JOINT NATURE CONSERVATION COMMITTEE

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Wildlife and pollution: 1997/98 Annual Report

I Newton, L Dale, JK Finnie, P Freestone, J Wright, C Wyatt & I Wylie

JNCC Project 018 (Contract F90-01-115)
ITE Project T08054c5

Annual Report to Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough
Cambs
PE1 1JY

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Institute of Terrestrial Ecology
(Natual Environment Research Council)
Monks Wood
Abbots Ripton
Huntingdon
Cambs
PE17 2LS

For further information please contact:
Dr Alastair Burn
English Nature
Northminster House
Peterborough
PE1 1UA

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1 PREFACE AND SUMMARY

1.1 Introduction

The Wildlife and Pollution contract covers a long-term monitoring programme to examine the levels of pollutants in selected wildlife species in Britain. The programme was started 35 years ago, when there were serious concerns over the effects of organochlorine insecticides and organomercury fungicides on several birds and mammals. This early work demonstrated the effects of the organochlorines, and eventually contributed to the ban on their use in this country and abroad. The programme has measured levels of these compounds in predatory and fish-eating birds since then. Investigations have also been made into the levels of industrial polychlorinated biphenys (PCBs), following their identification as pollutants in 1966. Mercury levels, derived from both agricultural and industrial sources, have also been tracked. In addition, the contract supports a wildlife incident investigation service, which can examine the causes of unexpected mortality incidents (that are not obviously related to oil pollution or to agricultural pesticides). In recent years, investigations have been made into the effects of the newest generation of rodenticides on barn owls. Gannet eggs are regularly collected biennially from two colonies and, when available, from other sites; eggs were collected from only one site in 1997.

As this programme is now the longest running of its kind anywhere in the world, the findings stimulate considerable interest internationally, as well as in Britain. Annual reports give an interim summary of results.Every three years these annual results are gathered together into a more substantial report (like the present one) in which they are integrated with previous findings. In addition, results are published periodically in the scientific literature. Recent key papers are listed in this report under sub-project summaries.

The Wildlife and Pollution contract was the subject of scientific assessment within JNCC's rolling programme of peer review in autumn 1993 and was further assessed in 1997.

Each sub-project within the Wildlife and Pollution contract is summarised below. Each is dependent on the provision of material from amateur naturalists and other interested parties, and it is not always possible to obtain desired material for analysis, especially from remote areas. No major incidents were investigated in 1997.

1.2 Organochlorines and mercury in predatory birds

The main objective of this work was to analyse the bodies of certain predatory and fish-eating bird species, supplied by members of the public, in order to continue the monitoring of organochlorine and mercury residues in livers. This enables us to keep a watch on the effects of previous hard-won withdrawals of permitted uses of some of these chemicals, and to examine geographical variation in residues. For 1997 the livers from 165 birds were analysed, including those from 29 kestrels, 72 sparrowhawks, 8 herons, 7 kingfishers, 1 great-crested grebe and 47 birds of various other species. These birds came from various localities in England, Scotland and Wales.

Over the whole monitoring period (1963-97), the overall data for most species have revealed significant long-term downward trends in residues (except for PCBs in kestrels). Declines may be levelling off for DDE (the main metabolite of DDT) and HEOD (derived from aldrin and dieldrin). There were four significant changes in geometric mean levels between 1996 and 1997, with increases in DDE levels in kestrels and sparrowhawks, in HEOD levels in herons and PCB levels in sparrowhawks, and a decrease in mercury levels in sparrowhawks. It is impossible to say whether these differences reflect real year-to-year changes in exposure.

1.3 Organochlorines and mercury in peregrine eggs

Single eggs from 16 peregrine clutches were analysed in 1997, from various parts of England and Scotland. The levels of organochlorine pesticides in British peregrine eggs continue to decline and at least inland areas are unlikely now to cause breeding failures and mortality. Levels of PCBs have declined in some regions but not others, while mercury levels (analysed since the mid-1980s) have changed little.

1.4 Organochlorines and mercury in merlin eggs

Single eggs from 16 merlin clutches were analysed in 1997, from various parts of England and Scotland. The results confirm that the merlin remains the most contaminated of the British raptors. However, over the period 1967-97, DDE and HEOD levels in British merlin eggs declined greatly, and shell indices improved. PCB levels declined in some regions while mercury levels (measured only from 1978) declined in the mid-1980s and then increased again.

1.5 Organochlorines and mercury in golden eagle eggs

Single eggs from nine clutches (seven from Scotland and two from England) were analysed in 1997. These confirm the low levels of contamination in eggs from inland districts found in recent years.

Over the period 1963-97, levels of organochlorines and mercury were highest in eggs from western coastal districts of Scotland, somewhat lower in eggs from western inland districts, and lower still in eggs from eastern districts. Over the years, levels of DDE and HEOD declined in eggs from all regions, PCB levels declined only in eggs from western inland districts, and mercury levels increased in eggs from western inland districts. However, levels of all contaminants were generally too low to influence breeding success.

1.6 Organochlorines and mercury in gannet eggs

Eggs from only one colony, namely Ailsa Craig, were analysed in 1997. Residue levels were low and within the range of previous eggs from this colony. Over the long term (1971-97), eggs from Ailsa Craig showed declines in all residues, those from Bass Rock showed declines in HEOD and DDE, those from Hermaness showed a decline in DDE, those from St Kilda showed an increase in mercury, and those from Scar Rocks showed declines in DDE, PCB and mercury. Levels of mercury were consistently and significantly higher in eggs from Ailsa Craig than from Bass Rock. The gannet is the only British seabird in which residue levels have been monitored continuously over the past 27 years, and so it has become a key indicator species in marine pollution.

1.7 Organochlorines and mercury in sea eagle eggs

One egg was received in 1997 from the Western Isles. Relatively high levels of both DDE and PCB were found, presumably a reflection of the high proportion of marine food in the diet.

1.8 Rodenticide residues in barn owls

The second-generation anticoagulant rodenticides (currently difenacoum, brodifacoum and flocoumafen) were considered possibly to pose a particular threat to barn owls. These rodenticides are rapidly replacing warfarin and are both more toxic to vertebrates and more persistent. Sixty-five birds were examined in 1997. The residues of one or more rodenticides were found in the livers of 19 (29%) birds, and four (6%) of these had levels likely to be associated with mortality. The proportion of contaminated owls has remained at about this level for the past eight years, following an earlier apparent increase. Despite widespread exposure, there is as yet no evidence that these chemicals have caused substantial mortality, or have had any serious impact on barn owl numbers in Britain.

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Wildlife and pollution

Part 2 Organochlorines and mercury in predatory birds

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2 ORGANOCHLORINES AND MERCURY IN PREDATORY BIRDS

2.1 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. Findings from previous years are given in earlier reports in this series and in a published paper by Newton *et al.* (1993).

2.2 Results from 1997

During the past year, the livers from 165 birds were anlysed, including those from 29 kestrels, 73 sparrowhawks, 8 herons, 7 kingfishers, 1 great-crested grebe and 47 others. These totals included some birds that had died in earlier years, but which were analysed in the current year. The results from all these birds are listed in Table1, and the geometric means for each chemical from the main species (1997 specimens only) are given in Table 2. As usual, mercury levels were higher in the aquatic than in the terrestrial species.

Several birds from 1997 had expectedly high levels of pollutants. They included a kestrel (from Merseyside) with 9 ppm DDE and 136 ppm PCB; one sparrowhawk (from Cambridgeshire) with 57 ppm DDE, 7 ppm HEOD and 20 ppm PCB, another sparrowhawk (from Cambridgeshire) with 31 ppm DDE and 17 ppm PCB, one (from Merseyside) with 18 DDE and 100 ppm PCB, and one (from Gloucestershire) with 18 ppm DDE and 51 ppm PCB. There were also seven other sparrowhawks with DDE levels of 14-72 ppm and four with PCB levels of 16-25 ppm. Amongst other species, a peregrine from Humberside had DDE levels of 73 ppm and PCB levels of 326 ppm.

Out of 16 comparisons, four significant differences in geometric mean values were found between the 1996 and 1997 results. There were significant increases in DDE in kestrels and sparrowhawks, an increase in HEOD in herons, an increase in PCB in sparrowhawks and a decrease in Hg in sparrowhawks (Table 3). It is impossible to say whether these differences reflected real changes in exposure, especially as levels were generally low. Because only one great-crested grebe was received in 1997, no comparisons between residues in 1996 and 1997 could be made for this species.

2.3 Long-term trends

An earlier analysis of long-term trends in the five main species to 1994 was included in the 1995 report. The analysis has been repeated here, incorporating extra data to 1997. The nationwide trends for each species are shown in Figures 1-5 by three-year moving geometric means. Analyses for DDE and HEOD were started in 1963-64, analyses for PCB in 1967-68 and for mercury in 1970-80, depending on species.

In each case the significance of the long-term trend was assessed by regression analayses of individual residue levels against year (Table 4), covering the whole analytical period for each chemical. Separate regression analyses covered the last six years (1992-97) 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 (Figure 5).

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 great-crested grebe, in which the downward trend in mercury was not statistically significant. However, sample number for this species were much smaller than for the others. The peak in PCB levels in kingfishers in the late 1970s was also associated with small numbers of samples.

Over the shorter period (1992-97), when levels of most chemicals were generally low, few significant trends emerged. They included increases in DDE residues in kestrel, declines in HEOD and PCB residues in sparrowhawk and decline in HEOD residues in great-crested grebe, and increases in mercury in sparrowhawk, kestrel and kingfisher.

Another major change of recent years has been the increasing relative importance of PCBs. In some species these chemicals have not declined since the 1970s, so in many specimens they now predominate among organochlorine residues.

2.4 Conclusions

The general picture is of long-term declines in pesticide and mercury residue levels. This would be expected from the progressive restrictions placed on the use and release over the years of the parent chemicals. PCB levels have shown significant long-term declines in only four of the five species, and only sparrowhawk shows significant decline over the past six years. As this programme is now the longest running of its kind anywhere in the world, the findings stimulate considerable interest internationally, as well as in Britain.

2.5 Reference

Newton, I, Wyllie, I, & Asher, A 1993 Long term trends in organochlorine and mercury residues in some predatory birds in Britain. *Environmental Bulletin,* 79: 143-151.

Table 1. **Levels of organochlorines (ppm wet weight) and mercury (ppm dry weight) in the livers of predatory birds analysed between April 1997 and March 1998**

ND=none detected; J=juvenile in first year; A=adult other than first year.
M=male; F=female; D&G=Dumfries & Galloway; H&W=Hereford & Worcester.

Specimen no.	Date found	County	Age	Sex	pp'-DDE	HEOD	PCB	Hg
Kestrel *Falco tinnunculus*								
12368	Jan-97	Salop	J	F	0.035	0.256	0.772	1.320
12370	Jan-97	Devon	J	F	0.031	0.194	0.127	0.660
12374	Dec-96	Cumbria	J	F	0.626	0.394	1.788	1.430
12375	Dec-96	Cumbria	J	F	0.324	0.740	1.313	0.560
12384	Jan-97	Lancashire	J	M	0.279	0.335	1.906	0.730
12389	Jan-97	North Yorks	J	F	0.190	0.381	1.440	0.650
12399	Feb-97	Northants	J	M	0.654	0.553	0.787	0.950
12414	Feb-97	West Midlands	J	F	0.409	0.273	7.596	0.500
12431	Mar-96	Highland	J	F	ND	0.135	0.187	0.170
12455	Mar-97	Northants	A	F	0.123	0.085	0.080	0.190
12457	Feb-97	Merseyside	A	F	9.010	0.805	136.378	23.040
12458	Mar-97	Salop	J	F	0.066	0.045	5.149	0.270
12463	Mar-97	Hampshire	J	M	2.087	0.326	2.252	0.410
12467	Mar-97	Essex	A	M	0.164	0.187	1.200	0.220
12482	Apr-97	Suffolk	J	M	0.309	0.282	0.990	0.420
12506	May-97	Warwickshire	A	M	ND	0.583	0.054	0.240
12519	Jul-97	Surrey	J	F	0.208	0.573	1.213	0.290
12525	Aug-97	Norfolk	J	F	7.680	1.093	1.172	0.540
12536	Feb-97	Warwickshire	-	-	1.005	0.117	3.679	0.410
12562	Sep-97	Avon	J	F	0.108	0.391	1.369	1.690
12569	Oct-97	Cambridgeshire	J	F	2.585	0.482	4.501	0.340
12576	Oct-97	Kent	J	F	0.186	0.833	0.763	1.920
12579	Oct-97	Nottinghamshire	J	F	ND	0.199	0.342	0.160
12583	Oct-97	Avon	J	F	0.213	0.234	0.402	1.020
12588	Oct-97	West Yorkshire	J	M	0.059	0.146	1.429	0.400
12589	Oct-97	Kent	J	F	1.400	0.444	1.530	2.730
12610	May-97	Cambridgeshire	A	M	0.530	1.416	0.298	0.430
12624	Nov-97	Kent	A	M	8.661	0.156	3.333	1.038
12632	Dec-97	Powys	J	M	0.214	0.096	2.045	0.711

Specimen no.	Date found	County	Age	Sex	pp'-DDE	HEOD	PCB	Hg
Sparrowhawk *Accipiter nisus*								
12364	Feb-96	Wiltshire	J	M	2.150	0.221	6.918	0.673
12376	Jan-97	Lincolnshire	J	F	9.922	1.208	9.426	1.555
12379	Aug-96	Northants	J	F	0.170	0.035	0.442	0.434
12383	Jan-97	Wiltshire	J	M	0.424	0.033	0.592	1.460
12403	Feb-97	Buckinghamshire	J	F	1.253	0.077	1.663	1.314
12404	Jan-97	Bedfordshire	J	M	0.569	0.042	0.527	0.175
12406	Feb-97	Essex	A	F	3.916	0.134	1.698	0.949
12407	Feb-97	Salop	A	M	0.550	0.072	1.204	1.219
12416	Feb-97	Surrey	J	M	0.474	ND	0.690	0.525
12418	Feb-97	Norfolk	J	M	1.196	0.064	0.510	0.710
12424	Aug-96	Sussex	J	M	0.276	0.115	0.538	0.294
12425	Feb-97	Strathclyde	J	M	0.678	0.066	1.092	1.287
12429	Mar-97	Humberside	J	M	11.571	0.800	17.395	1.137
12432	Nov-95	Highland	J	F	2.115	0.363	5.577	2.697
12434	Feb-96	Highland	A	F	0.312	0.061	0.472	3.221
12435	Sep-96	Highland	J	F	0.812	0.094	1.098	2.055
12436	Aug-96	Highland	J	F	0.197	0.033	0.464	1.375
12437	Jan-97	Highland	A	F	4.178	0.352	4.148	1.619
12438	Dec-95	Highland	J	M	3.740	0.264	3.541	1.969
12439	Aug-96	Highland	J	F	0.191	0.038	0.372	1.756
12446	Mar-97	Essex	J	M	24.895	0.904	13.051	3.686
12447	Mar-97	Dyfed	J	M	0.349	0.059	1.098	0.747
12451	Mar-97	Kent	J	F	10.727	0.576	2.858	0.473
12454	Mar-97	Essex	J	M	9.280	0.288	4.229	1.390
12460	Mar-97	Gloucestershire	J	F	1.083	0.162	3.330	1.684
12462	Mar-97	Kent	J	F	14.241	0.648	1.511	1.256
12465	May-95	Grampian	J	M	0.430	0.048	0.875	0.742
12466	Aug-96	Grampian	J	F	0.268	0.029	0.213	0.265
12468	Apr-97	Cambridgeshire	A	M	57.656	7.483	20.966	2.967
12470	Mar-97	Surrey	J	F	1.205	0.170	3.585	1.163
12471	-	-	J	M	1.101	0.043	1.789	0.306
12472	Apr-97	Hampshire	J	M	7.885	0.277	20.431	1.479
12481	Apr-97	D&G	A	F	8.092	0.424	6.745	5.074
12489	Apr-97	Cambridgeshire	J	M	31.564	0.951	17.161	2.980
12492	-	Isle of Man	A	F	17.946	2.053	16.102	6.951

Specimen no.	Date found	County	Age	Sex	pp'-DDE	HEOD	PCB	Hg
Sparrowhawk *Accipiter nisus* cont.								
12494	Apr-97	D&G	J	F	4.369	0.216	4.036	6.056
12495	Apr-97	Cumbria	A	M	4.775	0.187	19.807	1.891
12496	Apr-97	Hampshire	J	F	1.347	0.365	1.758	0.504
12498	-	-	-	-	3.439	0.171	3.792	0.703
12501	May-97	North Yorkshire	J	F	0.529	0.083	0.525	1.321
12502	Apr-97	Derbyshire	J	F	1.059	0.131	2.004	1.051
12504	May-97	Cambridgeshire	J	F	45.336	1.731	11.851	6.197
12508	May-97	Sussex	J	F	1.139	0.121	1.656	1.104
12513	Jun-97	Cleveland	J	M	0.752	0.048	4.194	0.429
12520	Jul-97	Bedfordshire	A	M	1.062	0.12	4.134	2.341
12523	Jul-97	Berkshire	J	F	0.140	0.060	0.223	0.021
12526	Aug-97	Hertfordshire	J	F	1.386	0.226	3.787	5.835
12528	Aug-97	Grampian	J	F	0.225	0.036	0.108	2.605
12530	Aug-97	Nottinghamshire	J	M	0.733	0.159	0.946	0.348
12539	Apr-97	Gloucestershire	-	-	18.839	1.445	51.797	8.320
12540	Mar-97	Hertfordshire	-	-	5.232	0.181	20.699	1.196
12541	May-97	H&W	-	-	5.796	0.182	0.958	1.885
12543	Sep-97	Sussex	J	F	1.768	0.204	1.887	0.723
12546	Sep-97	Clwyd	J	M	0.492	0.081	0.916	1.609
12549	Sep-97	Merseyside	A	F	19.364	1.972	100.864	0.438
12555	Sep-97	Norfolk	J	F	0.384	ND	0.373	0.712
12556	Sep-97	South Yorkshire	J	M	0.250	0.073	0.125	0.301
12557	Sep-97	Warwickshire	J	M	0.197	0.113	0.564	0.456
12559	Aug-97	Clwyd	J	M	0.367	0.078	0.634	1.473
12564	Sep-97	Kent	J	M	72.737	0.098	2.264	0.318
12565	Jul-97	Derbyshire	J	F	1.802	0.283	4.896	0.830
12570	Oct-97	Grampian	J	F	1.325	0.031	0.329	1.220
12581	Oct-97	Devon	J	F	0.079	ND	0.224	1.030
12584	Oct-97	Cheshire	J	F	0.329	0.182	0.648	0.160
12585	Oct-97	Derbyshire	J	F	1.052	0.093	4.342	0.880
12596	Nov-97	Humberside	A	F	3.285	0.314	9.671	0.110
12611	May-97	Cambridgeshire	J	F	1.579	0.103	0.687	0.400
12618	Nov-97	Leicestershire	J	F	0.143	ND	0.230	0.500
12621	Dec-97	Cambridgeshire	J	M	6.526	0.493	3.025	1.204
12625	Dec-97	Cornwall	A	F	4.947	0.595	25.232	2.449

