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^{134}Cs AND ^{137}Cs ACTIVITY IN VEGETATION OF NORTH YORKSHIRE IN JANUARY 1988

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1 SUMMARY

Grassy vegetation and/or heather were sampled from 256 sites in North Yorkshire during January 1988. Few of the grass samples had ^{137}Cs activity concentrations greater than 340 Bq kg^{-1} dry weight. In contrast 58% of the heather samples had ^{137}Cs activity concentrations exceeding 500 Bq kg^{-1} dry weight suggesting a comparatively high uptake of radiocaesium by heather compared with grasses.

Most of the heathers with comparatively high radiocaesium activities were from an area north of Settle which received high rainfall during the passage of the Chernobyl cloud. The ^{134}Cs:^{137}Cs ratio of these samples was characteristic of the Chernobyl fallout. Heather samples from outside this area had ^{134}Cs:^{137}Cs ratios which indicated that a significant proportion of their ^{137}Cs content originated from before the Chernobyl accident.

2 INTRODUCTION

Surveys of ^{137}Cs levels of vegetation conducted soon after the Chernobyl accident showed that the highest deposition had taken place in north Wales, Cumbria and parts of Scotland, all of which had experienced heavy rainfall during the passage of the air mass contaminated by Chernobyl (Allen 1986).

Temporary restrictions had to be placed on the movement and slaughter of sheep in these areas. Unfortunately the restrictions have had to be retained in some of these areas as the radiocaesium has not been immobilised in the acidic soils, allowing significant plant uptake of radiocaesium.

Subsequently information became available from the Meteorological Office (Smith 1986) which showed that parts of North Yorkshire had also received high rainfall during the passage of the Chernobyl cloud (Figure 1).

I.T.E., under contract to the Ministry of Agriculture, Fisheries and Food, has sampled vegetation from 256 sites in North Yorkshire. Although most of the samples were of grassy vegetation, recent heather growth, which is grazed by sheep, was also sampled when present.

3 MATERIALS AND METHODS

Two hundred and fifty-six sample sites were selected on a random basis and the soil type at each site was noted using soil survey maps (Soil Survey 1983). Grassy vegetation at each site was clipped from $1m^2$ to $4m^2$ quadrats (depending on the amount of vegetation present), to a height of 1cm above ground level. Dead vegetation and species other than grasses were avoided. At some sites where heather (Calluna vulgaris) was present 1986 and 1987 extension growth with associated side shoots was also sampled. On 7 sites heather alone was sampled.

The samples were dried at 80°C, weighed, ground and counted in plastic containers (130ml) on a Na(Tl) detector to determine ^{137}Cs activity. If the ^{137}Cs activity concentration was detectable (ie > 340 Bq kg^{-1} dry weight) the samples were also counted on a high resolution germanium (Ge) detector to determine both ^{137}Cs and ^{134}Cs activity.

As counting progressed it became evident that the radiocaesium activity concentration of the heather samples was consistently higher than the corresponding grasses and that the ratio of ^{134}Cs to ^{137}Cs was variable. It was therefore decided to count all the heather samples on the Ge detectors.

4 RESULTS AND DISCUSSION

4.1 Grassy vegetation

Only 9 of the 249 grassy samples had ^{137}Cs activity concentrations exceeding 340 Bq kg^{-1} dry weight (Table 1). All of these were growing on areas dominated by acid peat soils; 5 on millstone grit and 4 on limestone. The most contaminated samples (Figure 2) were obtained from areas which had received heavy rainfall (Figure 1) during the passage of the Chernobyl cloud. However, there were numerous samples with low radiocaesium activity from either (i) acidic soils or (ii) areas which had received heavy rainfall.

4.2 Heather

The total radiocaesium content of the heather samples (Table 2) was noticeably higher than the grasses. At sites where both grasses and heather were sampled, sometimes growing adjacent to each other, the heathers were more contaminated than the grasses, suggesting greater uptake of radiocaesium by heather in comparison with grasses.

The majority of heather samples had a ^{134}Cs:^{137}Cs ratio characteristic of the Chernobyl fallout (c. 1:4.0) in January 1988, particularly in the areas of heavy rainfall where radiocaesium levels were highest (Figure 3). The relationship between the ^{137}Cs:^{134}Cs ratio and the rainfall (mm) can be described mathematically by fitting a sigmoid curve to the data (Figure 4) producing an equation of the form:

$$y = A/(1 + B \times X^{N})$$

where $A = 0.30$
$B = 1.26$
$N = -0.71$

$r^2 = 0.695$ thus 70% of the variation was explained.

There were, however, a few heather samples, mainly from the north of the county, where the ratio ranged from between 1:6 to 1:14.3 (Figure 5). In these cases there was obviously a significant proportion of ^{137}Cs originating from before the Chernobyl accident, presumably originating as fallout from nuclear weapons testing. Therefore, the aged caesium deposit in these soils must still be available for uptake, especially by heather.

5 REFERENCES

ALLEN, S.E. 1986. Radiation: A guide to a contaminated countryside. The Guardian. July 25, 17.

BERESFORD, N.A. & HOWARD, B.J. 1988. Investigations of methods to reduce caesium activity of sheep in upland areas affected by Chernobyl fallout. Final Report 22pp. Ministry of Agricuture Fisheries and Food. TFS Project T07007f1/c1.

