Health of *Sphagnum* flush vegetation and the conservation of populations of *Drosera rotundifolia* (Round-leaved Sundew)

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1. Background and Objectives

Observations on *Sphagnum denticulatum/S. papillosum* flushes in three localities on the Northern Moors of the Peak District during 2003/04 suggested that there has been considerable peripheral drying of the mires and the consequent reduction in populations of the Round-leaved Sundew (*Drosera rotudifolia*). There are indications that this insectivorous plant, in many ways an icon of a healthy moorland environment, has become rarer in the Peak District since Anderson and Shimwell (1981) noted its presence "in some twenty known localities" in soligenous mires (p.165). Additionally, there is strong evidence that the plant was once quite a common species of the blanket peat vegetation (*ibid*., pp 34, 36). The existing localities provide a reservoir of both sundew and bog-moss species for the future colonisation of the blanket peat habitats as they recover from a century of atmospheric pollution, and their conservation would seem to be of vital importance. The research concentrated on the only three apparent extant populations of *Drosera rotundifolia* in the National Park in Oldham M.B. (SE 0305), Kirklees M.C. (SE 0805) and northern Longdendale, High Peak (formerly Cheshire) (SE 0902). The methodology followed the techniques of the National Vegetation Classification and the type of water sampling and analytical methods used by the MFTF projects led by Drs T.E.H. Allott and M.G. Evans. Field survey was undertaken during two weeks in late April and August.

The major objectives of the project were thus to:

a. attempt an assessment of the actual rarity of *Drosera rotudifolia* and establish accurate baseline population figures in three sites (Section 2);
b. characterise the plant sociology of the *Sphagnum/Drosera* flushes, with particular reference to the association of *D. rotundifolia* with certain species of *Sphagnum* (Section 3);
c. undertake analyses of water chemistry of the spring-fed flushes to characterise pH, conductivity and the major cations (Section 4);
d. identify suitable blanket peat sites for re-introduction through a survey of the distribution of *Sphagnum* species and water chemistry of blanket peats; data for this investigation comes from a complementary research project on a study of past and present land use and vegetation as a key to understanding the distribution of *Sphagnum* species (Section 5).

2. Commonness and rarity

An assessment of the commonness and rarity of moorland plants in the national park is not possible, but it is possible within the county of Derbyshire using data derived from the Derbyshire Records Centre. Details are shown in Table 1, in which selected species are ordered in terms of the numbers of monads (1 km^2) in which they have been recorded; the second column refers to the number of individual records in the database and the third column represents the ratio of monads to records. The first column would seem to be a relatively sound definition of commonness and rarity, but the data demand several additional questions, including -

Does the lower number of records for certain species suggest that fewer botanists see the plants?

Do low ratios indicate species in decline?

What do the figures for *Vaccinium oxycoccus* and *Drosera rotundifolia* indicate?

Why are there so many records and relatively few monads, hence lowered ratios?

Are they simply pretty species that more people want to see?

Is the data a clear indication of species in decline due to the drying of mire systems?

There would seem to be an affirmative response to the latter question.

Table 1. Commonness and Rarity of Moorland Plant Species in Derbyshire
data derived from Derbyshire Biological Records Centre at www.dbrc.freeserve.co.uk/html/plants.html

