RADIOACTIVITY IN OTTER SCATS IN BRITAIN FOLLOWING THE CHERNOBYL REACTOR ACCIDENT

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Abstract. Radioactivity was determined in samples of otter (*Lutra lutra*) faeces (scats) collected from various regions of Great Britain in 1986 and 1987, following the Chernobyl nuclear reactor accident, and compared with a sample of scats collected in 1985 from central Wales. Samples of scats were also collected from the seashore adjacent to the Dounreay nuclear power station, northern Scotland, and compared with a control site, 40 to 60 km distant. Samples collected in 1986 from central Wales, Galloway and northern Scotland all contained significantly higher amounts of radioactivity than the 1985 sample from central Wales, with Galloway (mean 13 000 Bq kg^{-1} dry weight) having significantly more radioactivity than other regions. A sample collected in central Wales in January 1987 had returned to the 1985 level of radioactivity, but a sample from Galloway in January 1987 remained high; this difference in response may be related to the acidic nature of Galloway rivers. No significant differences were found between samples collected from near Dounreay and the control site, though fallout from Chernobyl may have masked the effects of local discharges of radioactivity. The significance of the results to otter populations is discussed.

1. Introduction

The explosion at the Chernobyl nuclear power station, U.S.S.R., on April 26, 1986, resulted in the fallout of radioactive materials over Britain from May 2, 1986, with most of the material being deposited with heavy rain over North Wales, northwest England and Scotland (Fry *et al.*, 1986).

The otter (*Lutra lutra*), a top carnivore with a diet consisting largely of fish, has been shown to be sensitive to bio-accumulating pollutants, with widespread decreases in both range and numbers recorded over the last 30 yr (Mason and Macdonald, 1986a). Otter faeces (scats) have been analyzed to detect and monitor the presence of heavy metals (Mason and Macdonald, 1986b) and organochlorine residues (Mason, 1987). During fieldwork in 1986 we took the opportunity of collecting scats to analyze for radioactivity following the Chernobyl incident, comparing the results with radioactivity in scats collected from one site in January 1985.

The British nuclear industry has itself received considerable criticism, much of it speculative, from environmental groups. One such example is the proposed plant for reprocessing spent fuel at Dounreay in northern Scotland (Milne, 1986). In this paper we also report on the amounts of radioactivity found in a sample of otter scats collected along the seashore adjacent to the Dounreay nuclear power station.

2. Material and Methods

The areas from which samples were collected are shown in Figure 1. Samples of scats were collected from riverbanks in Galloway (Area 2) between July 13 to 17, 1986 and