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SMITH, F.B. 1986. Chernobyl - the radioactive plume and its consequences. Bracknell: Meteorological Office 48pp.

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Table 1. Radiocaesium activity concentration of grassy vegetation sampled from North Yorkshire (Bq kg^{-1} dry weight).

Grid Reference	Location	Bq kg^{-1} dry weight ^{137}Cs	^{134}Cs	Total ^{137}Cs	Ratio ^{134}Cs:^{137}Cs
NY 833025	Birkdale Common	< 340			
NY 844055*	Davy Mea, Swaledale	< 340			
NY 863034	Ravenseat, Keld	< 340			
NY 885022	West Stonesdale, Keld	< 340			
NY 894007	Keld	< 340			
NY 925013*	Gunnerside Moor	< 340			
NY 944073	Arkengarthdale	< 340			
NY 965095	Bow Hills, Bowes	< 340			
NY 966075	Arkengarthdale	< 340			
NY 967068	Arkengarthdale	< 340			
NY 963022*	Great Pinseat	< 340			
NY 985003*	N. of Feetham	< 340			
NZ 004044	Arkengarthdale	< 340			
NZ 066053	Holgate Moor	< 340			
NZ 074052	Holgate Pasture, Marske	< 340			
NZ 075028	Helwith, Marske	< 340			
NZ 087018	Marske	< 340			
NZ 095098	Newsham	< 340			
NZ 118022	Marske	< 340			
NZ 146085	Ravensworth	< 340			
NZ 155057	Richmond	< 340			
NZ 154015	Richmond	< 340			
SD 765837*	Blea Moor, Ribblehead	< 340			
SD 777954	Mallerstang	< 340			
SD 797873	Widdale Fell	< 340			
SD 797847	Old Widdale Head	< 340			
SD 802845	Redshaw Moss	310	60	370	1:5.5
SD 805805	Cam Fell	< 340			
SD 818967	Abbotside Common	< 340			
SD 818918	Moorcock Inn	< 340			
SD 822972	Abbotside Common	< 340			
SD 826804	Langstrothdale	680	160	840	1:4.4
SD 825796*	Langstrothdale	< 340			
SD 847954	Great Shunner Fell	< 340			
SD 846843	Dodd Fell	400	90	490	1:4.4
SD 845805*	Langstrothdale	< 340			
SD 855954	Fossdale Moss	< 340			
SD 857886	Hawes	< 340			
SD 867937	Simonstone, Hawes	< 340			
SD 865875	Hawes	< 340			
SD 875937	Simonstone, Hawes	< 340			
SD 888976	Muker	< 340			
SD 886869	Countersett Bardale, Hawes	< 340			
SD 896836	Raydale, Bainbridge	< 340			
SD 906994	Muker	< 340			
SD 904945*	Giles Gt. Stone Hags Muker	< 340			
SD 913920	Bainbridge	< 340			

Table 1. (continued)

Grid Reference	Location	Bq kg^{-1} dry weight ^{137}Cs	^{134}Cs	Total Cs	Ratio ^{134}Cs:^{137}Cs
SD 915815*	Hunters Hole	< 340			
SD 926982	Muker	< 340			
SD 922915	Bainbridge	< 340			
SD 937856	Stake Allotments	< 340			
SD 935816	Cray Moss, Hubberholme	< 340			
SD 958927	Bainbridge	< 340			
SD 955865	Stake Fell	< 340			
SD 951846*	Stake Allotments	< 340			
SD 973902	Woodhall, Wensleydale	< 340			
SD 984964	Whitaside, Swaledale	< 340			
SD 986863	Bishopdale	< 340			
SD 986856	Bishopdale	< 340			
SD 989915	Carperby, Wensleydale	< 340			
SE 009921	Carperby, Wensleydale	< 340			
SE 018984	Healaugh, Swaledale	< 340			
SE 018817*	Fleensop Moor	< 340			
SE 025945	Castle Bolton	< 340			
SE 028936*	Castle Bolton	< 340			
SE 023872	West Burton, Wensleydale	< 340			
SE 036964*	Grinton	< 340			
SE 032867	West Burton, Wensleydale	< 340			
SE 032823	Fleensop	< 340			
SE 042952*	Grinton Moor	< 340			
SE 045895	Swinithwaite, Wensleydale	< 340			
SE 044804	Arklesidē, Coverdale	< 340			
SE 075891	Bolton Hall, Leyburn	< 340			
SE 093893	Wensley, Leyburn	< 340			
SE 105965	Stainton, Swaledale	< 340			
SE 106932	Bellerby, Leyburn	< 340			
SE 116893	Leyburn	< 340			
SE 123857	Middleham	< 340			
SE 143908	Leyburn	< 340			
SE 152936	E. Hauxwell	< 340			
SE 153866	East Witton	< 340			
SE 168947	East Hauxwell, Catterick	< 340			
SE 164843	Ellingstring	< 340			
SE 175963	Catterick	< 340			
SE 185883	Thornton Grange	< 340			
SE 183805	Healey, Masham	< 340			
SE 197981	Hipswell	< 340			
SE 194954	Scotton, Catterick	< 340			
SD 663746	Galegreen, Ingleton	< 340			
SD 667703	High Bentham	< 340			
SD 677692	High Bentham	< 340			
SD 683669	Gruskham, High Bentham	< 340			
SD 704731	Storrs, Ingleton	< 340			
SD 709634*	Burn Moor	430	50	480	1.8.6
SD 707613*	Burn Moor	430	70	500	1.5.9
SD 705607*	Burn Moor	< 340			
SD 718785	Whernside	< 340			

