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The Distribution of Nitrate in the UK Surface Water and its Implication for Calculating Critical Loads: A Preliminary Assessment

R.W. Battarbee, A.M. Kreiser, R. Harriman, K. Bull, A. Jenkins & S.J. Ormerod

A Report for the DoE from the Critical Loads Advisory Group, Freshwaters Sub-Group

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THE DISTRIBUTION OF NITRATE IN UK SURFACE WATERS AND ITS IMPLICATION FOR CALCULATING CRITICAL LOADS: A PRELIMINARY ASSESSMENT.

Report for the Department of the Environment from the Critical Loads Advisory Group, Freshwaters sub-group.

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1. Introduction

Although increased nitrogen deposition is likely to have most serious consequences for soils and vegetation in the United Kingdom, surface waters are also affected, especially in areas of very high N deposition and where uptake by vegetation is reduced. In these areas high nitrate levels contribute significantly to lake acidity and may independently cause changes to the structure of aquatic communities.

2. Methods

As a preliminary assessment of this problem we have used the water chemistry data for UK surface waters being collected for sulphur (S) critical loads (CLAG 1992). So far data are available for Scotland, Wales and parts of England and Northern Ireland. A complete dataset should be available later in 1992.

3. Results

Figure 1 shows surface water nitrate distribution based on a single water sample from either a standing water or headwater stream in each 10 km grid square sampled. Values range from >200 μeq NO_3 l^{-1} to <5 μeq l^{-1}. The most striking patterns are the very low levels of nitrate across most of Scotland north of the central lowlands, with the exception of the Angus area, and the higher values to the south. The low values (<5 μeq l^{-1}) are in good agreement with the recent decision at the Lökeborg meeting to fix background nitrate values at <4 μeq l^{-1}) (Kämäri *et al.* 1992). The higher values are a combination of catchment and atmospheric sources of N because these data do not differentiate between lowland sites, with agricultural catchments, and upland sites, sensitive to acid deposition, with moorland and afforested catchments.

Figure 2 shows the distribution of nitrate values after the removal of non-sensitive sites, conservatively taken here as sites with >200 μeq Ca^{++} l^{-1}. The values now range from >30 μeq l^{-1} down to <5 μeq l^{-1}. On this map only a few sites with relatively high nitrate values remain in Scotland, and these are principally in the Galloway region. Many more sites occur further south in Cumbria, the Pennines, north, central and south-west Wales.

Although it is probable that the nitrate at these sites is predominantly derived from atmospheric sources the main concern about nitrate is its influence at acidified sites. Figure 3, consequently, shows surface water nitrate distribution at sites where the critical load for sulphur is exceeded, according to the diatom model (CLAG 1992). The Henriksen model (CLAG 1992) exceedance plot would be similar, but with somewhat fewer sites. The general distribution of values is not unlike that in Figure 2 except that there are more sites in the Pennines and less in south-west Wales, illustrating the difference in S deposition between those two regions. It is clear in the majority of cases that high nitrate occurs where high excess sulphate also occurs.

In Figure 4 the relative importance of nitrate to the strong acid anion total is shown for all the exceedance sites. This is an indication of the extent to which nitrate levels might interfere with the successful reduction of acidity based on sulphur abatement. Again the values are for the diatom model with exceedance for sulphur plotted against the ratio of nitrate to nitrate plus excess sulphate. Typically nitrate contributes less than 25% to the total acid anion concentration, but 37 squares have values over 20%.

The geographical distribution of sites plotted in Figure 4 is shown in Figure 5, and these are listed in order of relative importance in Table 1. There is a scatter throughout the country but some of the highest values occur in Cumbria and north Wales.

4. Discussion

Although some of these data are provisional and the map for the whole UK has not yet been completed, the data so far support the view that nitrate values in sensitive upland waters, where the main N sources are atmospheric, are well above background levels for many parts of the country. In some cases, they constitute an important fraction of the total acidity.

These observations have both indirect and direct consequences for critical loads research. At some sites an achievement of critical loads for sulphur by the year 2005 may not be possible without a complementary reduction in nitrogen deposition. Moreover as S deposition declines the relative importance of N as a cause of acidity will increase. If the net retention of nitrate within the catchment decreases, the critical load for sulphur will be further decreased, as indicated by the MAGIC model scenario for the Round Loch of Glenhead in Figure 6. Moreover future climate warming might increase the rate of organic nitrogen mineralisation and so decrease the relative net retention of N in catchments, thereby accelerating this process.

