-day, 3-day and 6-day feeding trials, allowing the owls to recover between successive trials; (3) assessing the response of the owls by measuring (a) blood-coagulation times at intervals after each feeding trial, and (b) survivorship. In addition, the owls were then killed at various intervals after the last feeding trial and their livers were analysed for bromadiolone and other rodenticide residues. The work was undertaken in August - September 1991 on the same captive-bred owls used in earlier trials. None of the owls were moulting at the time.

8.2 Toxicity trials on mice

All dosed mice died 2-9 (mostly 3-6) days after dosing (Table 16) In efficacy, and time between dosing and death, bromadiolone showed no significant differences from difenacoum and brodifacoum. Some of the poisoned mice were fed to owls, while others were analysed to find the total weight of bromadiolone in their bodies. As in previous trials, the liver and the rest of the carcass were analysed separately.

Bromadiolone contents (mass and concentration) varied greatly in different mice, but individuals with relatively high levels in liver also had high levels in the rest of the carcass (Table 17). Taking the averages of these values, a 32g mouse was estimated to contain a total of 2.8 μg of bromadiolone or 0.09 μg bromadiolone per gram of mouse.

8.3 Toxicity trials on owls

All six owls fed on bromadiolone-dosed mice survived the 1-day, 3-day and 6-day treatments, and none showed external bleeding. After the 1-day treatment, owls were blood-sampled 4-10 days later, and coagulation times were found to be 'normal' (Table 18).

None of the owls died after any of the treatments. When they were killed, some 44, 83, 253, 321, 515 and 515 days after the end of the last feeding trial respectively, none contained detectable bromadiolone residues in their livers.

8.4 Bromadiolone-intake by owls

From knowledge of the numbers and weight of mice eaten by the owls, and the average mass of rodenticide in the mouse bodies at the time, the total mass of bromadiolone consumed by the owls in the 1-, 3- and 6-day treatments could be calculated (Table 19). On this basis, individuals consumed an estimated 10.8-11.9 μg, 12.1-13.5 μg and 22.0-24.4 μg bromadiolone in 1, 3 and 6 days respectively, equivalent to doses of approximately 0.04, 0.05 and 0.08 mg per kg owl body weight in the three trials. There was little difference between the 1-day and 3-day doses because for unknown reason the owls consumed more mice per day in the 1-day trial than in the 3-day one. Considering the variability in residue levels in individual mice (Table 17), these figures should be regarded as no more than rough approximations. Moreover, by analogy with the earlier study, some of the rodenticide that was consumed by the owls would have been regurgitated in pellets, so would not have passed through the gut.

8.5 Discussion

Compared to the previous findings these results suggest that Barn Owls are less likely to suffer from adverse effects if they eat mice poisoned by bromadiolone than if they eat mice poisoned by brodifacoum. None out of six owls fed bromadiolone-mice died, compared with four out of six fed on brodifacoum-mice (Newton *et al.* 1990). Also, the blood-coagulation times returned to normal more rapidly on bromadiolone than on brodifacoum. One of the reasons for this difference in apparent toxicity may have been the smaller doses (mg/kg) that the owls received of bromadiolone, itself probably the result of more rapid elimination of bromadiolone from the mouse body. Survivorship and blood-coagulation times did not differ between the bromadiolone and difenacoum treatments, but again the doses of bromadiolone received by the owls were lower than those of difenacoum.

We had hoped in this study to obtain the liver levels of bromadiolone that were associated with death. This would then have helped in the interpretation of levels found in wild Barn Owls. However, as none of the dosed owls died from bromadiolone poisoning, this was not possible. Subsequent analyses of these owls, when they were killed 44-515 days after the 6-day treatment, revealed no detectable bromadiolone residue in the liver, indicating that it had been metabolised or excreted by this time.

Table 16. Time to death in mice dosed with different rodenticides.

	Number of mice which died the following number of days after dosing										Mean (±SD) number of days to death
	2	3	4	5	6	7	8	9	10	11	
Difenacoum	1	12	26	36	16	18	3	0	0	1	5.12 ± 1.44
Brodifacoum	0	9	16	12	11	11	6	0	0	0	5.26 ± 1.56
Bromadiolone	5	28	31	24	23	7	7	4	0	0	4.78 ± 1.68

Table 17. Bromadiolone levels in livers and remaining carcass of bromadiolone-poisoned mice. ND = none detected.

