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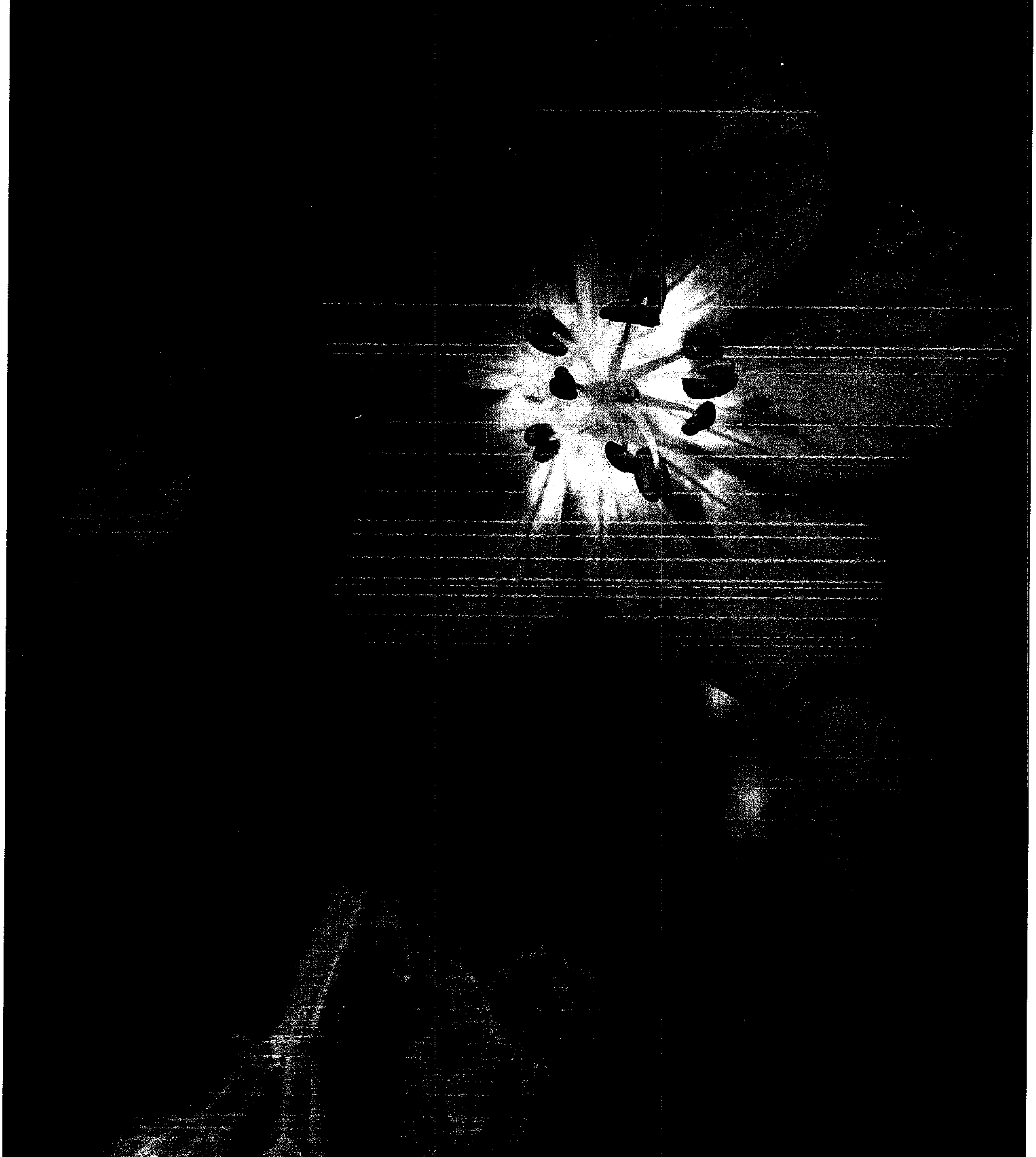
UNDERSTANDING TO ALL

HOW MUCH IS THERE STILL TO LEARN?



The Malham Tarn Research Seminar

18th – 20th November 2005

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Cover photograph of Wood Cranesbill by Robin Sutton

FOREWORD

The 2005 Seminar "How much is there still to learn?" drew out a fascinating series of presentations by a widely experienced group of authors; from Robin Sutton and Tim Wilson explaining how the Field Centre works with Biology and Geography students to Katherine Hearn describing the National Trust work on catchment management in Upper Wharfedale. Attendees gained a wide ranging insight into the activity that is taking place around Malham Tarn.

Two facets of research work were more strongly represented than at previous seminars- Geology and Archaeology. These were key areas of interest for Arthur Raistrick, in whose honour the newly refurbished Tarn House Tea Room was formally opened by Robert White, archaeologist for the Yorkshire Dales National Park Authority.

As usual most of the proceedings mainly present abstracts of papers that will be published elsewhere. The publication of the whole paper by Bryan Wheeler, Sue Shaw and Roger Meade is a departure from the norm that presents a paper cutting across many areas of common interest. It poses questions that could be answered from a number of disciplines, for this reason it is included whole.

The Abstract for Tom Nash's thought provoking talk on Science and Art does not contain the images he used as there are various printing and copyright issues that proved too challenging to overcome.

Once again the work of the Cowside Beck Research group featured at the weekend and the second Cowside Beck Research report has since been published: the first edition by the Field Centre with a more recent second edition published as an occasional paper by Field Studies Council Publications Unit. Another publication by the Centre that will be taken up through FSC Publications is the "Malham Tarn Bird, Butterfly, Dragonfly and Weather report" for 2006, written by Brian Shorrocks with photographs by Robin Sutton. All of these are available from the Centre or from the Field Studies Council website section on Malham Reports: www.field-studies-council.org/malhamtarn/reports

Once again thank you to all contributors and attendees. In 2007 we celebrate the sixtieth birthday of Malham Tarn Field Centre - some regular attendees have been visiting and studying the place for longer than that. The Fifth Malham Tarn Research Seminar takes place over the weekend of November 16-18th 2007. I hope the 2007 seminar will allow our most experienced contributors to reflect on the changes they have seen and for everyone to consider possible events of the next sixty years. Ideas for contributions or contributors who I should invite will be gratefully received.

Adrian Pickles
Head of Centre, Malham Tarn, February 2007

ACKNOWLEDGEMENTS

All contributors and attendees
Keith Orrell for chairing the sessions
Malham Tarn Field Centre Staff for looking after us so well
Robin Sutton for the cover photograph
Elizabeth Judson for compiling proceedings and co-ordinating the weekend
Douglas Richardson for sending the first round of his data set as promised

The Fourth Malham Tarn Research Seminar

HOW MUCH IS THERE STILL TO LEARN?

Friday 18 – Sunday 20th November 2005

A series of talks, displays and discussions about landscape, conservation and the future, hosted and supported by the Field Studies Council at **Malham Tarn Field Centre.**

Work presented at previous Malham Tarn Research Seminars has highlighted changes in our understanding of this well studied area. On national and local levels significant changes are occurring in the way the landscape is used and managed. The impact of these changes will only be known if a suitable programme of research activity is taking place.

Malham Tarn Field Centre is the focal point for teaching and research activity in the Malham area. Thus the Centre educates students about what is currently known but needs to remain involved with the new understanding that comes from research and monitoring.

"**How much is there still to learn?**" is intended to bring together anyone with an ongoing interest in the area to identify what is already known and what needs further or new investigation.

Objectives

- Sharing a baseline of understanding about how the landscape has evolved as a result of the geology, geomorphology, ecology, archaeology and current human activity
- Identifying gaps in our shared understanding of the landscape
- Establishing priorities and opportunities for research and monitoring
- Considering appropriate systems for management and co-ordination of research

This meeting is open to anyone amateur, professional, local or international who is interested in this unique area. Attendance can be on a residential or daily basis. The seminar will take the form of paper presentations, static displays, discussion groups and walks.

PROGRAMME

Friday

Welcome and introduction *Adrian Pickles and Keith Orrell*

Cowside Beck Project *Michael Proctor*

Our hidden landscape *David Hodgson*

In the footsteps of Oliver Gilbert *Douglas Richardson*

Saturday

What is the accepted story?