The data also suggest that nitrate concentrations in some upland waters may be sufficiently elevated to cause changes to the structure of aquatic ecosystems, not only in contributing to high H^+ and Al^{3+} (especially from mature forest catchments) but also in altering the nutrient balance between nitrate and phosphate. In P limited systems it is unlikely that additional N will cause any major increase in primary productivity but the shift in nutrient ratios might well alter the composition of some communities.

In view of these conclusions we consider it important:

- to incorporate nitrogen in our calculations of critical loads for acidity (already recommended at the recent Lökeborg conference),

- to develop further the MAGIC model to incorporate explicitly nitrogen processes within the catchment and to cater for projected changes in N deposition,

- to measure total P levels at selected sites to assess the likely impact of elevated nitrate levels on primary productivity,

- to evaluate the need to measure reduced forms of N in upland waters, in the context of expected future increases,

- to carry out exploratory studies of the biology of high nitrate streams and lakes in selected regions of the country to assess the impact of high nitrate concentrations on community structure.

Figure 1 Distribution of nitrate values in surface waters

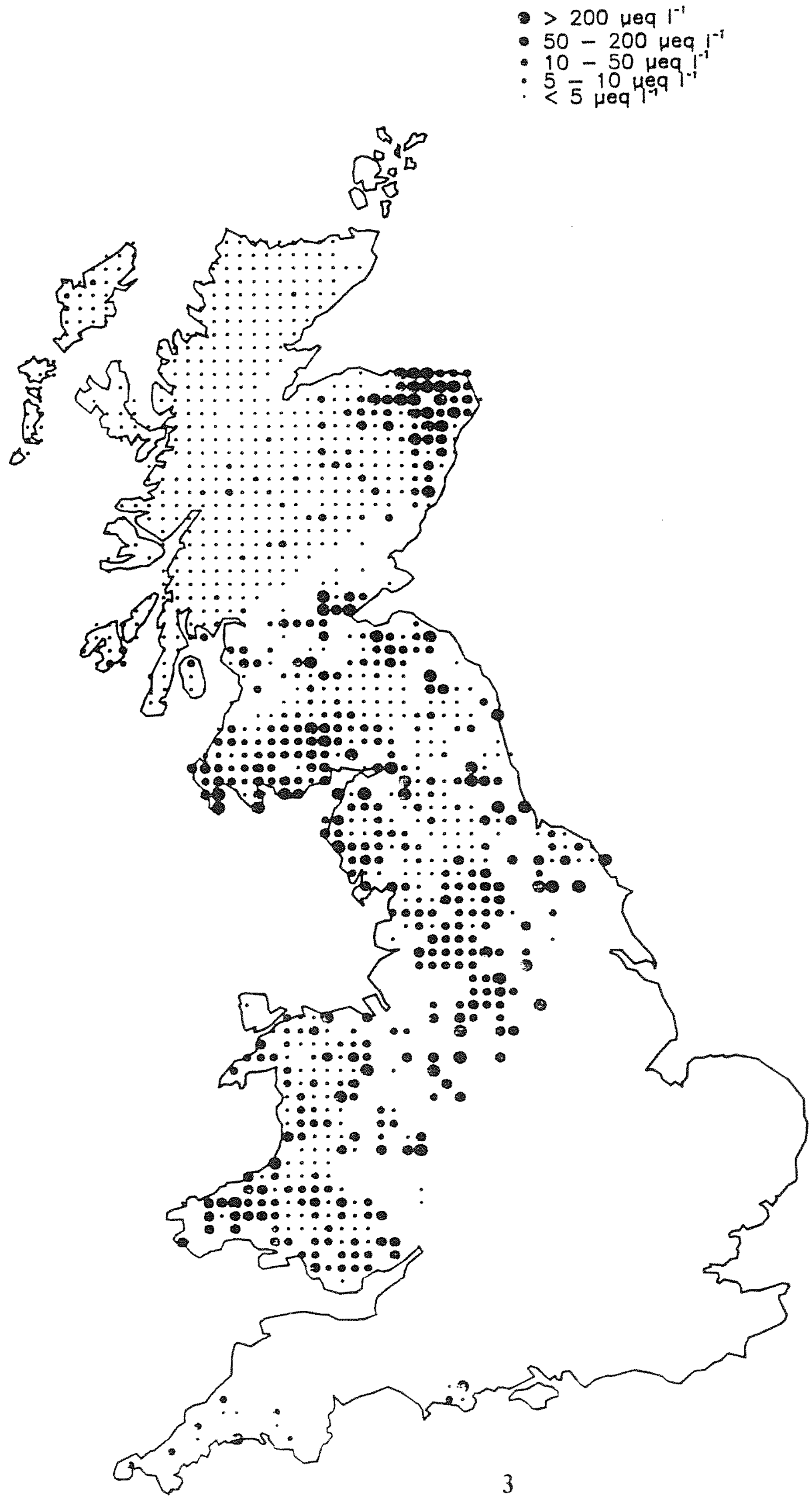

Figure 2 Distribution of nitrate values in 'sensitive' (Ca^{++} <200 μeq l^{-1}) surface waters

