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PCBs and organochlorine pesticide residues in otters (*Lutra lutra*) and in otter spraints from SW England and their likely impact on populations

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Abstract

PCB and organochlorine pesticide residues were determined in otter (*Lutra lutra*) spraints (faeces) from nine catchment regions in SW England over the period 1989–1991. Results of analyses of tissues from 22 otters are also presented. Dieldrin occurred in the majority of spraint samples and *p,p*-DDE and total PCBs in all. Lindane occurred mainly in samples collected in spring. Lindane was not found in otter tissues collected after 1991, but dieldrin, *p,p*-DDE and PCBs were found in all tissues. Dieldrin and *p,p*-DDE concentrations were strongly correlated in otter tissues, but there were no correlations with lindane or PCBs. Mean concentrations of contaminants varied widely between catchments. It was considered that PCBs were the compounds of most concern in influencing otter populations and that levels in spraints from one catchment were likely to be sufficiently high to exert a negative effect on populations. While levels of PCBs were elevated above background level in several other catchments and some individual otters had high levels of PCBs, it was considered that they were not sufficient to significantly hinder further population consolidation of otters in SW England.

Key words: Otter; *Lutra lutra*; Pesticides; PCBs

1. Introduction

In the late 1950s and 1960s, a steep decline in otter (*Lutra lutra*) populations took place over much of Britain and western Europe (Mason and Macdonald, 1986). Although a number of factors have adversely affected otters, the widespread and sudden decline is likely to have been caused by the introduction of a bioaccumulating contaminant which reached critical levels at that time, PCBs and dieldrin having been particularly implicated (Mason, 1989).

Before the 1950s, the otter was generally distributed through SW England. However, in the first comprehensive survey of the region in 1977–1979, only 17.2% of 540 sites proved positive for otters (Lenton et al., 1980), the most extensive populations being on the rivers Taw, Torridge and Tamar

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in north and west Devon. The species was absent from the far west of the region and almost so in the east. A repeat survey of the same sites in 1984–1986 (Strachan et al., 1990) recorded 31% of sites positive, with consolidation and expansion to the immediate east and west of the main population centre, but with no improvement in the extreme east and west. A further survey in 1991 (R. Strachan, pers. commun.) has revealed further expansion.

The present study examines the possible role of contamination by organochlorines in influencing otter distribution. As few tissues become available for analysis, this study additionally reports measures of contaminants in otter spraints (faeces) which can be collected easily over large areas. Mason and Macdonald (1993a) described an intensive study of contaminant levels in spraints from three catchments in Wales and the Border Counties, while Mason et al. (1992) presented an extensive survey from western Scotland. The aim of the present study is to identify regions or parts of catchments in SW England where organochlorines may still be posing a threat to otters and where further investigations might be advisable.

2. Materials and methods

Twenty rivers or subcatchments in SW England (Fig. 1) were surveyed for otters between April 1989 and December 1991. Sampling stations were visited throughout each catchment and, at each station, starting at a bridge, a maximum of 600 m of river bank was searched for otter spraints, following the standard survey method (Macdonald,