What do we tell the children? *Robin Sutton, Tim Wilson*

What is happening on Malham Moor? *Martin Davies*

Malham Moor the designation situation *Paul Evans*

Hydrology and history

Some ecohydrological questions about the Malham Tarn mires *Bryan Wheeler and Sue Shaw*

How Goredale Beck has provided clues to the past 2 billion years of Earth history *Allan Pentecost*

The Malham Tarn Sedimentary cores: an introduction to the Fossil Record *Pietro Coletta*

Climate and ecology

Long term ecological trends in Malham Tarn *George Hinton*

Malham's Vascular plants - What is left to find out? *Paul Ashton*

Hay meadow production at Newhouse Farm *John Rodwell*

Current species research

White clawed crayfish in Northern England *Paul Bradley*

Comparative analysis of three adjacent vegetation areas at Malham Tarn NNR *Sue Willis*

New research on the Dark Green Fritillary in the Yorkshire Dales National Park *Terence Whitaker*

The mollusca of the Malham Tarn Estate *Adrian Norris*

New light on archaeological and geological history

Interim results: Yorkshire Dales Karst Depression Survey *Margaret Marker*

Re-thinking the archaeology of Victoria Cave *Tom Lord*

Art and Science is there surface tension? *Tom Nash*

Sunday

The Way Ahead

Asbian-Brigantian boundary facies change on the southern Askrigg block *Marion Dunn*

Recent National Trust initiatives in the Malham Area and the gaps we see in them *Katherine Hearn*

Some thoughts on availability of data *Douglas Richardson*

Moving research work forward

Poster and table displays - *Judith Allinson, Cynthia Burek, Steve Gill, Helen Goldie, Margaret Marker, Mike Samworth*

Renaming of Tea Room in honour of Arthur Raistrick.: Arthur Raistrick in the Dales - *Robert White*

IN THE FOOTSTEPS OF OLIVER GILBERT - THORAGILL BECK

Investigations into the water chemistry, flora and fauna of Thoragill Beck and its immediate environs along the lines proposed by the late Dr. Oliver Gilbert for the Cowside project are being carried out by a small group of enthusiasts. We dedicate this work to the memory of Oliver: those of us who had the pleasure of working with him in the field retain a special affection for him. What follows is a summary of the work carried out between January and the end of October 2005.

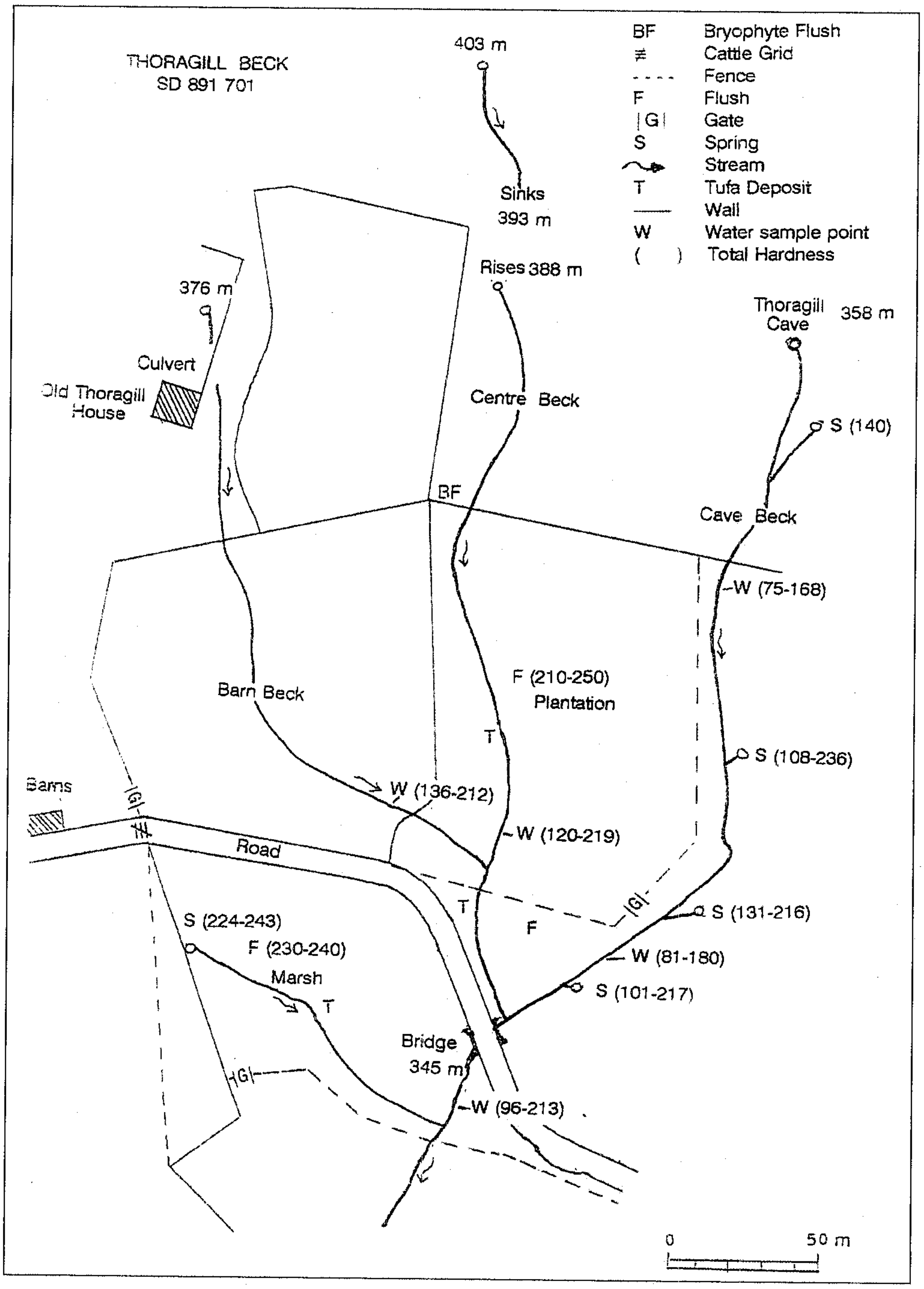

Fig. 1

Thoragill Beck, length 0.8 km, is a minor tributary of Cowside Beck which originates as three separate streams between 376 and 403 m O.D. on the lower S.E. part of Fountains Fell. There is also a small plantation, a marsh and a number of springs. Investigations have been restricted to the upper 0.4km of the system (Fig.1). For ease of identification the becks have been allocated the names Barn, Centre and Cave.

Water chemistry: Conductivity and temperature readings have been taken once a week and samples for chemical analysis once a month from three stations along cave beck and one each on barn and centre becks. To take but one parameter, the figures for total hardness show that the barn and centre beck are very similar and have a consistently higher total hardness than cave beck.

Barn beck ceases to flow during dry spells and all three respond to rainfall with flow rates reaching flash flood proportions. Following rain, the cave beck water shows an immediate drop in hardness, but there is a delay before the effects of dilution are obvious in barn and centre becks. This occurred between March and May and again, to a much lesser degree, between July and August, where the hardness increased before the fall. This poses the question what is happening underground?

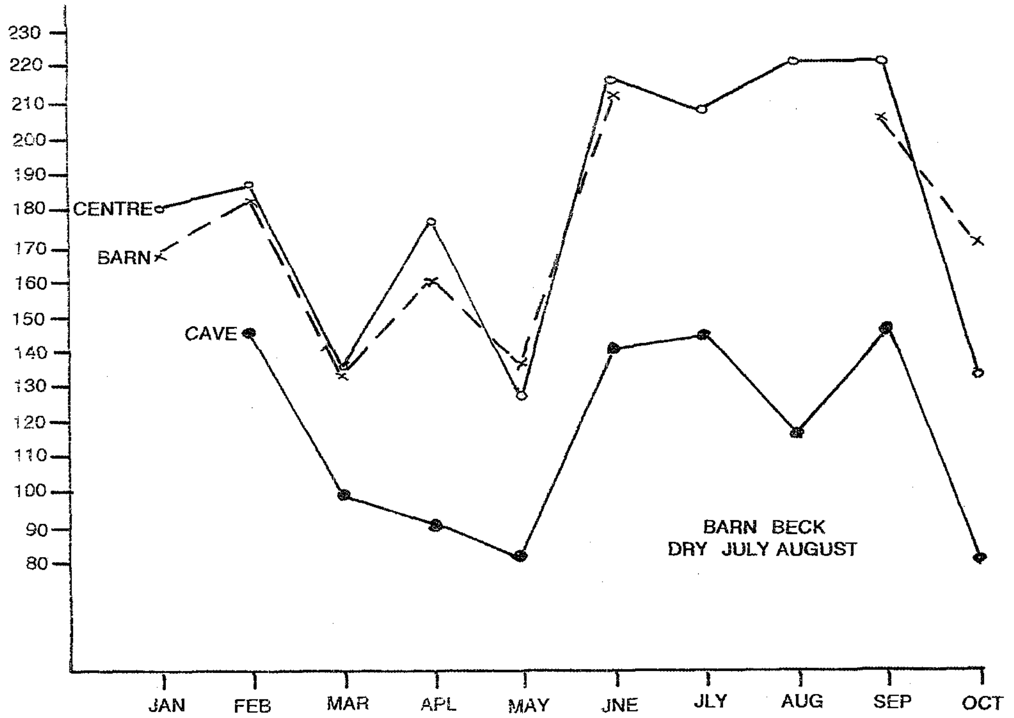

Fig 2

Barn and centre becks have deposits of tufa; there are no deposits in cave beck.

Of the four springs discharging into cave beck only the three along the lower part of the beck have been sampled on a regular basis, these have, for convenience, been named lower, middle and upper. The fourth is situated approximately 50 m below Thoragill Cave and, at the time of writing, has only been sampled once. The springs react rapidly to rainfall and during drought the upper and lower ones cease to flow.