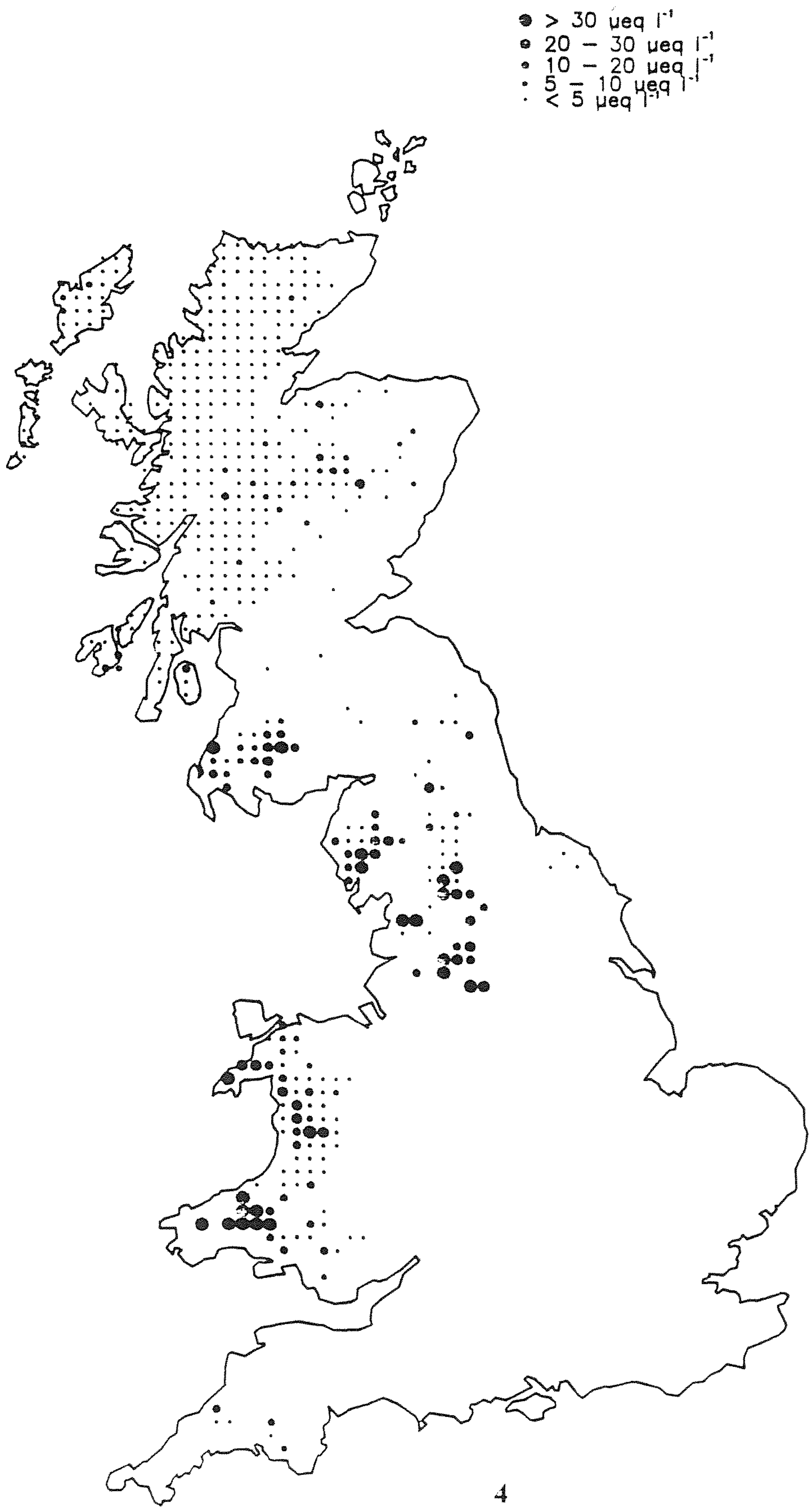

Figure 3 **Distribution of nitrate values in surface waters where the critical load for S is exceeded (diatom model)**