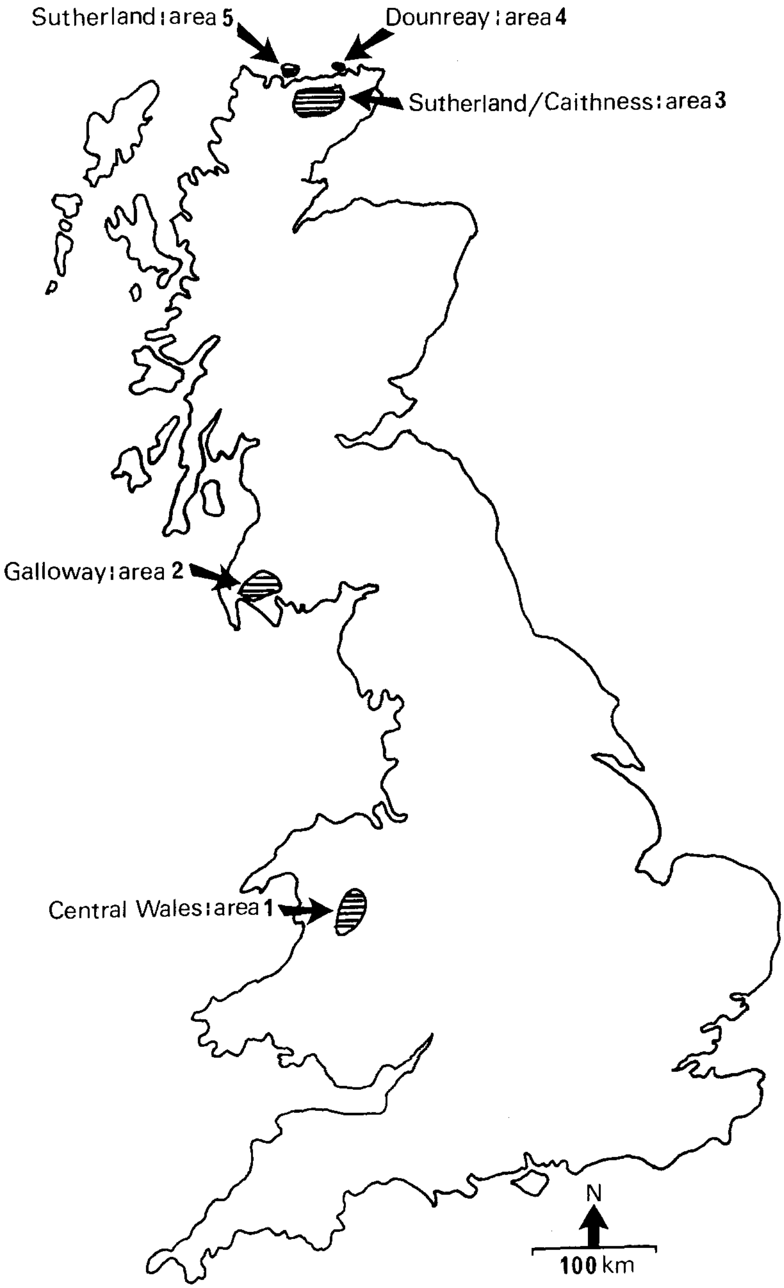

Fig. 1. Map of Britain showing areas from which otter scat samples were collected.

January 3 to 7, 1987, in northern Scotland (Sutherland and Caithness, Area 3) between August 16 to 19, 1986, and in central Wales (Area 1) between August 29 to September 1, 1986.

On August 20, 1986 samples of scats were collected along the sea shore within 5 km east and west of the Dounreay nuclear power station (Area 4). As a control, samples were collected on August 21, 1986 along the sea shore of Sutherland, 40 to 60 km west of Dounreay (Area 5).

All samples were stored in pastic tubes for return to the laboratory, where they were counted for radiation within 10 days. A sample of scats from central Wales (Area 1), collected in January 1985 and stored deep frozen in polythene bags, was used as a control.

All samples were dried to constant weight at 60 °C. Approximately 100 mg of sample material was accurately weighed out and 10 mL of scintillation fluid (Fluorosol) added, the samples being digested overnight at 60 °C. Radioactivity of samples was counted in a liquid scintillation counter (Packard counter, type 460C), using a wide window. The degree of quenching related to color and solvent effects is independent of the individual isotopes present within samples and the efficiency of counting was determined by spiking samples with ^{14}C labelled sodium bicarbonate.

3. Results

The scat samples were counted for radioactivity with a constant efficiency of 54%. The degree of quenching for a wide range of samples was very similar and all reported values are corrected for quenching effects. The results of the analyses are summarized in Table I, and Figure 2 illustrates the frequency distribution of radioactive counts amongst samples. Calculations and statistical tests were performed on transformed data ($\log n + 1$). The sample of scats collected from Area 1 (Figure 1) in January 1985, before the Chernobyl accident, is considered to be a control, representing natural levels of radioactivity.