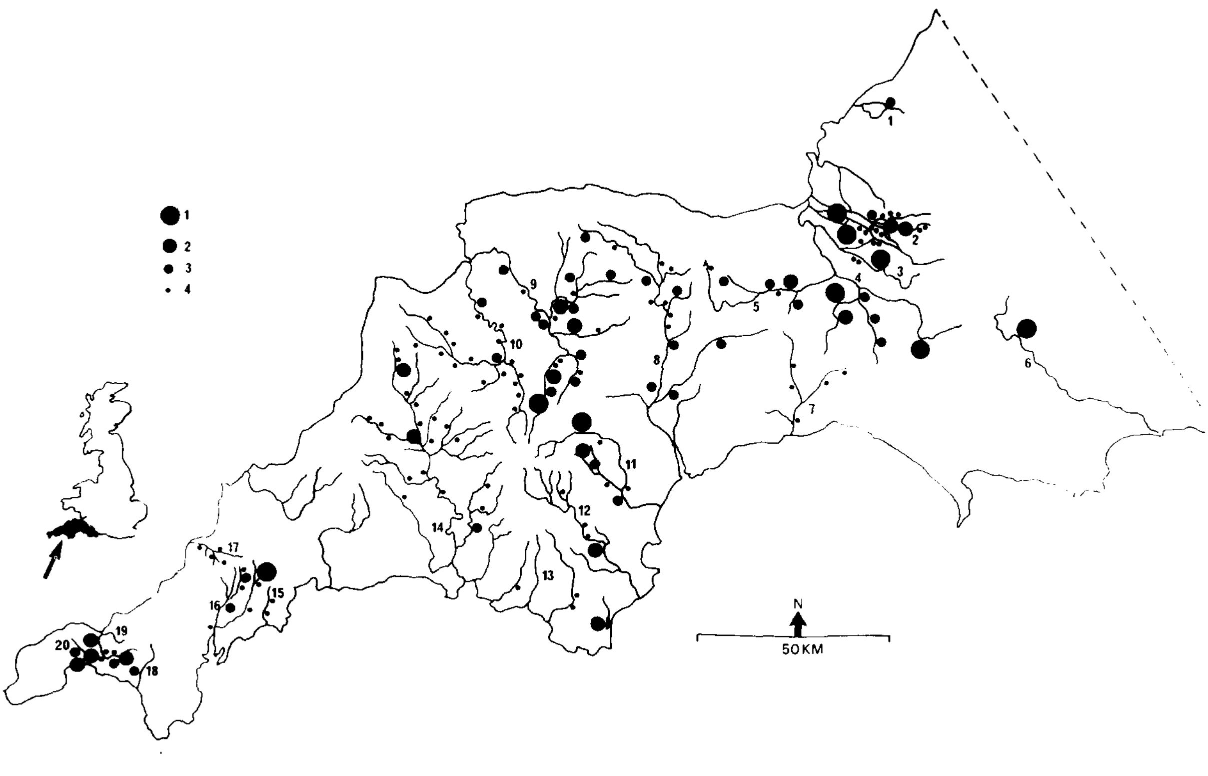

Fig. 1. The study area in SW England showing the catchments studied and organochlorine contaminants at four levels of concern (see text for details). Where more than one sample was collected from a station the mean level is illustrated. Catchments are: 1, Land Yeo; 2, North Somerset Levels; 3, South Somerset Levels; 4, Parrett; 5, Tone; 6, Stour; 7, Axe; 8, Exe; 9, Taw; 10, Torridge; 11, Teign; 12, Dart; 13, South Hams rivers; 14, Tamar; 15, Polmassick; 16, Tresillian; 17, Gannel; 18, Cober; 19, Hayle; 20, Marazion.

1983). However, individual searches were continued after first finding positive evidence of otters until a sample sufficient for analysis had been collected. Spraint samples (all spraints from a station combined) were wrapped in aluminium foil, placed in labelled polythene bags and deep frozen prior to analysis.

Concentrations of organochlorines in spraints were determined with a Varian 3300 gas chromatograph using a 25-m column. PCBs were determined against an Aroclor 1260 standard. Details of the extraction technique and analysis are given in Mason and Macdonald (1993a). The detection level was 0.01 mg$\cdot$ kg^{-1}.

Otters from the region were obtained between November 1983 and May 1992. Samples of liver, or muscle, were thinly sliced, weighed and prepared and analysed as for the spraint samples.

To assess the significance of contaminant levels in spraints, a hierarchy of concentrations is used:

(i) *critical levels*
concentrations in spraints >16 mg$\cdot$kg^{-1} of PCB and dieldrin, singly or combined, or concentrations in spraints of total OCs >20 mg$\cdot$kg^{-1};
(ii) *levels of concern*
concentrations in spraints > 9–16 mg$\cdot$kg^{-1} of PCB and dieldrin singly or combined, or concentrations in spraints of total OC > 16–20 mg$\cdot$kg^{-1};
(iii) *maximum allowable concentration*
concentrations less than the level of concern but greater than the no effects level; and
(iv) *no effects level*
less than 4 mg$\cdot$kg^{-1} for all individual contaminants, as described above.

This approach is based on a single compartment model relating PCB concentrations in spraints to tissue concentrations (Mason et al., 1992; Mason and Macdonald, 1993a). Because of concern regarding the possible role of dieldrin in the decline of otters (Chanin and Jefferies, 1978), we have used identical target values for both PCBs and dieldrin. The values for total OCs are arbitrary. We are, in effect, taking a precautionary approach to conserving otter populations. We adopt a compliance level of 90% of samples within a catchment falling below levels (i) and (ii), in a manner analagous to that of regulatory authorities protecting water resources from polluting discharges.