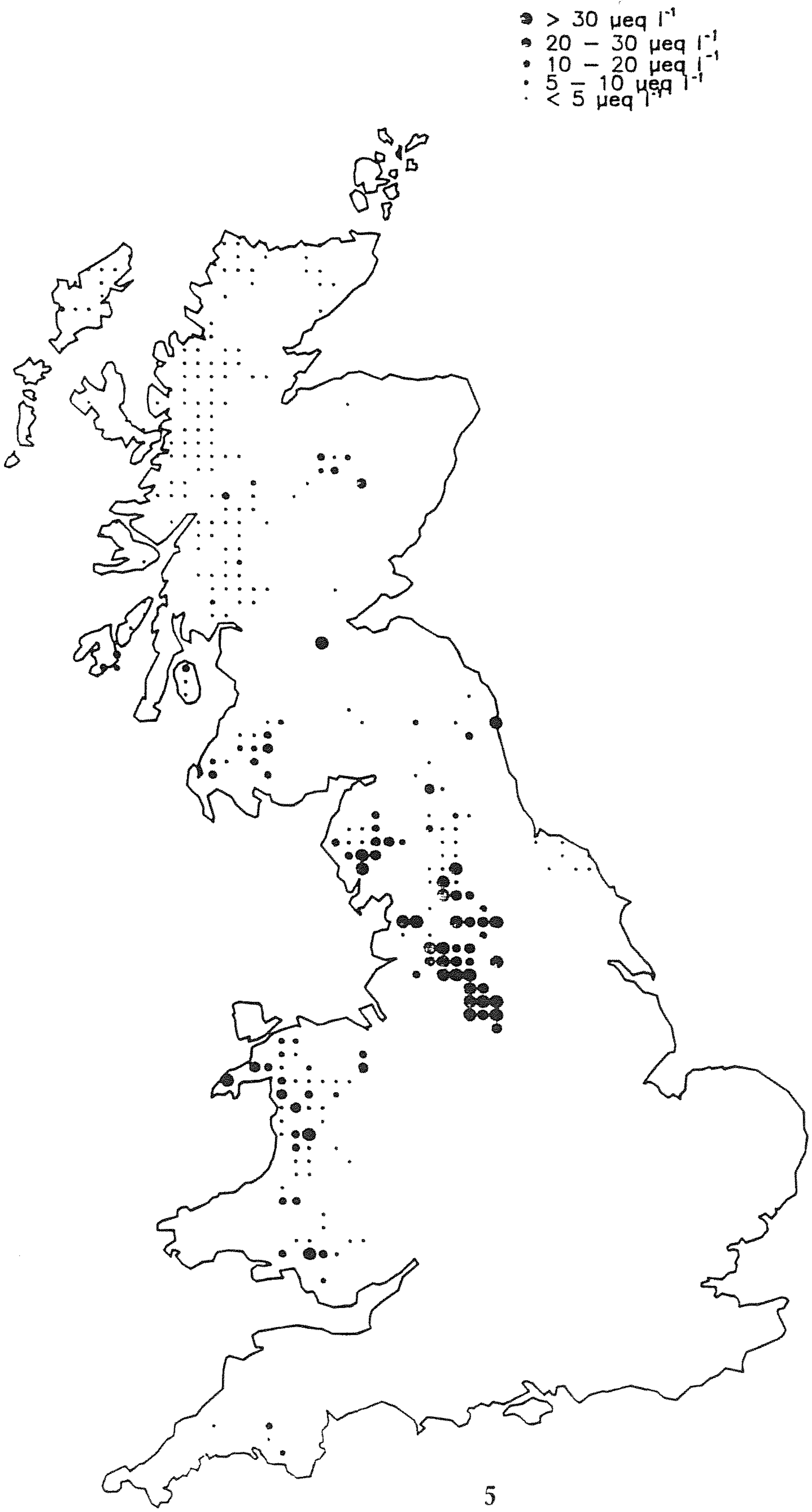

Figure 4 Nitrate as a proportion of nitrate & excess sulphate against critical load exceedance (diatom model)