Specimen no.	Date found	County	Age	Sex	pp'-DDE	HEOD	PCB	Hg
Sparrowhawk *Accipiter nisus* cont.								
12626	Nov-97	Surrey	J	M	0.228	0.038	0.742	1.442
12628	Dec-97	Cambridgeshire	J	F	0.159	0.026	0.133	0.294
12630	Dec-97	Hertfordshire	J	F	0.698	0.050	0.603	0.290
Peregrine falcon *Falco peregrinus*								
12417	Feb-97	Devon	A	F	0.121	0.078	1.063	0.418
12483	Mar-97	Powys	-	-	6.927	1.464	28.524	4.105
12491	-	Isle of Man	A	F	9.329	6.676	36.456	2.847
12509	Jun-97	Dorset	J	F	0.060	0.068	0.280	0.138
12511	Jun-97	Isle of Man	A	F	5.305	3.104	14.329	3.255
12531	Aug-97	Lothian	J	F	0.122	0.123	0.918	0.867
12560	Sep-97	Humberside	A	M	73.279	2.190	326.184	0.207
Merlin *Falco columbarius*								
12105	May-96	Highland	J	M	5.578	0.344	5.595	2.947
12127	Oct-95	Shetland	J	F	0.612	0.041	2.037	4.622
12139	Jul-96	Humberside	J	M	1.563	0.374	10.056	2.142
12144	Aug-96	Humberside	J	M	3.512	0.311	4.124	3.243
12204	Mar-96	Tayside	A	M	11.414	0.855	19.469	1.365
12442	Nov-96	Highland	J	M	3.176	0.093	5.479	5.722
12548	Sep-97	West Yorkshire	J	M	1.070	0.140	5.286	2.347
12595	Nov-97	Dyfed	J	F	0.248	0.167	0.732	3.248
12613	1996	Cambridgeshire	-	M	11.465	0.386	9.832	0.639
Hobby *Falco subbuteo*								
12087	May-96	Wiltshire	J	M	10.457	1.639	20.416	1.203
12122	Jun-96	Bedfordshire	A	F	0.214	1.473	1.029	0.76
12357	Aug-96	Cambridgeshire	J	F	3.651	0.427	1.185	0.73
12505	May-97	Wiltshire	J	M	2.218	0.211	12.633	3.005
12544	Aug-97	Berkshire	J	M	0.857	0.693	1.475	2.207
12614	1996	Cambridgeshire	-	M	15.247	0.829	17.806	3.085
12615	1996	Cambridgeshire	A	F	10.194	0.023	2.604	0.097
Golden eagle *Aquila chrysaetos*								
12395	Jan-97	Strathclyde	-	-	0.166	0.050	5.591	0.183

Specimen no.	Date found	County	Age	Sex	pp'-DDE	HEOD	PCB	Hg
Buzzard *Buteo buteo*								
12069	-	Grampian	-	-	1.016	0.413	3.525	2.556
12116	Nov-95	Strathclyde	A	F	0.036	0.178	0.377	0.236
12182	Sep-96	Wiltshire	J	F	ND	0.071	0.159	1.003
12191	Sep-96	Gloucestershire	J	M	ND	0.038	ND	0.611
12200	Oct-96	H&W	J	F	ND	0.208	ND	0.515
12208	Mar-95	Salop	-	-	0.025	0.258	ND	0.399
12209	Mar-95	Hants	-	-	ND	0.056	ND	0.341
12211	Mar-95	Somerset	-	-	0.070	0.148	ND	0.302
Hen harrier *Circus cyaneus*								
12137	Apr-96	Orkney	A	M	12.459	0.853	49.682	13.433
12306	Jul-95	Gwynedd	J	F	0.052	0.049	ND	0.913
12307	Jul-95	Gwynedd	J	M	0.040	0.044	ND	0.884
Osprey *Pandion haliaetus*								
12120	Jun-96	Powys	A	M	0.115	0.097	0.225	4.902
12138	Jun-96	Cheshire	A	F	3.498	0.269	43.223	13.000
Long-eared owl *Asio otus*								
12256	Oct-96	Co.Durham	A	F	0.369	0.046	3.069	0.139
12297	Nov-96	Isle of Man	A	M	5.641	0.185	10.436	2.045
12193	Sep-96	Kent	A	M	8.000	ND	14.553	1.104
12319	Aug-96	Shetland	A	F	0.181	0.046	0.178	0.434
Little owl *Athene noctua*								
12124	Jun-96	Wiltshire	A	F	0.594	0.199	0.320	0.542
12130	Jul-96	Essex	J	M	1.329	0.131	ND	0.569
12181	Sep-96	Oxfordshire	J	M	0.033	0.049	ND	0.367
12252	Oct-96	Cheshire	A	M	ND	0.030	0.103	0.256
12291	Nov-96	Suffolk	J	F	0.735	0.125	ND	0.6
Heron *Ardea cinerea*								
12365	Jan-97	Cambridgeshire	J	F	0.925	0.092	6.323	20.958
12378	Jan-97	Essex	J	F	1.997	0.056	3.299	21.06
12385	Jan-97	Nottinghamshire	J	M	0.852	0.182	2.747	5.21
12430	Jun-96	Highland	A	F	0.795	0.045	8.904	23.95
12499	May-97	Norfolk	A	M	6.622	0.173	34.111	26.28
12503	May-97	Dorset	J	F	0.058	ND	0.516	11.41

Specimen no.	Date found	County	Age	Sex	pp'-DDE	HEOD	PCB	Hg
Heron ***Ardea cinerea*** cont.								
12534	Jan-97	H&W	-	-	0.031	0.066	0.254	1.24
12551	Aug-97	Hampshire	-	-	0.191	0.219	0.748	8.85
Bittern ***Botaurus stellaris***								
12390	Jan-97	Hertfordshire	A	M	2.222	0.038	10.378	126.318
Kingfisher ***Alcedo atthis***								
12412	Feb-97	London	A	M	0.442	1.536	2.817	11.7
12512	Jun-97	Lincolnshire	J	M	0.783	0.550	ND	2.36
12547	Sep-97	South Glamorgan	J	F	0.164	0.365	0.385	0.78
12573	Sep-97	Leicestershire	J	M	0.166	0.327	1.624	1.939
12622	Nov-97	Kent	J	F	2.877	0.265	8.561	4.743
12636	Dec-97	S. Yorkshire	A	M	0.036	0.074	1.565	1.336
12637	Dec-97	S. Yorkshire	J	M	0.176	0.137	2.734	1.713
Great-crested grebe ***Podiceps cristatus***								
12518	Jul-97	Norfolk	A	M	0.515	0.027	9.931	2.471

Table 2. **Geometric mean levels of pollutants in the various species in Table 1, for 1997 specimens only**

GSE = geometric standard error

	pp'-DDE	HEOD	PCB	Hg
Kestrel				
Geometric mean	0.359	0.206	1.225	0.638
N	26	26	26	26
Range within 1 GSE	0.294-0.438	0.135-0.314	0.903-1.661	0.521-0.781
Sparrowhawk				
Geometric mean	1.865	0.143	2.180	0.954
N	62	62	62	62
Range within 1 GSE	1.509-2.305	0.116-0.177	1.788-2.658	0.835-1.089
Heron				
Geometric mean	0.448	0.115	2.118	9.609
N	8	7	7	7
Range within 1 GSE	0.216-0.930	0.093-0.143	1.26-3.984	6.419-14.387
Kingfisher				
Geometric mean	0.3379	0.245	0.813	2.396
N	7	7	7	7
Range within 1 GSE	0.200-0.571	0.148-0.405	0.246-2.678	1.712-3.353

Note: nil detected values were taken as 0.001 for all residues.

Table 3. **Comparison of geometric mean residue levels (log values) from birds collected in 1996 and 1997; t-values are shown. Minus values indicate a decrease and plus values indicate an increase from 1996.**

	pp'-DDE	HEOD	PCB	Hg
Kestrel	t_{43}=+2.53*	t_{43}=+0.08	t_{43}=+0.54	t_{43}=-.96
Sparrowhawk	t_{131}=+3.83***	t_{131}=+1.48	t_{131}=+2.56*	t_{131}=-2.41*
Heron	t_{13}=+0.96	t_{13}=+3.26**	t_{13}=+1.51	t_{13}=+-0.52
Kingfisher	t8=-0.06	t8=-0.85	t8=-0.11	t8=+2.08

Notes: None detected values taken as 0.001 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 1963-1997 and 1992-1997. Figures show sample sizes (N) and linear regression coefficients (b) based on log values regressed against year.**

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

	1963-1997			1992-1997		
	N	**b**		**N**	**b**	
Kestrel						
pp'-DDE	1404	-0.0423	***	214	0.0701	*
HEOD	1375	-0.033	***	214	0.0556	**
PCB	1263	0.00227	ns	214	-0.0167	ns
Hg	1068	-0.033	***	214	0.0289	ns
Sparrowhawk						
pp'-DDE	1731	-0.0354	***	517	0.007	ns
HEOD	1731	-0.0342	***	517	-0.0505	**
PCB	1687	-0.0142	***	517	-0.094	***
Hg	1483	-0.0277	***	517	-0.0371	*
Heron						
pp'-DDE	798	-0.0438	***	63	0.0071	ns
HEOD	788	-0.0511	***	63	-0.0638	ns
PCB	664	-0.0242	***	63	-0.0577	ns
Hg	501	-0.0217	***	63	0.0136	ns
Kingfisher						
pp'-DDE	216	-0.0472	***	34	-0.119	ns
HEOD	215	-0.0256	***	34	-0.0683	ns
PCB	210	-0.0179	*	34	-0.116	ns
Hg	137	0.0007	ns	34	0.0162	ns
Great-crested grebe						
pp'-DDE	184	-0.0253	**	15	0.0824	ns
HEOD	163	-0.0294	***	15	-0.267	*
PCB	171	-0.028	**	15	-0.0204	ns
Hg	103	-0.0271	**	15	0.133	*

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 kestrels, 1963-1997.
Three-year moving geometric means with one geometric standard error on either side.

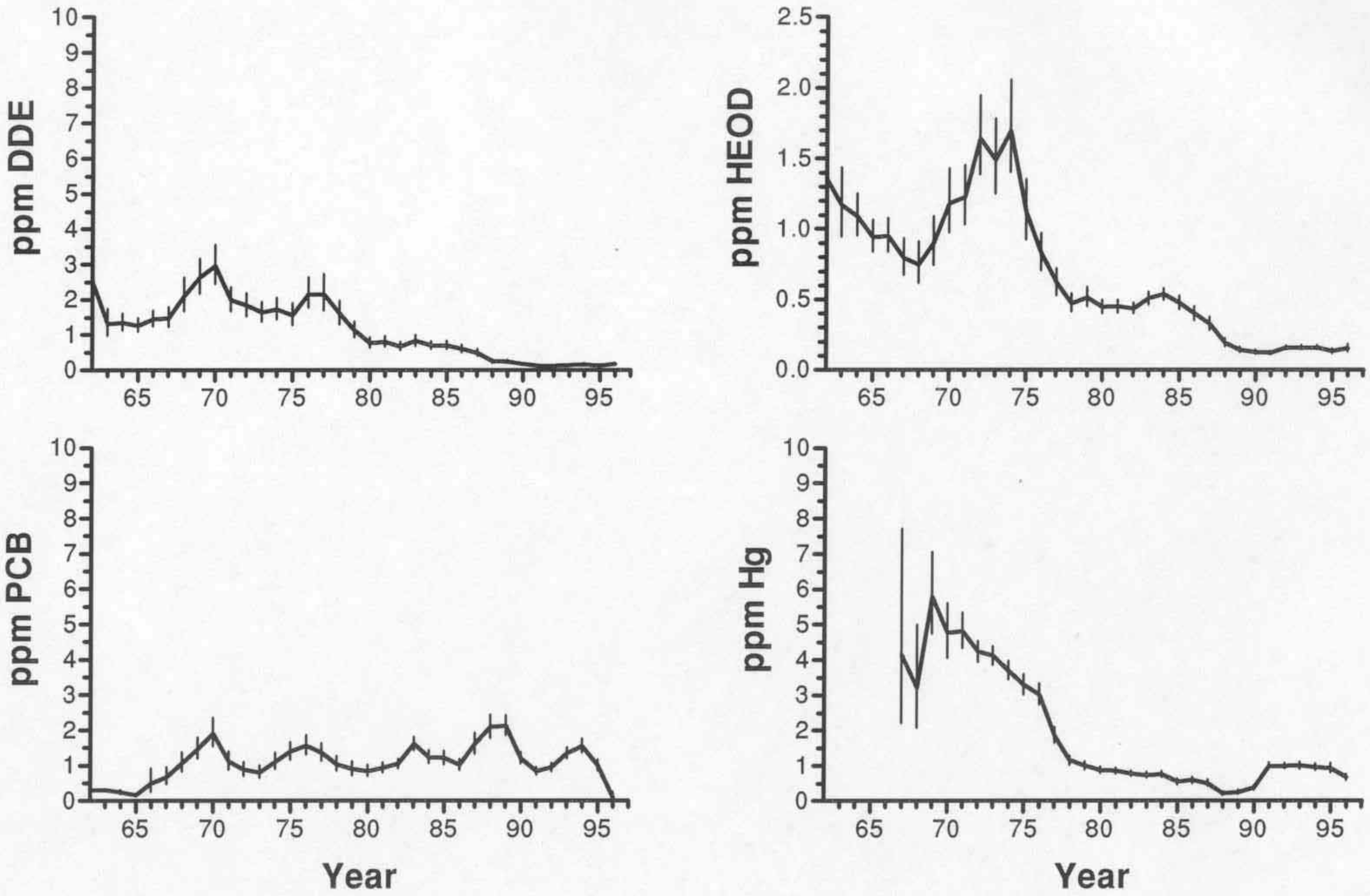


Figure 2. Trends in pollutant residues in livers of sparrowhawks, 1963-1997.
Three-year moving geometric means with one geometric standard error on either side.

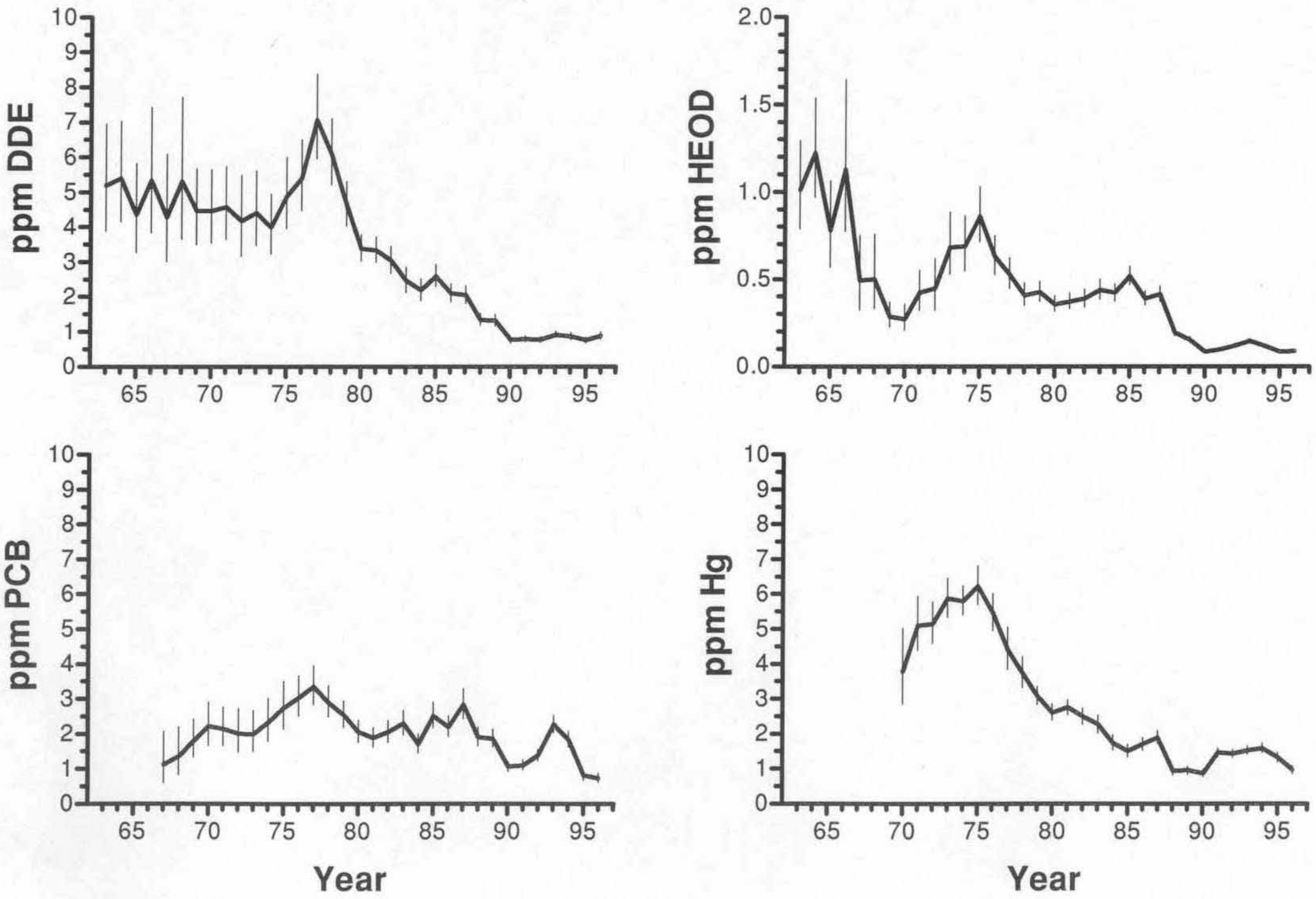


Figure 3. Trends in pollutant residues in livers of herons, 1963-1997.
Three-year moving geometric means with one geometric standard error on either side.

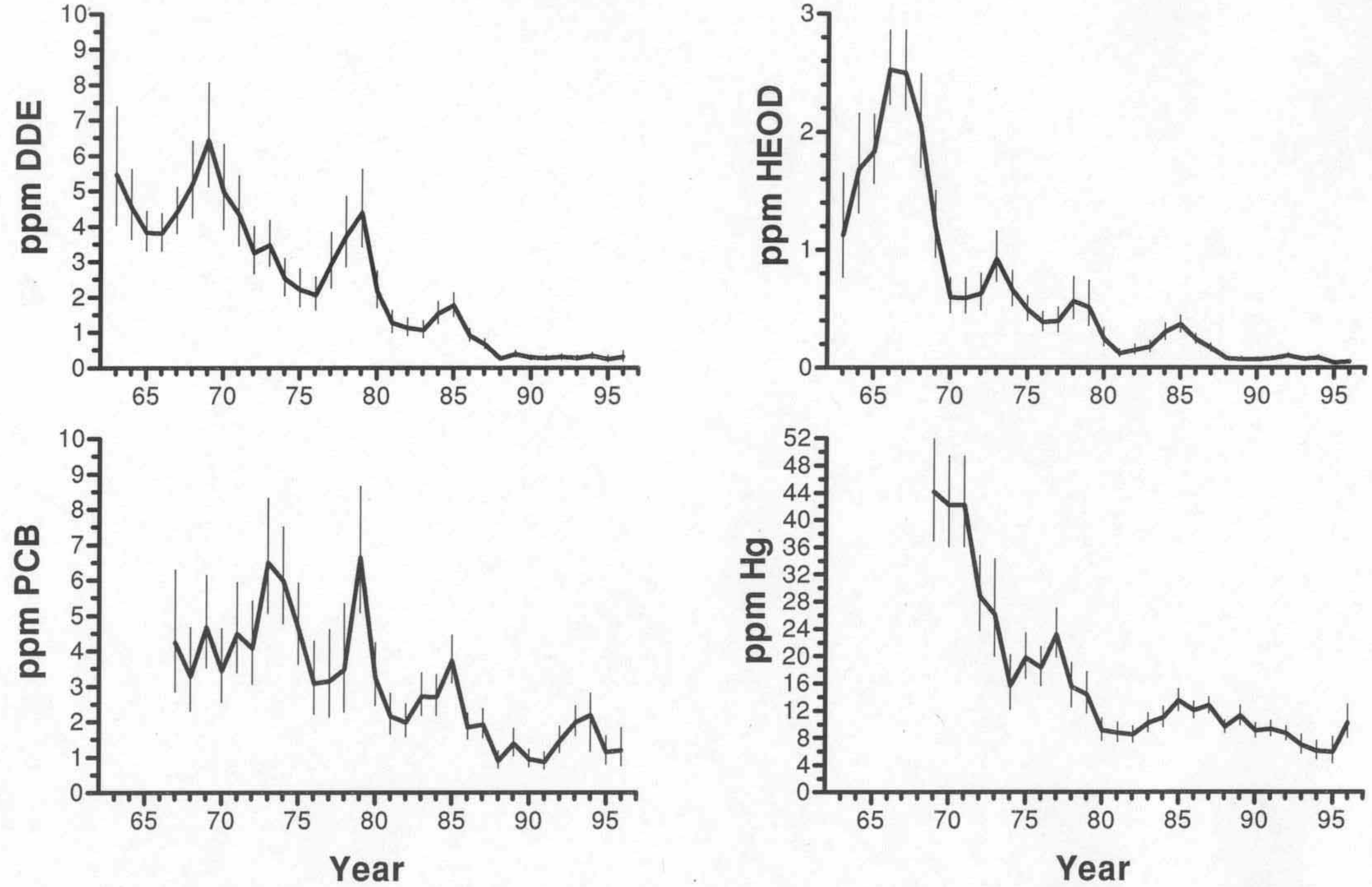


Figure 4. Trends in pollutant residues in livers of kingfishers, 1963 - 1997.
Three-year moving geometric means with one geometric standard error on either side.