To protect otter populations from PCBs, a concentration not exceeding 10 mg$\cdot$kg^{-1} fat in otter tissues has been suggested as a standard (Ministerie van Landbouw en Visserij, 1989). Reproductive failure in mink (*Mustela vison*) has been associated, in dosing experiments, with tissue concentrations of PCBs in excess of 50 mg$\cdot$kg^{-1} fat (Olsson et al., 1981) and this has been taken as a critical value for the otter in the absence of experiments on this species. de Vries (1989) has pointed out that arithmetic means are elevated by a few specimens and suggested that the geometric mean should be compared against a critical value of 30 mg$\cdot$kg^{-1}. Standards have not been proposed for organochlorine pesticides. We will use the same standards as for PCBs here, though organochlorine pesticides have proved less toxic to mink than PCBs (see review in Mason, 1989).

3. Results

The 20 rivers were placed into nine catchment groups for analysis (Table 1); the single site on the Dorset Stour (catchment 6) was included with the South Levels for convenience. Otters were distributed throughout the region but the percentage of positive stations varied markedly between catchment groups. Otters were most widely distributed in the catchments of the Taw (100% of survey stations positive), Torridge (100%) and Tamar (95%), situated in north and west Devon. Fewest positive survey sites were found in south Devon (52%), east Devon (51%) and south Somerset Levels (41%), the latter two catchment groups being in the current eastward expansion zone of the otter population.

A total of 167 spraint samples was analysed for organochlorine residues and the distribution of stations from which spraints were collected is shown in Fig. 1. Lindane was present in 90/92 (98%) of samples collected between March and May inclusive, but in only 12/72 (17%) of samples collected at other times of the year. Samples from the Somerset Levels were collected in both spring

Table 1
Arithmetic means and ranges (mg·kg^{-1}) of dieldrin, *p,p*-DDE and total PCBs in otter spraints from SW England (numbers in parentheses following catchment name refer to rivers in Fig. 1)

Catchment	*n*	Dieldrin		*p,p*-DDE		PCB	
		Mean	Range	Mean	Range	Mean	Range
North Levels (1,2)	25	1.46	nd-7.40	1.11	0.17–5.15	5.11	0.23–40.16
South Levels (3–6)	17	2.61	nd-15.01	3.57	0.46–16.26	9.44	1.20–46.55
East Devon (7,8)	14	0.83	0.18–2.23	1.74	0.45–4.36	3.70	0.51–7.90
South Devon (11–13)	15	0.77	0.10–1.83	0.83	0.26–2.77	6.04	0.86–25.58
Taw (9)	23	0.94	0.05–2.10	2.94	0.60–9.60	5.71	1.27–19.59
Torridge (10)	21	0.28	nd-0.73	0.69	0.10–2.19	2.51	0.54–6.07
Tamar (14)	21	0.38	0.03–1.37	0.42	0.05–1.99	2.42	0.18–14.31
East Cornwall (15–17)	16	0.55	0.07–1.90	0.60	0.10–1.40	4.15	0.76–30.46
West Cornwall (18–20)	15	1.04	nd-2.70	1.63	0.12–4.08	5.52	0.93–14.41

and autumn; lindane occurred in 26/28 (96%) of spring samples but only 1/14 (7%) of autumn samples. Amounts of lindane were generally small, with only one sample containing more than 4 mg·kg^{-1} (11.7 mg·kg^{-1}).

Dieldrin occurred above the level of detection in 98% of samples and *p,p*-DDE and total PCBs in all samples. The means and ranges of these contaminants in samples from catchment groups are given in Table 1. The means of dieldrin, *p,p*-DDE and PCBs were significantly different between catchments (Anovars on log-transformed data, $F =$ 4.83, 16.60, 5.56, respectively, $P < 0.001$) The 'no effects' level of 4 mg·kg^{-1} was exceeded for dieldrin only in samples from the Somerset Levels, but only in 12% of samples. Small numbers of samples from several rivers, again including the Somerset Levels, exceeded the 'no effects' level for *p,p*-DDE. Mean concentrations of PCBs exceeded the 'no effects' level in six of the nine catchments: South Levels, south Devon, Taw, west Cornwall, North Levels and east Cornwall, in decreasing order of mean concentration.

Table 2 shows the percentage of samples in the four levels of concern. Catchments with greater than 10% of samples in levels (i) and (ii) were South Levels (41%), south Devon (27%), west Cornwall (27%), North Levels (20%) and Taw (17%). However, west Cornwall had no samples in level (i).

Table 2
Percentage of samples in four contaminant concentrations: (i), critical; (ii), concern; (iii), maximum allowable concentration; (iv), background. See text for definition of levels.