Mouse	Body Weight	Days between dosing & death	Liver only μg	Liver only $\mu g\ g^{-1}$	Carcass minus liver μg	Carcass minus liver $\mu g\ g^{-1}$
1	45.7	2	0.150	0.077	0.061	0.002
2	35.6	2	0.060	0.080	ND	ND
3	30.1	2	0.373	0.267	0.041	0.002
4	27.1	3	0.060	0.042	0.063	0.003
5	22.1	3	0.081	0.085	ND	ND
6	30.6	3	0.121	0.102	0.636	0.029
7	31.2	3	2.813	2.306	5.089	0.230
8	34.2	3	1.325	0.884	0.625	0.026
9	22.6	4	0.060	0.053	0.019	0.012
10	30.4	4	0.665	0.578	0.267	0.015
11	23.7	4	ND	ND	ND	ND
12	36.4	4	27.339	14.465	9.067	0.356
13	36.6	4	0.333	0.215	ND	ND
14	36.1	5	0.393	0.280	0.129	0.005
15	28.6	5	0.750	0.752	0.797	0.039
16	31.8	5	2.450	2.178	ND	ND
17	45.1	5	ND	ND	ND	ND
18	40.5	5	3.375	2.206	ND	ND
19	24.8	6	ND	ND	ND	ND
20	23.5	6	0.600	0.615	ND	ND
21	33.6	7	1.417	1.191	ND	ND
Mean ± SE	31.9 ± 1.5		2.017±1.284	1.256±0.681	0.800±0.479	0.034±0.019

Note: The average weight of bromadiolone contained in a 31.9g mouse was 2.82 μg (the sum of the liver and carcass values), which gave 0.088 μg per gram of mouse. This figure was used in calculating the dosages in Table 3.

Table 18. Coagulation times (minutes, seconds) for Barn Owl blood-samples taken before bromadiolone dosing and on different dates after end of dosing.

	Owl number					
	1	2	3	4	5	6
Pre-treatment	2,0	1,0	2,0	1,15	1,0	0,45
After 1-day dose						
7 days	-	-	-	-	2,0	4,0
8 days	-	-	-	1,30	-	-
9 days	-	1,15	2,15	-	-	-
10 days	0,30	-	-	-	-	-
After 3-day dose						
4 days	-	-	-	-	-	1,30
7 days	5,0	3,30	7,0	2,30	0,30	-
After 6-day dose						
4 days	3,15	-	9,0	-	1,30	13,50
6 days	-	3,15	-	1,15	-	-
7 days	-	-	5,30	-	-	3,45

Table 19. Mice and bromadiolone consumed by Barn Owls during feeding trials. N = number of mice eaten or partly eaten; W. = total weight of mice; B = weight (μg) of bromadiolone calculated from mean of 0.088 μg bromadiolone per gram of mouse tissue (see Table 19); D = dose calculated as mg of bromadiolone per kg of owl body weight.

	Own Number 1	2	3	4	5	6	Mean ± SE
1-day treatment							
N	3	3	3	3	3	3	3.0 ±0.0
W	126	135	133	125	123	129	128.5±1.9
B	11.09	11.88	11.70	11.00	10.82	11.35	11.31±0.17
D	0.04	0.05	0.04	0.04	0.04	0.04	0.042±0.002
3-day treatment							
N	6	6	6	6	6	6	6.0 ±0.0
W	152	150	138	153	138	137	144.7±3.2
B	13.38	13.20	12.14	13.46	12.14	12.06	12.73±0.28
D	0.05	0.05	0.04	0.05	0.04	0.04	0.045±0.002
6-day treatment							
N	12	12	12	13	12	12	12.2 ±0.2
W	253	250	277	277	267	254	263.0±5.0
B	22.26	22.00	24.38	24.38	23.50	22.35	23.15±0.44
D	0.08	0.09	0.08	0.09	0.08	0.07	0.082±0.008

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JNCC/NERC CONTRACT HF3/08/01
ITE PROJECT T07061f5
Annual report to Joint Nature Conservation Committee

BIRDS AND POLLUTION

Part 9 Incident Investigations

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9 INCIDENT INVESTIGATIONS

9.1 Main investigations during the period of the current contract

During the three years period of the current contract, the most notable incidents investigated were the deaths of about 600 juvenile Kittiwakes *Rissa tridaclyla* off the Yorkshire coast, near Filey, and the deaths of auks and other species washed up along the borders of the Irish Sea. Results for these investigations have been supplied in earlier reports (Newton *et al.* 1990). The cause of the kittiwake incident was probably food shortage; the cause of the auk incident was unknown, but probably not pollution.