Table 1. (continued)

Grid Reference	Location	Bq kg^{-1} dry weight ^{137}Cs	^{134}Cs	Total Cs	Ratio ^{134}Cs:^{137}Cs
SD 715775	Whernside	< 340			
SD 713711	Cold Cotes	< 340			
SD 718688	Newby Moor, Clapham	< 340			
SD 718658	Hawks Heath Farm	< 340			
SD 725778	Whernside	480	140	620	1:3.4
SD 723757	Twisleton, Ingleton	< 340			
SD 723735	Crina Bottom, Ingleborough	< 340			
SD 738743	Ingleborough	< 340			
SD 747747	Ingleborough	< 340			
SD 743714	Clapdale Scars	< 340			
SD 733637	S. of Austwick	< 340			
SD 733615*	Austwick Common	< 340			
SD 744637	S. of Austwick	< 340			
SD 745615*	Austwick Common	< 340			
SD 752656	S. of Austwick	< 340			
SD 756647	S. of Austwick	< 340			
SD 775786	Ribblehead	< 340			
SD 775704	Wharfe, Austwick	< 340			
SD 774645	Lawkland	< 340			
SD 795785	Ribblehead	< 340			
SD 802756	Horton in Ribblesdale	< 340			
SD 806665	Giggleswick	< 340			
SD 815774	Birkwith Moor	< 340			
SD 815645	Giggleswick	< 340			
SD 828653	Langcliffe, Settle	< 340			
SD 837730	Penyghent	< 340			
SD 834688	Sannat Hall Farm	< 340			
SD 845768	Blaydike Moss, Foxup	< 340			
SD 841740*	Plover Hill/Penyghent	< 340			
SD 854779	Cosh, Foxup	< 340			
SD 857721	Fountains Fell	< 340			
SD 855699*	Coronation Pot/Fount.Fell	410	100	510	1:4.1
SD 865645	N. of Rye Loaf Hill	< 340			
SD 867635	Rye Loaf Hill	< 340			
SD 874798	Langstrothdale	< 340			
SD 877702	E.side Fountains Fell.	< 340			
SD 885692	Tennant Gill, Fount.Fell	< 340			
SD 893657	S. of Malham Tarn	< 340			
SD 927628*	The Weets, Malham	< 340			
SD 922705	Clowder, Arncliffe	< 340			
SD 936793	Cray, Hubberholme	< 340			
SD 936731*	Old Cote Moor, Arncliffe	< 340			
SD 934721	Arncliffe	< 340			
SD 937715	Arncliffe	< 340			
SD 946655	Malham Moor	< 340			
SD 957618*	Boss Moor	< 340			
SD 968792	Buckden Pike	< 340			
SD 969751	Cam Head, Kettlewell	< 340			
SD 961641	Malham Moor	< 340			
SD 968630*	Threshfield Moor	< 340			

Table 1. (continued)

Grid Reference	Location	Bq kg^{-1} dry weight ^{137}Cs	^{134}Cs	Total Cs	Ratio ^{134}Cs:^{137}Cs
SD 970742	Cam Pastures, Kettlewell	<340			
SD 975631	Threshfield	<340			
SD 982782	North Moor, Starbotton	<340			
SD 984763	North Moor, Starbotton	<340			
SD 980740	Park Rash, Kettlewell	<340			
SD 984738	Kettlewell	<340			
SD 989681	Conistone	<340			
SD 985624	Threshfield	<340			
SD 995708	Conistone	<340			
SD 996665	Conistone	<340			
SE 005765	Great Whernside	<340			
SE 008636	Grassington	<340			
SE 013767	Great Whernside	<340			
SE 013757	Great Whernside	<340			
SE 017699	Mossdale Scar, Conistone	<340			
SE 018663*	Grassington	<340			
SE 029639*	Scar Top House, Hebden	<340			
SE 035745	Great Whernside	<340			
SE 034704	Conistone Moor	<340			
SE 034697	Conistone Moor	<340			
SE 048646	Grimwith Resr.	<340			
SE 055737	Aygill Pike	<340			
SE 055698	N. of Grimwith Resr.	<340			
SE 058602	Appletreewick	<340			
SE 060655	Grimwith Resr.	<340			
SE 061652*	Grimwith Resr.	310	70	380	1:4.6
SE 063713*	Stean Moor	<340			
SE 086792*	Masham Moor	<340			
SE 098755	Middlesmoor	<340			
SE 106714	Ramsgill	<340			
SE 105695	Gouthwaite Moor	<340			
SE 104688*	Gouthwaite Moor	<340			
SE 106642	Lily Green, Pateley Bridge	<340			
SE 114714	Ramsgill	<340			
SE 118627*	Katty Whites Allotment	<340			
SE 155682	Pateley Bridge	<340			
SE 154668	Pateley Bridge	<340			
SE 183735	Carlesmoor	<340			
SE 183657	Pateley Bridge	<340			
SD 787574	Wigglesworth	<340			
SD 805562	Wigglesworth	<340			
SD 832569	Long Preston	<340			
SD 835551	Long Preston	<340			
SD 844573	Long Preston	<340			
SD 865544	Swinden, Hellifield	<340			
SD 874562	Hellifield	<340			
SD 887526	Stainton, Barnoldswick	<340			
SD 886502	West Marton, Barnoldswick	<340			
SD 904585	Airton	<340			
SD 914575	Eshton Moor, Gargrave	<340			
SD 914534	Gargrave	<340			
SD 927522	Gargrave	<340			