Catchment	*n*	Level			
		(i)	(ii)	(iii)	(iv)
North Levels	25	8	12	16	64
South Levels	17	24	12	29	30
East Devon	14	0	0	50	50
South Devon	15	7	20	13	60
Taw	23	4	13	48	35
Torridge	21	0	0	14	86
Tamar	21	0	9	5	86
East Cornwall	16	6	0	19	75
West Cornwall	15	0	27	33	40

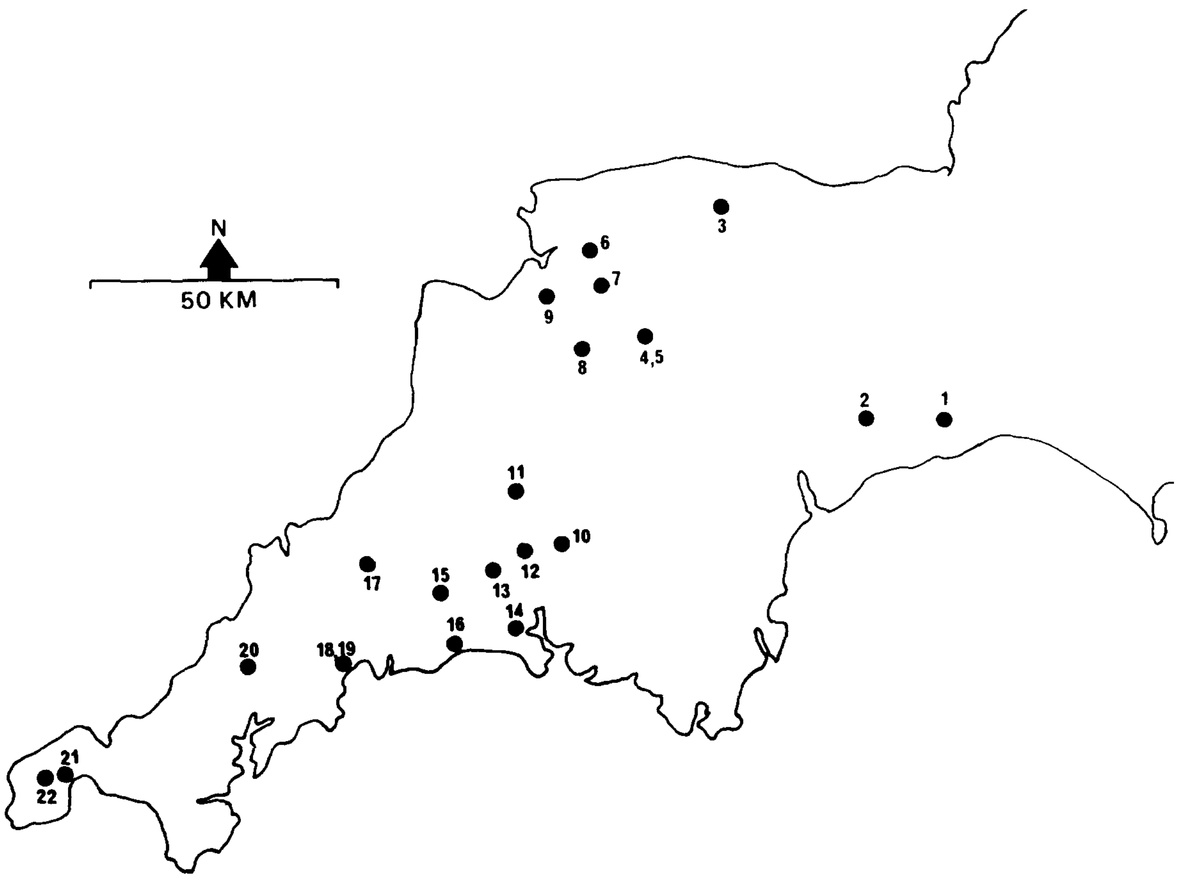

Fig. 2. Sites from which otters were obtained.

The localities from which 22 otter bodies came are shown in Fig. 2. Of these 17 were road casualties, 2 were killed together by a train, one was found dead in a snare, one was found dead of unknown causes and one died of sepsis following bite wounds. The results of the analyses for organochlorine residues are given in Table 3. Two of the analyses (1 and 7) refer to muscle tissue, the remainder refer to liver. Lindane was present in generally small amounts and was below the limit of detection in all samples received from 1991. The suggested background level of 10 $mg \cdot kg^{-1}$ was exceeded for dieldrin in seven animals, for *p,p*-DDE in 11 animals and for PCBs in 16 animals. Only one otter had dieldrin levels above 50 $mg \cdot kg^{-1}$ and only two animals exceeded this value for *p,p*-DDE. However, nine animals had PCB concentrations greater than 50 $mg \cdot kg^{-1}$. Of those animals (3–14) from north and west Devon, where otters were most widely distributed, three (25%) had PCB concentrations above 50 $mg \cdot kg^{-1}$, compared with six (60%) from the remainder of the study area.