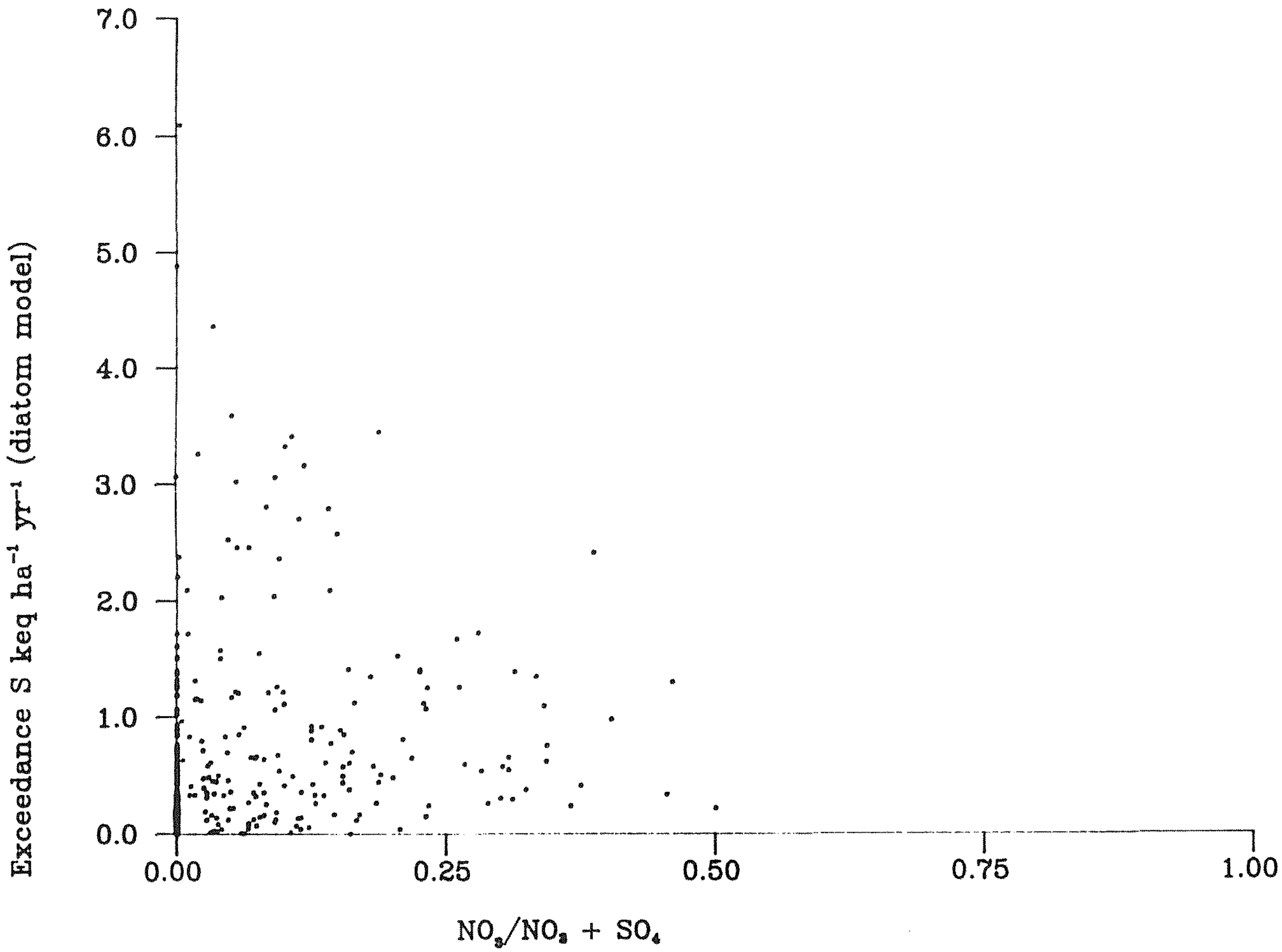

Figure 5 Distribution of nitrate values as a proportion of nitrate & excess sulphate where critical load for S is exceeded (diatom model)