The mean levels of radioactivity in samples of scats collected from central Wales (Area 1) on three occasions were significantly different (analysis of variance, $F = 5.19$, $P < 0.01$). Comparisons between pairs of samples were made using a t-test. The September 1986 sample contained significantly more radioactivity than samples collected in January 1985 ($t = 2.81$, $P < 0.01$) and January 1987 ($t = 2.97$, $P < 0.01$), though the means of the two January samples were not significantly different ($t = 0.42$, n.s.). Figure 2 illustrates the increased frequency of contamination in the sample in September 1986, which had returned to the January 1985 pattern by January 1987. Thus there was an increase in radioactivity in otter scats from central Wales following the Chernobyl accident, but levels had returned to the 1985 level by January 1987.

Comparisons were made between samples collected from Areas 1, 2, and 3 during summer 1986 and the means were significantly different ($F = 26.47$, $P < 0.001$). Scats from Galloway (Area 2) contained significantly more radioactivity than scats from central Wales ($t = 7.52$, $P < 0.001$) and Sutherland/Caithness (Area 3; $t = 3.22$,

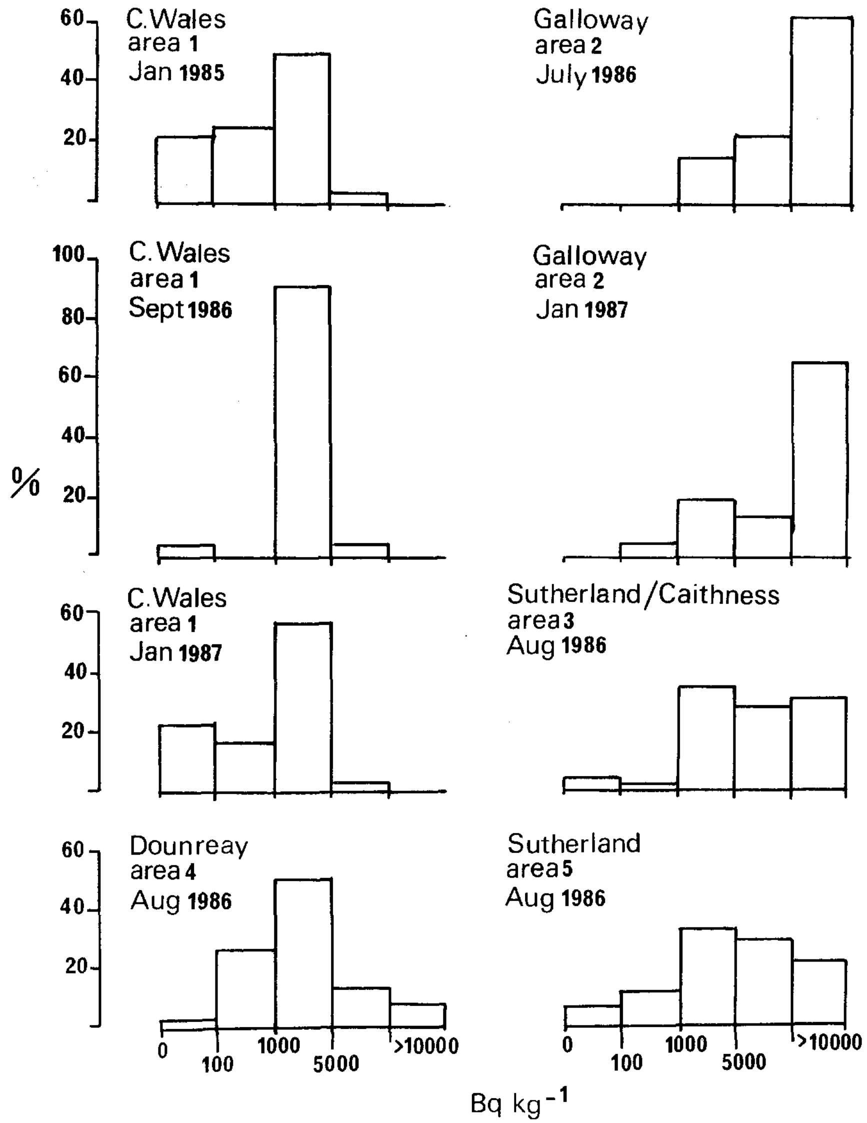

Fig. 2. Frequency distribution of levels (Bq kg^{-1}) of radioactivity in otter scats from five areas in Britain.