Arithmetic mean concentrations ($mg \cdot kg^{-1}$ fat) of contaminants in otter tissues were; 10.4 $mg \cdot kg^{-1}$ for dieldrin, 22.3 $mg \cdot kg^{-1}$ for *p,p*-DDE and 60.51 $mg \cdot kg^{-1}$ for PCBs. Excluding the exceptionally high PCB level in otter 12, the mean PCB concen-

Table 3
Concentrations (mg · kg^{-1} lipid) of dieldrin, *p,p*-DDE and total PCBs in tissues of otters from SW England (numbers refer to localities on Fig. 2).

Otter	Lindane	Dieldrin	*p,p*-DDE	Total PCB
1	5.20	6.50	4.00	109.00
2	1.80	0.01	21.03	0.31
3	ND	1.26	1.40	2.74
4	0.26	0.01	25.00	48.60
5	0.44	0.01	15.10	48.20
6	ND	3.94	9.41	61.00
7	8.90	18.70	3.10	25.00
8	2.60	0.01	1.53	0.01
9	1.20	0.01	4.66	0.01
10	ND	0.02	2.52	4.16
11	ND	0.01	36.70	51.0
12	0.87	11.65	57.05	521.94
13	ND	7.58	5.69	19.60
14	0.93	23.27	22.52	21.27
15	0.40	10.84	8.46	99.78
16	ND	0.38	27.70	59.40
17	1.16	9.53	10.71	35.25
18	0.88	3.29	4.99	15.31
19	ND	72.40	161.30	82.90
20	0.27	9.22	42.00	68.69
21	0.35	38.08	20.84	50.36
22	ND	13.10	5.53	6.63

ND, Not detected (below limit of detection).

tration was 38.5 mg·kg^{-1}. The geometric mean PCB concentration, determined from all 22 animals, was 13.6 mg·kg^{-1}.

There was a significant correlation between amounts of dieldrin and *p,p*-DDE in tissues (r = 0.77, $P < 0.001$). PCB amounts correlated with neither those of dieldrin nor *p,p*-DDE. Lindane also showed no correlations.

4. Discussion

With only 17% of survey sites positive for otters in SW England during the national survey in the late 1970s (Lenton et al., 1980), the otter population was at a low ebb, being restricted largely to north and west Devon (rivers Taw, Torridge and Tamar). This remained the stronghold in the second national survey in the mid 1980s (Strachan et al., 1990), although expansion to the east and west of this area had begun. By the time of the present study in 1989–1991, otters had expanded further in range (Fig. 1). For example, rivers in west Cornwall have been recolonised in recent years. This region contains several disused mines and some samples contained contaminants at levels of concern although none exceeded critical levels. During the present study, the strongholds of the species, as judged by the number of positive stations in catchment surveys, remained in north and west Devon. Further consolidation is required before the potential carrying capacity of the region for otters is approached. Furthermore, in some catchments at least, expansion is proving difficult. For example Williams (1990) reported that, in the south Somerset Levels, an apparently widely distributed population in 1977/78 had all but disappeared 18 months later and appeared absent until at least 1988. This region remained the least occupied of catchments during the present survey in 1989, while J. Williams (pers. commun.) found very little evidence of otters in autumn 1992. Thus, colonisation occurs, but otter populations seem unable to establish. This catchment had the greatest mean level of contamination in otter spraints (see below).

Dieldrin, *p,p*-DDE and total PCBs occurred in the great majority of spraint samples. By contrast, lindane was found in samples mostly between March and May. In Wales, lindane was found mostly in samples collected in summer (Mason and Macdonald, 1993b). The sample of otter tissues in the present study (n = 22) was too small to look for seasonal differences, but in a larger sample from Denmark (Mason and Madsen 1993) no seasonal differences in lindane concentrations were detected (unpublished data). This would seem to provide further evidence that organochlorine residues measured in spraints derive largely from the undigested remains of the food (Mason et al., 1992). It may be that fish, the dietary component of otters, can metabolize lindane fairly rapidly, so that presence reflects agricultural applications, but the process of metabolism is slower in otters, hence the lack of seasonality. It is of interest that lindane was not recorded in otter tissues received from 1991, while a reduction in frequency of lindane occurred in otter spraints in 1991 from Welsh sites sampled regularly over several years (Mason and Macdonald, 1993a). This could reflect the reduced usage of lindane in agriculture.