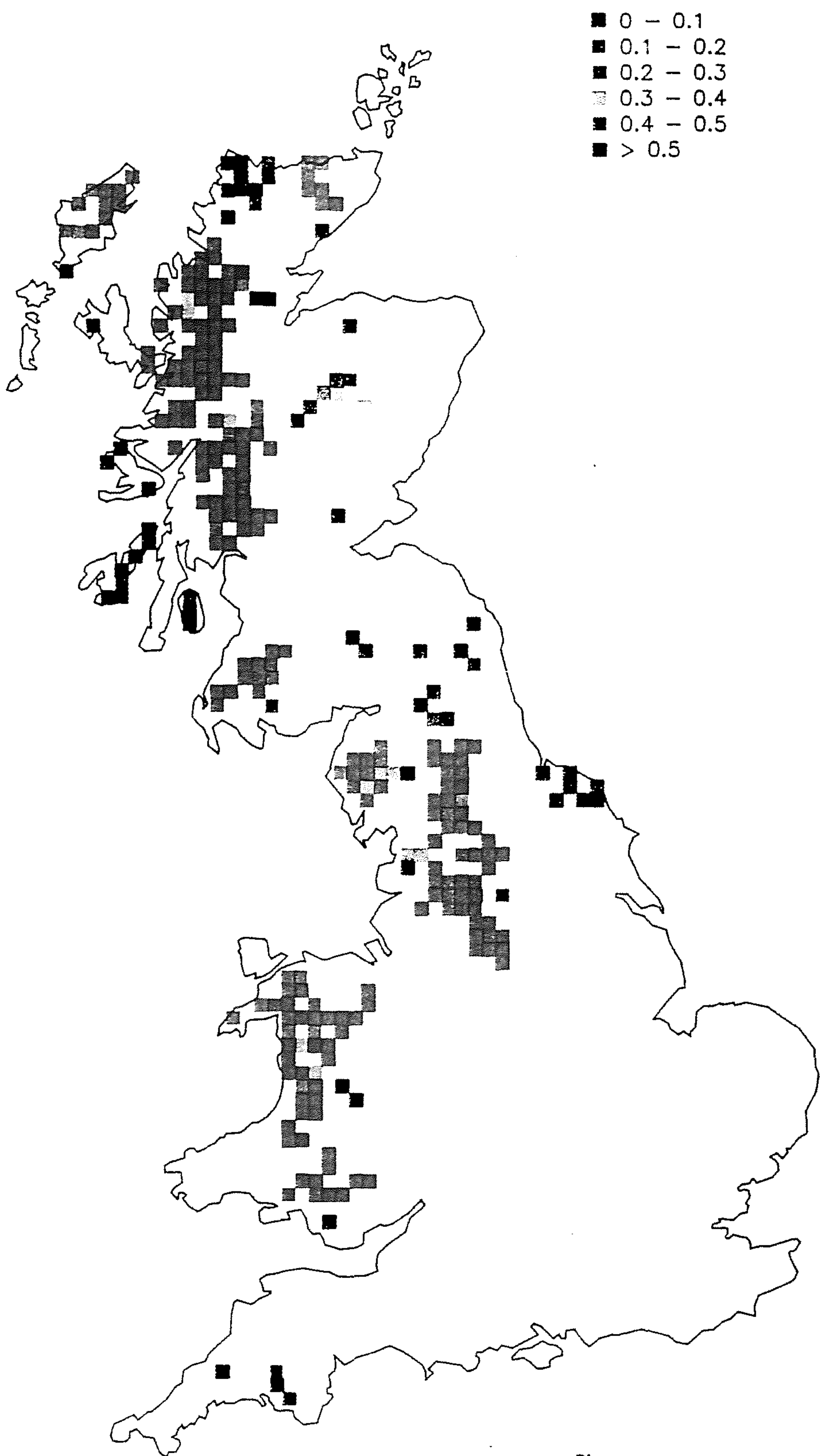

Figure 6 **Magic model scenario for the Round Loch of Glenhead showing effect on critical loads for sulphur of a reduction in nitrate uptake**