Table 1. (continued)

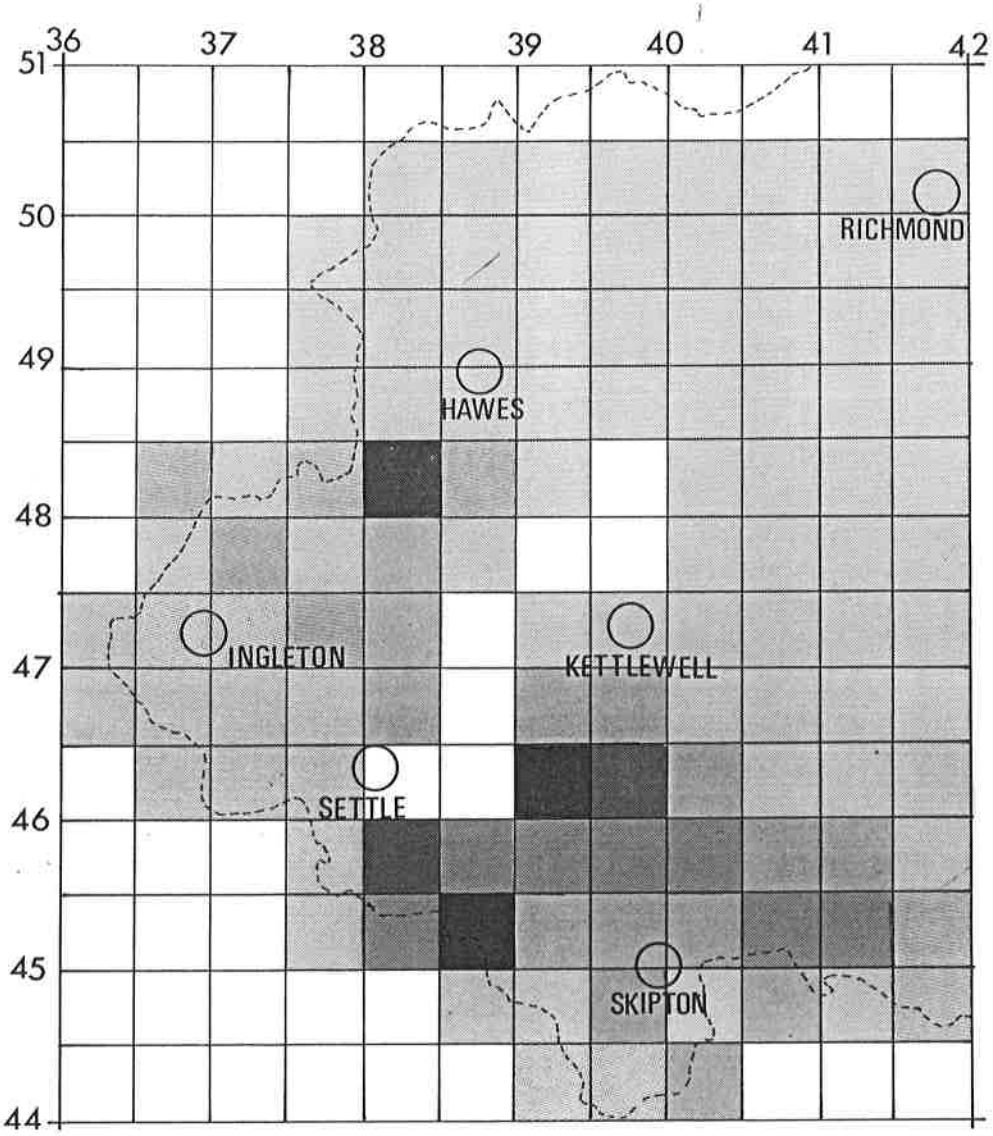
Grid Reference	Location	Bq kg^{-1} dry weight ^{137}Cs	^{134}Cs	Total Cs	Ratio ^{134}Cs:^{137}Cs
SD 926484	Elslack	< 340			
SD 936593	Winterburn	< 340			
SD 932527	Gargrave	< 340			
SD 934485	Elslack Resr.	< 340			
SD 945545	Holme Ho., Gargrave	< 340			
SD 947464	Lothersdale	< 340			
SD 955585	Hetton	< 340			
SD 956572	Hetton	< 340			
SD 961568	Flasby Fell	< 340			
SD 967523	Skipton	< 340			
SD 963513	Skipton	< 340			
SD 965495	Carleton	< 340			
SD 963477	Cross Green, Carleton	< 340			
SD 962435	Cowling	< 340			
SD 982564	Nettlehole Wood, Skipton	< 340			
SD 999598*	Peters Crag, Cracoe	< 340			
SD 998544	Embsay Resr.	< 340			
SE 008598*	Thorpe Fell, Cracoe	< 340			
SE 001549*	Embsay Resr.	< 340			
SE 015424	Sutton in Craven	< 340			
SE 026464	Silsden	< 340			
SE 039569	Lower Barden Resr.	< 340			
SE 033544	Halton East, Skipton	< 340			
SE 057557	Bolton Abbey	< 340			
SE 061533	Bolton Abbey	< 340			
SE 070590*	Barden Fell	< 340			
SE 076545	Bolton Abbey	< 340			
SE 088564	Bolton Abbey	< 340			
SE 104493	Ilkley	< 340			
SE 113545	Blubberhouses Moor	< 340			
SE 114506	Middleton Moor	< 340			
SE 126551	Blubberhouses Moor	< 340			
SE 122521*	Middleton Moor	450	130	580	1:3.5
SE 146598	Thornthwaite, Blubberhouses	<340			
SE 148525*	Denton Moor	< 340			
SE 143485	Denton	< 340			
SE 153503	Denton	< 340			
SE 175585	Thornthwaite, Blubberhouses	<340			
SE 178473	Weston, Otley	< 340			
SE 186465	Weston Park, Otley	< 340			