9.2 Incidents investigated during the current reporting year

We have not investigated any major wildlife mortality or morbidity incident during this reporting year. A number of small incidents were investigated, but no carcasses suitable for analysis were obtained. A number of enquiries were referred to MAFF for investigation under the terms of their statutory incident scheme, and some telephone calls about possible incidents led to predatory birds being submitted for analysis in the normal way.

9.3 Incident 90/3: Filey kittiwakes, metal residues

Mercury residues were detected in 3 of 4 livers examined, at levels of 1.5, 0.9, and 1.1 ppm in dry weight. They are not high enough to have contributed to death.

9.4 Incident 90/4: Isle of Man/Welsh gannets

Following the deaths of auks and other species in the Irish Sea area in spring 1990, some gannet mortality was noted on the Isle of Man. Tissues from 3 birds were received for organic pollutant and metal analysis via the local VIC and ADAS offices, along with tissues from a Guillemot *Uria aalge* (Table 20).

9.5 Incident 91/1: Mute Swans, north-west England

Some 10 - 20 mute swans *Cygnus olor* died in unusual circumstances in February 1991 at Fleetwood boating lake, near Blackpool. There was considerable local interest in the mortality and morbidity and a local veterinarian contacted ITE for advice on the possible involvement of pollutants.

Samples of tissues were received from the local VIC that did post-mortem work. Standard organic analyses were conducted on 7 livers and 6 fat samples. Livers were examined for toxic metals.

Only 3 samples contained detectable residues. One contained 0.03 ppm DDE; another 0.13 ppm DDE and 0.04 ppm PCB; and the third contained 0.01 ppm DDE and 0.03 ppm PCB.

Analysis for PCB congeners showed that there were no detectable residues in the liver samples and low levels in fat. Of the 9 congeners included in this analysis (Nos 8, 18, 52, 101, 118, 153, 138, 180, and 170) only residues of the last four were detected, with different combinations of congeners found in 4 of the fat samples (the other 2 fat samples contained no detectable congeners). All these residues were below 0.1 ppm. None of the levels of organic pollutants was high enough to have contributed to death.

There were no significant levels of toxic metals in the livers of the birds, as determined by inductively coupled mass-spectrometry used in scanning mode (there appeared to be a small amount of silver in one bird).

It was concluded that pollutants had not played a significant part in the mortality. Later veterinary investigation identified the most likely cause of death and morbidity as pinto beans that had been supplied as food to the flock during the winter.

9.6 Incident 92/1: Poor breeding amongst upland waders

Reports of poor breeding (and possible egg-shell thinning) amongst upland waders in the Teesdale area were received in spring 1992. Arrangements were made for the collection of addled or abandoned eggs under licence, but none have yet been received.

9.7 Reference

NEWTON *et al.* (1990). Birds and Pollution. NERC report to NCC. Abbots Ripton: Institute of Terrestrial Ecology.

Table 20. Results of analysis of further birds from the Irish Sea area collected in 1990.

Metals: Mercury residues in livers (ppm dry wt).

Gannet	10.5
Gannet	6.0
Gannet	18.5
Guillemot	5.7

No other toxic metals of significance were detected by scanning and ICPMS.

Organic pollutant residues in liver (ppm wet wt).

	HCB	gamma-HCH	pp-DDE	HEOD	PCB
Gannet	0.01	nd	0.35	0.14	9.1
Gannet	nd	nd	0.04	0.06	0.2
Gannet	nd	nd	0.04	0.07	0.3

Notes: nd = none detected, limit of detection, less than 0.01 ppm. No residues of TDE or DDT were detected.

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