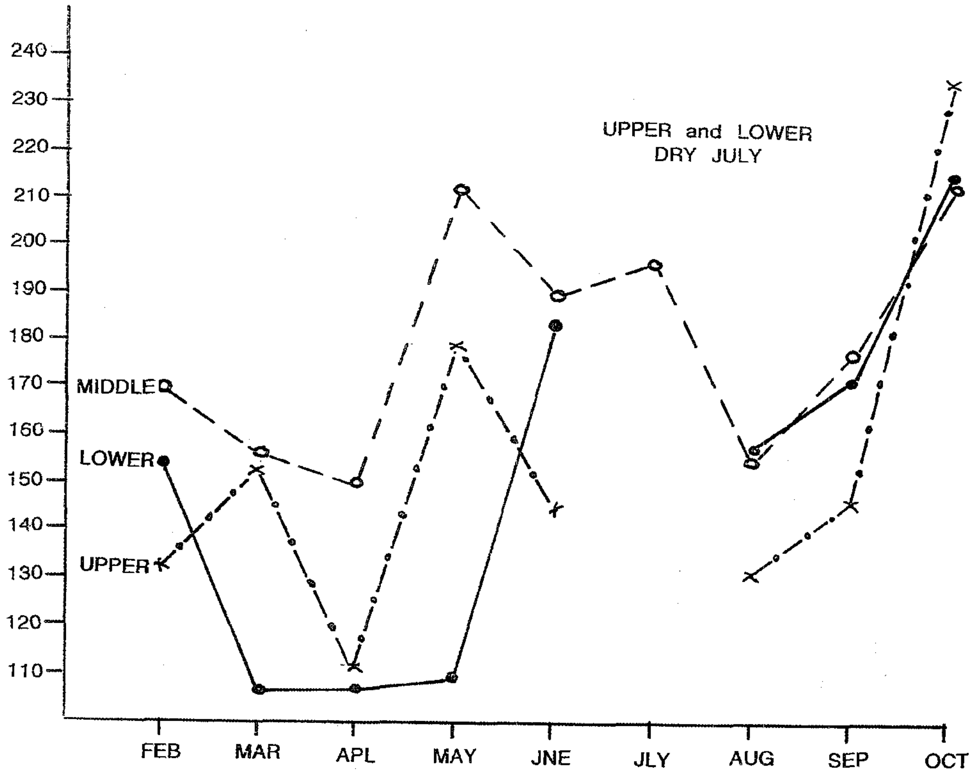

Fig 3

There is a highly calcareous tufa depositing spring on the marsh. There are also a number of calcareous flushes in the plantation (total hardness 210 - 250) and in the marsh (hardness 230 - 240) all of which are actively depositing tufa.

Aquatic invertebrates: Twenty eight species of aquatic invertebrates have so far been identified, they include the triclad Crenobia alpina, amphipod Gammarus pulex, 1 ostracod, 2 mayflies, 6 stoneflies, 8 caddis, 4 molluscs, 2 diptera and 3 water beetles.

These have been found in different, possibly species specific locations: C.alpina has only been found amongst the watercress in the lower spring and under stones in the marsh streamlet. The Caddis Beraea mauris is found in the watercress choked springs. Melamophylax mucoreus is found in large numbers in all the streams: interestingly the only British lake it is found in is Malham Tarn. The watercress beds of the cave beck streams are the only sites where the mollusc Pisidium personatum and the Cypris sp. Copepods have been found. The beetle Riolus subviolaceus is only encountered beneath tufa encrusted stones of the centre stream. There is a good deal of research still to be done on the habitat preferences of individual species.

Aquatic flora: Not much time has been spent on this aspect but of note is the presence of the alga Chara vulgaris in runnels in the marsh, Rivularia biasolettiana in the marsh and centre stream and Nostoc commune in a flush between the road bridge and plantation.

The small plantation, planted in the 1980's (125 x 100 m i.e.1.25 hectare), has turned out to be the jewel in the crown. It consists mainly of larch of 20 -25 years of age, dense in the north-east corner and down the east side, which seems to have failed in part. The stream and west side is devoid of cover and has luxuriant vegetation, a few recent plantings of larch and rowan have been made in this area and there are also a few birch, sycamore, and ash. There are several limestone exposures and calcareous flushes, and extensive deposits of travertine on stones in the stream. Whilst most of the plant species in this area are neutral to calcicole the presence of Molina caerulea (Purple Moor-grass) in small patches indicates a build up of acid humus.

Flora: Sixty six species have so far been recorded, of note are the fine stands of Cowslip, Bird's-eye Primrose, Grass-of-Parnassus, Butterwort, Saw-wort, Fragrant and Common Spotted-orchid.

The variety of flowering plants, coupled with the south facing aspect is possibly the reason for the wealth of butterflies, despite the altitude 350 m O.D. The following 10 species have been recorded: Red Admiral, Small Tortoiseshell, Peacock, Small Skipper, Large Skipper, Large White, Green-veined White, Common Blue, Meadow Brown and Small Heath, there are also eight species of mollusc.

There is little doubt that some form of management/conservation is needed if the plantation is to be kept in good condition e.g. there are a number of dead larch and a lot of brash which if removed along with selective thinning of the larch, particularly in the N.E. corner, would go some way to improving ground vegetation and a watchful eye should be kept on the walls and fences if the indigenous chainsaw- jawed sheep are to be denied access. Examination of the adjacent fell side has added a further 8 molluscs, 43 flowering plants, ferns and sedges, 21 birds, and three mammals to the lists.

How much is there still to learn? Investigating the lower reaches of the beck, the effect of flash flooding, species habitat preference, lichens, fungi, plant galls, other arthropods, arachnids, insects, moths and perhaps give consideration to putting up bird and bat boxes. I am sure Oliver would have approved.

Acknowledgements
The National Trust for sanctioning access to the area; Mr Hall of Darnbrook Farm for letting us roam willy-nilly over his land; David Hodgson for his unflinching weekly sampling of the streams, lists of birds, lepidoptera and mammals; Tom Bailey for list of plants and detailed notes on the plantation; Adrian Norris for his list of mollusca.

Author: Douglas T. Richardson

ECOHYDROLOGICAL CHARACTERISTICS OF THE MALHAM TARN MIRES

Description

Malham Tarn is a large (62 ha), shallow (*c.* 3 m deep), more-or-less isodiametric upland lake at about 375 m aOD, located some 3.5 km north of Malham village and 7 km north-east of Settle. It occupies a broad basin formed from steeply-rising slopes of craggy limestone fells along the northern boundary, rising to some 525 m aOD, and from low, subdued hills around much of the western, southern and eastern sides. These hills appear to be fluvio-glacial deposits and include rounded, drumlin-like kames and small esker-like deposits (Clark, 1967).The lake is fed in the north-west corner by a spring-sourced stream which rises some 1.3 km west of the tarn at about 402 m aOD (and has been variously referred to as the Inflow Stream (Proctor, 1974), Tarn Beck (Pentecost, 2000) and Cow Beck (Proctor, 2003)) and by a smaller stream which enters the north-east corner sourced from springs near the foot of Great Close Scar. There are also thought to be submerged springs along part of the steep northern margin of the Tarn. The Tarn drains from the southern corner southwards to a sinkhole about 1.5 km north of Malham Cove. Its water level was apparently raised by about 1.3 m in 1791 by the construction of a dam at the outflow (Holmes, 1965).

The mires considered here include three discrete areas of wetland broadly associated with the Tarn. (1): Tarn Moss is a large area of mire along the western side of the Tarn. It is primarily an ombrogenous bog but has some substantial areas of base-rich fen, in the lagg and especially along the northern edge of the site where small streams flow through the mire and into the Tarn. (2): Ha Mire is a quite large area of gently sloping mire alongside part of the eastern side of the Tarn. It mostly slopes down towards the Tarn, but towards its eastern edge it spreads over a shallow watershed, so that the easternmost part of the mire drains south-eastwards into the catchment of Gordale Beck. (3): Great Close Mire is an area of flushed, wet grassland and soligenous fen towards the head of the Gordale Beck valley. It is located east of the Tarn watershed and has no real connection with the Tarn system. It is included here with the other mires because of its proximity to them and because previous workers have considered it part of the Malham Tarn wetland resource (*e.g.* Sinker, 1960).

Tarn Moss and Fens

Tarn Moss and associated fens occupy an area of *c.* 39 ha. Much of this area is covered by Tarn Moss, an ombrogenous surface which has developed over and within a kame and kettle complex which once produced several small islands within the shallow western end of the original Tarn basin. In some respects it is perhaps better regarded as a 'ridge-raised mire' (*sensu* Moore & Bellamy, 1974) than as a 'raised mire', though it is generally referred to as a 'raised bog'. The Moss is flanked on its southern and western sides by a mostly narrow, but more-or-less continuous lagg, which separates the ombrogenous surface from the rising slopes of the adjoining mineral ground. However, the largest area of fen (the 'North Fen') is located between the northern edge of the ombrogenous deposit and the northern margin of the mire, alongside spring-sourced streams which flow in from the south-west, west and north, and which discharge eastwards into the Tarn. The eastern edge of the ombrogenous area borders directly, and abruptly, upon the Tarn, forming a low cliff of peat some 1–3 m high. Pentecost (2000) has suggested that this is currently eroding back at a rate of *c.* 7 cm a^{-1}, apparently in response to the increase in water level in 1791. For most of its length it is not separated from the Tarn by an interface of minerotrophic vegetation (and there is generally very little hydroseral colonisation of the Tarn margins, except very locally in sheltered situations, such as at the mouth of the Tarn Beck). Cooper & Proctor (1998) suggest that the rise in water level that followed the damming of the Tarn in 1791 may have flooded about 1 ha of fen at the mouth of the Tarn Beck, and a band of fen some 30–40 m to the east of Spiggot Hill.