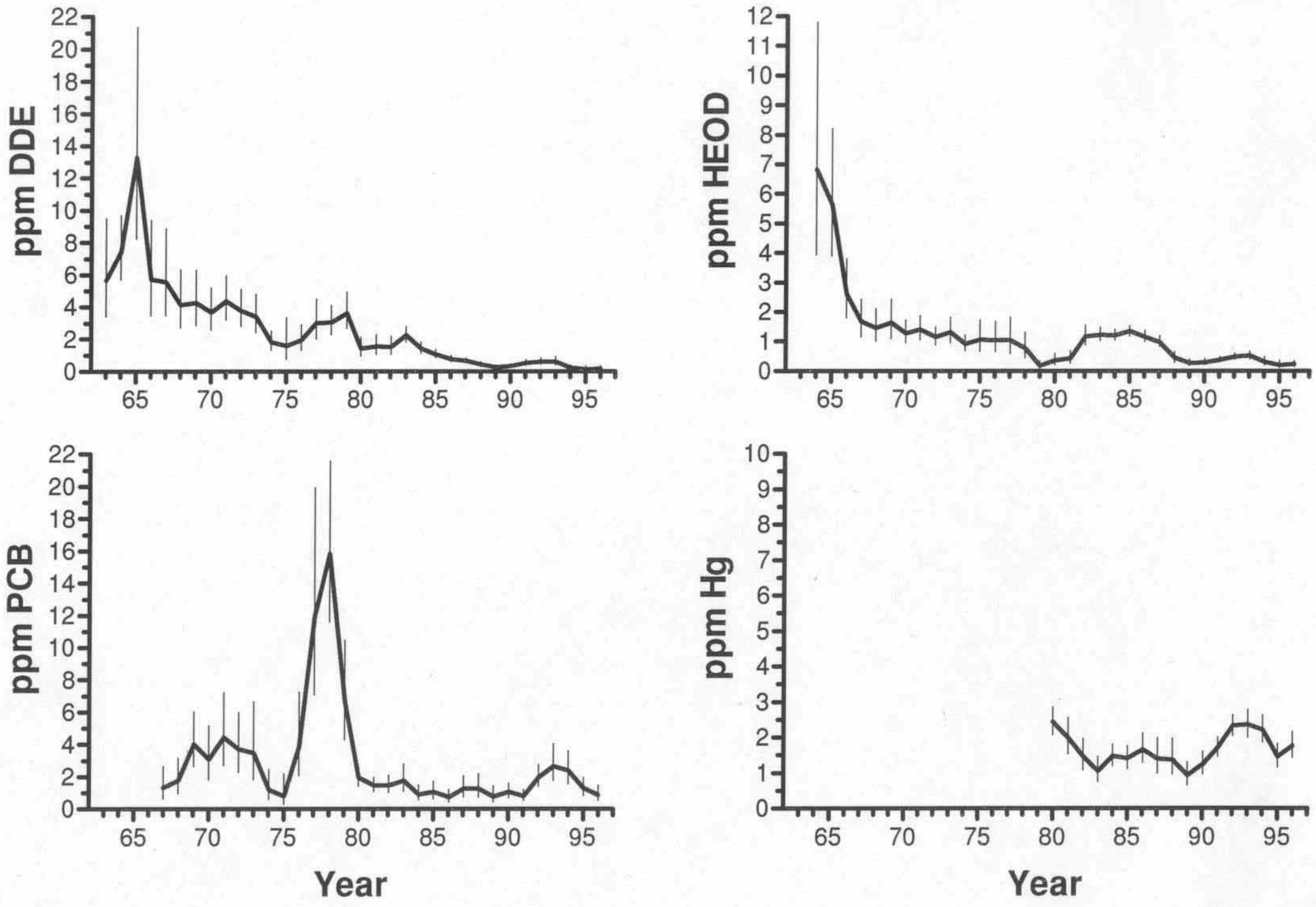
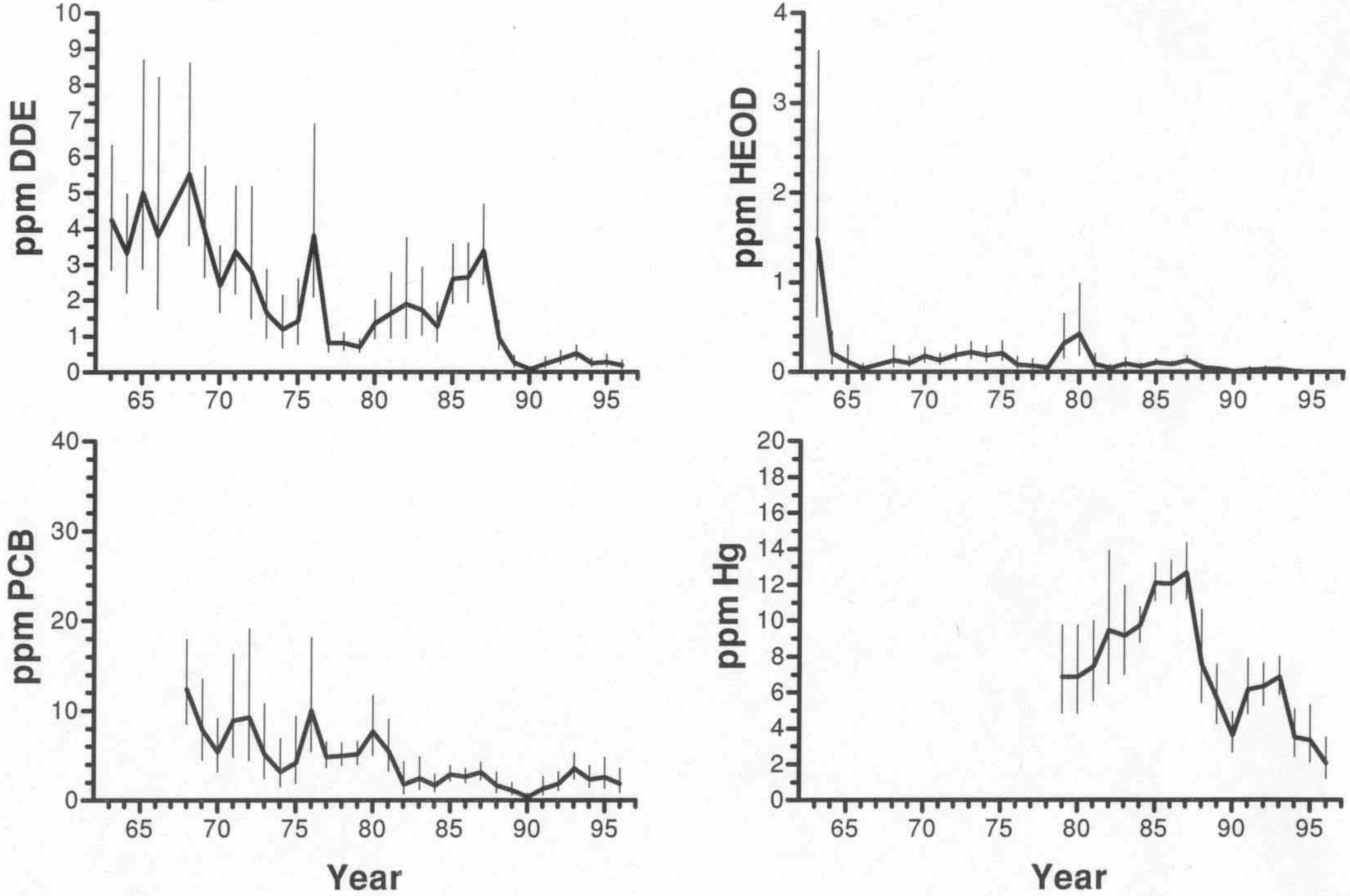


Figure 5. Trends in pollutant residues in livers of great-crested grebes, 1963-1997.
Three-year moving geometric means with one geometric standard error on either side.
Note that no grebes were received in 1967.



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Annual report to the Joint Nature Conservation Committee

Wildlife and pollution

Part 3 Organochlorines and mercury in peregrine eggs

I Newton, L Dale, JK Finnie, P Freestone,
J Wright, C Wyatt & I Wyllie

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

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3 ORGANOCHLORINES AND MERCURY IN PEREGRINE EGGS

3.1 Introduction

The peregrine *Falco peregrinus* was one of the bird species most affected by organochlorine pesticides, as its number crashed in the 1960s in both Europe and North America (Cade *et al*. 1988). As the use of organochlorines in the year since then has been progressively reduced, residues in peregrine eggs have declined, and breeding success and numbers of peregrines on both continents have gradually recovered. Continued monitoring of events, following reductions in organochlorine use, has provided important confirmation of the role of organochlorines in population decline. Nowhere have events been better documented than in Britain (Ratcliffe 1993).

In this section, we give the findings from 16 eggs (one per clutch) analysed in 1997 (Table 5), and summarise the long-term trends in organochlorine and mercury residues from 706 eggs analysed over the period 1963-97. The findings to 1979 were given by Cooke *et al*. (1982) and to 1986 by Newton *et al*. (1989). This section includes all these data, together with those from another 237 eggs analysed during 1987-97. Results on trends in residues are shown in three ways: (1) as plots of three-year moving geometric mean levels (with geometric standard errors) based on eggs from Britain as a whole (Figure 6); (2) as regression analyses of individual $\log_{10}$ residue levels against year for eggs from different regions, and from Britain as a whole (Table 6); and (3) as geometric mean levels for eggs from different regions (and from Britain as a whole) in 1963-75, 1976-86 and 1987-97 (Table 7). The data were split at 1976 because this was the first year of the voluntary ban on the use of aldrin and dieldrin in cereal seed treatments (until then a major use), and at 1987 because this was the first year with a complete ban on all uses of DDT, aldrin and dieldrin in Britain. In all analyses, details from only one egg per clutch were included. Geographical regions (Tables 6 & 7) are as defined by Ratcliffe (1993), except that Wales is counted as one region.

3.2 Residues in eggs from 1997

The findings from the 16 eggs from 1997 confirm continuing widespread contamination of British peregrine eggs with organochlorines and mercury (Table 5). However, most of the residues were present at relatively low levels. The highest DDE level recorded in 1997 was 0.6 ppm wet weight (in an egg from Dyfed), the highest HEOD was 0.2 ppm (in an egg from Derbyshire), the highest PCB level was 1.45 ppm (in an egg from Gwent) and the highest mercury level was 1.28 ppm dry weight (in an egg from Dyfed). As in previous years, eggs that were high in DDE also tended to be relatively high in HEOD and PCB. Shell-index could be measued on nine eggs from 1997, and the mean value was 1.79, some 2% less than the pre-DDT mean.

3.3 Geographical and long-term trends

Significant regional variation was apparent in the levels of all four contaminants in all three time periods, except for PCB in 1989-97 and mercury in 1976-86 (Table 7). The pesticide residues (DDE and HEOD) tended to be highest in the southern two-thirds of Britain, decreasing northwards. Although in some regions the highest PCB levels were from coastal eggs, no significant differences in the geometric mean residue levels emerged between coastal and inland eggs from the same region, so data from both types of site were pooled.

Over the whole study period 1963-97, DDE and HEOD residues declined in eggs from all seven regions and overall (Table 6). In only one of these regions (North and Western Highlands) was the downward trend in HEOD not statistically significant (although the geometric mean value for 1987-97 was significantly lower than that for 1976-86, Table 7). PCB levels showed significant net declines in only three regions (and overall), while mercury levels showed no significant net trend in any region, apart from an increase in the Central and Eastern Highlands region. However, few mercury analyses were done before 1986. Shell-indices increased in all regions, but significantly in only three regions and overall.

3.4 Discussion

Regional variation in the levels of DDE and HEOD, with a general decline from south to north within Britain, broadly fitted with the extent of arable land (and hence with pesticide use) and with the extent of population decline, both of which were greatest in the south. In some southern and eastern parts of the range, with most arable land, peregrines disappeared before 1961 and have only recently reappeared, so these areas were not represented in the earlier years. Throughout the period of study, the lowest organochlorine levels were found in eggs from the Central and Eastern Scottish Highlands, where shell-thinning was slight and no obvious decline in numbers occurred (Ratcliffe 1993). Here falcons feed largely on red grouse, which are herbivorous year-round residents in a non-agricultural habitat. The higher organochlorine levels in peregrine eggs from the Northern and Western Highlands, compared with the Central and Eastern Highlands, could be attributed to the lesser importance of red grouse in the north-west and the greater dependence on other, more contaminated, prey.

General declines in the levels of DDE and HEOD in peregrine eggs, apparent over the study period, followed progressive reductions in the agricultural uses of DDT, aldrin and dieldrin, leading to their almost total withdrawal in 1983-86 (for details see Newton & Haas (1984), summarising Strickland (1966), Wilson (1969), Sly (1977, 1981, 1986), Cutler (1981)). The slower decline of DDE compared to HEOD could be attributed to the greater persistence of DDE in the physical and biotic environments, and to the fact that DDR was used in quantity until a later date.

Levels of PCBs in peregrine eggs during 1967-97 presumably reflect continuing contamination of the relevant prey species. Manufactured since the 1930s, these chemicals have many uses, chiefly in transformers and hydraulic systems. From 1971 the manufacturer of PCBs for Britain (Monsanto) restricted their use to 'closed' systems, least likely to lead to pollution. However, almost all uses pollute to some extent and a continuing escape to the environment would be expected from products made in earlier years. Moreover, some PCBs are extremely persistent. This is presumably why levels in peregrine eggs have declined in some areas, but not in others.

3.5 Summary

Following reductions in the use of organochlorine pesticides, levels of DDE and HEOD in peregrine eggs have declined in all regions of Britain. Levels of PCBs have declined in some regions and not in others, while mercury levels (analysed since the mid-1980s) have changed little.

3.6 References

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Table 5. Residue levels (organochlorine ppm wet weight (lipid weight); mercury ppm (dry weight) and shell indices (SI) for peregrine eggs received in 1997

Number	Year	County	SI	pp'-DDE		HEOD		PCB		Hg
CENTRAL AND EASTERN HIGHLANDS										
E7144	97	Grampian	-	0.63	(13.00)	0.06	(1.20)	0.372	(7.63)	0.45
E7145	97	Grampian	-	0.41	(5.55)	0.03	(0.38)	0.367	(4.93)	0.20
E7146	97	Grampian	-	0.54	(13.35)	0.05	(1.24)	0.295	(7.34)	0.50
E7147	97	Grampian	-	0.59	(12.60)	0.05	(1.08)	0.387	(8.30)	0.65
E7171	97	Grampian	1.81	2.55	(41.42)	0.08	(1.29)	1.61	(26.15)	0.57
E7203	97	Tayside	-	0.25	(4.86)	0.02	(0.43)	0.57	(11.22)	0.19
E7204	97	Tayside	-	0.08	(5.31)	0.01	(0.86)	0.11	(7.01)	0.18
SOUTHERN SCOTLAND										
E7140	97	Strathclyde	1.93	0.42	(8.74)	0.05	(0.99)	2.23	(46.60)	0.27
NORTHERN ENGLAND										
E7148	97	Cleveland	1.79	0.02	(0.33)	0.03	(0.50)	0.25	(4.63)	ND
E7188	97	Cheshire	1.78	0.65	(13.22)	0.06	(1.21)	1.47	(29.98)	0.26
E7191	97	Cumbria	1.72	3.28	(46.87)	0.3	(4.28)	12.05	(172.23)	0.84
E7192	97	Cumbria	-	1.6	(23.51)	0.16	(2.40)	10.16	(149.60)	1.18
E7193	97	Cumbria	1.98	1.08	(16.07)	0.16	(2.39)	3.06	(45.51)	0.40
E7211	97	North Yorks	1.62	0.3	(5.60)	0.01	(1.14)	1.128	(21.47)	0.29
E7322	97	Northumberland	1.77	0.76	(13.94)	0.16	(2.97)	8.148	(149.15)	0.91
E7323	97	Northumberland	1.67	0.03	(107.03)		ND		ND	1.01

Table 6. Trends in pollutant levels in peregrine eggs as revealed by regression analyses of individual residue levels against year. N=number of clutches represented at one egg per clutch, b=regression coefficient (slope), *P<0.05, **P<0.01, ***P<0.001.