Species	***Monads***	***Records***	***Ratio***
Vaccinium myrtillus	*528*	*1104*	*0.47*
Calluna vulgaris	*454*	*958*	*0.47*
Juncus squarrosus	*267*	*439*	*0.61*
Empetrum nigrum	*250*	*439*	*0.57*
Eriophorum angustifolium	*231*	*422*	*0.55*
Eriophorum vaginatum	*200*	*354*	*0.56*
Carex nigra	*176*	*303*	*0.58*
Molinia caerulea	*156*	*291*	*0.53*
Erica tetralix	*153*	*252*	*0.61*
Vaccinium vitis-idaea	*125*	*234*	*0.53*
Vaccinium oxycoccus	***94***	***258***	***0.36***
Erica cinerea	*90*	*172*	*0.52*
Carex binervis	*86*	*143*	*0.60*
Rubus chamaemorus	*78*	*151*	*0.52*
Trichophorum cespitosum	*54*	*107*	*0.50*
Narthecium ossifragum	*50*	*97*	*0.52*
Potamogeton polygonifolius	*40*	*86*	*0.47*
.....40 monads/0.40 ratio.....			
Carex curta	*31*	*84*	*0.37*
Carex rostrata	*30*	*92*	*0.33*
Drosera rotundifolia	***27***	***131***	***0.21***
Pinguicula vulgaris	*24*	*82*	*0.29*
Vaccinium myrti x vitis-idaea	*19*	*63*	*0.30*
Menyanthes trifoliata	*15*	*86*	*0.17*
Anagallis tenella	*11*	*63*	*0.17*
Wahlenbergia hederacea	*11*	*52*	*0.21*
Arctostaphylos uva-ursi	*8*	*36*	*0.22*
Huperzia selago	*7*	*40*	*0.18*
Potentilla palustris	*6*	*45*	*0.13*

3. Population sizes. Only one of the three sites under detailed study, at Binns (SE0902) in the Heyden Brook valley, Longdendale (formerly Cheshire) falls within the Derbyshire Flora Project. First recorded in 1978, the site held a population of 1000 individuals of *D. rotundifolia*; in 2003, there were 350 and in 2005, 360. The population clearly fluctuates annually, but there would seem to be a reduction by almost a third of the population size twenty-five years ago. The second population in Issues Clough (SE0805), Kirklees was first recorded in 2005 and had a small population of 30 individuals, whilst the third site, on the side of an overflow conduit at Greenfield Reservoir, Oldham (SE0305), was by far the largest population with nigh on 1200 individuals.

4. Sociological Associations
The communities in which *D. rotundifolia* grows in the Dark Peak are forms of the M6 *Carex echinata-Sphagnum recurvum/auriculatum* mire - specifically M6aii *Carex echinata* sub-community, *Sphagnum auriculatum* variant) – and M21b *Narthecium ossifragum-Sphagnum papillosum* mire, *Vaccinium oxycoccus-Sphagnum recurvum* community (Rodwell 1991)*. The full potential range of sociological affinities in the various bog pool communities of the blanket peats is shown below and one can only surmise that these were the main communities in which the plant was found in the mid-nineteenth century.
(*Since the publication of this work, the nomenclature for certain *Sphagnum* species has changed. *S. auriculatum* has become S. *denticulatum* and *S. recurvum* is now *S. fallax*. The modern nomenclature is used for all future references.)

Details of the habitats and plant communities at the two main sites are as follows.
The mires at ***Binns, Heyden Brook*** (SK 095025, 380-400m) form three main complexes. A Southern mire system comprises a lower mire, 30x8m in area, dominated by *Carex rostrata* and *Carex nigra* with *Eriophorum angustifolium, Sphagnum fallax, Sphagnum capillifolium* and *Polytrichym commune;*there is peripheral *Juncus effusus* and *Molinia caerulea*. A small middle basin mire 10x5m in area, south of a dividing wall is dominated by *Eriophorum vaginatum* and *Vaccinium myrtillu,* with *Sphagnum papillosum* and *Vaccinium oxycoccus.*
A Central mire system, downslope from the three eroding corrugated spurs, c100x40m has a mosaic of communities, originating in *Philonotis fontana/Montia fontana* springhead with seepages and streams irrigating *Carex rostrata/Eriophorum angustifoliun/Sphagnum fallax* schwingmoor (c.70x20) against the backslope of the landslip, with *Equisetum fluviatile, Sphagnum papillosum* and *Vaccinium oxycoccus*. To the north and south the mire yields to *Molinia*-rich *Eriophorum vaginatum/Vaccinium myrtillus* bog. There is another *Carex rostrata/Juncus effusus* community (20x20m) at a slightly lower level adjacent to the main flow of the emergent stream. The Northern mire system is a ribbon complex comprising an upper part, 5x10m long with some chalybeate influence and composed of an *Eriophorum angustifolium/Sphagnum capillifolium/Sphagnum denticulatum* community. The lower part is 10x30 long, east facing, with a 5^{o} slope and with a species-rich *Eriophorum angustifolium/Nardus stricta/Sphagnum denticulatum* community which includes *Narthecium ossifragum, Vaccinium oxycoccus, Juncus bulbosus* and *Drosera rotundifolia*, the latter favouring slightly drier, decaying *Sphagnum* areas.