$P < 0.01$). Samples from Sutherland/Caithness contained significantly more than those from central Wales ($t = 2.98$, $P < 0.01$). There was no significant difference between means of radioactivity in scats collected in Galloway in July 1986 and January 1987 ($t = 0.42$, n.s.) so, unlike the situation in central Wales, radioactivity did not fall through the winter.

Samples collected from Areas 2 and 3 can also be compared to the control sample collected from central Wales in January 1985. Significantly higher levels of radioactivity

TABLE I

Total radioactivity in otter scats (n = number of samples) from five sampling areas in Wales and Scotland ($Bq\ kg^{-1}$ dry weight, geometric means, $\bar{x}$, and ranges).

Region	Date	n	$\bar{x}$	Range	% contaminated
Area 1	January 1985	52	640	0–7400	83
Central Wales	September 1986	24	1980	0–6900	96
	January 1987	30	530	0–5300	77
Area 2	July 1986	32	13000	1200–79500	100.0
Galloway	January 1987	48	11900	400–49400	100.0
Area 3	August 1986	46	5190	0–73100	96
Sutherland/Caithness					
Area 4	August 1986	38	1950	0–37700	97
Dounreay nuclear station					
Area 5	August 1986	48	3110	0–16500	94
Sutherland, coastal control					

than in controls were found in samples of scats from Area 2 in July 1986 ($t = 9.12$, $P < 0.001$), and January 1987 ($t = 9.01, P < 0.001$) and Area 3 in August 1986 ($t = 5.66$, $P < 0.001$).

There was no significant difference in the mean radioactivity of scats collected from the seashore in Area 4 (Dounreay nuclear power station) and Area 5 (40 to 60 km west of Dounreay; $t = 1.42$, n.s.). There was no significant difference between levels of radioactivity in samples from Area 3 and Area 5 ($t = 1.49$, n.s.) but samples from Dounreay were significantly lower in radioactivity than samples collected from Area 3, i.e., adjacent inland sites ($t = 3.10, P < 0.01$).

4. Discussion

Using liquid scintillation techniques alone it is not possible to determine which radionuclides are responsible for the overall counts of radioactivity. However, the method does enable the measurement of large numbers of small samples (such as scats) and hence statistical comparisons can be made of amounts of radioactivity between sites and seasons. High resolution gamma spectroscopy allows the quantification of individual gamma emitters, but large or bulked samples are required, often resulting in insufficient data on individual sites for statistical comparisons to be made (e.g., Camplin *et al.*, 1986). The otter scats collected from Areas 1, 2, and 3 in summer 1986 were bulked and compared with the bulked 1985 sample from area 1 by gamma spectroscopy, using a Ge detector (D. Hornsey, personal communication). Significant peaks of ^{134}Cs were present in the 1986 sample, but not in the 1985 sample. ^{137}Cs was also present in the 1986 sample, but was contaminated with ^{110m}Ag. ^{228}Ac was also present.

There were substantial amounts of radioactivity in otter scats. Samples collected in the summer of 1986 had significantly higher amounts than samples collected from Wales in January 1985. This January sample is treated as a control for comparing radioactivity in spraints from Areas 1 to 3 and is justified because all areas have a solid geology which is primarily Palaeozoic (granite and old red sandstone), with a natural level of radiation high relative to areas of lowland Britain.