	DDE			**HEOD**			**PCB**			**Hg**			**Shell index**		
	N	b		N	b		N	b		N	b		N	b	
Southern England	13	-0.069	**	13	-0.087	**	13	-0.053	*	11	0.055	ns	11	0.004	ns
Wales	46	-0.028	***	46	-0.041	***	46	-0.019	ns	34	-0.010	ns	43	0.009	*
Northern England	143	-0.048	***	143	-0.047	***	136	0.008	ns	70	-0.007	ns	122	0.006	*
Southern Scotland	235	-0.050	***	235	0.046	***	218	0.001	ns	38	-0.010	ns	191	0.014	***
Southern Highland Fringe	94	-0.041	***	94	-0.055	*	93	-0.027	*	21	-0.029	ns	61	0.004	ns
Central & Eastern Highlands	141	-0.033	***	141	-0.023	*	133	-0.014	*	56	0.056	*	109	0.003	ns
North & Western Highlands	34	-0.051	**	34	-0.005	ns	34	-0.023	ns	9	-0.155	ns	27	0.011	ns
All areas	706	-0.043	***	706	-0.-39	**	673	-0.010	**	239	0.0004	ns	564	0.009	***

Table 7. Geometric mean pollutant levels and arithmetic mean shell indices for peregrine eggs from various regions of Britain in three different period.
N=number of clutches represented at one egg per clutch, *P<0.05, **P<0.01, ***P<0.001

	1963-75				1976-86				1987-97		
DDE	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
Southern England	-	-	-		3	2.582	2.438 - 2.735	**	10	0.665	0.482 - 1.054
Wales	-	-	-		-16	2.618	2.291 - 2.992	***	30	1.205	1.050 - 1.384
Northern England	24	4.508	3.499 - 5.808	**	54	1.936	1.637 - 2.291	***	65	0.670	0.558 - 0.804
Southern Scotland	85	5.861	3.370 - 6.397	***	118	2.471	2.270 - 2.704	***	32	0.393	0.337 - 0.458
Southern Highland Fringe	14	3.828	3.069 - 4.775	ns	59	2.541	2.198 - 2.938	***	21	0.357	0.284 - 0.450
Central & Eastern Highlands	37	1.614	1.321 - 1.972	**	58	0.782	0.649 - 0.942	***	46	0.275	0.227 - 0.333
North & Western Highlands	13	1.875	1.455 - 2.455	ns	15	2.317	0.999 - 2.917	**	6	0.090	0.043 - 0.097
ANOVA	$F_{4,168}$=13.17; P<0.001				$F_{6,316}$=8.31; P<0.001				$F_{6,203}$=7.61; P<0.001		
HEOD	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
Southern England	-	-	-		3	0.337	0.255 - 0.444	**	10	0.058	0.039 - 0.086
Wales	-	-	-		16	0.336	0.249 - 0.453	**	30	0.110	0.094 - 0.129
Northern England	24	0.834	0.709 - 0.979	***	54	0.185	0.151 - 0.226	***	65	0.071	0.059 - 0.085
Southern England	85	0.637	0.545 - 0.779	***	118	0.176	0.153 - 0.202	***	32	0.046	0.039 - 0.054
Southern Highland Fringe	14	0.661	0.479 - 0.912	**	59	0.163	0.137 - 0.193	***	21	0.035	0.027 - 0.046
Central & Eastern Highlands	37	0.116	0.090 - 0.150	**	58	0.048	0.039 - 0.059	ns	46	0.036	0.030 - 0.043
North & Western Highlands	13	0.047	0.031 - 0.070	ns	15	0.102	0.079 - 0.132	*	6	0.020	0.011 - 0.034
ANOVA	$F_{4,168}$=26.10; P<0.001				$F_{6,316}$=7.48; P<0.001				$F_{6,203}$=4.28; P=0.001		

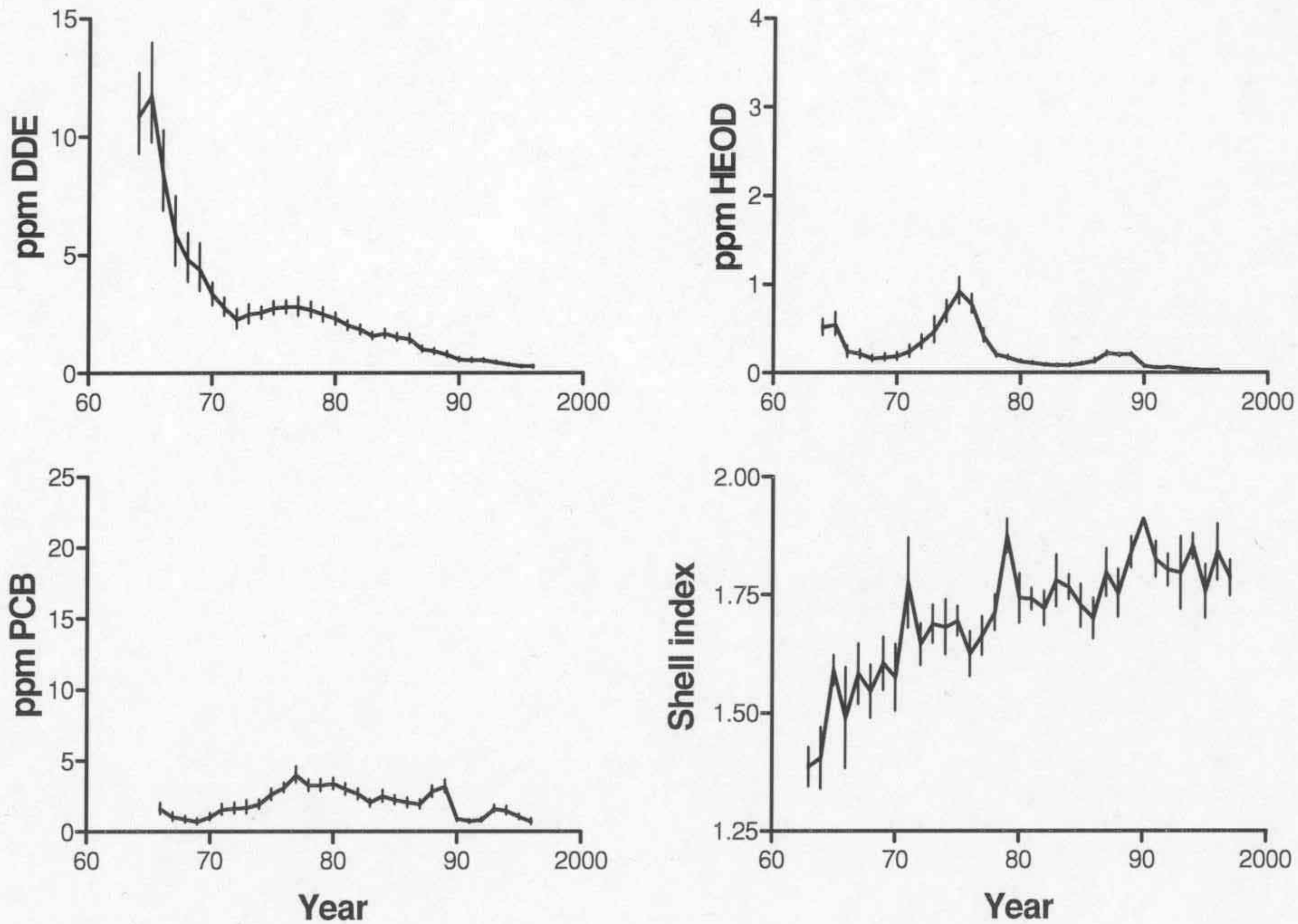
PCB	1963-75				1976-86				1987-97		
	N	Geometric mean	Range within one geometric SE		N	Geometric mean	Range within one geometric SE		N	Geometric mean	Range within one geometric SE
Southern England	-	-	-		3	5.140	2.636 - 10.023	ns	10	2.692	1.950 - 3.715
Wales	-	-	-		16	2.685	2.158 - 3.342	ns	30	1.524	1.211 - 1.919
Northern England	17	0.398	0.214 - 0.741	*	54	1.824	1.570 - 2.118	ns	65	1.679	1.343 - 2.099
Southern Scotland	68	1.384	1.222 - 1.567	***	118	3.177	2.864 - 3.524	***	32	1.306	1.072 - 1.592
Southern Highland Fringe	13	2.218	1.276 - 3.855	ns	59	5.070	4.305 - 5.970	***	21	0.566	0.366 - 0.877
Central & Eastern Highlands	29	1.191	0.883 - 1.607	ns	58	1.245	1.002 - 1.545	ns	46	0.745	0.634 - 0.875
North & Western Highlands	13	3.076	1.770 - 5.346	ns	15	8.166	5.781 - 5.781	ns	6	0.537	0.151 - 1.905
ANOVA	$F_{4,135}$=3.72; P=0.007				$F_{6,316}$=9.46; P<0.001				$F_{6,203}$=2.89; P=0.010		

Hg	1963-75				1976-86				1987-97		
	N	Geometric mean	Range within one geometric SE		N	Geometric mean	Range within one geometric SE		N	Geometric mean	Range within one geometric SE
Southern England	-	-	-		-	-	- -		10	0.384	0.311 - 0.474
Wales	-	-	-		4	0.979	0.743 - 1.291	ns	30	0.557	0.459 - 0.676
Northern England	1	2.612	-		4	0.212	0.075 - 0.597	ns	57	0.394	0.327 - 0.473
Southern England	-	-	-		6	0.444	0.249 - 0.789	ns	31	0.300	0.238 - 0.378
Southern Highland Fringe	-	-	-		-	-	- -	-	21	0.953	0.820 - 1.107
Central & Eastern Highlands	-	-	-		10	0.102	0.066 - 0.158	ns	39	0.089	0.066 - 0.120
North & Western Highlands	-	-	-		3	2.339	1.656 - 3.304	ns	6	0.459	0.196 - 1.076
ANOVA	$F_{4,22}$=3.21; P=0.011				$F_{6,187}$=8.89; P=<0.001				$F_{6,203}$=4.28; P=0.001		

	1963-75				1976-86				1987-97		
Shell Index	**N**	**Arithmetic mean**	**Range within one arithmetic SE**		**N**	**Arithmetic mean**	**Range within one arithmetic SE**		**N**	**Arithmetic mean**	**Range within one arithmetic SE**
Southern England	-	-	-		3	1.820	1.749 - 1.891	ns	8	1.876	1.840 - 1.912
Wales	-	-	-		15	1.698	1.654 - 1.739	*	28	1.818	1.786 - 1.850
Northern England	14	1.637	1.582 - 1.692	*	48	1.785	1.755 - 1.815	ns	60	1.801	1.779 - 1.823
Southern Scotland	70	1.603	1.580 - 1.626	***	101	1.739	1.721 - 1.757	***	20	1.855	1.829 - 1.881
Southern Highland Fringe	8	1.530	1.485 - 1.575	**	46	1.711	1.680 - 1.742	ns	7	1.651	1.583 - 1.719
Central & Eastern Highlands	25	1.738	1.705 - 1.771	ns	52	1.738	1.710 - 1.766	ns	32	1.799	1.762 - 1.836
North & Western Highlands	9	1.574	1.515 - 1.633	ns	12	1.684	1.638 - 1.730	ns	6	1.788	1.648 - 1.928
ANOVA	$F_{4,121}=3.33$; P=0.013				$F_{6,270}=0.97$; P=0.444				$F_{6,148}=0.55$; P=0.739		
All Regions	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
DDE	173	3.802	3.499 - 4.130	***	323	1.941	1.816 - 2.075	***	210	0.490	0.447 - 0.537
HEOD	173	0.378	0.337 - 0.425	***	323	0.140	0.129 - 0.153	***	210	0.054	0.049 - 0.059
PCB	140	1.297	1.129 - 1.489	***	323	2.773	2.570 - 2.992	***	210	1.186	1.062 - 1.324
Hg	1	2.612	-		27	0.276	0.199 - 0.381	ns	194	0.326	0.292 - 0.364
Shell index	126	1.627[1]	1.610 - 1.643[2]	***	277	1.738[1]	1.726 - 1.750[2]	***	161	1.808[1]	1.793 - 1.823[2]

[1] arithmetic mean
[2] arithmetic standard error

Figure 6. **Trends in pollutant residues and shell index in UK peregrine eggs, 1963-97.**
Residues - three-year moving geometric means and geometric standard errors
Shell index - annual arithmetic means and standard errors



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Annual report to the Joint Nature Conservation Committee

Wildlife and pollution

Part 4 Organochlorines and mercury in merlin eggs

I Newton, L Dale, JK Finnie, P Freestone,
J Wright, C Wyatt & I Wyllie

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

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4 ORGANOCHLORINES AND MERCURY IN MERLIN EGGS

4.1 Introduction

The merlin *Falco columbarius* is one of several bird-of-prey species whose numbers declined markedly in Europe and North America between the 1950s and 1970s, following the widespread introduction of DDT and other organochlorine pesticides (Ratcliffe 1970; Fox 1971; Fyfe *et al.* 1976; Newton *et al*. 1978, 1981). Several studies on both continents reported marked eggshell thinning or reduced breeding success (Ratcliffe 1970; Fox 1971; Temple 1972; Newton 1973; Fyfe *et al*. 1976; Crick 1993), and some examined the relationship between organochlorine levels in eggs and eggshell-thinning, breeding success or population trend (Fyfe *et al*. 1976, Newton *et al*. 1978, 1982; Fox & Donald 1980; Newton & Haas 1988). The findings from most previous analyses of British merlin eggs were given in Newton & Haas (1988), and those from 1987-1996 in previous reports in this series, while those from 16 eggs (one per clutch) analysed in 1997 are summarised in Table 8.

In this section, we use all these data to examine the trends in organochlorine and mercury levels in British merlin eggs over the past 34 years. This period coincided with a time of progressive reduction in the use of organochlorine pesticides in Britain, leading to the complete banning of DDT, aldrin and dieldrin from 1986. At least in the latter half of this period, it also corresponded with a time of increase in the numbers of merlins found breeding in various parts of Britain (Bibby & Nattrass 1986; Rebecca & Bainbridge 1998).

Over the period 1967-97, eggs were received at Monks Wood Research Station from a total of 630 different merlin clutches, with far fewer per year in the earlier years than in the later ones. These eggs came from various parts of the country (Table 9), but 32% of the total were from north-east England, collected by members of the Northumbria Ringing Group.

Results on trends in residues are shown in three ways: (1) as plots of three-year moving geometric mean levels (with geometric standard errors) for Britain as a whole, and separately for north-east England (Figures 7 and 8); (2) as regression analyses of annual means of $\log_{10}$ residue levels against year for Britain as a whole, and separately for seven different regions (Table 9); and (3) as geometric mean levels for Britain as a whole and separately for each of seven regions in two periods, 1967-1986 and 1987-1997 (Table 10). The data were split at 1987 because this was the first year with a complete ban on the use of DDT, aldrin and dieldrin in Britain. This last procedure also facilitated analysis of regional variation in residue levels during the two periods. In all analyses, each clutch was represented only once, by values from a single egg (selected at random where more than one egg per clutch was analysed).

4.2 Residues in eggs from 1997

The results from the 16 merlin eggs collected in 1997 serve to confirm the continuing widespread contamination of British merlins with organochlorines and mercury (Table 8). Levels of all contaminants were generally higher than those in peregrine eggs. The highest DDE level was 20 ppm (in an egg from Grampian), the highest HEOD level was 0.75 ppm (in an egg from North Yorkshire) and the highest PCB level was 17 ppm (in an egg from North Yorkshire). As in previous years, the highest levels of mercury (2-4 ppm) were found in eggs from the Northern Isles, and eggs that were high in DDE tended also to be relatively high in HEOD and PCB. Shell-indices were available for 13 eggs in 1997, and averaged 1.21, some 4% less than the pre-DDT value.

4.3 Long-term trends in residue levels

Over the period 1967-97, residues of DDE showed significant downward trends in the eggs from most of the different regions and overall (Figures 7 & 8, Tables 9 & 10). Only on Orkney did no trend emerge, but most eggs from this area were collected in the 1980s, when levels of DDE in eggs from other parts of Britain had already dropped. Levels of HEOD were generally much lower than those of DDE, but downward trends were apparent in all regions except Orkney, and were significant in four of the seven regions and overall. Residues of PCBs fluctuated considerably over the years, but over the whole period showed significant net downward trends in three of the seven regions and overall (Table 9). Levels of mercury showed no significant trends by regression analyses, except for Shetland where they decreased (Table 9). Eggs from Wales, north-east England and northern Scotland had significantly higher mean mercury levels in the years after 1986 than in the years up to this time (Table 10), but this difference was probably a product of the way that levels varied over the years (with low levels in the early 1980s) rather than a real net increase (Figure 7).

In addition to the temporal trends, significant regional variation in residues was apparent in all the chemicals examined, apart from HEOD and mercury up to 1986 and PCBs after 1986 (Table 10). In general, up to 1986, DDE levels were higher in the southern parts of Britain (England, Wales and southern Scotland) than further north, but after 1986 these differences became less marked. For PCBs, although significant regional variation was apparent up to 1986, this variation followed no obvious north-south or east-west trend, and after 1986 (when levels were lower) the regional variation was no longer singificant.

For mercury, significant regional variation was apparent in the later (post-1986) period, but it also showed no obvious geographical trend. As described elsewhere (Newton & Haas 1988), some eggs with unusually high mercury levels were collected in Shetland and Orkney and in other parts of north-west Scotland (a tendency still apparent in the 1997 eggs). Over the period as a whole, shell indices showed a progressive improvement, which was significant in most regions (except Orkney and Wales) and overall (Tables 9 & 10, Figure 9). This trend would be expected from the decline in residues of DDE, the main causal agent of shell-thinning (Cooke 1973; Newton 1979). The statistical significance in the regional variation in shell indices, evident before 1986, was no longer apparent in the later years (Table 10).

4.4 Discussion

For much of the period considered, the merlin remained the most contaminated of the British raptors, in terms of the magnitude of residues recorded, and so far no eggs have proved free of organochlorine or mercury residues (but some mercury would be expected naturally). Perhaps the most important findings, however, were the marked temporal declines in residue levels of organochlorine pesticides (DDE and HEOD), and the associated increase in shell-indices. These changes followed progressive reductions in the use of organochlorine pesticides in Britain and elsewhere in Europe over the period concerned. They also coincided with widespread increase in the numbers of breeding merlins found in various parts of Brtiain (Rebecca & Bainbridge 1998). A survey of merlin numbers in large parts of the British range during 1983-84, in which figures were adjusted to allow for suitable areas not covered, resulted in an estimate of 550-650 pairs in Brtiain as a whole (Bibby & Nattrass 1986). A repeat survey in 1993-94, covering more of the potential range but again correcting for areas not covered, resulted in an estimate of 1,300±200 pairs (Rebecca & Bainbridge 1988). These figures suggest that the overall population could have doubled in this ten-year period. The increase was by no means uniform across the range, and in some areas where comparisons were made between surveys, merlins remained stable. Moreover, in at least one area (Orkney), breeding numbers decreased, in associated with habitat degradation (Meek 1988). An overall increase would have been expected if organochlorine pesticides were the main causal agents of earlier declines, as previous studies suggested (Fox 1971; Temple 1972; Fyfe *et al*. 1976; Newton *et al*. 1978, 1981, 1982, 1986; Newton & Haas 1988). Moreover, these various events were paralleled by residue reductions and population recoveries in other affected species in Britain, notably peregrine *Falco peregrinus* (Ratcliffe 1980; Newton *et al*. 1989; Crick & Ratcliffe 1995) and Eurasian sparrowhawk *Accipiter nisus* (Newton & Haas 1984; Newton *et al*. 1993).

The PCB levels in merlin eggs from some regions also declined during the study period but, to our knowledge, PCBs have not been implicated in the population declines of raptors. It was hard to discern any net trend in the levels of mercury in merlin eggs, because levels declined to the mid 1980s and then increased again. Also, no analyses of mercury in merlin eggs were made before 1978, so any longer-term trend could not have been documented. In other British raptors examined as part of the same programme, namely peregrine *Falco peregrinus*, kestrel *F. tinnunculus* and sparrowhawk *Accipiter nisus*, mercury levels in liver tissue declined between the 1970s and the 1990s, but none showed quite the same pattern of residue fluctuation in the latter years as did merlin (Newton *et al.* 1993, Section 1).

Although the data were split by region, some of the merlins breeding in these regions, together with most of the main prey species, leave the uplands for the winter, moving to lowlands and coastal areas, either nearby or further south within Britain and Europe. The residue levels found in eggs would not, therefore, be expected entirely to reflect levels in the local breeding environment, as part of the contaminant loads could have been accumulated elsewhere.

4.5 Summary

Over the period 1967-97, eggs from 630 merlin clutches, obtained in various parts of Britain, were analysed for residues of DDE, HEOD, and mercury. The organochlorine pesticides (DDE and HEOD) had previously been held responsible for an earlier decline in the numbers of merlins in Britain, along with some other birds of prey. During the study period, the pesticide residues (DDE and HEOD) declined markedly. PCB levels also declined in some regions, while mercury levels (measured only from 1978) declined to the mid-1980s and then increased again. The decline in pesticide residues, and associated improvement in shell indices, coincided with a marked increase between 1983-84 and 1993-94 in the numbers of merlins found breeding in Britain.