At ***Greenfield Reservoir*** (SE 030055, 300m) the Sundew is present along a 40m length of the marginal conduit or overflow channel on the north side of the reservoir east of a black pipe crossing the channel. It grows in a large but disjunct population with over 1200 individual flowering spikes in August 2005, on the southwest-facing, sandstone faced wall of the conduit, in carpets of *Sphagnum auriculatum* with some *S. subnitens* and *S. fallax* that are kept moist by seepage from damp *Molinia caerulea* grassland on the slopes above. The greater number of individuals are found in the zone of fluctuating water level and +/- 50 to 100mm above the late summer low level and there is a pronounced association with leafy liverwort turves of *Nardia scalaris* where downwashed mineral soil has accumulated. *Carex viridula ssp oedocarpa* is the most common associate and other species of rare occurrence include *Erica tetralix, Calluna vulgaris* and *Juncus effusus.* The habitat is entirely anthropogenic and the plant does not apparently grow in similar *Sphagnum-Scapania* communities on natural sandstone outcrops by Greenfield Brook. At ***Chew Green, Chew Valley*** (SE 023018, 350-390m) is a series of springs and issues forming flushes down $340^{o}/30^{o}$ slope, some 20m apart, emerging at sandstone/shale boundaries in Kinderscout Grit Series which would seem to have been an original, natural habitat for *D. rotundifolia*. The eastern system has a *Sphagnum fallax/Eriophorum angustifolium* flush which irrigates a community of *Narthecium ossifragum, Carex viridula ssp oedocarpa* and *Carex panicea* dominant. The central flush originates from a *Scapania undulata/Dicranella palustris* springhead and forms a similar community to the eastern flush, but with a little *Sphagnum capillifolium*. The western flush is a complex network of seepage lines also originating in a *Scapania undulata/Dicranella palustris* springhead at c.390m and forming communities in which *Sphagnum auriculatum, Eriophorum angustifolium*, *Narthecium ossifragum, Carex viridula ssp oedocarpa* and *Aneura pinguis* are dominant or prominent.

4. Water chemistry of extant sites
Analyses of the water chemistry of the two main localities revealed quite different and distinct values for all the five components. These values provide indications of the ranges within which *Drosera rotundifolia* might colonise given the opportunity. It is noteworthy that the concentrations of all components analysed are lower in the Binns flushes where there appears to be a problem of survival, than in the Greenfield locality, in which the population is probably the largest in the national park. The data presented below exemplify these features.

	pH	***Ca***	***Mg***	***K***	***Na***

			---------- (mg/l^{-1}) ----------		
Binns, Heyden Brook (n=20)	4.54-5.22	1.20-2.54	0.09-1.05	0.56-1.14	3.24-4.68
Greenfield Reservoir (n=6)	6.50-6.75	5.50-7.10	3.50-3.70	0.75-1.19	8.10-8.20

5. Past and present land use and vegetation as a key to understanding the distribution of Sphagnum *species*.

Species of *Sphagnum* are by no means uncommon in the moorland areas of the Dark Peak. *S. fallax* can be found in many a *Juncus effusus* flush; *S. palustre* is not uncommon in springheads with *Philonotis fontana* and *Dicranella palustris*; *S.denticulatum* is frequently seen in the soligenous or minerotrophic mires associated with these springs and issues; and *S. papillosum* occurs in the mires formed behind many of the major landslides in the region. A key question on which much academic research has focused has concerned the fact that only small quantities of bogmoss are to be found as components of the predominant M20 *Eriophorum vaginatum* blanket peat community, a surprising feature since much of the peat was formed by bogmosses. The cause for the death of dominant peat-formers such as *S. affine* (syn. *S. imbricatum*) is universally accepted as the impact of acid precipitation during the Industrial Revolution of the nineteenth century.