Dieldrin and *p,p*-DDE concentrations were positively correlated in the present sample of otter tissues, but there were no correlations with PCBs or lindane. Positive correlations between all of these compounds were found in a sample of Danish otters (Mason and Madsen, 1993), the weakest correlations being with lindane. Dieldrin, *p,p*-DDE and PCBs were highly intercorrelated in a sample of otters from Ireland (Mason and O'Sullivan, 1992) while only PCBs and *p,p*-DDE were correlated in a sample from Shetland (Kruuk and Conroy, 1991). These differences may reflect regional patterns of use, both historic and recent, of individual compounds.

Dieldrin levels in spraints were generally low, the only samples above the 'no effects' level (level (iv)) originating from the lowland area of the Somerset Levels. Only one sample was placed in the concern categories (i) and (ii) due solely to dieldrin, although a third of samples were placed in this category when dieldrin and PCBs were considered together. Two-thirds of samples placed in categories (i) and (ii) were there due solely to the amounts of PCBs. No samples were placed in the concern categories due to amounts of lindane or *p,p*-DDE. Concentrations of contaminants were lowest in samples from the Tamar and Torridge, which formed the centre of the population in the region throughout the period of decline, but the Taw, which also held a population throughout, had elevated levels of PCBs and *p,p*-DDE. The River Taw (catchment 9) rises close to the source of the river Teign (catchment 11) which also had several spraint samples with high PCBs, suggesting a possible common source of contaminants in the area.

Five of the nine catchments failed the compliance level of 90% of spraint samples being below the concern levels (i) and (ii), but West Cornwall had no samples in level (i). In a similar study in Wales (Mason and Macdonald, 1993b), four rivers had more than 10% of samples in the critical level of concern (i); three of these had been surveyed on a regular basis and were known to support poor populations of otters (Mason and Macdonald, 1993a) and it was considered that their presence was due to regular recruitment from thriving populations upstream. In the present study, only the South Levels had more than 10% of spraint samples above the critical level and this area appears unable to support a permanent otter population (Williams, 1990, and pers. commun.). The South Levels are generally similar in habitat to the North Levels where otters are now widely distributed. However, the North Levels have been subject to extensive peat digging and the water-filled pools which remain may provide an off-river food supply with lower levels of contamination than the river systems; Mason and Macdonald (1993c) reported lower levels of contamination in spraints from rivers in East Anglia with extensive marshes compared with samples from rivers without this habitat.

Of the 22 otters analysed, 9 had tissue concentrations of PCBs greater than 50 $mg \cdot kg^{-1}$ lipid, which is associated with reproductive problems in experimentally-dosed mink (Olsson et al., 1981). However, if the exceptionally high value of otter 12 is excluded, the mean PCB content of the sample (38.5 $mg \cdot kg^{-1}$ lipid) lies well below this critical value of 50 $mg \cdot kg^{-1}$, while the geometric mean of all 22 samples (13.6 $mg \cdot kg^{-1}$) lies well below the critical value of 30 $mg \cdot kg^{-1}$ suggested by de Vries (1989). If these mean concentrations reflect levels in the population as a whole then we should expect continued consolidation of the population within the region. Whether eastward expansion will proceed apace is more doubtful for, from contaminant levels in spraints, the lowland Somerset Levels remain a relatively highly contaminated area and the samples from one site on the most easterly river (6, Dorset Stour), where colonisation by otters remains hesitant, also give cause for concern. A similar concern over eastward expansion has been raised following studies in Wales (Mason and Macdonald, 1993a,b).

In conclusion, within the study area of SW England, the contaminant levels, as measured in otter spraints, in only one catchment region, south Somerset Levels, might prevent the establishment of an otter population. Contaminant levels in otter tissues support the view that consolidation of populations within most of the region should continue. Nevertheless, the results of this study should give no grounds for complacency, for the amounts of PCBs in a significant number of both otters and spraints were elevated above what we would consider background levels. The study has also revealed a widespread contamination of freshwater ecosystems in SW England with organochlorine pesticides and PCBs, which is not apparent from the statutory monitoring of surface waters carried out by the regulatory authorities.

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