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Table 8. Residue levels (organochlorine ppm wet weight (lipid weight); mercury ppm dry weight) and shell indices (SI) for merlin eggs received in 1997
ND=none detected

Number	Year	County	SI	pp'-DDE	HEOD		PCB		Hg	
CENTRAL AND EASTERN HIGHLANDS										
E7255	97	Tayside	-	5.45	(68.08)	0.20	(2.45)	3.61	(45.13)	1.35
E7310	97	Tayside	1.21	10.045	(266.39)	0.401	(10.62)	8.075	(214.16)	0.95
E7311	97	Tayside	1.15	9.546	(289.28)	0.575	(17.41)	7.847	(237.81)	1.80
E7338	97	Grampian	1.17	13.989	(414.96)	0.668	(19.82)	15.92	(472.23)	1.79
E7339	97	Grampian	1.20	7.007	(177.82)	0.349	(8.86)	8.749	(222.05)	1.87
E7340	97	Grampian	-	20.062	(560.74)	0.694	(19.40)	16.621	(464.56)	1.18
SOUTHERN SCOTLAND										
E7345	97	Borders	1.12	3.598	(92.29)	0.427	(10.94)	7.385	(189.41)	1.51
NORTHERN ENGLAND										
E7158	97	North Yorks	1.18	2.98	(50.21)	0.31	(5.18)	17.30	(291.82)	1.27
E7214	97	North Yorks	1.21	3.88	(51.97)	0.75	(10.08)	16.85	(225.62)	0.86
E7313	97	N'humberland	1.49	4.662	(155.46)	0.311	(10.38)	1.892	(63.10)	1.99
E7316	97	N'humberland	1.09	5.911	(203.64)	0.483	(16.64)	8.357	(287.92)	2.75
E7319	97	N'humberland	1.32	7.686	(255.91)	0.317	(10.89)	11.129	(370.52)	1.69
E7320	97	N'humberland	1.15	6.074	(197.27)	0.146	(4.73)	5.519	(179.26)	1.27
NORTHERN ISLES										
E7287	97	Shetland	-	1.20	(21.85)	0.05	(0.87)	3.30	(60.06)	3.71
E7290	97	Shetland	1.19	1.56	(41.39)	0.06	(1.72)	2.57	(68.15)	4.49
E7292	97	Shetland	1.27	1.27	(21.30)	0.27	(4.69)	0.85	(14.52)	2.40

Table 9. Trends in pollutant levels in merlin eggs as revealed by regression analyses of annual means of log residue levels against year, 1967-97. Organochlorine levels expressed as ppm in lipid weight and mercury as ppm in dry weight. N=number of clutches represented at one egg per clutch, b=regression coefficient (slope), *P<0.05, **P<0.01, ***P<0.001.

Region (years)	**DDE**			**HEOD**			**PCB**			**Hg**			**Shell index**		
	N	**b**		**N**	**b**		**N**	**b**		**N**	**b**		**N**	**b**	
Wales (1977-93)	51	-0.029	**	50	-0.024	ns	51	-0.041	**	43	0.023	ns	41	0.00873	*
North-west England (1974-96)	29	-0.033	**	29	-0.007	ns	29	-0.028	*	25	0.022	ns	25	0.0058	ns
North-east England (1970-97)	201	-0.026	***	197	-0.030	***	201	-0.008	ns	159	0.010	ns	175	0.009	***
Southern Scotland (1973-94)	118	-0.038	***	110	-0.020	ns	118	0.004	ns	110	-0.009	ns	100	0.00641	*
Northern Scotland (1971-97)	127	-0.022	ns	122	-0.041	**	127	-0.013	ns	110	0.042	ns	118	0.008	**
Orkney (1974-96)	30	0.006	ns	28	0.019	ns	30	0.010	ns	23	0.002	ns	25	-0.002	ns
Shetland (1967-97)	74	-0.017	***	73	-0.025	**	72	-0.003	ns	76	-0.017	ns	56	0.006	ns
All areas (1967-97)	630	-0.024	***	609	-0.027	***	628	-0.008	ns	535	0.015	ns	565	0.007	***

Footnote: In most of the above analyses a linear model gave the best fit to the data, but for three data sets a curvilinear pattern was apparent, with positive quadratic terms for HEOD, all areas, Hg, northern England, and PCBs, northern Scotland.

Table 10. Geometric mean pollutant levels and arithmetic mean shell indices for merlin eggs from various regions of Britain in two different periods. Organochlorine levels expressed as ppm in lipid weight and mercury levels as ppm in dry weight. N=number of clutches represented at one egg per clutch, *P<0.05, **P<0.01, ***P<0.001.

	Pre 1987			Post 1986				
DDE	**N**	**Geometric mean**	**Range within one geometric SE**	**N**	**Geometric mean**	**Range within one geometric SE**	**% change**	
Wales	22	109.65	98.86 - 121.56	29	64.57	55.98 - 74.47	-41.11	**
North-west England	22	123.03	107.15 - 141.25	7	40.74	37.28 - 44.52	-66.89	***
North-east England	78	117.49	108.64 - 127.06	123	47.86	44.77 - 50.38	-59.26	***
Southern Scotland	17	112.2	93.36 - 135.83	101	58.88	52.97 - 65.40	-47.52	**
Northern Scotland	52	65.92	53.83 - 80.72	75	44.16	40.46 - 48.19	-33.01	ns
Orkney	14	69.18	55.46 - 86.30	16	69.18	61.02 - 78.43	0.00	ns
Shetland	34	104.71	94.49 - 116.01	40	61.66	55.91 - 67.99	-41.11	***
ANOVA	$F_{6,232}=2.97$; P=0.008			$F_{6,384}=2.23$; P=0.040				
HEOD	**N**	**Geometric mean**	**Range within one geometric SE**	**N**	**Geometric mean**	**Range within one geometric SE**	**% change**	
Wales	22	6.92	6.03 - 7.93	28	5.11	4.06 - 6.41	-26.16	ns
North-west England	22	7.41	6.46 - 8.59	7	4.90	3.42 - 7.01	-33.87	ns
North-east England	78	7.76	7.08 - 8.49	119	2.94	2.70 - 3.24	-62.11	***
Southern Scotland	17	5.01	3.77 - 6.67	93	3.89	3.56 - 4.26	-22.36	ns
Northern Scotland	52	5.83	5.15 - 6.61	70	2.82	2.48 - 3.19	-51.63	***
Orkney	14	4.79	3.56 - 6.43	14	4.68	3.03 - 7.23	-2.30	ns
Shetland	33	6.81	5.71 - 8.13	40	3.47	2.99 - 4.03	-49.05	**
ANOVA	$F_{6,231}=1.31$; P=0.253			$F_{6,364}=2.25$; P=0.038				

	Pre 1987			Post 1986				
PCB	**N**	**Geometric mean**	**Range within one geometric SE**	**N**	**Geometric mean**	**Range within one geometric SE**	**% change**	
Wales	22	66.07	54.33 - 80.35	29	43.65	36.06 - 52.89	-33.93	ns
North-west England	22	85.11	71.94 -100.46	7	58.84	50.00 - 69.34	-30.87	ns
North-east England	78	75.86	69.18 - 82.99	123	54.95	50.35 - 59.84	-27.56	*
Southern Scotland	17	57.54	44.98 - 73.62	101	58.88	54.83 - 63.24	2.33	ns
Northern Scotland	52	38.99	32.81 - 46.34	75	48.98	41.98 - 57.15	25.62	ns
Orkney	14	81.28	62.78 -105.24	16	89.13	70.31 - 112.98	9.66	ns
Shetland	32	63.1	56.53 - 70.42	40	60.26	54.82 - 66.24	-4.50	ns
ANOVA	$F_{6,230}$=3.37; P=0.003			$F_{6,384}$=1.33; P=0.243				
Hg	**N**	**Geometric mean**	**Range within one geometric SE**	**N**	**Geometric mean**	**Range within one geometric SE**	**% change**	
Wales	13	1.78	1.52 - 2.08	30	3.47	3.04 - 3.95	94.94	**
North-west England	18	2.69	2.29 - 3.16	7	3.72	2.74 - 5.05	38.29	ns
North-east England	37	1.81	1.65 - 1.98	122	2.45	2.31 - 2.61	35.36	**
Southern Scotland	9	2.69	2.38 - 3.04	101	2.57	2.45 - 2.70	-4.46	ns
Northern Scotland	39	2.19	1.89 - 2.54	71	3.72	3.42 - 4.04	69.86	**
Orkney	7	2.69	2.28 - 3.24	16	2.45	2.13 - 2.83	-8.92	ns
Shetland	25	2.95	2.44 - 3.56	40	2.24	2.05 - 2.44	-24.07	ns
ANOVA	$F_{6,141}$=1.66; P=0.134			$F_{6,380}$=5.19; P<0.001				

	Pre 1987			Post 1986				
Shell Index	**N**	**Arithmetic mean**	**Range within one SE**	**N**	**Arithmetic mean**	**Range within one SE**	**% change**	
Wales	20	1.08	1.06 - 1.10	21	1.13	1.11 - 1.15	4.65	ns
North-west England	19	1.12	1.10 - 1.15	6	1.15	1.10 - 1.19	1.87	ns
North-east England	66	1.03	1.02 - 1.05	109	1.16	1.15 - 1.17	12.68	***
Southern Scotland	11	1.04	1.01 - 1.07	92	1.14	1.13 - 1.15	9.97	**
Northern Scotland	47	1.11	1.09 - 1.12	71	1.18	1.17 - 1.19	6.41	***
Orkney	13	1.12	1.09 - 1.15	12	1.12	1.08 - 1.16	0.09	ns
Shetland	20	1.05	1.02 - 1.07	36	1.13	1.11 - 1.15	7.84	**
ANOVA	$F_{6,189}$=3.80; P=0.001			$F_{6,340}$=1.70; P=0.121				
All Regions	**N**	**Geometric mean**	**Range within one geometric SE**	**N**	**Geometric mean**	**Range within one geometric SE**	**% change**	
DDE	239	95.94	90.36 - 101.86	391	53.83	51.99 - 55.72	-43.89	***
HEOD	238	6.40	6.05 - 6.76	371	3.44	3.26 - 3.62	-46.25	***
PCB	237	60.95	57.41 - 64.71	391	56.10	53.46 - 58.88	-7.96	ns
Hg	148	2.31	1.24 - 4.31	387	2.76	2.67 - 2.85	19.48	*
Shell index[1]	214	1.08	1.07 - 1.08	351	1.16	1.51 - 1.162	7.53	***

[1]Arithmetic mean and standard error

Figure 7. Trends in pollutant residues in UK merlin eggs, 1967-97

Three-year moving geometric means with one standard error on either side

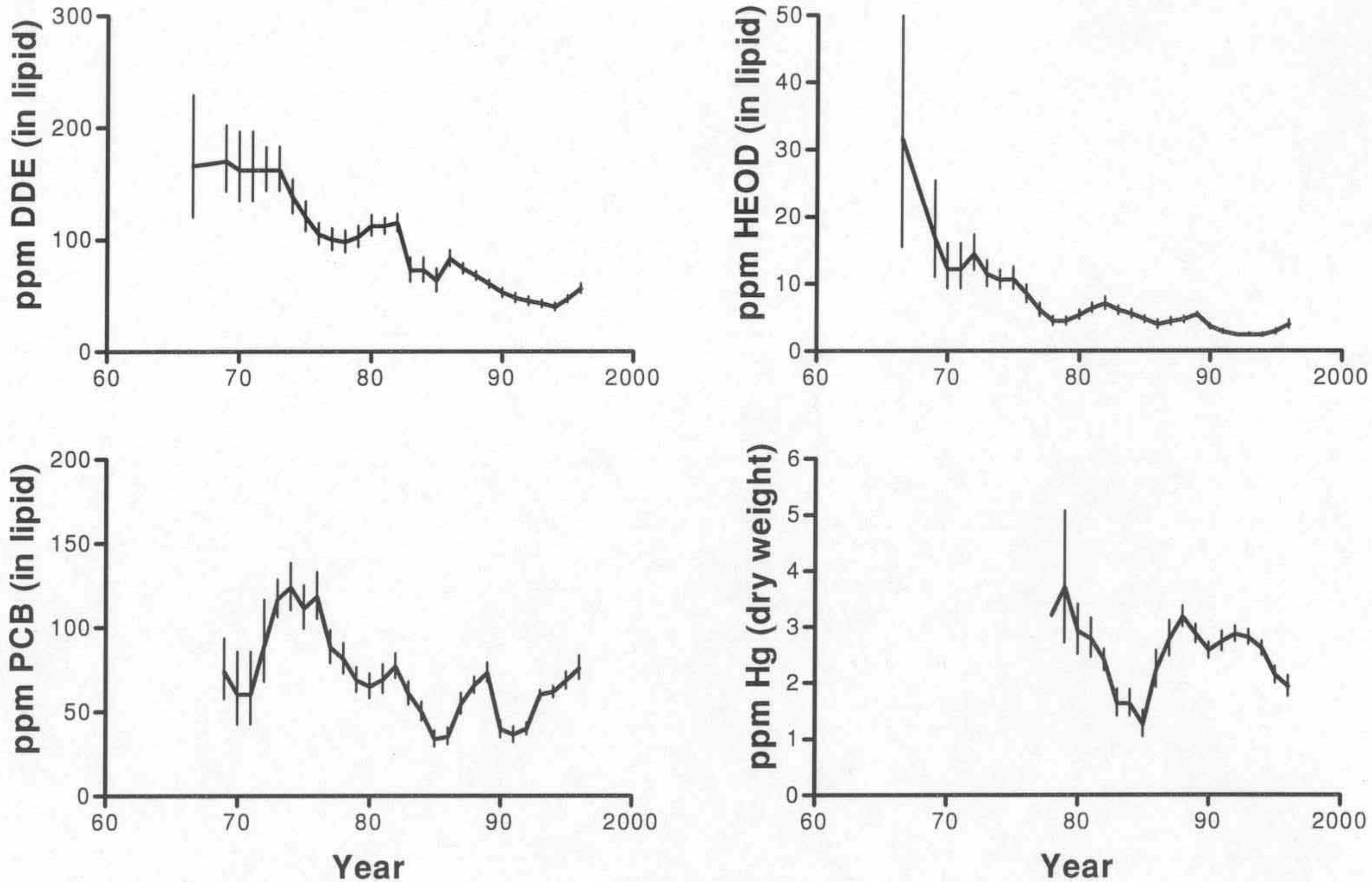


Figure 8. Trends in pollutant residues in merlin eggs from Northumbria, 1970-97
Three-year moving geometric means with one standard error on either side

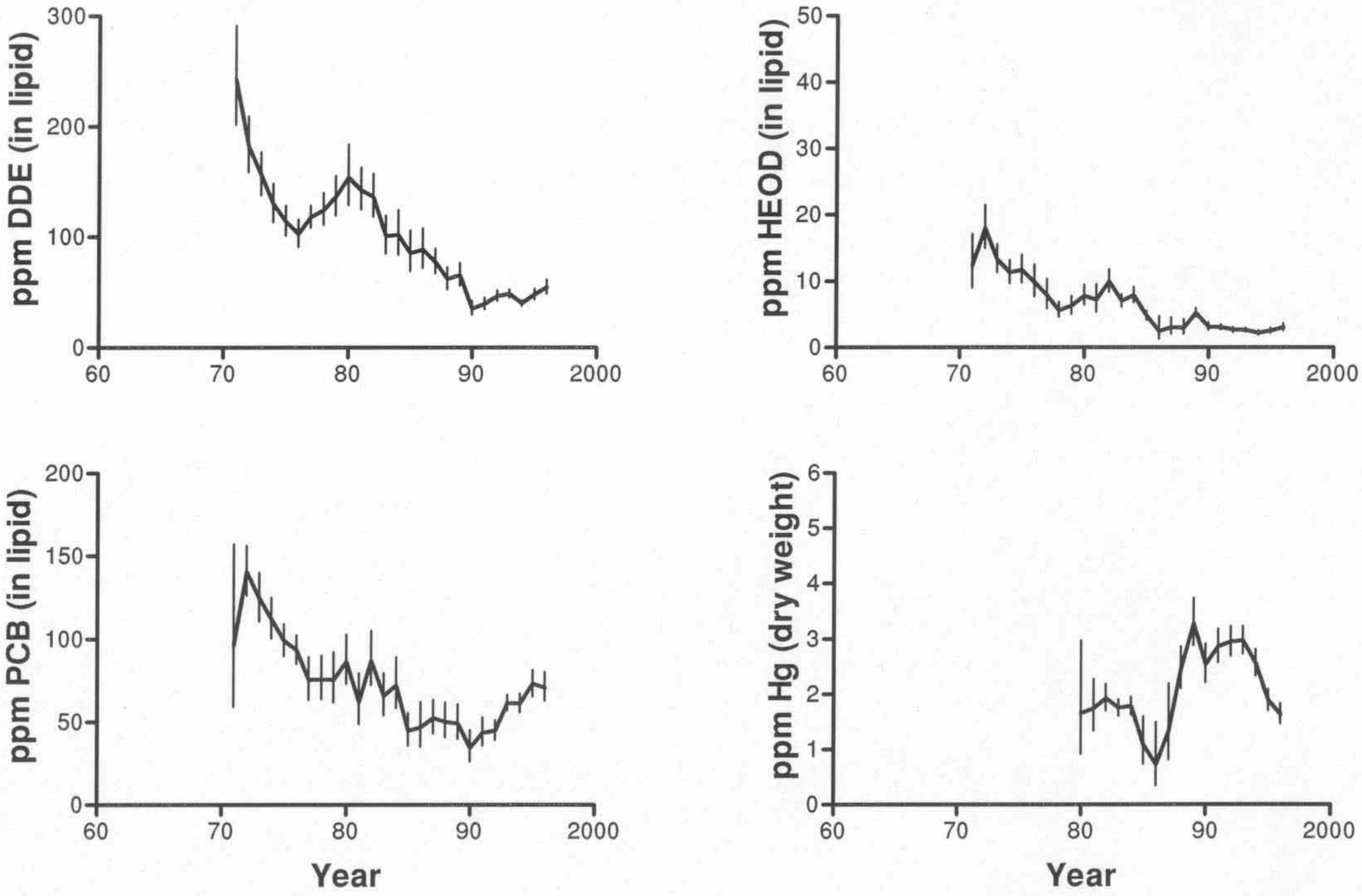
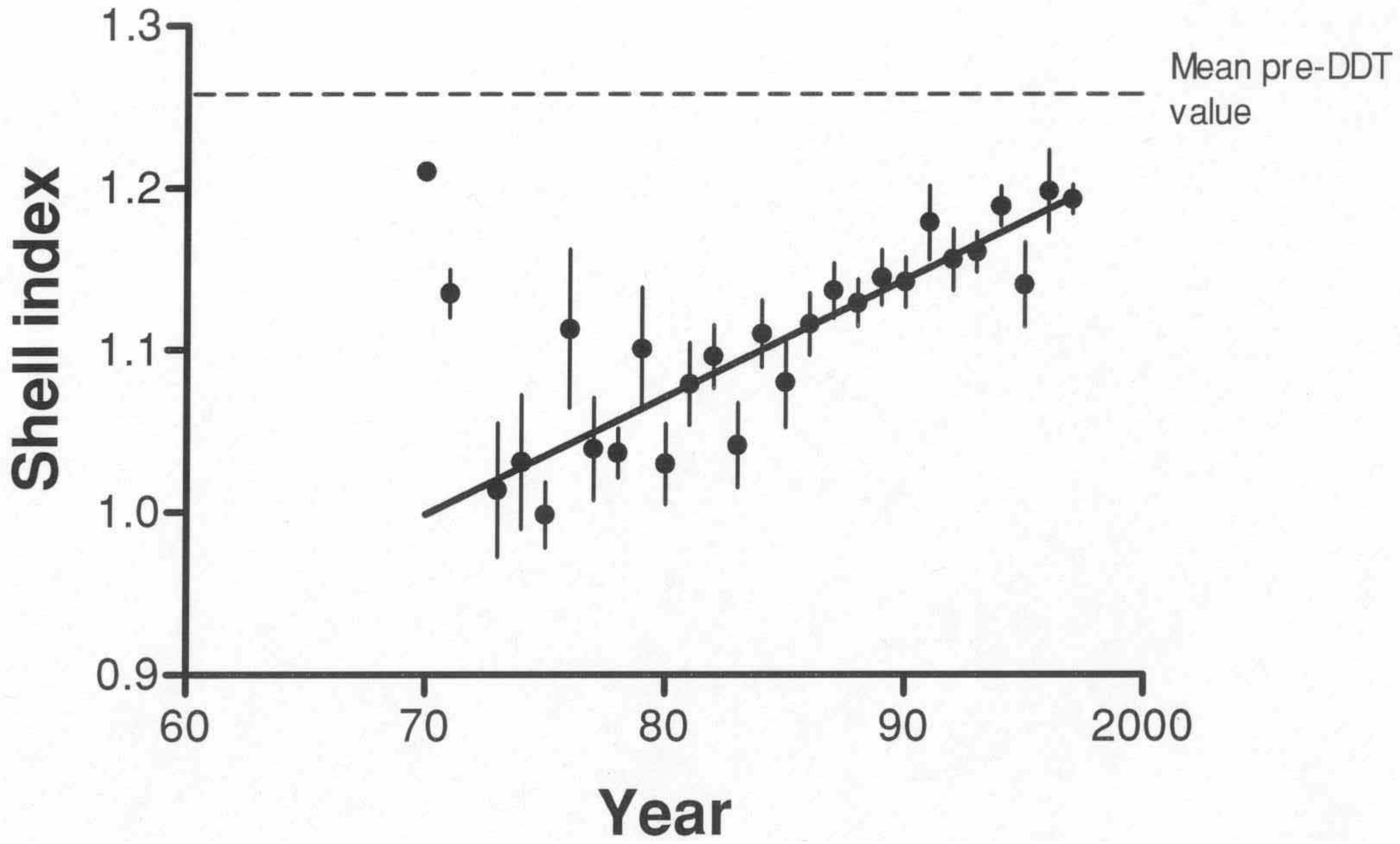