Towards the southern side of Tarn Moss, the ombrogenous surface is punctured by a small, tree-covered hill (Spiggot Hill). This was interpreted as a drumlin by Pigott & Pigott (1959) and – one suspects reluctantly – by Clarke (1967), but it appears to be a fluvio-glacial deposit comparable with the low hills the south. The hillock is surrounded by a band of minerotrophic vegetation, which is particularly well-developed (and wet) along the north-western side. From this point a broad minerotrophic soakway flows north-north-west across the ombrogenous surface, becoming narrower and more obviously ditched further north, to feed into the North Fen. Recently some dams have been built across this (some of which are fairly wide and likely to spread telluric water onto erstwhile ombrogenous surface). East of Spiggot Hill a broad, minerotrophic soakway falls quite steeply (and with visible flow) down from the base of the hill to feed into the south-west corner of the Tarn. A narrower soakway also runs west from Spiggot Hill to feed into the south-west lagg. The effect of these soakways is therefore to subdivide the main ombrogenous surface into three more-or-less discrete segments: two large ombrogenous areas on either side of the north-flowing soakway and a smaller area south of Spiggot Hill and south of the east- and west-flowing soakways. Although Spiggot Hill is generally considered to be a 'dry' island within the mire, when examined in April 2004 the lower slopes around the hill were very wet and gave the impression of a possible (intermittent?) diffuse seepage, in places stretching 1–2 m above the level of peat in the surrounding lagg fen.

In addition to the soakways, which seem generally considered to be natural (if somewhat modified) features (*e.g.* Pentecost, 2000; Proctor, 2003), the bog surface has been considerably damaged by past burning, by peat cutting, and by partial drainage, including a radial series of grips dating from the 19th century. Some of the latter have recently (post 1987) been dammed (though not always very effectively). These operations may have somewhat modified the natural topography of the bog. There appears to be little information about past peat digging on the site, though it has clearly occurred on a substantial scale. The possibility that the peat cliff which forms the eastern edge of the bog alongside the Tarn may have been formed partly as a peat-cutting face, rather than just as an erosion edge, with peat removed by boat, does not appear to have been considered.

Pentecost (2000) has plotted the contours of the bog surface, which broadly slopes from south to north. The north-west and north-east areas of ombrogenous peat form two broad lobes, sloping from Spiggot Hill respectively to the west / north-west and to the east / north-east, and separated by the north-flowing soakway, which occupies a very shallow valley between them. Only the north-eastern lobe is conspicuously domed, and that is truncated by the Tarn. The area of ombrogenous peat south of Spiggot Hill forms a separately-domed ridge, oriented east-west, but nonetheless rises southwards so that the southern lagg is higher than that on the south side of Spiggot Hill (Pigott & Pigott, 1959). The combination of features found in Tarn Moss, particularly the base-rich soakways, means that this is a singular site and it is difficult to concur with the proposition that "Malham Tarn Moss is a typical raised bog" (Proctor, 2003).

The northern limit of the main bog area is effectively fixed by the Tarn Beck. Along much of the northern edge a steep rand slopes down to the Beck. In places this is unusually steep, appearing as a truncated margin, either because further lateral expansion of bog peat (and therefore a gentler slope) has been inhibited by the Beck, or because of some erosion associated with the Beck. The Tarn Beck has three main sources. One is from the western lagg, which doubtless receives some 'true' lagg water but which is particularly sourced by a deep spring (a 'well-eye') within the lagg. Near the western end of the fen, this stream is joined by another flowing in from the west, from fields above the mire. Towards the eastern end of the fen, this is joined by a stream flowing across the fen from the north. This is sourced from two springs below Water Houses, north of the fen;

the westernmost of these has very strong flow, whilst the easternmost is rather less strong (and is apparently enriched from a nearby septic tank overflow). Thus although the Tarn Beck is in some senses a "lagg stream", it is largely exotelmic and is more akin to a stream which happens to flow through the north end of Tarn Moss than a true, endotelmic lagg stream. Moreover, it does not occupy the northern edge of the mire, but mostly flows hard against the ombrogenous deposit to the south, so that the main area of fen is located between the stream and the land margin to the north. Springs are not generally obvious within the North Fen, but two seasonal springs are reported to occur along the northern edge of the West Fen portion (Proctor, 1995).

The habitat (and vegetation) of the area north of the Tarn Beck is quite complicated, partly on account of the influence of the streams, partly because of past excavation of peat. This appears to have been done partly for fuel peat, but at the western end of the fen two large excavations, now mostly covered with a quaking mat of vegetation, were apparently nineteenth-century fish ponds. More recently various other small pools have been dug (or re-opened) for conservation purposes to provide an open water habitat. Although this area is known generally as the 'North Fen', much of the area north of the Tarn Beck is (or once was) ombrogenous. In the central and eastern parts of the fen there is a prominent ridge of ombrogenous peat located between the Tarn Beck (and associated flanking fen) and a narrow lagg along the northern edge of the mire. It is broken by the stream flowing in from Waterhouses and its flanking fens. Towards the west end of the fen, ombrogenous areas still occur but are smaller and more isolated and at the head of the fen (*i.e.* the far western end) conditions appear to be entirely minerotrophic. The area of ombrogenous peat is smaller than it once was, on account of peat digging or flooding with telluric water consequent upon the increase in Tarn water levels, and it seems likely that in its natural state minerotrophic conditions in the North Fen may have been considerably more restricted than is currently the case. However, it is rather difficult to envisage the state, level and slope of the North Fen when the Tarn level was 1.3 m lower than at present[1].

Ha Mire

Ha Mire is a quite large area of mire along the east side of the Tarn, developed below Great Close Scar on gently undulating ground which rises south-eastwards to a low watershed with the Gordale Beck valley. The mire is developed over a series of gentle ridges, and in places is punctured by low outcrops of mineral ground supporting dry grassland. Although levelled topographical data are not available, most of the mire appears to slope gently north-westwards from the southern margin (the highest point) to the edge of the Tarn, with a north-eastern limit along the foot of Great Close Scar. However, the eastern-most part of the mire drains south-eastwards into the Gordale Beck valley along a small stream described appositely by Sinker (1960) as a "muddy trickle from Ha Mire". The mire contains a complicated mix of mire habitats, ranging from ombrogenous or near-ombrogenous surfaces to base-rich mire, with large areas transitional between the two, or mosaiciform. Some of the best examples of base-rich mire are

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[1] There is little difficulty here with respect to the deposits of bog peat, which are always likely to have been elevated above the Tarn level, but the former state of the surfaces on continuous fen peat are more difficult to reconcile with the changed water level. On the one hand, whilst it seems likely that the fen peat may have expanded, or grown, since 1791 in response to an increased water level, some of the uncut peat is rather consolidated and it is far from certain that more than 1 m depth of such peat would have accumulated in about 200 years. Moreover, there is little obvious indication of a hiatus in the stratigraphy of the fen peat deposits, such as might have been expected with a sudden major increase in water level across the fen . The previous lower water level also implies a former fall of 1.4–1.5 m along the length of the Tarn Beck through the North Fen, compared with the present 0.1-0.2 m drop reported by Proctor (1974). Cooper & Proctor (1998) comment that "There must have been some flooding of the fen bordering the inflow streams .. but this cannot have been very extensive because, except near the mouth where the maps and the stratigraphy both suggest some lateral shift, the course of the streams on the 1785-6 map matches the modern 1:10,000 map with remarkable fidelity". On the other hand, a lake level lower by 1.3 m is compatible with the lower boundary of the ombrogenous peat deposits, which is currently mostly slightly below the current lake level.

along the north-eastern margin (below Great Close Scar) and along the southern margin, though small base-rich areas can seemingly occur almost anywhere except on the shallow peat ridges. The north-eastern margin is fed by several springs along the footslope of Great Close Scar. These are located some 2–4 m above the bottom of the hillslope and small spring streams drain down to, and through the mire. These streams are initially restricted to the north-east margin of the mire by a low ridge of drier ground, and join to flow north-westwards before rounding the bottom of the ridge and flowing across the mire down to the Tarn. The southern (upper) margin of the mire is formed from a diffuse seepage zone below a drier field upslope. Runnels from the seepages converge to form water-tracks and streams across the mire.

Great Close Mire

Great Close Mire is a quite large area of wet land, which occupies a south-sloping, rather broad trough, towards the head of the Gordale Beck valley and below the steep eastern slopes of Great Close Scar. The eastern side of the valley rises much more gently. Most of the mire is located on a rather gentle south-east trending slope on the west side of Gordale Beck. Although mapped by the Ordnance Survey as an extensive area of marsh, much of the lower part of Great Close Mire is perhaps more accurately described as grassland which is subject to various degrees of flushing by base-rich water (it is crossed by several small, spring-fed streams). However, towards the head of the mire, on generally steeper slopes than those of Ha Mire, there is well developed soligenous mire. There are a number of strong springs along the north-western edge of this area, some with small mossy, tufaceous springheads, which feed an anastomosing series of small, quite fast-flowing streams and runnels. The main areas of calcareous mire are developed on less-strongly flushed slopes in between these. Several small streams converge near the north-east corner of the site and have a small 'floodplain' of deposited silt.