* Corresponding Heather Sample See Table 2.

Table 2. Radiocaesium activity concentration of recent growth of heather from upland areas of North Yorkshire (Bq kg^{-1} dry weight).

Grid Reference	Location	Bq kg^{-1} dry weight ^{137}Cs	^{134}Cs	Total ^{137}Cs	Ratio $^{134}Cs:^{137}Cs$
NY 844055	Davy Mea, Swaledale	510	90	600	1:5:7
NY 925013	Gunnerside Moor	350	30	380	1:10.9
NY 963022	Great Pinseat	110	10	120	1:9.8
NY 985003	N. of Feetham	120	20	140	1:6.6
SD 765837	Blea Moor, Ribblehead	770	190	960	1:4.0
SD 845805	Langstrothdale	480	100	580	1:5.0
SD 904945	Giles Gt. Stone Hags, Muker	670	60	730	1:11.5
SD 915953	Giles Gt. Stone Hags, Muker	530	40	570	1:12.7
SD 915815	Hunters Hole, Hubberholme	330	50	380	1:6.3
SD 951846	Stake Allotments	470	40	510	1:11.7
SE 018817	Fleensop Moor	180	20	200	1:9.6
SE 028936	Castle Bolton	100	20	120	1:6.3
SE 036964	Grinton	310	20	330	1:13.6
SE 042952	Grinton Moor	340	40	380	1:8.7
SE 124803	Gollinglith, Colsterdale	520	50	570	1:11.2
SD 709634	Burn Moor, Bowland	320	50	370	1:6.1
SD 707613	Burn Moor, Bowland	1410	280	1690	1:5.0
SD 705607	Burn Moor, Bowland	680	140	820	1:5.0
SD 733615	Austwick Common	730	180	910	1:4.1
SD 745615	Austwick Common	740	160	900	1:4.6
SD 825796	Langstrothdale	1770	350	2120	1:5.1
SD 835721	Penyghent	1060	260	1320	1:4.2
SD 841740	Plover Hill/Penyghent	2630	650	3280	1:4.1
SD 855699	Coronation Pot, Fount.Fell	1660	470	2130	1:3.5
SD 927629	The Weets, Malham	960	260	1220	1:3.7
SD 936731	Old Cote Moor, Arncliffe	160	30	190	1:4.8
SD 957618	Boss Moor	860	250	1110	1:3.5
SD 968630	Threshfield Moor	1240	320	1560	1:3.8
SE 018663	Yarnbury, Grassington	500	120	620	1:4.2
SE 029639	Hebden, Grassington	1050	220	1270	1:4.7
SE 051657	Grimwith Resr.	410	80	490	1:5.2
SE 063713	Stean Moor	230	40	270	1:5.7
SE 086792	Masham Moor	340	40	380	1:8.0
SE 104684	Gouthwaite Moor	170	30	200	1:5.2
SE 118627	Katty White's Allotments	500	180	680	1:2.8
SE 165757	Masham Moor	190	10	200	1:14.3
SE 177775	Ilton Resr.	240	30	270	1:8.2
SD 999598	Peter's Crag, Cracoe	660	170	830	1:3.8
SE 008598	Thorpe Fell, Cracoe	1050	310	1360	1:3.4
SE 001549	Embsay Resr.	850	240	1090	1:3.5
SE 020579	Upper Barden Resr.	320	80	400	1:3.9
SE 031588	Barden Moor	1200	310	1510	1:3.9
SE 070590	Barden Fell	880	230	1110	1:3.8
SE 122521	Middleton Moor	1110	280	1390	1:3.9
SE 148525	Denton Moor	960	260	1220	1:3.7