Figure 9. **Annual mean shell index of UK merlin eggs, 1970-97**
Trend is linear regression of individual shell indices against year



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Annual report to the Joint Nature Conservation Committee

Wildlife and pollution

Part 5 Organochlorines and mercury in golden eagle eggs

I Newton, L Dale, JK Finnie, P Freestone,
J Wright, C Wyatt & I Wyllie

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

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5 ORGANOCHLORINES AND MERCURY IN GOLDEN EAGLE EGGS

5.1 Introduction

In this section we report the findings from nine unhatched golden eagle eggs obtained in 1997. We also examine the long-term trends in organochlorine levels from 334 eggs obtained over the period 1963-97. These eggs incorporate earlier samples from 1963 to 1968 examined by Lockie *et al*. (1969), from 1963 to 1974 examined by Cooke *et al.* (1982), and from 1963 to 1986 examined by Newton & Galbraith (1991). Since these earlier studies, 100 additional eggs have been analysed, so we are now able to investigate trends in residues over a longer period, together with differences between coastal and inland areas. For a small proportion of eggs, obtained in the 1980s and 1990s, mercury levels were also determined.

Golden eagles are distributed throughout the mountainous parts of Scotland and around cliffs on the western coasts and islands. They feed mainly on medium-sized birds and mammals, such as grouse and hares, and on the young and dead of larger mammals, such as deer and sheep (Brown & Watson 1964; Watson *et al*. 1987; Watson 1996). Of the chemicals examined, both DDT and dieldrin were used in quantity within the eagles' range. After 1947, DDT came into wide use in sheep dips but sometime after 1956 it was largely replaced by the more effective dieldrin. From 1966, however, because of concern about the amount of dieldrin present in sheep meat intended for human consumption, the use of this chemical in dips was banned voluntarily, its place being taken by less persistent organophosphorus compounds. Smaller quantities of dieldrin may have been used after 1966, until stocks ran out. Nevertheless, following the ban, the mean level of HEOD in samples of sheep fat dropped from about 0.8ppm (maximum 12.4 ppm) in 1964 and 1.1 (maximum 8.2 ppm) in 1965 to 0.4 ppm (maximum 5.3 ppm) in 1966. Sheep are more numerous in the hills of western Scotland, and form a larger part of the diet of golden eagles there, than in eastern Scotland (Brown & Watson 1964; Watson *et al*. 1987; Watson 1996). Not surprisingly, therefore, earlier studies confirmed that DDT and HEOD levels were highest in eagle eggs from the west (Lockie *et al*. 1969; Cooke *et al*. 1982). These and other chemicals probably reached eagles not only from local sheep, but also from various avian prey species which had become contaminated locally or elsewhere.

For purposes of analysis, eastern Scotland was taken as regions A and B in Dennis *et al*. (1984), and western Scotland as regions C-H. (i.e including Galloway and the English Lake District). Coastal territories were defined as those which bordered the sea, but where no such information was available to us, we classed sites within 3km of the sea as coastal.

Results on trends in residues are shown in three ways: (1) as plots of three-year moving geometric mean levels (with geometric standard errors) for eastern inland, western inland and western coastal regions respectively (Figures 10-12); (2) as regression analyses of individual $\log_{10}$ residue levels against year for the same three regions (Table 12); and (3) as geometric mean levels for all three regions in 1963-66, 1967-86 and 1987-97 (Table 13). The data were split at 1967 because this was the first year of the voluntary ban on the use of dieldrin in sheep dips, and at 1987 because this was the first year with a complete ban on the uses of DDT, aldrin and dieldrin in Britain. Although golden eagles normally lay two eggs per clutch, details from no more than one egg per clutch were included in the analyses below.

5.2 Results for 1997

The analyses for the nine 1997 eggs served to confirm the low levels of contamination found in recent years in golden eagle eggs (Table 11). All residue levels were low, and well within the range of previous values. One coastal egg was received from North Uist. Its DDE and HEOD levels were within the range from inland eggs, but the PCB and mercury levels were higher.

5.3 Long-term trends in residue levels

Among the 334 golden eagle eggs examined during 1963-97, HEOD was usually present at less than 0.5 ppm, but occasionally up to 6.0 ppm: DDE was mostly present at less than 1.0 ppm, but occasionally up to 7.8 ppm; while for PCB the equivalent values were less than 1 ppm and 43 ppm. Most of the high PCB levels were from coastal eggs, but one exceptional inland egg from near Aviemore contained 18 ppm PCB.

In general, organochlorines were found at highest levels in eggs from western coastal areas, at somewhat lower levels in eggs from western inalnd areas, and lower levels still in eggs from eastern Scotland (Table 13). This geographical trend held in all three successive periods, 1963-66, 1967-76 and 1987-97. However, no analyses were made of PCB in the first of these periods, and from 1987, HEOD levels were generally very low and the regional differences had disappeared.

Over the whole study period (1963-97), DDE and HEOD levels declined in eggs from all three regions, and only for HEOD in eastern Scotland (where levels were lowest) was the downward trend not statistically significant (Tables 12 & 13). The decline in HEOD residues was especially marked in the late 1960s, following the ban on dieldrin use in sheep dips. PCB levels were analysed only from 1970, after which levels fluctuated over the years, and showed a significant net decline only in inland western Scotland (Table 13). A significant improvement in eggshell index was apparent only in eastern Scotland. Although this coincided with a decline in levels of DDE, the main causative agent of shell thinning, DDE levels were generally too low to have caused marked shell thinning and breakage.

Mercury levels showed the same geographical trends as the organochlorines, with the highest levels in western coastal eggs, lower levels in western inland eggs, and lower levels still in eastern inland eggs. In fact, in many of the eggs, mercury was not detected (limit of detection 0.01 ppm), including 34 out of 68 eggs from western inland areas, and in 23 out of 28 eggs from eastern inland areas. Over time, the only significant trend was for an increase in residues in eggs from western inland areas (Tables 12 & 13).

5.4 Discussion

The declines in HEO and DDE levels over the study period were associated with general reductions in the agricultural use of these chemicals over the years, as well as with the cessation of their use in sheep dips. The lack of a decline in PCB levels in two of the three regions over the study period must presumably reflect the high persistence of PCBs, together with a continuing input to the environment. We cannot explain the increase in mercury in eggs from western inland districts, unless it was due to a switch to the sampling of more seabird-feeding pairs in recent years.

The regional pattern in organochlorine contamination of golden eagle eggs fitted with the regional variations in eagle diet, with more contaminated prey-species being eaten in the west than in the east, and more contaminated prey on the coast than inland. In eastern districts, grouse and hares predominate in the diet (Brown & Watson 1964; Watson 1996), and grouse analysed at Monks Wood Research Station were free of organochlorine residues, apart from low levels of PCBs (Newton *et al.* 1989). Further west, the eagles take a wider range of prey, including a greater proportion of sheep carrion, and on the coast they also eat various seabirds, which are often heavily contaminated with organochlorines and mercury (Bourne 1976; Anon. 1983; Newton *et al*. 1989).

Golden eagle breeding success is also generally poorer in the west than in the east (Dennis *et al*. 1984; Watson 1996), matching the trend in organochlorine contamination. However, it is unlikely that organochlorines are the cause of poor breeding in the west, and more likely that both breeding success and organochlorine levels are dependent on the quality and type of food available. In the west, food suitable for breeding eagles in not only scarcer than in the east (leading to poorer breeding success (Watson *et al*. 1987; Watson & Langslow 1989)), but also different in composition, with more contaminated prey species (leading to more contaminated eagle eggs). This is not to say that golden eggs are immune to the effects of organochlorines, only that levels in Scottish birds were generally too low for such effects to be expected.

The presence of mercury in western coastal eggs probably also resulted from the inclusion of seabirds in the diet, but again all levels recorded here were lower than those found to influence reproduction in other bird species (Borg *et al.* 1969; Newton *et al*. 1989). Possibly, however, a larger sample of coastal eggs might have revealed occasional clutches with mercury at embryotoxic levels.

The declines in HEOD and DDE levels over the study period were associated with general reductions in the agricultural use of these chemicals over the years, as well as with the cessation of their use in sheep dips. The lack of a decline in PCB levels over the study period must presumably reflect the high persistence of PCBs, together with a continuing input to the environment.

5.5 Summary

Over the period 1963-97, single unhatched eggs from 334 golden eagle clutches were analysed. Levels of organochlorines and mercury were highest in eggs from western coastal districts, somewhat lower in eggs from western inland districts, and lower still in eggs from eastern districts. These regional trends were associated with corresponding dietary differences.

Levels of DDE and HEOD declined in eggs from all three regions (but the decline in HEOD in eastern districts, where levels were low throughout, was not statistically significant). PCB levels declined only in eggs from western inland districts (but with large annual fluctuations), mercury levels increased in eggs from western inland districts, while shell indices improved significantly only in eggs from eastern districts.

5.6 References

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Table 11. **Residue levels (organochlorine ppm wet weight (lipid weight); mercury ppm dry weight) and shell indices (SI) for golden eagle eggs received in 1997**
ND=none detected

Number	Year	County	SI	pp'-DDE		HEOD		PCB		Hg
SOUTHERN SCOTLAND										
E7172	97	D&G	3.17	0.78	(2.71)	0.25	(0.85)	2.27	(7.90)	0.14
E7280	97	Borders	3.20	0.07	(1.39)	0.06	(1.20)	0.74	(13.87)	0.12
E7281	97	Borders	3.52	0.06	(1.17)	0.04	(0.68)	0.66	(12.65)	0.10
CENTRAL AND EASTERN HIGHLANDS										
E7156	97	Tayside	2.71	0.08	(1.54)	0.03	(0.61)	0.58	(11.16)	ND
E7222	97	Grampian	2.87	0.004	(0.08)	0.03	(0.64)	0.03	(0.58)	ND
E7224	97	Tayside	-		ND	0.26	(1.01)	0.11	(4.40)	ND
WESTERN ISLES										
E7168	97	North Uist	-	0.30	(13.86)	0.03	(1.30)	2.88	(133.21)	0.55
NORTHERN ENGLAND										
E7189	97	Cumbria	2.88	0.05	(2.82)	0.02	(1.12)	0.22	(12.21)	0.34
E7190	97	Cumbria	3.01	0.04	(2.68)	0.02	(0.01)	0.19	(11.61)	0.25

Table 12. Trends in pollutant levels in golden eagle eggs as revealed by regression analyses of individual residue levels against year. N=number of clutches represented at one egg per clutch, b=regression coefficient (slope), *P<0.05, **P<0.01, ***P<0.001.

	DDE			HEOD			PCB			Hg			Shell index		
	N	**b**		**N**	**b**		**N**	**b**		**N**	**b**		**N**	**b**	
Western Scotland coastal	116	-0.0208	**	116	-0.0413	***	86	0.0055	ns	42	0.0355	ns	60	0.0018	ns
Western Scotland inland	166	-0.0200	***	166	-0.0302	***	117	-0.0128	*	68	0.0810	***	95	0.0030	ns
Eastern Scotland	52	-0.0314	***	52	-0.0003	ns	41	-0.0198	ns	29	0.0202	ns	25	0.0169	**
All areas	334	-0.0247	***	334	-0.0308	***	244	-0.0125	ns	139	-0.0305	*	180	0.0042	ns

Table 13. Geometric mean pollutant levels and arithmetic mean shell indices for golden eagle eggs from various regions of Britain in three different periods. N=number of clutches represented at one egg per clutch, *P<0.05, **P<0.01, ***P<0.001.

	1963-1966				1967-1986				Post 1986		
DDE	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
Western Scotland coast	19	0.793	0.630 - 0.998	**	77	0.301	0.256 - 0.355	*	20	0.109	0.075 - 0.157
Western Scotland inland	32	0.245	0.190 - 0.310	*	89	0.121	0.121 - 0.136	***	45	0.055	0.040 - 0.066
Eastern Scotland	3	0.093	0.043 - 0.199	ns	32	0.054	0.054 - 0.067	***	17	0.012	0.010 - 0.014
ANOVA	$F_{2,51}$=6.15; P<0.004				$F_{2,195}$=23.81; P<0.001				$F_{2,79}$=15.13; P<0.001		
HEOD	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
Western Scotland coast	19	0.695	0.570 - 0.847	***	77	0.081	0.070 - 0.095	***	20	0.036	0.031 - 0.041
Westerm Scotland inland	32	0.416	0.330 - 0.524	***	89	0.059	0.053 - 0.066	**	45	0.033	0.027 - 0.040
Eastern Scotland	3	0.058	0.034 - 0.099	ns	32	0.023	0.020 - 0.026	ns	17	0.036	0.026 - 0.050
ANOVA	$F_{2,51}$=6.14; P<0.004				$F_{2,195}$=13.97; P<0.001				$F_{2,79}$=0.06; P=0.937		
PCB	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
Western Scotland coastal	-	-	-		66	1.365	1.112 - 1.675	ns	20	1.161	0.785 - 1.718
Western Scotland inland	-	-	-		72	1.023	0.908 - 1.153	***	45	0.445	0.367 - 0.538
Eastern Scotland	-	-	-		24	0.257	0.257 - 0.174	ns	17	0.102	0.069 - 0.150
ANOVA					$F_{2,159}$=11.66; P=0.001				$F_{2,79}$=12.59; P<0.001		
Hg	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
Western Scotland coastal	1	0.010	-		21	0.083	0.055 - 0.125	ns	20	0.177	0.111 - 0.280
Western Scotland inland	-	-	-		23	0.014	0.011 - 0.017	***	45	0.099	0.077 - 0.128
Eastern Scotland	1	-	-		11	0.011	0.010 - 0.013	ns	17	0.024	0.017 - 0.033
ANOVA					$F_{2,52}$=12.12; P=<0.001				$F_{2,80}$=6.84; P=0.002		

	1963-1966				1967-1986				Post 1986		
Shell Index	**N**	**Arithmetic mean**	**Range within one arithmetic SE**		**N**	**Arithmetic mean**	**Range within one arithmetic SE**		**N**	**Arithmetic mean**	**Range within one arithmetic SE**
Western Scotland coastal	-	-	-		43	3.052	2.995 - 3.109	ns	17	3.038	2.942 - 3.134
Western Scotland inland	-	-	-		44	3.070	3.034 - 3.106	ns	44	3.129	3.084 - 3.174
Eastern Scotland	-	-	-		16	2.969	2.908 - 3.030	*	9	3.219	3.144 - 3.294
ANOVA					$F_{2,100}$=1.55; P=0.216				$F_{2,67}$=1.03; P=0.364		
All Regions	**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**		**N**	**Geometric mean**	**Range within one geometric SE**
DDE	54	0.351	0.288 - 0.428	**	198	0.151	0.137 - 0.167	***	82	0.048	0.048 - 0.056
HEOD	54	0.447	0.337 - 0.530	***	198	0.057	0.052 - 0.063	***	82	0.034	0.030 - 0.039
PCB	-	-	-		162	0.938	0.830 - 1.059	***	82	0.414	0.344 - 0.498
Hg	1	0.010	-		55	0.026	0.021 - 0.033	***	82	0.084	0.068 - 0.103
Shell index	-	-	-		110	3.049	3.020 - 3.078	ns	70	3.118	3.080 - 3.156

[1] arithmetic mean
[2] arithmetic standard error

Figure 10. Trends in pollutant residues in golden eagle eggs from coastal districts of western Scotland,1963-97.
Three-year moving geometric mean with one geometric standard error on either side