> But one hundred and fifty years on, fifty after the Clean Air Acts, why aren't the various species of *Sphagnum* recolonising the habitat on an extensive scale?
>
> Where and in what type of blanket peat habitats are the species of *Sphagnum* colonising?
>
> What part did direct human intervention play in the last 150 years and how might knowledge of historical effects provide pointers to future management?

The research area comprises a corridor, three kilometres wide and five kilometres long, either side the A635 Saddleworth-Holmfirth road, originally constructed as the Greenfield-Shepley Lane Head Turnpike Trust 1821-30. The road reached Blake Gate at the present Oldham/Kirklees boundary in 1824 and the final section over Wessenden Head Moss had been completed by 1830. The Wessenden Head branch down to Meltham was completed in 1825. In terms of land use history, concomitant with the indirect effects of the Industrial Revolution were several direct human intervention effects – the construction of turnpike roads and the changes in land use via enclosure of common lands and the establishment of grouse moors. At the time of the First Edition of the Ordnance Survey 1843, the land in the corridor fell into five different townships, each with different land use histories, but basically divisible into those townships whose common lands were subject to enclosure acts in the period 1782-1834, and Marsden, in which a great proportion of the moorland remains as common to the present day. For example, the Enclosure Act for *Saddleworth (Lord's Mere)* was passed in 1810, but it was not until 1834 that the Award was published. Featherbed Moss, South Clough Moss and part of Little Moss (320 acres) were awarded to one individual in three lots, whilst Middle Edge Moss and part of Little Moss (1156 acres in one lot, the largest) were awarded to a family from Oldham. Grouse moors were established. *Austonley (Detached No.1)* and *Upperthong*, both originally a part of the Graveship of Holme, were apparently allotted as common pastures by the Holme Enclosure Act 1828. The former was redefined by the Turnpike Trust so that the people of Austonley might fulfil their share of road maintenance and the latter fell into private ownership and was managed as both a grouse moor and sheep pasture from Wessenden Head (Isle of Skye) until the early twentieth century. The commons of *Meltham* were enclosed between 1816 and 1832 and the moorlands granted to six lords of the manor by right of soil (*jus solis*), all of whom proceeded to establish grouse moors. Little Moss and Flake Moss were separate shoots.

Since 2002 the corridor has been systematically fieldwalked, and the types of plant community and the presence of the various species of *Sphagnum* recorded as a primary criterion for more detailed research. Watershedding blanket peats with various species and varying quantities of *Sphagnum* have been selected for detailed analysis according to altitudinal, geological and 'human intervention' criteria:

a. Dean Head Moss (SE 065060) in Upperthong at 519m, underlain by Readycon Dean Series, marginally gully-blocked by the A635 and traversed by a North Sea gas pipeline in the 1970s

b. Featherbed Moss-White Moss complex (SE 046066) in Saddleworth and Marsden at 489-494m, underlain by Kinderscout Grits, traversed by a flagged section of Pennine Way (c. 1992) and the site of current gully-blocking experiments

c. Flake Moss-Little Moss complex (SE 080080) in Meltham at 479m, underlain by Huddersfield White Rock/Pule Hill Grit, marginally gully-blocked by Wessenden Head Road, marginal turbaries and a large central pool probably created artificially as a fire pool.