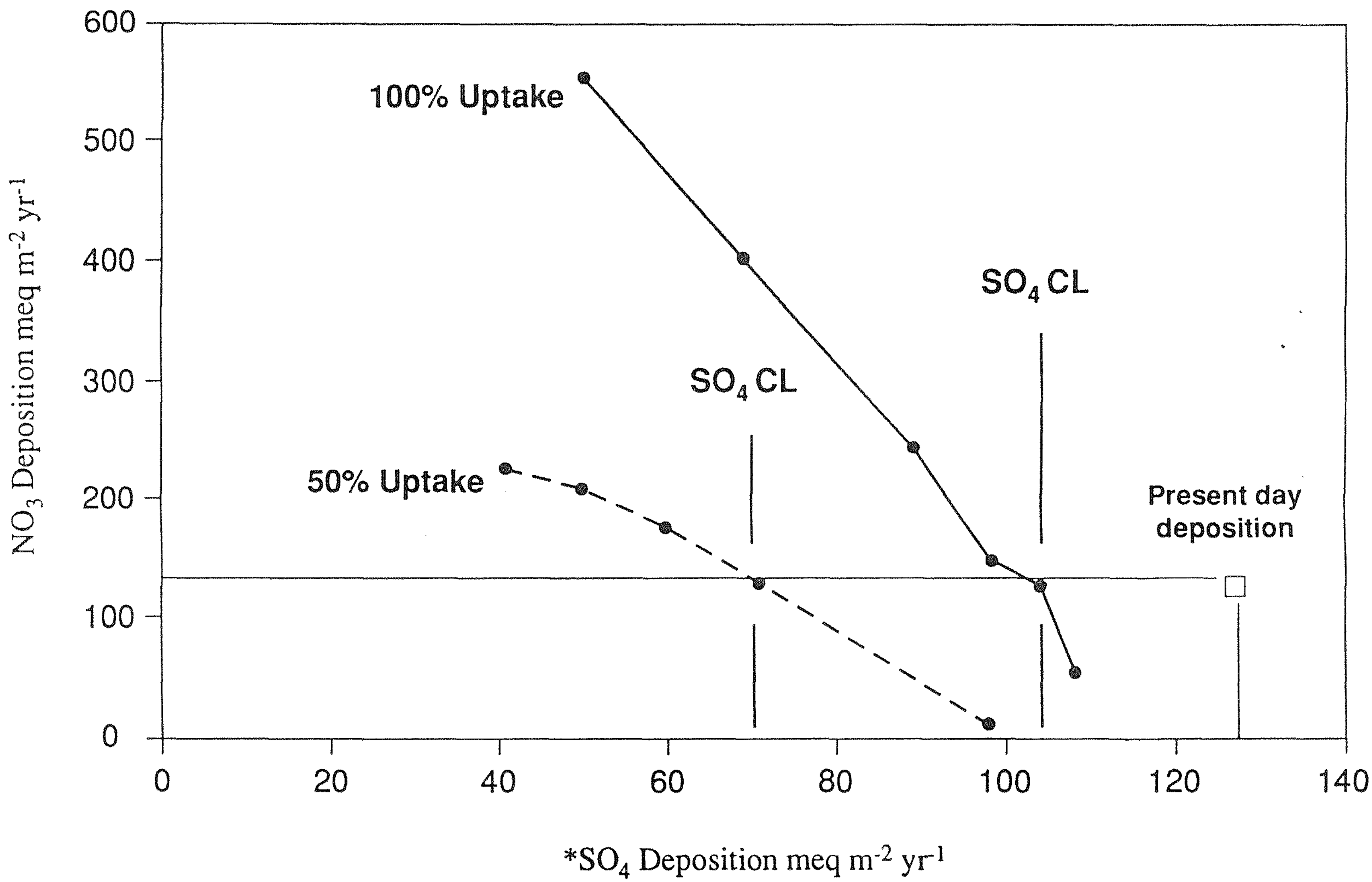

Table 1 **List of sites sampled (grid reference plus name) with nitrate >10% of nitrate plus excess sulphate where critical load (diatom model) is exceeded (see categories >0.1 in Figure 4).**