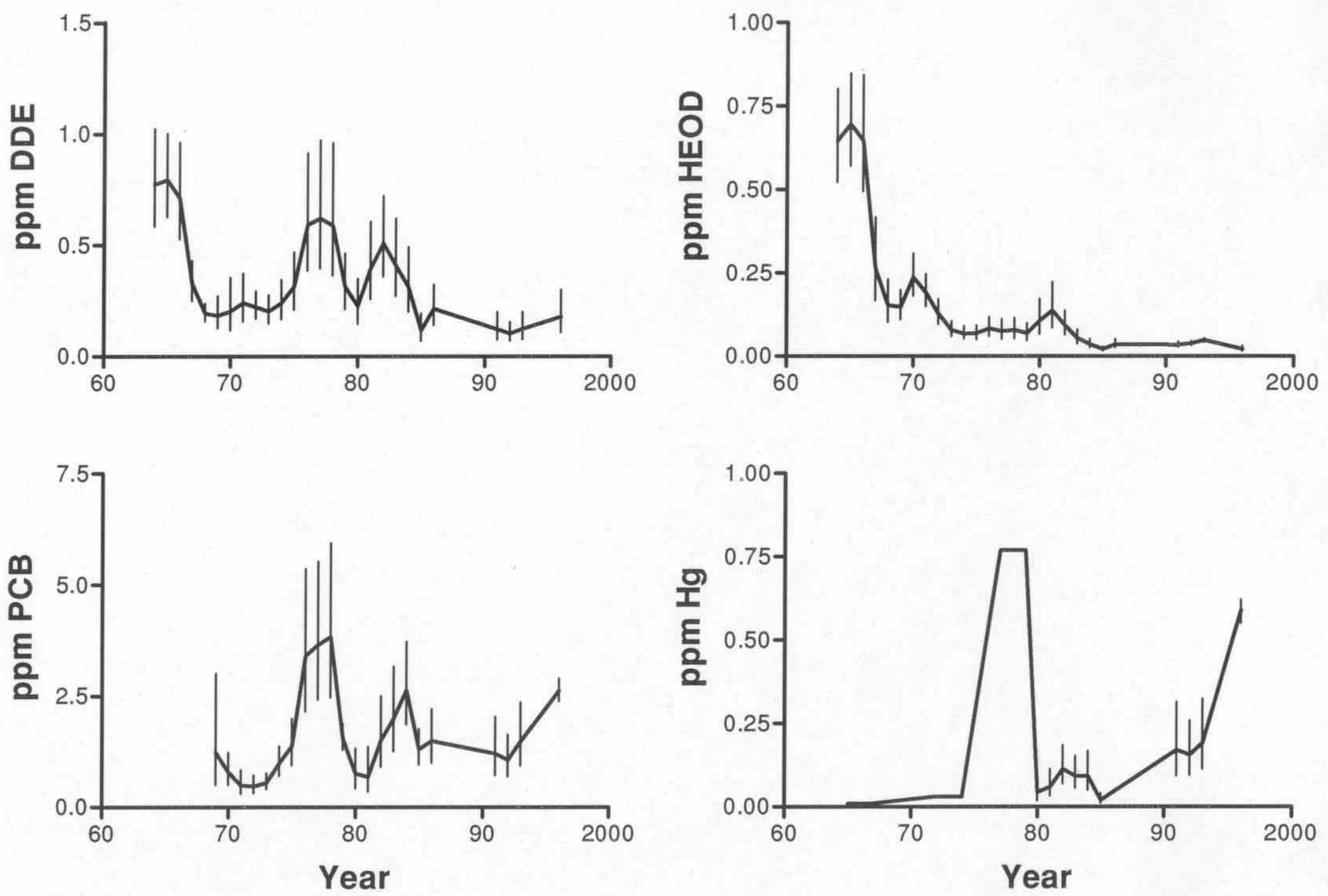


Figure 11. Trends in pollutant residues in golden eagle eggs from inland districts of western Scotland,1963-97.
Three-year moving geometric mean with one geometric standard error on either side

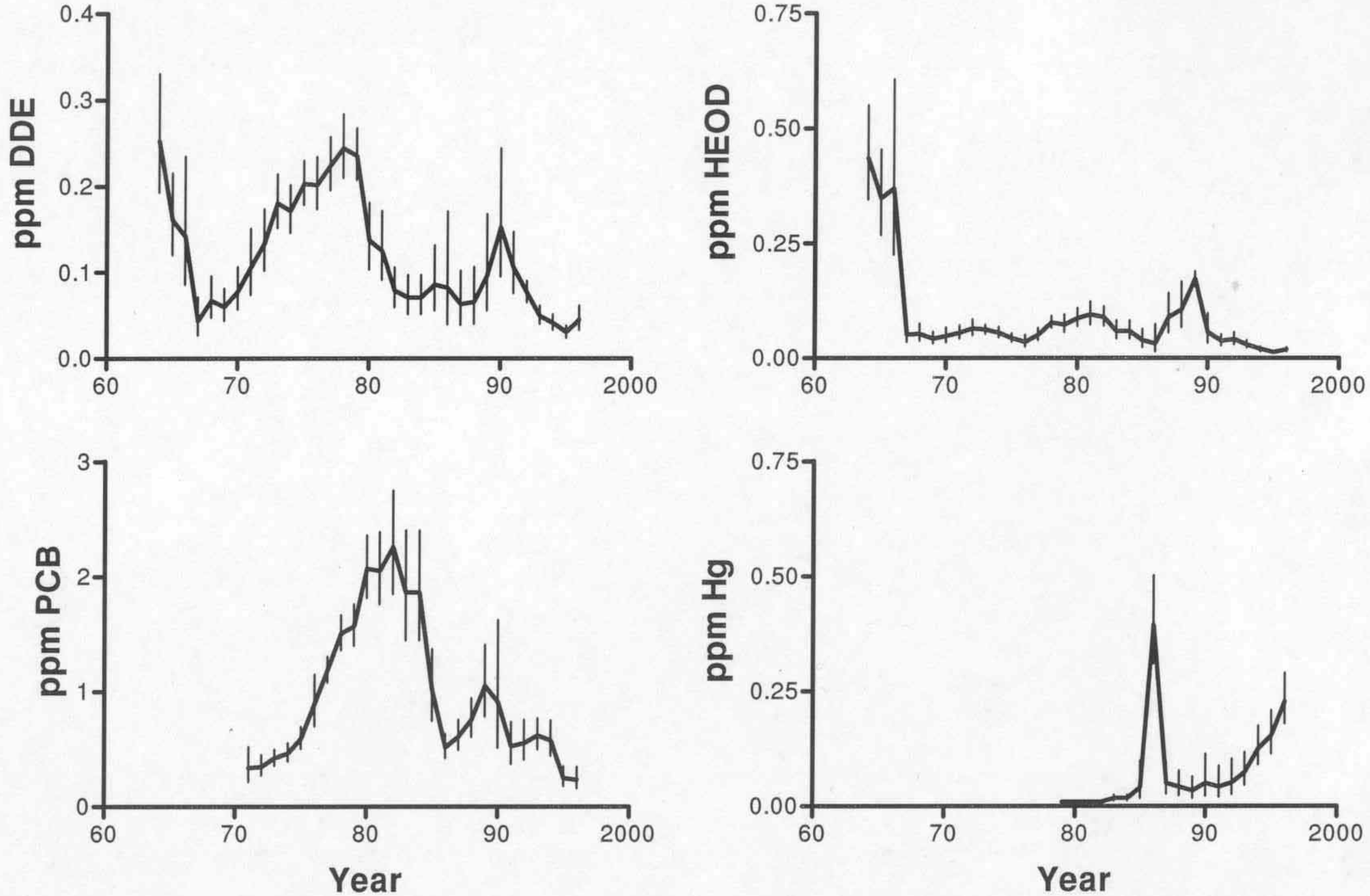
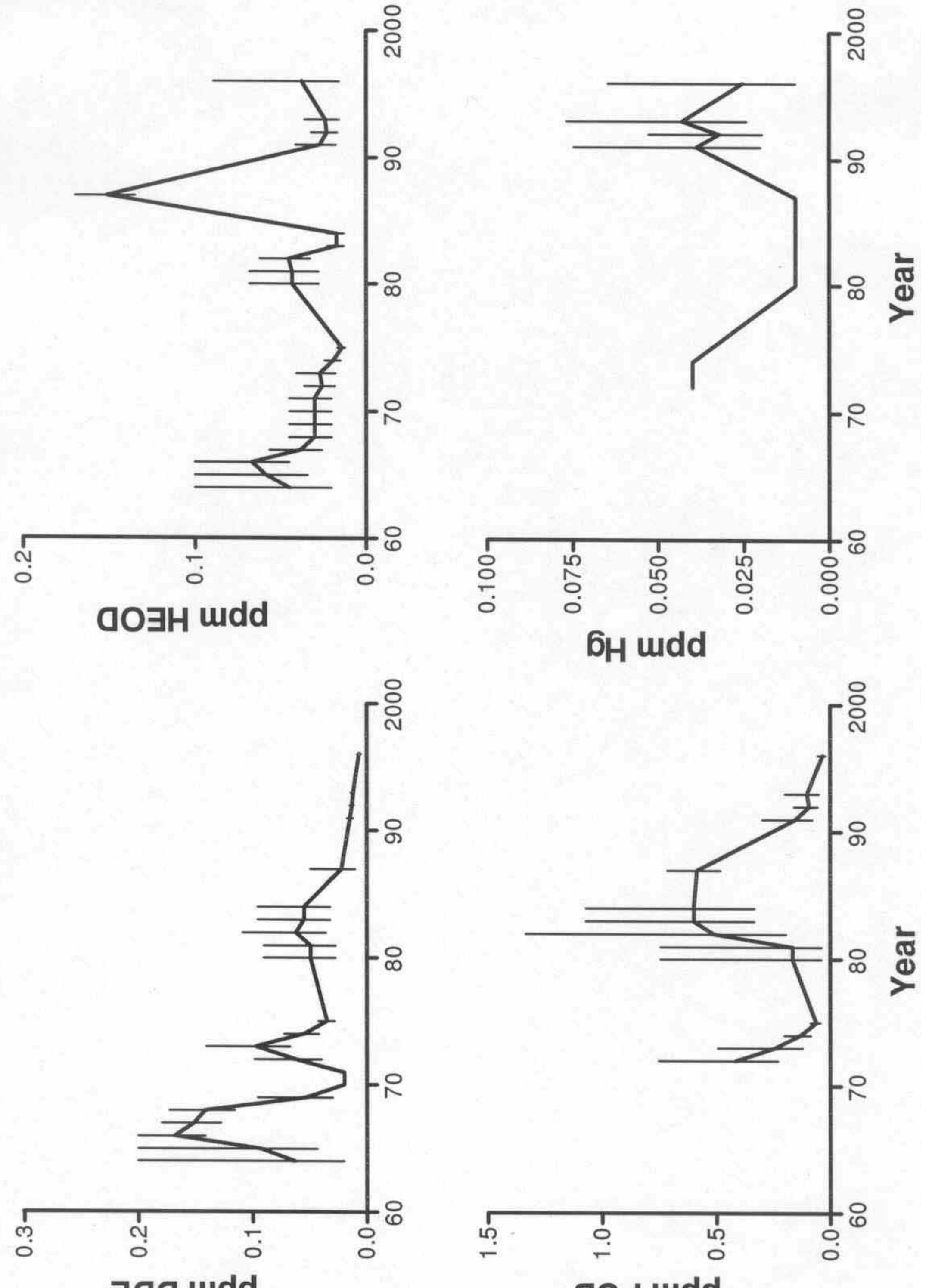


Figure 12. Trends in pollutant residues in golden eagle eggs from eastern Scotland,1963-97.
Three-year moving geometric mean with one geometric standard error on either side



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Annual report to the Joint Nature Conservation Committee

Wildlife and pollution

Part 6 Organochlorines and mercury in gannet eggs

I Newton, L Dale, JK Finnie, P Freestone,
J Wright, C Wyatt & I Wyllie

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

October 1998

6 ORGANOCHLORINES AND MERCURY IN GANNET EGGS

6.1 Introduction

In this section, we give the analytical findings from eggs obtained in 1997, and also assess the long-term trends in residues at several colonies during 1971-97. The analytical findings to 1976 were previously reported by Parslow & Jeffries (1977), to 1987 by Newton *et al*. (1990), and to 1996 in previous reports in this series. All these data are incorporated in this present analysis of long-term trends and colony differences in residues. The relationship between DDE levels and eggshell features were examined by Cooke (1979) and Newton *et al*. (1990), and will not be discussed further here. The conclusion of Newton *et al*. (1990) that organochlorine and mercury levels were too low to cause reductions in the breeding success of British and Irish gannets still holds, and will not be discussed further here. The aim is primarily to report changes in pollutant residues in gannet eggs over the 27 year period as an indication of long-term trends in the levels of these chemicals in gannet food-supplies, and by implication in the wider marine environment.

6.2 Procedure

Eggs were mainly collected from two colonies, at Ailsa Craig (Firth of Clyde) and Bass Rock (Firth of Forth) every 1-2 years, and from six other colonies periodically as opportunity allowed. Overall, eggs were obtained in 16 different years from Ailsa Craig, in 15 years from Bass Rock, in eight years from Hermaness (Shetland), in seven years from St Kilda (north-west Scotland), in five years from Scar Rocks (Solway Firth), in two years from Grassholm (south-west Wales) and Little Skellig (south-west Ireland), and in one year from Great Saltee (south-east Ireland). On each occasion, a colony was visited during the laying or early incubation periods, and usually around ten eggs were taken (gannets lay only one gg per clutch). In all, 598 eggs were analysed, including 141 from Ailsa Craig and 181 from Bass Rock. Long-term trends in residues were examined separately for each colony by regression analyses of individual log-transformed residue levels against year (Table 15).

In the earlier analysis (Newton *et al*. 1990), a one-way ANOVA was used to test for differences between colonies in each of the years 1971-88. The analysis detected differences between colonies in some years but not in others, and the pattern was not consistent between years; no one colony yielded the highest or lowest levels throughout. One problem was that a different subset of colonies was sampled in different years.

A more direct approach is used here, namely to compare colonies pairwise using the years with data for both colonies. Combining data over years, however, raises the question of the most appropriate null hypothesis (H) to test when comparing colonies. The choices are (H_1): equality of colony means over the years in question; and (H_2): a difference between colonies which varies randomly from year to year with zero mean. The second (H_2) seemed most appropriate, so the relevant sample size was the number of years. A test was therefore feasible for the five colonies with five or more years of data. The basis for the analysis was a two-way ANOVA. This could be used to test for a year x colony interaction, i.e. whether differences between colonies varied between years (Table 16).

6.3 Results for 1997 eggs

In 1997, eggs were obtained for only one colony, Ailsa Craig in the Firth of Clyde. The analytical findings are given in Table 14a. All residues were relatively low and within the range of previous values. The geometric mean mercury level was significantly lower than that found in 1994, the last year in which eggs were obtained from this colony (Table 14b).

6.4 Comparison of colonies

Over the whole period 1971-97, the highest concentrations of residues found in gannet eggs were 15.1 Φg g^{-1} in wet weight for PCB and 18.2 Φg g^{-1} in dry weight for mercury.

A summary of the two-way ANOVA tests for the pairwise comparisons of the main colonies examined is given in Table 16. Details are given only for the Scottish colonies because the remaining colonies (Grassholm off Wales, and Great Saltee and Little Skellig off Ireland) were represented in too few years to give meaningful comparisons.

In almost all comparisons, the null hypothesis of equal colony means was rejected by using one of the two tests (Table 16). Also, in many comparison, the interaction effect was statistically significant, confirming that differences between colonies varied between years. In some cases, the test for colony differences was not significant, whereas the interaction effect was highly significant, indicating that the differences between years were not consistent with colony effects, which tended to cancel out.

Differences in organochlorine levels between Ailsa Craig and Bass Rock (the comparison with the longest run of years) showed variation between years, but no overall difference on a paired t-test. In contrast, the average level of mercury was about 1.7 times higher at Ailsa Craig than at Bass Rock.

6.5 Long-term trends in residues

Trends or annual differences could be examined in only seven colonies, because at the eight (Great Saltee) eggs were obtained in only one year (Table 15). Levels of DDE showed significant declines in eggs from five colonies, but one was sampled in only two years. HEOD levels showed significant declines in eggs from two colonies, and an increase in eggs from Grassholm, which was sampled in only two years (1980 and 1984). PCB levels showed highly variable trends, decreasing in eggs from Ailsa Craig (Figure 13) and Scar Rocks, and increasing in eggs from Grassholm and Little Skellig, both of which were sampled in only two years. Mercury levels declined in eggs from Ailsa Craig (Figure 13) and Scar Rocks, and increased in eggs from St Kilda and Grassholm, the latter sampled in only two years. The trends from colonies sampled over the longest periods were probably the most meaningful (Figures 13 and 14). Other colonies were not sampled until organochlorine use had been much reduced, or in a small number of years.

6.6 Discussion

The different colonies (and associated feeding areas) lay at different distances from sources of contamination, and were also sampled over different time periods. Nonetheless, DDE levels showed overall negative trends in eggs from all colonies (significant at five colonies), while HEOD levels showed negative trends at all colonies (significant at two) except Grassholm, where HEOD levels increased significantly between 1980 and 1984. PCB and mercury levels showed more variable trends, decreasing at some colonies (over the sampling period) and increasing at others. One problem in interpreting trends in mercury levels is that, unlike the other contaminants, it is not entirely of human origin, being a natural component of sea water.

Long-term declines in organochlorine pesticide residues in gannet eggs could well reflect reduced inputs to sea-water, as the manufacture and use of these chemicals were reduced. Such declines have become apparent, not only in some British colonies, but also in a Norwegian colony (Fimreite *et al*. 1980), and on Bonaventure Island, off the Gaspϑ Peninsula in eastern Canada (Chapdelaine *et al*. 1987). In this latter colony, the decline in egg residues of DDE was substantial, and associated with known reductions in input to the sea.

6.7 Summary

During the period 1971-97, eggs were obtained in 1-16 different years from eight different gannet colonies around Britain and Ireland. Over the years, DDE residues declined significantly in eggs from five colonies, and HEOD residues declined significantly in two colonies, and increased in eggs from another sampled only twice, in 1980 and 1984. PCB levels declined in eggs from two colonies, increased in eggs from two colonies (both sampled only twice), and showed no significant overall trends in the eggs from the remaining colonies. Mercury levels declined in eggs from two colonies and increased in eggs from two others (one sampled only twice, in 1980 and 1984).

6.8 References

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Table 14a. Residue levels (organochlorine ppm wet weight; mercury ppm dry weight) and shell indices (SI) for gannet eggs *Morus bassanus* received in 1997

Colony	SI	pp'-DDE	HEOD	PCB	Hg
Ailsa Craig	2.19	0.036	0.045	0.714	1.57
	2.92	0.037	0.050	0.957	1.71
	3.08	0.114	0.067	1.683	1.31
	2.56	0.104	0.103	4.499	1.19
	3.14	0.071	0.054	2.703	1.89
	2.88	0.044	0.058	1.167	2.38
	3.14	0.046	0.064	1.062	0.92
	3.03	0.103	0.093	3.496	1.32
	3.20	0.167	0.130	4.415	1.59
	3.19	0.066	0.067	1.776	1.20
Mean	2.93	0.07	0.07	1.85	1.45
SD	0.33	0.23	0.14	0.29	0.12
Range within 1 SE	2.83-3.04	0.06-0.08	0.06-0.08	1.50-2.29	1.33-1.57

NB: Means are arithmetic for shell index; geometric for residues.

Table 14b. Comparison of shell index and geometric mean residue levels from gannet eggs collected from Ailsa Craig in 1994 and 1997.

t values shown. Minus values indicate a decrease and plus values an increase from previous eggs from the same site.

*P<0.05.

Shell index	t_{18}=0.531
pp'-DDE	t_{18}=+0.842
HEOD	t_{18}=+0.229
PCB	t_{18}=1.670
Hg	t_{18}=2.69*

Table 15. Trends or annual differences in residues in eggs from different gannet colonies around Britian and Ireland. Trends examined by regression of individual residue levels against year, or, where only two years of data were available, by a comparison of the geometric mean values for each year, using a t-test. D = decrease, I = increase, NT = no significant trend or difference. *P<0.05, **P<0.01, ***P<0.001.

Colony	Period of study	Number of years in which eggs were obtained	Number of eggs	Trend in residues of			
				DDE	HEOD	PCB	Hg
Ailsa Craig	1971-97	16	141	D***	D***	D***	D***
Bass Rock	1973-96	15	181	D***	D*	NT	NT
St Kilda	1979-96	7	56	NT	NT	NT	I*
Hermaness	1980-96	8	75	D*	NT	NT	NT
Grassholm	1980-84	2	20	D*	I*	I***	I***
Little Skellig	1973-88	2	13	NT	NT	I**	NT
Great Saltee	1988	1	31	-	-	-	-
Scar Rocks	1971-83	5	42	D***	NT	D***	D***

Table 16. Summary of two-way ANOVAs for pairwise comparison of pollutant residues in eggs from different gannet colonies 1971-97. The 'colony' p-value corresponds to a test of the null hypothesis of equality of colony means. The 'interaction' p-value tests for an interaction effect. This also provides a test of equality of means, because a non-zero interaction implies that the means are not equal. The fourth column gives an estimate of the mean difference between colonies, together with the significance level for a paired t-test. This provides a simple test of the null hypothesis that the observed differences are realisations of a random series with mean zero. †P<0.10, *P<0.05, **P<0.01, ***P<0.001.