In many places where there has been direct human intervention in past times, a community in which *Eriophorum vaginatum* forms large (0.3-0.45m), discrete tussocks has developed, particularly where there is some slight surface water movement. Good examples are to be seen at Hoe Grain (SE 062064), south of the A635 – where the road has acted as a major gully block; around the gamekeeper's pools at Wessenden Head Lodge (SE 075074); and north of the former peat cuttings in the Flake Moss/Little Moss area (SE 0790077). All three have varying quantities of *Sphagnum fallax*, *S. capillifolium* and *S. papillosum.* The best example is to be seen within the Flake Moss-Little Moss complex, one of the more diverse areas of blanket peat in terms of its plant communities – M17 *Trichophorum cespitosum-Eriophorum angustifolium*, M18 *Calluna vulgaris-Eriophorum vaginatum* and typical M20 *Eriophorum vaginatum* communities are all present. On Flake Moss at the head of Middle Clough at 479m (SE 081081) is an area comprising a large unvegetated pool (20 x 10m) and a second large pool (15 x 5m) vegetated by *Eriophorum angustifolium*, plus some *Warnstorfia fluitans* and marginal low hummocks (0.3m) of *Sphagnum fallax/capillifolium*. The pools either formed due to the collapse of underlying rocks along a major fault line or were excavated as fire pools. They are linked by an *Eriophorum vaginatum* tussock community with no less than six species of *Sphagnum – capillifolium, cuspidatum, fimbriatum, papillosum, fallax* and *subnitens*. Clearly, there are environments within the peat blankets that are capable of supporting a diversity of bogmoss species. The habitat is totally ombrotrophic, lacking inflow and outflow streams, is fully saturated throughout the year, and its two main components have the following water chemistry (mg/l^{-1} for samples taken monthly from May to September 2005).

	pH	Ca	Mg	K	***Na***	Fe	Al
Sphagnum pool (x = 5)	3.76	0.60	0.56	0.54	***4.08***	0.98	0
Unvegetated pool (x = 5)	4.13	0.66	0.36	0.64	***4.86***	0.37	0

One of the main features of this preliminary data confirms results from ombrotrophic sites throughout the UK, that pools colonised by *Sphagnum* tend to have pH values below 4.0, those lacking *Sphagnum* have higher pH values. Values for calcium, potassium and sodium are lower and those of magnesium and iron higher in the *Sphagnum* pool. Perhaps the most surprising feature is that in both pools, the concentrations of sodium are almost ten times higher than those for any other element.

This feature inspired a more detailed analysis of bog pools on the adjacent Little Moss (SE 081078), a totally ombrotrophic mire with a relatively uneroded surface dominated by a healthy M20 *Eriophorum vaginatum* community. Its surface has a number of ephemeral pools that are flooded after heavy regional precipitation which evaporates after a few days to leave bare expanses of peat, a common phenomenon on many ombrotrophic peat expanses in the Dark Peak. But it also has several sinuous and arcuate permanent pools with the M3 *Eriophorum angustifolium* bog pool community, several filled with the green alga (*Microspora amoena* var *gracilis*), but lacking *Sphagnum auriculatum, S. recurvum* and *S. cuspidatum,* the three species typical of the M1 and M2 bog pool communities. A survey of 30 pools of 150-200 mm depth, >3m long/0.5m wide, revealed algal veils in 21 and growths of *S. recurvum/S. capillifolium/S. papillosum* in association at the margins of six pools. The presence of alga and marginal *Sphagnum* was not mutually exclusive. A similar surface

topography is to be seen on Flake Moss top (SE 078080) but with fewer permanent pools and more ephemeral pools. Further samples of 12 pools, three with alga and one with marginal *Sphagnum papillosum* were taken and the results were as shown below (mg/l^{-1}).

	pH	Ca	Mg	K	***Na***	Fe	Al
All pools (n = 42)	4.08-4.70	0.74-0.90	0.34-0.44	0.18-0.60	***4.08-4.80***	0.48-0.61	0.03-0.18
Algal pools (n = 24)	4.14-4.70	0.74-0.90	0.34-0.44	0.36-0.60	***4.50-4.80***	0.48-0.61	0.03-0.18
Sphagnum pools (n = 7)	4.08-4.14	0.74-0.84	0.34-0.44	0.18-0.36	***4.08-4.50***	0.48-0.61	*0-0.03*

Such pools would seem to be one type of potential receptor site for the transplant of *Drosera rotundifolia.* The past and potential future sociological amplitudes of the species in the Dark Peak would seem to be in the bog-pool communities. The following data on the nationwide distribution of the species in such habitats is derived from (Rodwell 1991).