The mire is grazed and is strongly poached, apparently in response to a combination of the wet conditions, skeletal soils and relatively high stocking density.

Vegetation

Tarn Moss and Fens

Much of the large area of damaged ombrogenous surface that constitutes Tarn Moss is perhaps best regarded as a degraded form of M18a (*Erica tetralix–Sphagnum papillosum* mire, *Sphagnum magellanicum–Andromeda polifolia* sub-community). This view differs from that of Cooper & Proctor (1998), who map the entire ombrogenous surface as *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) (though they recognise that parts of it have affinities with M18). In our view, although the surface – which for the most part is strongly dominated by *Eriophorum vaginatum* and, locally, *Calluna* – is clearly not typical M18, most typical M18 species do occur (including *Andromeda polifolia* and *Sphagnum magellanicum*), so that the difference is primarily quantitative rather than qualitative. This is reflected in the fact that the highest coefficients of MATCH of samples collected by R. Meade (in 2002) from within the area mapped as M19 by Cooper & Proctor are with M18a (or *Sphagnum cuspidatum/recurvum* bog pool community (M2)) rather than with M19. It seems likely that, if the ditch-blocking operations are successful, the surface may also become physiognomically more similar to M18. Nonetheless, some individual patches, such as the area alongside the Tarn which is strongly dominated by *Calluna*, may be best referable to M19. Bog pools are not well developed on the site, but some occur (in old peat pits?) close to Spiggot Hill, where their well developed *Sphagnum* carpets – with much *S. cuspidatum* and *S. papillosum* – allow them to be variously, and clearly, assigned to either M2 or M18.

The lagg and soakways around Spiggot Hill support minerotrophic vegetation, which seems to be largely referable to *Molinia–Potentilla erecta* mire (M25) and, in wetter places, to *Carex rostrata–Calliergon* mire (M9). Some examples of the latter are species rich, with *Carex lasiocarpa, C. limosa* and the uncommon bryophyte *Cinclidium stygium.* However, parts are richer in eutraphent species (*e.g. Caltha palustris, Cardamine pratensis*) than might be expected to be the case in such a wetland context. It seems likely that this may be a response to guano deposition from the substantial bird populations on Spiggot Hill. The combination of M25 and M9 also occupies much of the southern and western lagg (Cooper & Proctor, 1998), with M25 typically forming the transition between the bog and the wetter M9 stands, but this area has not been examined by us and no data have been available. Likewise no data are available for the soakway that runs west from Spiggot Hill, but Cooper & Proctor (1998) map this mostly as M6b (*Carex echinata–Sphagnum recurvum/auriculatum* mire, *Carex nigra–Nardus stricta* sub-community), with some flanking M25.

The vegetation pattern of the North Fen is rather complex (Proctor, 1974; Cooper & Proctor, 1998). Quite a lot of the area is wooded. Rather low and open willow carr (W3: *Salix pentandra–Carex rostrata* woodland) occurs in minerotrophic conditions alongside the streams, especially in the centre of area where the Tarn Beck and northern inflow stream converge, and in the area west of this The main willow species are *S. pentandra* and *S. phylicifolia,* but *S. cinerea* and *S. nigricans* also occur. The carr is particularly notable for its large populations of *Carex appropinquata,* very isolated from other UK localities, and species such as *Pyrola rotundifolia* have been recorded. Areas more remote from the stream, and probably more elevated, tend to support birch woodland (W4: *Betula pubescens–Molinia caerulea* woodland). They may mostly occupy former ombrogenous peat that has been to some extent enriched consequent upon elevation of the water level in the Tarn.

The open fen is rather variable. Near the head (western end) of the Tarn Fens, the vegetation is mostly a form of fen meadow (M26: *Molinia caerulea–Crepis paludosa* mire), locally with much *Carex appropinquata* (Cooper & Proctor speculate that this may be a response to flooding of the fens). Patches of *Carex lasiocarpa* also occur. Some such stands show clear affinities to M9, but Cooper & Proctor (1998) regard them all as referable to M26. A sample collected from the shallow depression in this area (Wheeler & Shaw, 1987) had highest coefficients of MATCH with M9b (50.2) and not with M26a (44.0), though the difference between the coefficients is not great. There is some unambiguous M9 towards the east end of the fen, between the boardwalk and the Tarn. Cooper & Proctor consider that this type of vegetation was formerly more extensive but has been much reduced by the recent scrub encroachment that has been particularly prevalent in the eastern part of the North Fen.

For much of its length the Tarn Beck is largely bordered by herbaceous vegetation, mostly linear stands of *Carex rostrata–Potentilla palustris* tall herb fen (S27), M26 or tall herb vegetation. Cooper & Proctor (1998) refer the latter to M27 (*Filipendula ulmaria–Angelica sylvestris* mire), but note that it is variable in both its overall species composition and its dominant species. Many patches are strongly dominated by *F. ulmaria,* but elsewhere other species such as *Phalaris arundinacea* are prominent. The community is most extensive at the western end of the fen, perhaps in response to silt inputs, but continues as a narrow band alongside the Beck for much of its length down to the east bridge. *Filipendula*-dominated vegetation also forms a gently-sloping band along the land margin of the West Fen.

Various other communities are interpolated within the general vegetation pattern of the fens. For example, the large, terrestrialised pond towards the western end of the fens supports a curious community, comprised of a semi-floating raft rich in *Sphagnum* species but with much *Phragmites australis,* and referable to M5 (*Carex rostrata–Sphagnum squarrosum* mire). As with many examples of M5, this vegetation is perhaps best seen as a *Phragmites*-rich example of S27 where the semi-floating raft has been considerably colonised by *Sphagnum.*

Substantial parts of the east and central areas of the North Fen support an ombrogenous or near-ombrogenous surface, which has been much disturbed in places (by peat cutting). The higher and drier areas tend to be dominated by *Deschampsia flexuosa, Eriophorum vaginatum* and *Molinia caerulea.* They can be highly impoverished and show greatest floristic affinities to M19. However, lower patches embedded within this can have much more *Sphagnum,* including much *S. magellanicum* and *S. papillosum* and are clearly referable to M18. These locations appear to be old peat workings, and in some cases the vegetation is developed as a semi-floating mat upon shallow, fluid muds.

Ha Mire

The vegetation pattern of this site is complex, varying between base-rich seepages (*Pinguicula vulgaris–Carex dioica* mire (M10)) to wet heath and near-ombrogenous conditions, often over short distances so that in places transitions are more widespread than uniform stands. Nonetheless, some good, if rather small, examples of M10b (*Pinguicula–Carex dioica* mire, *Briza media–Primula farinosa* sub-community) vegetation do occur: along the southern margin of the site; in places on either side of the trackway; and below a spring near the foot of Great Close Scar near the north-west corner of the site. Elsewhere, flushes are often more intimately mixed with more acidic vegetation, and are referable to M10a (*Pinguicula–Carex dioica* mire, *Carex demissa–Juncus bulbosus* sub-community). Shallow base-rich depressions often contain much *Carex rostrata,* along with a range of basicolous species, such as *C. viridula* ssp *brachyrrhyncha.* Examples of this vegetation occur near the Tarn (where it grades down into *Carex rostrata* swamp (S9) around the open water) and beneath Great Close Scar, but their floristic affinities are not very clear. Some stands appear to be best referable to M9a (*Carex rostrata–Calliergon* mire, *Campylium–Scorpidium* sub-community), but they are hardly 'good' examples of this.

Only few sample data are available from the more acidic surfaces (sourced by R. Meade, 2002). Some surfaces in partly-flushed wet shallow depressions appear to be referable to the *Carex panicea* sub-community of M15 (*Scirpus cespitosus–Erica tetralix* wet heath). Others, with more *Sphagnum* and perhaps less strongly flushed, have highest coefficients of MATCH with M21b (*Narthecium–Sphagnum papillosum* mire, *Vaccinium oxycoccos–Sphagnum recurvum* sub-community), but may nonetheless still retain such species as *Carex flacca* and *C. viridula* ssp. *brachyrrhyncha,* and show clear affinities to M15a (*Carex panicea* sub-community). The higher acidic surfaces have strong affinities with M15b (typical sub-community), M17a (*Scirpus cespitosus–Eriophorum vaginatum* blanket mire, *Drosera rotundifolia–Sphagnum* sub-community) and M21b. It is not really possible, with existing data, to identify which of these communities are represented in Ha Mire.

Great Close Mire

Only the north-western area below the springs beneath Great Close Scar is considered here, based primarily on data collected by Wheeler (1975) and Wheeler & Shaw (1987). This consists of a poached, rather skeletal surface with a mosaic of stones and shallow clay and small peaty hummocks. Although in one sense 'damaged', this open habitat supports good and species-rich examples of M10b (*Pinguicula–Carex dioica* mire, *Briza media–Primula farinosa* sub-community), with such notable associates as *Bartsia alpina* and *Carex capillaris. Carex hostiana* is frequent in surprisingly wet conditions and *Carex viridula* is represented by both ssp. *brachyrrhyncha* and *oedocarpa.*

Geological Context

The following account of the geological context of the Malham Tarn mires is derived from an account by HSI (2004), slightly modified.