Comparison	Colony p-value	Interaction p-value	Mean difference (s.e.)
DDE			
Ailsa Craig - Bass Rock	0.001	0.001	0.078 (0.078)^{ns}
Ailsa Craig - Scar Rocks	0.053	0.028	-0.107 (0.137)^{ns}
Ailsa Craig - Hermaness	0.23	0.90	0.089 (0.032)†
Ailsa Craig - St Kilda	0.003	0.001	0.206 (0.156)^{ns}
Bass Rock - Hermaness	0.84	0.18	-0.000 (0.062)^{ns}
Bass Rock - St Kilda	0.001	0.12	0.221 (0.080)*
HEOD			
Ailsa Craig - Bass Rock	0.002	0.002	0.082 (0.057)^{ns}
Ailsa Craig - Scar Rocks	0.29	0.000	0.209 (0.391)^{ns}
Ailsa Craig - Hermaness	0.19	0.023	-0.016 (0.139)^{ns}
Ailsa Craig - St Kilda	0.66	0.000	0.065 (0.205)^{ns}
Bass Rock - Hermaness	0.006	0.000	-0.033 (0.141)^{ns}
Bass Rock - St Kilda	0.15	0.000	0.065 (0.216)^{ns}
PCB			
Ailsa Craig - Bass Rock	0.52	0.001	0.078 (0.119)^{ns}
Ailsa Craig - Scar Rocks	0.001	0.28	-0.285 (0.113)†
Ailsa Craig - Hermaness	0.001	0.88	0.352 (0.037)**
Ailsa Craig - St Kilda	0.001	0.001	0.187 (0.224)^{ns}
Bass Rock - Hermaness	0.001	0.87	0.215 (0.037)**
Bass Rock - St Kilda	0.23	0.001	0.260 (0.141)^{ns}
Mercury			
Ailsa Craig - Bass Rock	0.001	0.001	0.228 (0.052)***
Ailsa Craig - Scar Rocks	0.000	0.14	-0.425 (0.055)*
Ailsa Craig - Hermaness	0.88	0.009	0.005 (0.072)^{ns}
Ailsa Craig - St Kilda	0.001	0.001	0.154 (0.186)^{ns}
Bass Rock - Hermaness	0.001	0.003	-0.087 (0.049)^{ns}
Bass Rock - St Kilda	0.23	0.001	0.003 (0.140)^{ns}

Based on data for 12 years for Ailsa Craig - Bass Rock, 2 years for Ailsa Craig - Scar Rocks, 4 years for Ailsa Craig - Hermaness, 5 years for Ailsa Craig - St Kilda, 5 years for Bass Rock - Hermaness, 6 years for Bass Rock - St Kilda.

Figure 13. Trends in pollutant residues in gannet eggs from Ailsa Craig, 1971-97
Geometric means with one geometric standard error either side

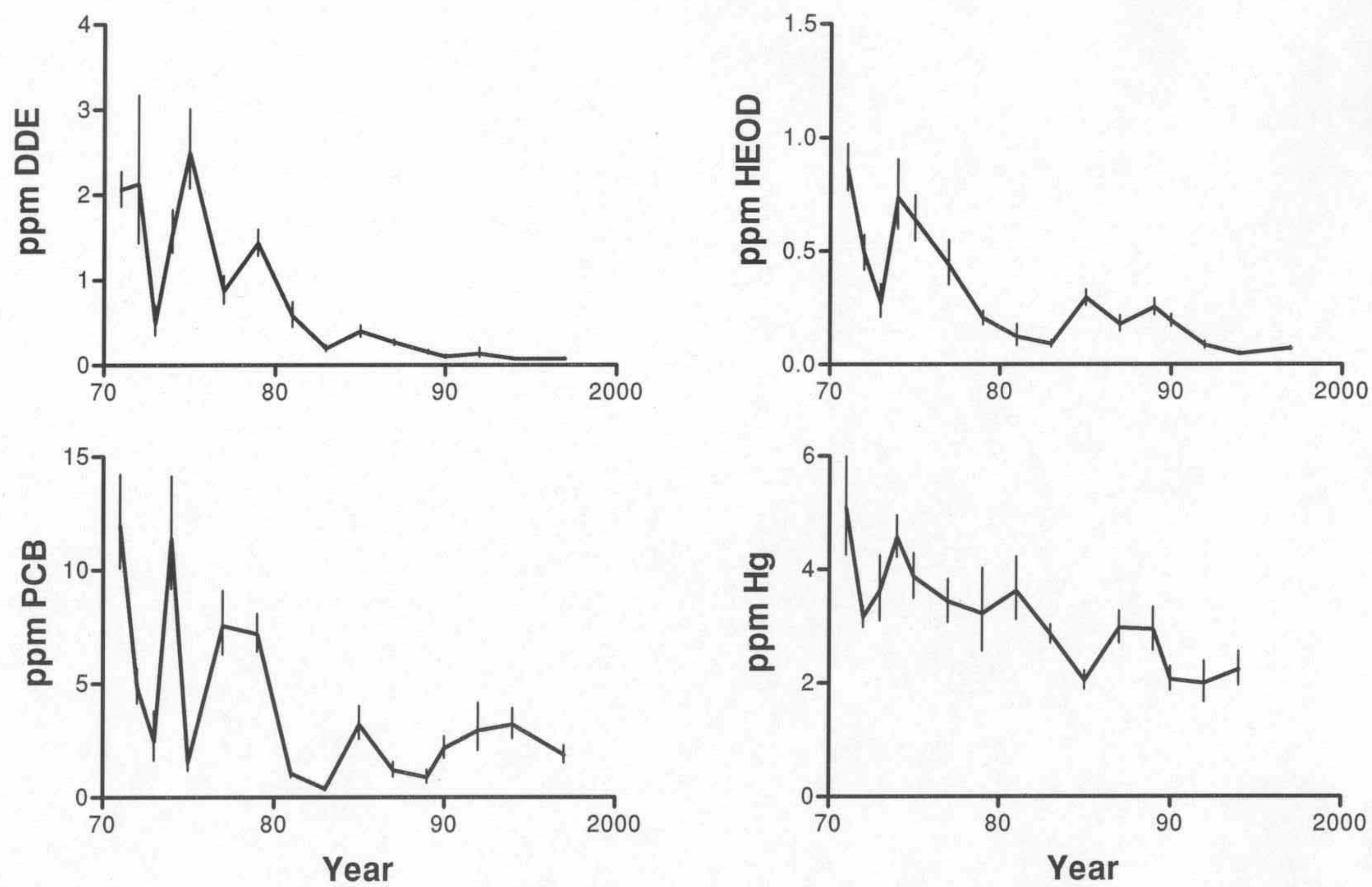
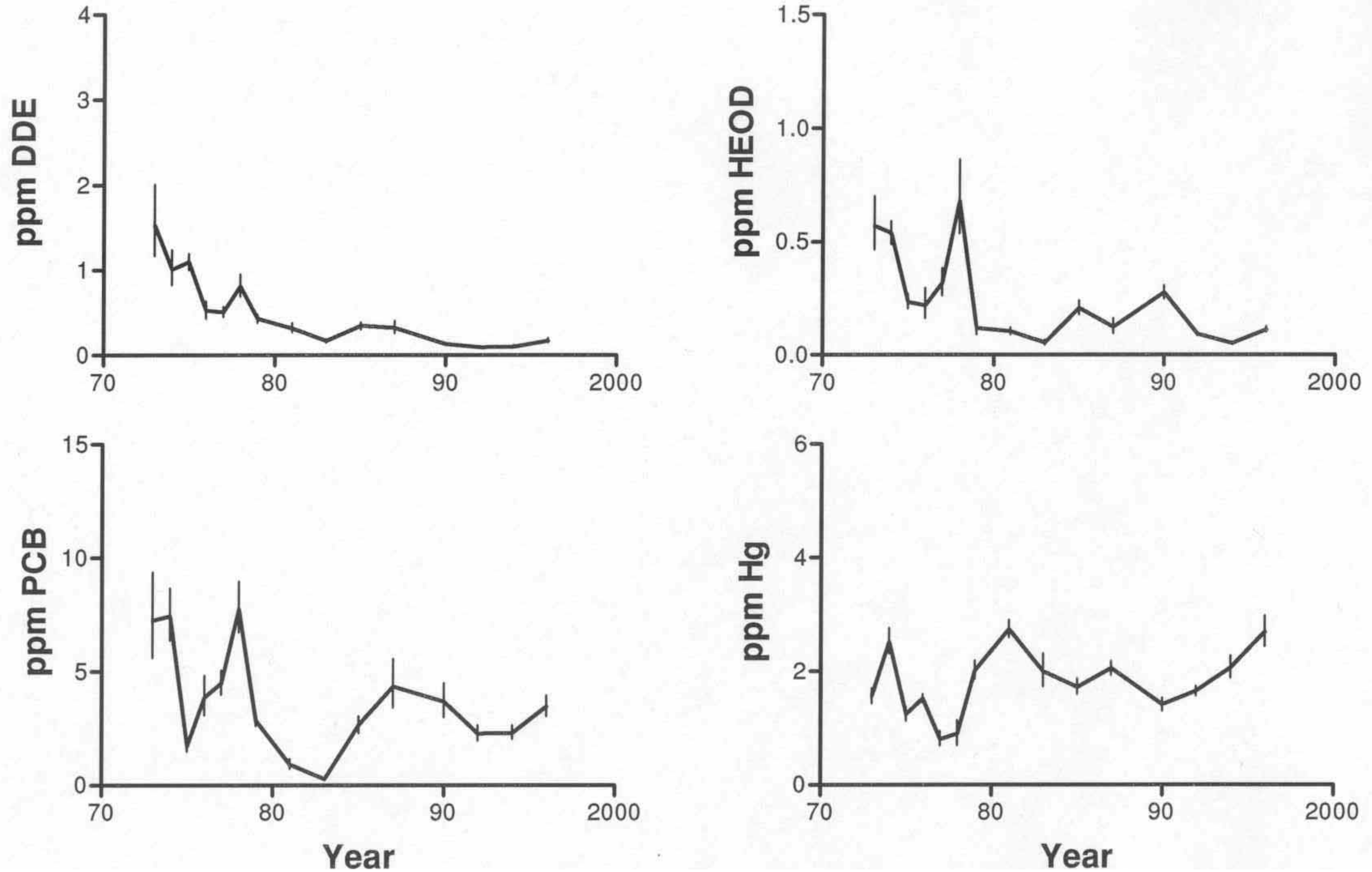


Figure 14. Trends in pollutant residues in gannet eggs from Bass Rock, 1973-97
Geometric means with one geometric standard error either side



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Annual report to the Joint Nature Conservation Committee

Wildlife and pollution

Part 7 Organochlorines and mercury in sea eagle eggs

I Newton, L Dale, JK Finnie, P Freestone,
J Wright, C Wyatt & I Wyllie

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

October 1998

7 ORGANOCHLORINES AND MERCURY IN SEA EAGLE EGGS

7.1 Introduction

So far, the sea eagles *Haliaeetus 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 in 1997 only one unhatched egg was obtained for analysis, from a nest abandoned in the Western Isles. This made a total of five eggs obtained so far, with no more than one per year.

7.2 Results and discussion

In general, residues in sea eagle eggs are much higher than those in golden eagles, reflecting the more contaminated prey-base of sea eagles (Table 17). DDE levels were high in two of the five eggs, and are likely to have caused substantial shell thinning (no measurements were obtained because the eggs were broken). The 1997 egg from the Western Isles contained very high levels of PCBs, around four times higher than the next highest. It is clearly important to analyse any further eggs that become available.

Table 17. Residue levels (organochlorine ppm wet weight (lipid weight); mercury ppm dry weight) and shell indices (SI) for sea eagle *Haliaeetus albicilla* eggs, 1986-97.

Year	Location	SI	pp'-DDE		HEOD		PCB		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
1994	-	3.50	0.79	(25.47)	0.02	(0.73)	10.90	(349.69)	0.34
1997	Western Isles	-	20.61	(204.99)	0.70	(6.85)	132.96	(1302.94)	0.36

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Wildlife and pollution

Part 8 Rodenticide residues in barn owls

I Newton, L Dale, JK Finnie, P Freestone,
J Wright, C Wyatt & I Wyllie

Monks Wood
Abbots Ripton
Huntingdon
Cambs PE17 2LS

October 1998

8 RODENTICIDE RESIDUES IN BARN OWLS

8.1 Introduction

The aim of this work was to screen barn owl *Tyto alba* carcasses for residues of 'second-generation' rodenticides. The carcasses were supplied by members of the public, and included birds which had died from various causes, mainly accidents. The chemicals of interest included difenacoum, bromadiolone, brodifacoum and flocoumafen. The findings from all barn owls analysed in previous years were given in Newton *et al.* (1997), and in previous reports in this series, while those from 65 birds examined in 1997 are given in Table 18.

8.2 Results

Residues were detected in 19 (29%) of the 65 birds examined in 1997, a slightly lower percentage than in the last four years. Brodifacoum was detected in 11 birds, difenacoum in nine, bromadiolone in one and flocoumafen in one. In three birds more than one residue was detected. Two birds with brodifacoum contained levels (0.122 and 0.195 ppm) that could have been lethal, as did one with difenacoum (0.158 ppm) and one with flocoumafen (0.124 ppm) (Newton *et al.* 1990; Newton *et al.* 1994). However, physical symptoms of rodenticide poisoning (haemorrhages) were seen in only one of these birds (with 0.158 ppm difenacoum). The remaining three high-residue birds were classed on post-mortem as collision or starvation victims. The appearance of flocoumafen in only one bird is in keeping with the more recent introduction and lesser usage of this chemical.

8.3 References

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Table 18. Levels of rodenticides (ppm in net weight) in the livers of barn owls *Tyto alba* received in 1997.

ND=none detected; J=juvenile in first year; A=adult other than first year; M=male; F=female; brod=brodifacoum; difen=difenacoum; brom=bromadiolone; floc=flocoumafen; D&G=Dumfries & Galloway; H&W=Hereford & Worcester.

Specimen no.	Date	County	Age	Sex	brod	difen	brom	floc
12339	Nov-96	East Sussex	J	F	ND	ND	ND	ND
12377	Jan-97	Lincolnshire	J	M	0.079	0.024	ND	ND
12391	Jan-97	Gloucestershire	J	F	ND	ND	ND	ND
12396	Feb-97	Humberside	J	M	ND	ND	ND	ND
12397	Feb-97	Cumbria	J	M	ND	ND	ND	ND
12398	Feb-97	Cumbria	A	F	ND	ND	0.035	ND
12400	Feb-97	Oxfordshire	A	F	ND	ND	ND	ND
12401	Feb-97	Oxfordshire	J	F	0.086	ND	ND	ND
12402	Feb-97	Bedfordshire	A	F	ND	0.158	ND	ND
12408	Feb-97	Norfolk	J	F	ND	ND	ND	ND
12410	Feb-97	Grampian	J	M	0.051	ND	ND	ND
12411	Feb-97	Norfolk	J	M	ND	ND	ND	ND
12415	Feb-97	Hertfordshire	J	F	ND	ND	ND	ND
12419	Jan-97	Essex	J	M	ND	ND	ND	ND
12420	Jan-97	Essex	J	M	ND	ND	ND	ND
12426	Mar-97	Gwynedd	J	F	ND	ND	ND	ND
12427	Feb-97	Cumbria	J	F	ND	ND	ND	ND
12428	Mar-97	Grampian	J	M	ND	ND	ND	ND
12440	Nov-96	Highland	J	F	ND	ND	ND	ND
12441	Jun-96	Highland	J	F	ND	ND	ND	ND
12444	Mar-97	Grampian	J	M	ND	ND	ND	ND
12449	Jan-97	Lincolnshire	J	M	0.195	ND	ND	ND
12450	Mar-97	Cambridgeshire	A	M	ND	ND	ND	ND
12469	Apr-97	Leicestershire	J	F	ND	ND	ND	ND
12473	Apr-97	Lincolnshire	A	F	ND	ND	ND	ND
12475	Mar-97	Cumbria	J	F	ND	ND	ND	ND
12476	Mar-97	Cumbria	A	M	0.027	ND	ND	ND
12477	Mar-97	Cumbria	J	M	ND	0.027	ND	ND
12478	Mar-97	Cumbria	J	M	ND	ND	ND	ND
12480	Apr-97	Salop	A	M	ND	ND	ND	ND
12485	Apr-97	Cumbria	J	M	0.122	ND	ND	ND
12497	Apr-97	Dyfed	J	M	ND	ND	ND	ND
12522	Jul-97	Derbyshire	J	M	ND	ND	ND	ND
12533	Dec-96	Lincolnshire	-	-	ND	ND	ND	ND
12535	Jan-97	Lincolnshire	-	-	ND	ND	ND	ND
12542	Sep-97	Norfolk	A	F	0.058	0.070	ND	ND
12554	Sep-97	Oxfordshire	J	F	0.033	ND	ND	ND
12567	Sep-97	Derbyshire	-	-	ND	ND	ND	ND
12571	Oct-97	East Sussex	J	F	ND	ND	ND	ND
12575	Oct-97	Tayside	A	M	ND	ND	ND	ND
12577	Oct-97	Norfolk	A	M	ND	0.015	ND	ND
12578	Oct-97	Berkshire	J	F	0.068	0.014	ND	ND
12582	Oct-97	Norfolk	J	M	ND	0.092	ND	ND
12587	Oct-97	Strathclyde	J	M	ND	ND	ND	ND
12590	Oct-97	Warwickshire	J	F	ND	ND	ND	ND
12591	Nov-97	Cambridgeshire	J	F	ND	ND	ND	ND
12594	Oct-97	Warwickshire	J	M	ND	ND	ND	ND

Specimen no.	Date	County	Age	Sex	brod	difen	brom	floc
12597	Nov-96	Cambridgeshire	J	F	ND	ND	ND	ND
12598	Nov-96	Suffolk	A	F	ND	ND	ND	ND
12599	Jan-97	Suffolk	J	F	0.056	ND	ND	ND
12600	Jan-97	Suffolk	J	M	ND	ND	ND	ND
12601	Jan-97	Cambridgeshire	J	F	ND	ND	ND	ND
12603	Feb-97	Suffolk	-	F	ND	ND	ND	ND
12604	Mar-97	Cambridgeshire	-	M	ND	ND	ND	ND
12605	Apr-97	Lincolnshire	-	M	ND	ND	ND	ND
12606	Apr-97	Lincolnshire	A	F	ND	ND	ND	ND
12607	Apr-97	Cambridgeshire	A	F	ND	ND	ND	ND
12608	Jul-97	Cambridgeshire	-	M	ND	0.015	ND	ND
12617	Nov-97	West Sussex	J	M	ND	ND	ND	ND
12619	Nov-97	Oxfordshire	J	F	ND	ND	ND	ND
12627	Dec-97	Warwickshire	J	M	ND	0.017	ND	ND
12629	Dec-97	H&W	J	F	ND	ND	ND	ND
12633	Dec-97	Norfolk	A	M	0.067	ND	ND	ND
12634	Dec-97	Lincolnshire	J	M	ND	ND	ND	ND
12635	Dec-97	South Yorkshire	J	M	ND	ND	ND	0.124