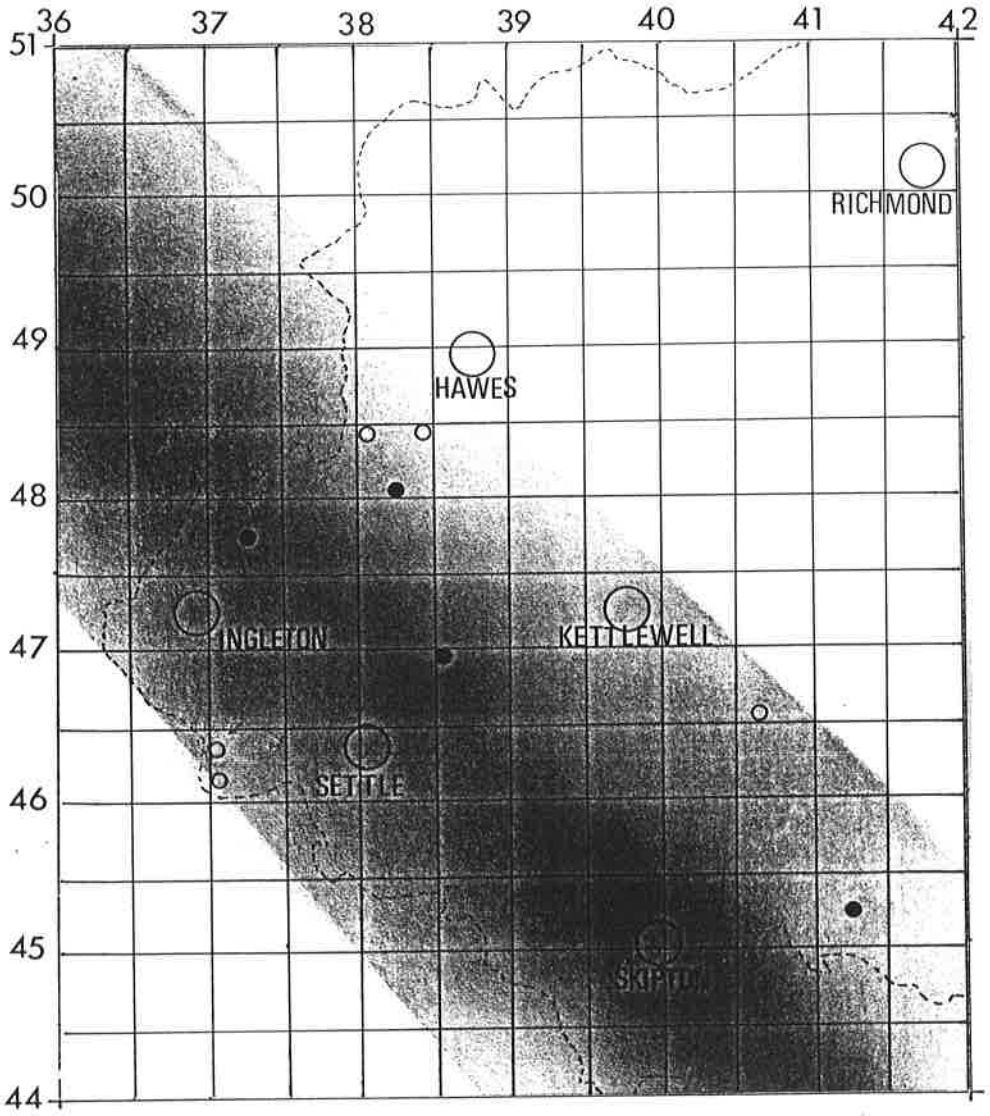
Figure 1. Total rainfall (mm) in the sampled area of North Yorkshire for the period of 3.5.86 - 5.5.86 extracted from Meteorological Office radar data.



Key

no data
0-10 mm
10-20 mm
20-30 mm
30-40 mm
40-40 mm
------ North Yorkshire County Boundary

Figure 2. Radiocaesium activity concentration of the samples of grassy vegetation which exceeded 340 Bq kg^{-1} dry weight of ^{137}Cs.