The bedrock of the Malham Tarn area comprises a Lower Palaeozoic folded basement, unconformably overlain by the Carboniferous Limestone Group. Over an area underlying Malham Tarn, the outflow stream from the Tarn, and Tarn Moss, the Carboniferous Limestone is absent and the Horton Formation, part of the Lower Palaeozoic basement, forms the bedrock surface. The escarpment and fells immediately north of the Tarn are formed of the overlying Garsdale Limestone, belonging to the Carboniferous Limestone Group. This dips very gently to the north, and on the higher fells is overlain by the Carboniferous Danny Bridge Limestone. To the east of Malham Tarn, the palaeo-erosive surface of the Palaeozoic basement dips down, and an older unit belonging to the Carboniferous Limestone, the Kilnsey Formation, occurs between the basement and the Garsdale Limestone. The Kilnsey Formation forms the bedrock surface beneath most of Great Close Mire, but is overlain on the northern margins by the Garsdale Limestone. Much of Ha Mire occurs on the Garsdale Limestone. The major east-southeast trending North Craven Fault passes approximately 0.4 km south of Malham Tarn. On the far side of this fault, younger limestone units belonging to the Carboniferous Limestone are downthrown to the surface. These units are chopped by a dense series of northeast and north-northeast trending minor faults. North of the North Craven Fault, there are a few northwest and northeast trending minor faults, including one that passes west-northwest through the southern tip of Great Close Mire, and one that passes northwest from the northern tip of the mire.

The Horton Formation, occurring at the bedrock surface beneath Malham Tarn and Tarn Moss, comprises mainly laminated siltstones but includes a turbiditic sandstone unit. Other Lower Palaeozoic rocks likely to occur just beneath the Carboniferous Limestone north and east of the Tarn comprise sandstones, siltstones and mudstones, many turbiditic. The Lower Palaeozoic rocks are mostly cleaved and are folded along west-northwest trending axes. The Garsdale Limestone forming the escarpment and fells north of the Tarn, and underlying much of Ha Mire, comprises massive, light grey, pure packstones[2] and grainstones[3]. The Danny Bridge Limestone which overlies it further north is made of well-bedded packstones, wackestones[4] and subordinate grainstones, with marginal reef limestones at its southern limit. The Kilnsey Formation, forming the bedrock surface beneath the eastern Tip of Ha Mire and much of Great Close Mire comprises well bedded grey limestones, and in places dark grey limestone with mudstone beds and partings. In the lower part of Great Close Mire, an area of muddy Kilnsey Formation occurs at the bedrock surface.

Drift cover is sparse on the craggy fell uplands, but relatively widespread in the slightly lower areas. An east-southeast trending band of Till deposits occurs in the generally lower area between the fells to the north and south of the area of interest. It extends around 0.025–0.05 km beyond the north shore of the Tarn, and an oblique finger of Till extends west-southwest along the hillside from the northeast corner of the Tarn. Some Till also occurs within the dry valley that drains towards Tarn Moss and the northwest corner of Malham Tarn. In general, the Till is absent from the steep slopes of the northern escarpment and the higher parts of the northern fells. The

[2] Packstone: grain supported limestone with intergranular spaces filled by matrix

[3] Grainstone: grain supported limestone with little matrix

[4] Wackestone: limestone supported by mud-grade calcite matrix, where matrix comprises less than 75% of rock by volume

northern edge of the Till is a little beyond the boundaries of North Fen and Ha Mire and coincides with the flushes at Great Close Mire. The Till extends beneath the wetland areas and Malham Tarn to the lower slopes of the southern fells. The location of the water sinks from the Tarn outfall is within the area of Till outcrop, around 0.15 km before its southern edge. Much of the broad band of Till is overlain by more recent Glaciofluvial Deposits. Although they are partially obscured themselves by recent Peat and Alluvium, the outcrop pattern suggests that the Glaciofluvial deposits exist beneath at least the southern part of Tarn Moss, the eastern and southern parts of Ha Mire, and the southern part of Great Close Mire. They are also likely to be present beneath parts of Malham Tarn. The outflow stream from Malham Tarn has eroded through the Glaciofluvial deposits to the underlying Till. A Peat sequence occurs at the surface of Tarn Moss and North Fen, more or less coinciding with the wetland area. Spiggot Hill is formed of a mound of Glaciofluvial Deposits protruding through the Peat. Peat deposits are mapped beneath the mire area of Ha Mire, and also beneath much of Great Close Mire, occurring as a fan that converges eastward to the main south flowing stream. A strip of recent Alluvium underlies the stream which flows from the east-draining section of Ha Mire into Great Close Mire, and converges with a narrow fan of Alluvium associated with the main south flowing stream, before continuing as a strip along the south flowing Gordale Beck. Recent Talus forms steep screes of limestone fragments over Till on the lower slopes of the escarpment near the northeast part of Malham Tarn and along the northeast boundary of the mire area in Ha Mire.

The Till is described by O'Connor (1964) to be limestone rich, and to "consist of unsorted stones and pebbles embedded in a matrix of limestone rock flour, which may be of clay particle-size." She describes the Glaciofluvial deposits occurring at the surface south of Tarn Moss to be well-sorted gravels and sands, composed almost entirely of limestone clasts.

Wetland Substratum

Tarn Moss and Fens

Pigott & Pigott (1959) provide some levelled sections of the peat stratigraphy across Tarn Moss and Fens which, in conjunction with other data, permit a broad reconstruction of the development of the site. In outline, much of this area was a kame and kettle moraine which once formed a shallow-water extension of the Tarn, with at least three drumlin-like islands, separated from Spiggot Hill by a quite deep trough. Spiggot Hill itself appears to have occupied the south-east margin of the lake – the trough which separates the hillock from the ridge to the south appears to have been above the lake level. The entire 'basin' generally slopes from south to north. The former lake is marked by a basal deposit of Late-Devensian silts and clays which are covered by a thinner, co-extensive layer of marl, mostly fairly thin but up 1.8m thickness below the inflow stream (both the silt and marl are absent from the area south of Spiggot Hill). The lake appears to have experienced the 'normal' progress of hydroseral terrestrialisation, with reedswamp, fen and fen woodland coming to cover the former water surface. Fen peat also accumulated, by paludification, around the footslopes of the various islands, and in the trough south of Spiggot Hill, in locations where there had not been a preceding phase of open water. The fen peats are mostly rather thin (*c.* 1–2 m), except towards the margins of the basin, and over most of the area were replaced abruptly, and perhaps surprisingly early, by ombrogenous peat, which now forms a thick (in places more than 5 m) deposit, much of which is dominated by *Sphagnum imbricatum*. This ombrogenous cover also extends – if only rather thinly – across the three original islands, and banks up around Spiggot Hill. However, the mineral ground of Spiggot Hill remains separated from the ombrogenous peat by a continuous column of fen peat which extends up from below the bog peat to the surface of the lagg around the hillock. Fen peat is also continuous to the surface of the lagg around the whole Moss and, particularly, in parts of the North Fen. In addition, observations made in April 2004 indicated that a wet peaty deposit occupies the footslope of Spiggot Hill, for some 1–2 m above the level of the adjoining Moss. The deposit was formed from a highly amorphous organic material, varying between 40 and 90 cm depth in individual cores and overlying a 'solid' material that could not be penetrated by the hand-auger used.

At its northern margin the deposit of ombrogenous peat is truncated abruptly by the Tarn Beck, the course of which appears to occupy the deepest part of the basin. North of the bog there is a quite thick deposit of fen peat which, alongside the Beck and near the northern margin, forms a continuous column from the lake marls to the surface, and in places is almost 3 m deep. However, between the Beck and the margin the fen peats are covered by a ridge of bog peat, representing a similar successional development to the main area of bog, except that only a much thinner deposit of bog peat appears to have accumulated here. The fen peats contain numerous wood fragments, especially at depth, and represent a vegetation in which woody plants were frequent, but many examples examined are perhaps better described as 'monocot-moss peat with wood fragments' rather than as 'brushwood peat'. They are mostly rather strongly humified, firm, chestnut-brown peats. At the head (west end) of the fen, the peats are shallow. A core made in an area of fen meadow at SD88292 67092 revealed some 60 cm of a stiff, amorphous black peat overlaying some 20 cm of a stiff grey clay, beneath which was material that could not be penetrated with the hand auger used. The deposit alongside the Tarn Beck is typically enriched with mineral material and in some locations the Beck is flanked by an organic silt. This is especially – but not exclusively – the case in some stands of fen carr alongside the northern inflow stream and alongside the Tarn Beck in the general area. The top 1.5 m of a core made at SD 88716 67165 was formed from a continuous column of organic silt (with some sand near the base).

The Pigott & Pigott (1959) sections show evidence of apparent surface peat cutting, in various locations, both on the main area of bog and in the ridge of bog peat in the northern fens. The peat cuttings on the main bog are still evident as abrupt steps, and the workings are mostly firm-bottomed. However, some of the pits in the North Fen have become reflooded and consist of a surface mat of *Sphagnum*-rich vegetation overlying loose muds and water (B.D. Wheeler, unpublished data).