Bog pool communities	M1	M2a	M2b	M3
Drosera rotundifolia	**II(1-4)**	**III(1-3)**	**III(2-3)**	**I(3)**
Sphagnum denticulatum	**IV(1-10)**	-	-	-
Sphagnum cuspidatum	IV(1-10)	**V(3-10)**	III(2-7)	II(1-6)
Sphagnum fallax	I(8-9)	-	**V(2-10)**	I(4)
Vaccinium oxycoccus	-	-	**V(1-5)**	-
Eriophorum angustifolium	IV(1-7)	V(3-9)	V(1-9)	**V(3-9)**

But there would seem to be a problem in that many features of the water chemistry fall below the lower limits of the current habitats of the plant in the Dark Peak and alternative habitats should therefore be sought. Three such habitats in the immediate vicinity of the bog pools proved to have water chemistries that fell within the range of extant sites, at Harden Moss (SE), Magdalen Springs (SE ??) and the Isle of Skye Quarry (SE ??) Their details are as follows.

	pH	Ca	Mg	K	Na
Flake Moss/Little Moss (SE 080080)					
1-Sphagnum pools *(n=17)*	4.08-4.14	0.74-0.84	0.34-0.44	0.18-0.36	4.08-4.50
5-Sphagnum pool *(n=8)*	3.76-4.00	0.60-0.70	0.48-0.56	0.50-0.54	4.08-4.50
Harden Moss (SE 100090)					
S. denticulatum flushes *(n=6)*	4.49-4.72	1.20-2.04	0.07-0.92	0.52-0.96	2.52-4.44
Magdalen Springs (SE 093082)					
M6aii flushes *(n=4)*	6.91-7.58	5.62-13.5	3.50-8.50	1.00-1.52	5.62-7.75
Isle of Skye Quarry (SE 088078)					
Colonising pools *(n=5)*	4.74-6.80	1.50-7.04	0.95-5.60	0.50-2.00	5.64-13.75

6. Some conclusions and pointers for future work by the MFTF programme

- This primary survey has yielded a baseline data set relating specifically to the status of *Drosera rotundifolia* in two field sites in the Northern Moors area of the Dark Peak District, upon which a programme of future monitoring might be based. The data suggests that the species is in decline due to the desiccation of mire systems and its modern habitats are soligenous mires and man-made habitats, marginal to its former ombrotrophic blanket peat habitats.

- Analyses of certain features of the water chemistry of ombrotrophic bog-pools suggests that such sites are unsuitable as receptor habitats for the transplant of *Drosera*, even though there are healthy and often specifically diverse carpets of *Sphagnum* species. Such sites and a range of several other habitats with suitable water chemistries would recommend the inception of a broadbrush transplantation experiment as a test of the gradual recovery of the upland environment fron the effects of acid precipitation.

- In relation to this potential programme, it is interesting to note that several species of peat-forming bogmosses will grow in certain types of modified blanket peat environments, particularly in areas that have been traditionally managed for grouse shooting rather than sheep grazing. Future practical

programmes to encourage widespread bogmoss recolonisation should therefore concentrate on ungrazed moorlands.

- Such environments are typically tussocky growths of *Eriophorum vaginatum* the formation of which has been encouraged by major human interventions, such as the construction of roads and metalled footpaths, and by peat cutting. The present programmes of gully-blocking should selectively aim to recreate this type of environment and should be augmented by turbary and hydrological bund construction.

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