Key

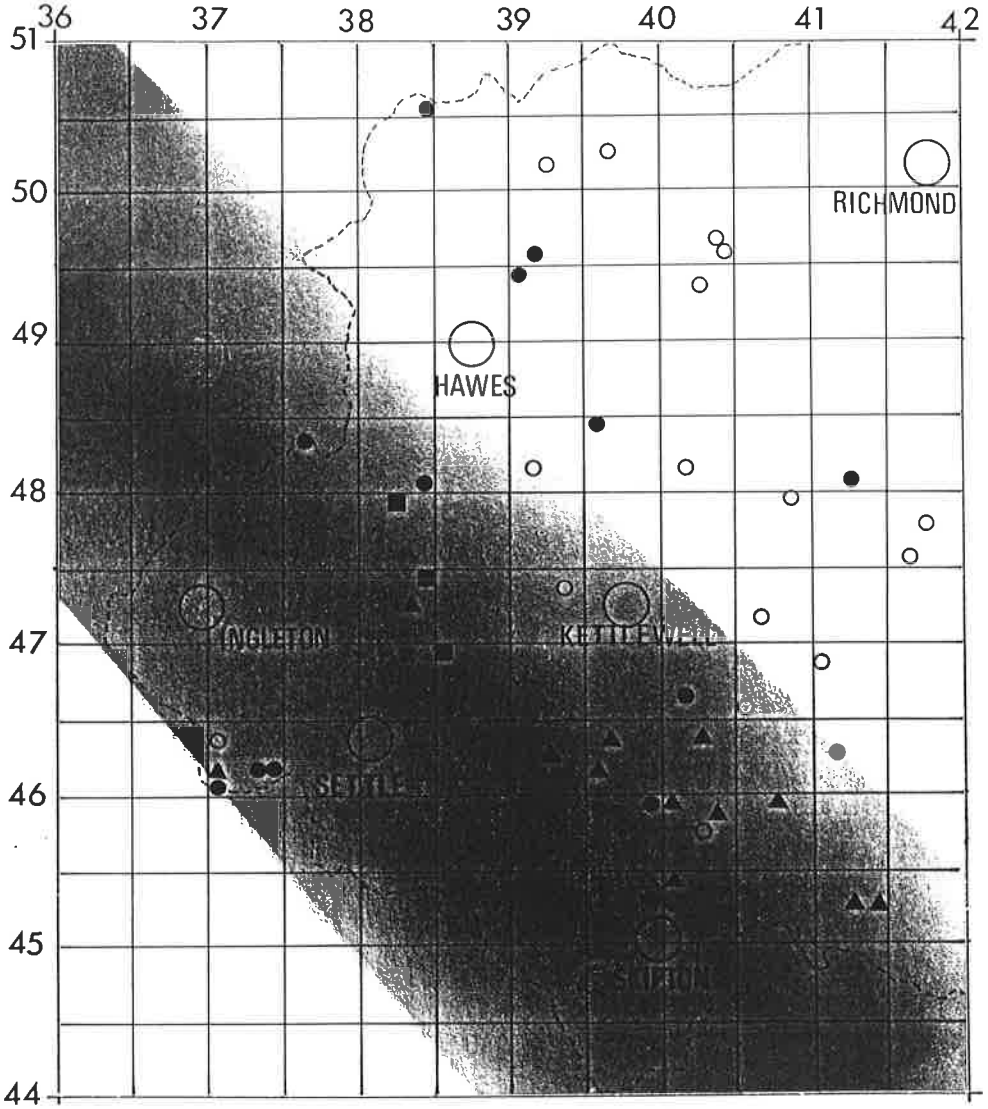
$^{137}Cs + ^{134}Cs$ Bq kg^{-1} dry weight

○ 0-50

● 500-1000

approximate area where rainfall exceeded 10 mmm

Figure 3. Radiocaesium activity concentration of the heather samples.



Key

$^{137}Cs + ^{134}Cs$ Bq kg^{-1} dry weight

○ 0-500

● 500-1000

▲ 1000-2000

■ >2000

Figure 4. Plot of the relationship between the $^{137}Cs:^{134}Cs$ ratio in heather and rainfall