The variation in amounts of radioactivity recorded from individual areas was very large, e.g., 1200 to 79 500 Bq kg^{-1} in samples collected from Area 2 in July 1986. Camplin *et al.* (1986) found a very wide range of concentrations in individual fish (the major food of otters) of the same species from the same localities. The data in Figure 2 show that the majority of samples from Galloway, and a substantial proportion from northern Scotland, contained amounts of radioactivity greater than 10 000 Bq kg^{-1}. The mean values of the samples collected from Area 1 to 3 in summer 1986 were significantly different from one another, with Galloway containing the most radioactivity and Wales the least. This reflects the pattern of fallout of nuclides from the Chernobyl accident following heavy rain in early May 1986 (Fry *et al.*, 1986).

The amounts of radioactivity measured in samples collected in Wales in January 1987 had returned to the level recorded in January 1985 but there was no significant decline in radioactivity in samples from Galloway. This difference in response may have been partly due to the much lower level of contamination in Wales, scats from Galloway in summer 1986 averaging more than six times the radioactivity present in samples from Wales. However, the pH of water in the regions may also be important. In Galloway in January, 48% of sites from which samples were collected had values of pH less than 5.5 in river water, which could have mobilized metals, including radionuclides, from vegetation and soils. By contrast, although the headwaters of the catchment in Wales are known to be acidified (Mason and Macdonald, 1987), sites from which samples were taken have minimum pH values in water greater than pH 6. High concentration factors for Cs are known to occur in fish living in soft waters (Preston *et al.*, 1968).

The amounts of radioactivity found in a sample of scats collected along the seashore adjacent to the Dounreay nuclear power station (Area 4) were not significantly different from those in a sample of scats collected along the coast 40 to 60 km west of Dounreay (Area 5) and indeed were significantly lower than in samples collected from adjacent inland areas (Area 3). However, any local effect of materials derived from the power station may have been masked by the greater contamination by fallout from Chernobyl.

Radionuclides have the potential to concentrate in biological systems and the otter, feeding extensively on fish, is known to be susceptible to accumulating pollutants (Mason and Macdonald, 1986a). Following the Chernobyl accident, Camplin *et al.* (1986) recorded amounts of radioactivity in fish as high as 2000 Bq kg^{-1} (fresh weight), while considerably higher levels, up to 18 700 Bq kg^{-1} (fresh weight) were reported from Sweden (Petersen *et al.*, 1986). Although our data are for scats only, the peak count of 79 500 Bq kg^{-1} (dry weight) suggests that considerable bioaccumulation may have occurred in otters.

For assessing individual doses to humans from continuous consumption of freshwater fish contaminated with Chernobyl fallout, Camplin *et al.* (1986) took data from brown trout (*Salmo trutta*) from Ennerdale, Lake District, as reasonably representative of the highest level of Chernobyl nuclides (315 Bq kg^{-1} ^{134}Cs and 657 Bq kg^{-1} ^{137}Cs). Assuming a rate of consumption of 150 g d^{-1}, Camplin *et al.* (1986) estimated the effective dose to the critical group in the area of highest observed concentration to be 1.1 mSv in 1 year, 21% of the 5 mSv effective dose at which a foodstuffs ban may be considered (NRPB, 1986). While such a high preponderance of freshwater fish in the human diet is unlikely, otters may eat 1.0 to 1.5 kg fish daily (Mason and Macdonald, 1986a). Assuming otters ate 1 kg d^{-1} of fish containing 315 Bq kg^{-1} ^{134}Cs and 657 Bq kg^{-1} ^{137}Cs and using values of effective dose given in Haywood (1987) for man (making no allowance for the lower body weight or higher metabolic rate of otters) the effective dose equivalent in 1 year would be 4.8 mSv, equivalent to a risk of 5 deaths per 100 000 otters, a clearly unmeasurable mortality in a wild population. It is, however, possible that increased doses of radioactivity might impair fecundity.

Otter scats have already been used to compare burdens of heavy metals and organochlorine residues in otters between regions (Mason and Macdonald, 1986b; Mason, 1977). The current data on radioactivity confirm the value of this technique in assessing pollutant burdens in rare top carnivores such as the otter.

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