The sections also show that in all bog areas (*i.e.* the main Moss and the ombrogenous ridge in the 'North Fen') the fresh *Sphagnum* peats that form the bulk of the deposits are capped by a thinner surface layer of strongly humified peat with much *Eriophorum vaginatum.* This probably represents a response to partial drainage, burning and grazing of the bog surface.

Interestingly, the stratigraphical data presented by Pigott & Pigott (1959) provide no evidence for any of the minerotrophic soakways that extend across the mire surface from Spiggot Hill. In the case of the northern soakway this may be because the soakway crosses the section over the top of the largest buried 'island' where the peat cover is rather thin and partly disturbed. Nonetheless, there is no indication of any fen peat at this point, nor is any shown corresponding with the western soakway (which is over deep peat where crossed by the section). Possible reasons for this discrepancy include: (a) the sections were not sampled sufficiently intensively to reveal a narrow band of minerotrophic peat; (b) the minerotrophic influence is relatively small and has limited influence upon the character of the peat that accumulates (however, the lagg around Spiggot Hill occurs over a column of fen peat); and (c) the northern and western soakways are recent, superficial features, perhaps of artificial origin. Possible evidence in support of the latter proposition is that the northern soakway crosses the top of a buried island: an ancient soakway might be expected to have followed a course along the channel between the islands (though this course need not necessarily have persisted). This matter could be resolved by more detailed stratigraphical investigations.

Pigott & Pigott (1959) relate that "Most of the borings reached the bottom of the sediments and enough boulder-clay adhered to the auger head to show that this is the underlying material", and they show all of the profiles as underlain by boulder clay, in some places separated from the overlying lake deposits by a very thin seam of sand. However, it is likely that in many cases, particularly in the southern part, the borings were actually driven to the surface of the Glaciofluvial Deposits

The warden of the field centre (A. Pickles) has stated that although boulder clay covers the footslopes of the limestone hill north of the tarn, it is thought to be only very thin.

Ha Mire

Little information is available about the wetland substratum at Ha Mire. Pigott & Pigott (1959) comment that "a thin layer of clay underlies a skin of black peaty soil on Ha Mire". They consider that the basal clay was deposited in open water, as part of a late-glacial lake that was much deeper and bigger than the present tarn, but HSI (2004) describe the basal clay as Till.

A series of casual, hand-augered cores made by R. Meade and B.D. Wheeler (unpublished data) essentially confirmed the description of the Pigotts. They recorded a variable depth of peat, mostly strongly humified and rather amorphous. The greatest depths (> 1m) were mostly associated with the more acidic, perhaps ombrogenous, surfaces, though a deep deposit also occurred in a trough immediately below Great Close Scar. However, much of the peat was less than 50 cm deep, with as little as 20 cm in some of the base-rich flushes. The peat was mostly underlain by a layer of fawn-grey – khaki-grey clay, of unknown thickness, but presumed (based on the comments of the Pigotts) to be 'thin'. Much of this was a fine, rather plastic, deposit which in some locations contained a variable amount of gritty material. However, near the top (south) margin of the mire, some samples beneath flushed, base-rich surfaces at the head of the mire consisted of peat over a coarse grey sand, which appears to correspond to Glaciofluvial material between the peat and Till (HSI, 2004). More systematic coring is required, but it seems possible that the upper margin of the mire is developed over sandy material, whereas much of the mire below this is over clay, though locally with a gritty component. Some of the base-rich flushes lower down the mire appear to be associated with shallow peats and gritty clays, though again more systematic data are needed to confirm this apparent trend.

Great Close Mire

Only sparse stratigraphical data are available for this site, and these relate only to the flushes and seepages at the head of the mire. The most strongly flushed surfaces tend to be stony and could not be penetrated with the hand auger used and appear to be directly on limestone. In the more gentle, and less poached, seepages there is, in places, some 10–15 cm of a soft marly clay overlying stony material, which may represent a thin smear of Till over limestone bedrock. The main flushes appear to be located beyond the mapped northern edge of the Till (HSI, 2004). In places small peaty hummocks may have up to 15 cm of organic soil elevated above the water level.

Water Supply Mechanisms

Hydrogeological context

The following material is modified from HSI (2004). The Carboniferous Limestone is generally well cemented, and has poor primary permeability, but is expected to permit groundwater flow along joints and fractures. The extent to which these partings are interconnected, and solution enhanced, will determine the extent of groundwater flow through the limestone. Karstic features are well developed in the area of Malham Tarn, and locally the limestone may be considered to be a major aquifer. Groundwater flow networks in the Carboniferous Limestone are formed of solution-enhanced fractures and joints, which often form complex branching systems, ranging in scale from extensive cave systems to microfractures. The muddy unit of the Kilnsey Formation, occurring in the southern part of Great Close Mire, is likely to be an exception, as mudstone interbeds will impede the development of a solution enhanced groundwater flow network. In the Malham area flow velocities have been measured by tracer testing from about 240 m d^{-1} (Carter and Cash, 1902) to over 9,600 m d^{-1} in 1972 and up to 4,800 m d^{-1} in 1973 (Smith and Atkinson, 1977). Smith and Atkinson attributed the differences encountered in the 1970s to variations in rainfall. By nature, Karst systems are dynamic[5], and it has been suggested[6] that they tend to evolve towards a simplified network of a few main routes. Generally, groundwater flow directions within the Carboniferous Limestone aquifer are likely to be southwards, in line with the surface drainage pattern. Variations in spring flows and drainage have been observed following very high rainfall, when "bursts" may occur at levels a little higher than the normal spring discharges[7] and the outflow stream from the Tarn sometimes continues on the surface through the gorge to Malham Cove.

The Palaeozoic basement rocks are likely to be very well cemented, with no significant primary permeability. Joints, fractures and cleavage plains may permit groundwater flow, but not on the scale seen in the solution-enhanced fracture networks of the Carboniferous Limestone. They may be considered as a minor aquifer, but will permit significantly less groundwater flow than the Carboniferous Limestone.

The Till is expected to impede groundwater flow. It may locally confine the Carboniferous Limestone aquifer, and beneath Malham Tarn and Tarn Moss it may confine the Palaeozoic basement minor aquifer. Although few data are available, the Glaciofluvial Sand & Gravel unit is thought to be water bearing, and is generally perched over the Till aquitard. Given the lithology of the sand and gravel clasts, it is likely to possess groundwater of calcium carbonate type.

Generally, springs rise from the Carboniferous Limestone aquifer at the base of the northern escarpment, at locations which are controlled partly by the edge of the confining Till and partly by the intersection of the ground surface with groundwater levels. Many of the springs, such as at Ha Mire and the northwest corner of Tarn Moss, rise from the Carboniferous Limestone at the edge of the Till. Some, such as at Water Houses and along the submerged northern lakeshore of Malham Tarn, appear to rise through localised breaches in the Till cover. Due to their topographic situation, these springs are likely to be driven by strong hydraulic gradients. A few springs rise from the Glaciofluvial Sand & Gravel.

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5 Processes such as spring capture, linking of previously separate systems and abandonment of old conduits probably occur to varying degrees (Allen et al, 1997)

6 Ewers, 1982, in Allen at al, 1997

7 Carter & Cash (1902). " 'Bursts' have been known to occur on Chapel Fell just above Water Houses, when these springs were unable to discharge an abnormal supply"

Tarn Moss and Fens

The basal silt, clay and marl horizons beneath North Fen and the main body of Tarn Moss are expected to act as aquitard units. The hydrogeological role of the overlying Peats is not certain. The more humified horizons occurring within the middle of the sequence and on the surface of the moss are likely to impede groundwater flow. The silty Peat occurring near the base of the sequence is also likely to impede groundwater flow.

The dominant water supply to much of this moss is clearly precipitation, as Tarn Moss is very largely ombrogenous. However, despite the high rainfall the surface of the moss tends to be rather 'dry'. This may partly be a natural feature of a mature bog, but it is also a product of past drainage attempts and of the erosion of the tarn-ward side of the moss which has created a series of tension cracks orthogonal to the oversteepened east slope and which may be presumed to assist lateral drainage of surface water. Moreover, the surface of the moss has rather little *Sphagnum* and is rather 'solid', probably in consequence of both drainage and repeated past burning. It seems very likely that much of the moss no longer has a surface acrotelm layer with well-developed hydroregulatory functions attributed to this horizon (especially water storage and reduction of surface run-off). Various workers (*e.g.* Sinker, 1960) have expressed the view that the surface may be so degraded as to be unrecoverable, but it will be of interest to examine the results of the current grip-blocking initiatives which, dating mainly from 1987, are thought to have led to an increase in the water table of the bog. With an annual precipitation of 1412 mm and potential evaporation of 484 mm it may be expected that regeneration of the moss may be less dependent upon a functional acrotelm than is the case with many raised bogs in drier lowland regions.