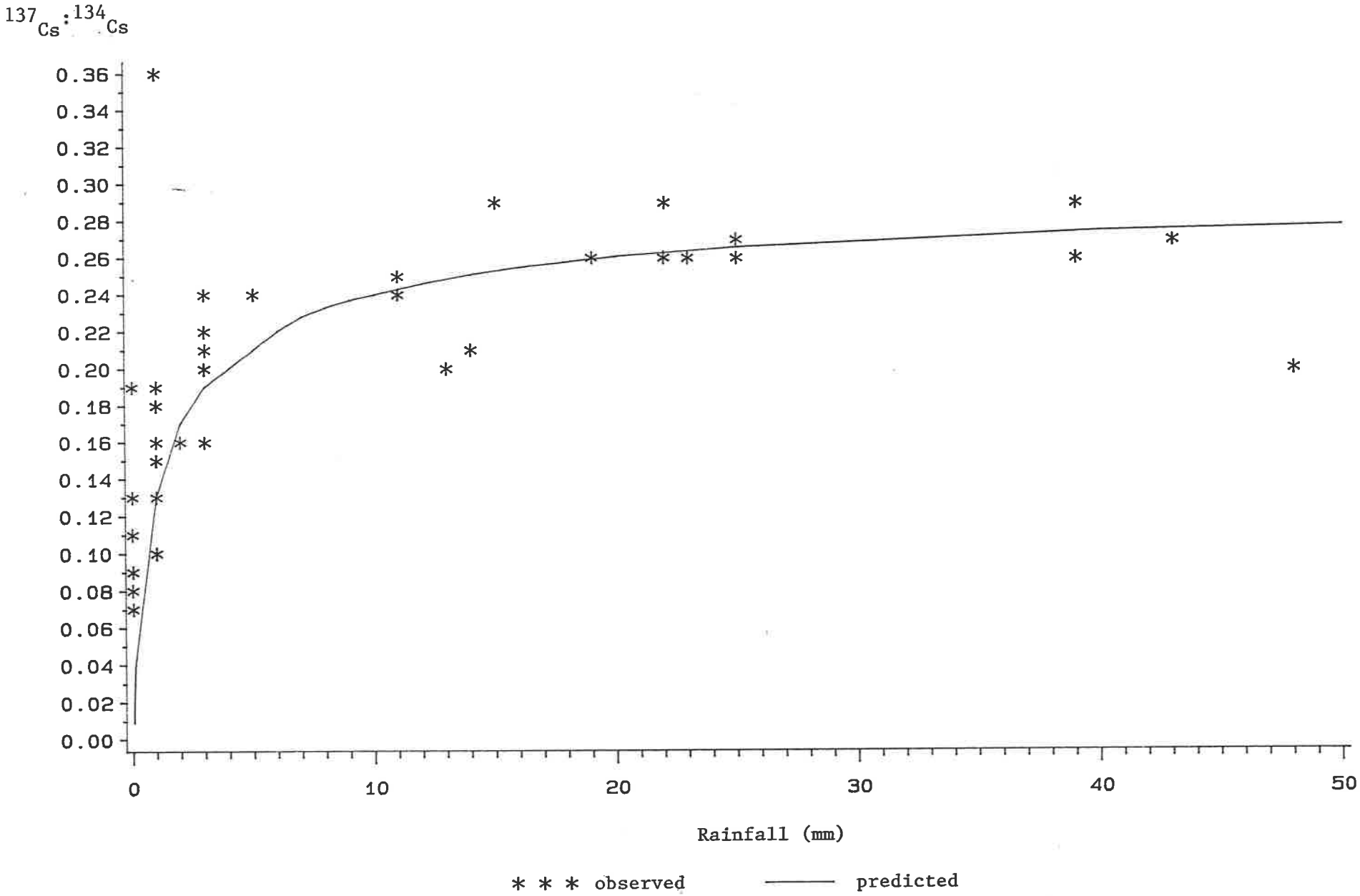
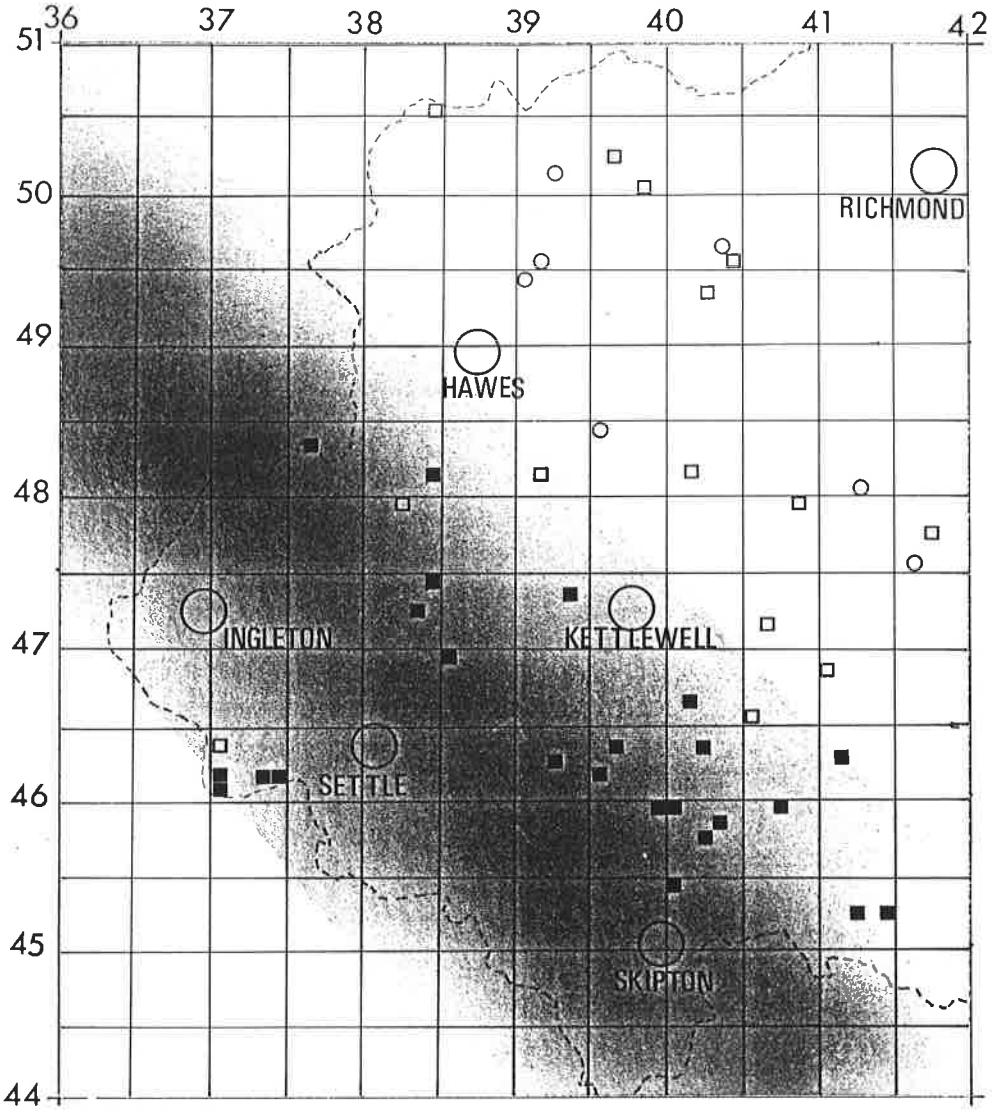


Figure 5. $^{134}Cs:^{137}Cs$ ratios of the heather samples.



Key

■ Ratio dominated by Chernobyl (1:2.8 - 1:5.0)

□ Ratio influenced by Chernobyl (1:5.0 - 1:10.0)

○ Ratio dominated by pre-Chernobyl ^{137}Cs (1:10.0 - 1:15.0)