>50%

NH 316 858	Loch Coire Mhic Mhathain

40% - 50%

SD 279 993	Levers Water
SH 493 495	Llyn cwm Dulyn
SX 658 596	Spurrells Cross Pool

30% - 40%

NG 942 608	Loch Coire Mhic Fhearchair
NG 970 525	Lochan Uaine
NG 977 575	Loch Bharranch
NH 943 004	Loch Coire an Lochan
NN 263 749	'Loch Coire-na Ceannain'
NO 001 981	Lochan Uaine
NO 252 859	Lochnagar
NY 248 060	Three Tarns
NY 272 037	Red Tarn
NY 348 153	Red Tarn
SD 526 574	Damas Gill
SD 612 578	Hare Syke
SD 950 950	Summer Lodge Tarn
SH 707 136	Llyn y Gadair
SN 825 941	Glaslyn

20% - 30%

NH 332 799	Gorm Loch
NN 421 881	Lochan Uaine
NN 959 980	Lochan Uaine
NX 525 844	Loch Dungeon
NY 095 195	Congra Moss
NY 308 087	Easedale Tarn
NY 328 281	Scales Tarn
NY 336 314	Bowscale Tarn
NY 449 107	Blea Water
NY 724 544	Whitfield Lough
SD 868 713	Fountains Fell Tarn
SD 882 821	Oughtershaw Tarn

Table 1 cont.

SD 922 759	Birks Tarn
SH 277 363	Cefn Madryn Stream
SH 664 266	Llyn Hywel
SH 702 656	Melynllyn
SH 867 226	Creiglyn Dyfi
SN 792 877	Llyn Llygad Rheidol

10% - 20%

NB 046 121	Loch Braigh Bheagharais
NB 181 109	Loch nan Learg
NB 218 424	Loch Airigh a' Chreagain
NC 326 448	Lochan na Fraoileige
NC 450 360	Loch Coire na Saidhe Duibhe
NG 792 070	Loch Coire na Caillich
NH 012 106	'Loch Sgurr an Lochain'
NH 240 695	Loch Gorm
NJ 148 037	Lochan nan Gabhar
NN 219 673	'Loch Binnein Beag'
NN 302 219	Lochan Creag nan Caerann
NN 490 750	Loch an Sgoir
NR 401 491	Lochan Sholum
NR 405 505	Loch Uigeadail
NR 942 460	Coire Fhionn Lochan
NS 170 975	Lochain nan Cnaimh
NS 694 048	Polvaird Loch
NX 103 698	Loch Ree
NX 364 866	Kirriereoch Loch
NX 372 855	Kirriemore Loch
NX 446 853	Loch Enoch
NX 469 758	White Lochan of Drigmorn
NX 470 790	Loch Dee
NX 541 698	Loch Grannoch
NX 552 930	Garryhorn Burn
NX 553 928	Halfmark Burn
NX 564 950	Benloch Burn
NY 165 010	Blea Tarn
NY 248 060	Three Tarns
NZ 012 947	Fallowlees Lough
SD 784 384	Churn Clough Reservoir
SD 805 397	Upper Ogden Reservoir
SD 827 195	Scout Moor Reservoir
SD 843 202	Cowpe Reservoir
SD 997 545	Embsay Reservoir

Table 1 Cont.

SE 015 130	March Haigh Reservoir
SE 031 317	Warley Moor Reservoir
SE 038 020	Chew Reservoir
SE 134 040	Snailsden Reservoir
SE 291 249	Ardsley Reservoir
SH 562 499	Llyn Llywelyn
SH 618 557	Llyn Glas
SH 665 321	Llyn Pryfed
SH 678 650	Ffynnon Caseg
SH 827 417	Llyn Arenig Fach
SK 057 883	Kinder Reservoir
SK 170 930	Howden Reservoir
SK 230 905	Strines Reservoir
SN 662 063	Upper Lliw Reservoir
SN 740 932	Llyn Conach
SX 582 705	Crazy Well Pool

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