The lagg along the south-west sides of the raised bog is in places rather well developed, with stands of wet fen vegetation. It is not clear to what extent its minerotrophic character stems from run-off from the rising upland or from groundwater outflow, but groundwater discharge from the Glaciofluvial Sand & Gravel appears to contribute to the lagg stream, at one point forming a distinct spring. It also seems feasible that groundwater discharge from the Sand & Gravel feeds the soakways that surround and radiate outwards from Spiggot Hill, with the hydraulic gradient driven by rainfall recharge to the Sand & Gravel outcrop on slightly higher land to the south and west of the Moss. This suggestion does not appear to have made before, possibly because Pigott & Pigott (1959) considered Spiggot Hill to be a drumlin with boulder clay rather than a kame, potentially in hydraulic continuity with the Glaciofluvial deposit south of the mire.

Water supply to the North Fens also raises some interesting questions. In general, the basal clays, silts and marls probably act as aquitard units, except perhaps locally. The Sand & Gravel fed lagg stream and minerotrophic soakways from Tarn Moss discharge to the Tarn Beck. Two strong flowing springs rise at Waterhouses from the Carboniferous Limestone at the base of the escarpment, where it pinches out sharply over the underlying Palaeozoic basement, through breaches in the Till cover, and flow southward through North Fen to feed into the Tarn Beck. Two smaller limestone springs also contribute to the Beck at the western boundary of the Fen, at the edge of the Till. There may be other, smaller, discrete discharges from the Carboniferous Limestone at the margins of the Till near the base of the escarpment. Although groundwater discharge from the Carboniferous Limestone and, to a lesser extent, the Glaciofluvial Sand & Gravel contributes to Tarn Beck, the Fen generally drains to the Beck.

The Beck appears to be rather 'flashy', and parts of the fen are reported to experience short periods of temporary flooding, with water levels rising and falling within a couple of hours (A. Pickles, *pers. comm.*), and in summer the western stream may dry up above the site. However, Proctor (1974) observed that over the period August 1965 to February 1967 the total measured water level fluctuation of most sample sites within the fen did not exceed 20 cm, with greatest fluctuations occurring alongside the stream and upland margin. He also suggests that "the fen itself is very nearly flat, and there is normally no more than 15 or 20 cm difference between the level of the inflow stream in the West Fen and the level of the Tarn". Proctor (1995) further points out that "Only the lower-lying parts of the West and Middle Fen and the wet carr and *Carex diandra*–brown moss areas of the East Fen are subject to regular episodes of winter inundation by water from the inflow streams". Much of the rest of the fen is above the flood level, which doubtless accounts for the propensity for *Sphagnum* growth on some of the elevated surfaces.

Hydrographs presented by Proctor (1974) suggest that water level fluctuations in the stream and adjoining fen tend to be greater near the west end of the fen than near the east end. However, there is not an exact relationship between changes in the stream water level and that in the fen. For example, in February 1966 a sharp increase in water level was observed in most fen sample sites, especially those closer to the stream, but near the east end of the fen this was accompanied by a *decrease* in stream level whilst near the west end an increase in stream level apparently occurred sometime after the increase in fen level. More frequent monitoring is required to establish the real relationship between stream and fen water levels, but there can be little doubt that for much of the time most of the fen drains into the stream. Near the east end of the fen particularly small fluctuations of water level were measured by Proctor in the narrow lagg along the upland margin and in the ridge of ombrogenous peat between the lagg and the Tarn Beck.

Parts of the fen are episodically flooded by the Beck, as evidenced by flanking deposits of silt. The importance of groundwater inputs into the fen is not really clear. The inflow streams are clearly groundwater fed, but much of their flow normally passes through the North Fen and may make only limited contribution to the summer water supply of the minerotrophic areas. When examined in April 2004, water was observed seeping down in several places from the fen into the stream, but the source of the fen water is not clear. The peat and clay infill of the main mire basin may preclude significant upflow into much the fen, except perhaps at the margins above the lake deposits and where the boulder clay cover is thought to be thin. However, it is not clear to what extent in this context the boulder clay, thick or thin, actually does confine the limestone aquifer – the distribution of significant outflows may relate more to the pattern of fissure flow than to the boulder clay deposits. Nonetheless, seasonal springs feed into the West Fen and Proctor (1995) has shown that minerotrophic parts of the fen have high Ca/Mg quotients. Highest values (just slightly lower to those from springs at the foot of Great Close Scar and the two seasonal springs along the northern edge of the West Fen) were reported from the northern inflow streams and the adjoining carr, with slightly lower quotients from parts of the West Fen and parts of the East Fen. Proctor (1995) concludes that "The northern edge of the fen is fed by the discharge of a number of springs at the base of the limestone, probably with a more or less continuous zone of seepage between them", and he raises the possibility that some of these fens may have "grown up over calcareous seepage fens similar to those now seen on Great Close Mire".

Proctor (1995) indicates that Ca/Mg quotients based on analyses in April 1986 show that the northern inflow stream, which is fed by strong springs at the foot of the limestone, has a considerably higher quotient (51.9) than that from the inflow stream at the extreme western end of the fen (32.9), which is again higher than that of the tributary draining from the west lagg (20.0). Other samples from the south lagg also point to low quotients (10.9–21.8). Whilst allowance must be made for water draining from the bog into the lagg, these samples have higher concentrations of marine-derived ions than sources fed from the limestone and point to a source of telluric water different to that of the North Fen. This may support the view of HSI (2004) that the southern lagg is fed from the Glaciofluvial Sands & Gravels.

Ha Mire

Sinker (1960) may have been expressing a widely held view when he stated that Ha Mire was "fed mainly by springs below Great Close Scar", but this does not stand up to close scrutiny. Some strong springs do feed into the north-eastern margin of the mire from Great Close Scar, but much of their water tends to be funnelled into a discrete stream which flows through the mire to the Tarn. Also they feed only into the lower end of the mire (on the east side of the trackway) and cannot really account for the extensive mire surfaces that occur above them. It is likely that the clay-rich Till which covers much of Ha Mire may help confine the Garsdale Limestone aquifer.

Over much of Ha Mire the dominant water source to the surface is precipitation, which accounts for the large areas of ombrogenous or near-ombrogenous peat. However, there are also some considerable areas apparently flushed with base-rich water, especially near the top (southern) margin of the mire. They start rather abruptly below a drier field, apparently in association with a sandy horizon below the peat. Lower down the slope the sandy layer tends to be replaced by clay (though some samples were described as a 'gritty clay'). These seepages appear to be fed by groundwater discharge from the Glaciofluvial Sand & Gravel, as this thins out beneath the southern part of the mire. Although this input apparently makes a direct contribution to the mire, it is apparently modest in size. Below the seepages there is surface or near-surface flow of seepage-sourced water through the peat across the basal clay, which gradually dissipates into the peatland or become focussed into runnels and small streams. A similar mechanism may account for the base-rich areas lower down the mire (*e.g.* west of the trackway), but it is possible that some of these are fed by localised upflow through more permeable layers of clay.

Great Close Mire

The soligenous area of mire at the head of Great Close Mire is developed beneath some strong springs and is doubtless partly fed by lateral flow of water from these. However, when examined in April 2004, it appeared that there was also some direct groundwater upflow into the flushes, through the stony substratum, but it is not clear how strong this is. R. Meade (*pers. comm.*) has pointed out that there is a tendency for the skeletal surfaces to be rather 'dry' in late summer (*i.e.* without surface water), though an area sampled by B.D. Wheeler and S.C. Shaw on 29th August 1985 then had water just at the surface of the skeletal material.

In essence, the springs that feed the hillside flushes at Great Close Mire appear to rise from the Carboniferous Limestone at the margins of the confining Till. The Till aquitard extends beneath the main mire area, preventing vertical hydraulic continuity with the underlying Carboniferous Limestone and Glaciofluvial Sand & Gravel aquifers.

Conclusions

Tarn Moss: The raised bog is primarily rainfall fed. Groundwater discharge from the Glaciofluvial Sand & Gravel contributes to the lagg stream and sustains the minerotrophic soakways emanating from Spiggot Hill.

North Fen: Although strong springs from the Carboniferous Limestone feed into the Tarn Beck, they normally have but a limited influence on the Fen, which drains to the Beck. The Beck is also fed by surface inflows from the Moss and lagg and by rain-generated run-off from adjoining higher land. Although the Beck floods relatively frequently, parts of the Fen are beyond its influence. Some appear to receive slow groundwater seepage;

others are predominantly rainfall-fed and are ombrogenous or near-ombrogenous.

Ha Mire: Although springs from the Carboniferous Limestone contribute to the site, they appear to be largely collected into a stream which flows through the mire but does not contribute to it. Diffuse seepage from the Glaciofluvial Sand & Gravel occurs at the southern margin of the mire basin where it thins out, but is likely to be a modest water input. Rainfall may be a relatively important input to parts of the mire, which is ombrogenous or near ombrogenous in places.

Great Close Mire: Groundwater discharge from the Carboniferous Limestone aquifer, occurring at the margins of the confining Till, is the main source of water to the hillside flushes.

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FACIES CHANGES ACROSS THE ASBIAN-BRIGANTIAN BOUNDARY ON THE SOUTHERN PART OF THE ASKRIGG BLOCK

The position of the Asbian-Brigantian Boundary was located on the southern part of the Askrigg Block in the shallow-water Dinantian carbonate successions in the Settle district of North Yorkshire, UK. The succession consisted of sedimentary packages less than ten metres thick, above and below the Boundary. The distribution of lithofacies and biofacies within individual packages represented deposition during a shallowing-up phase.

Emergent and diagenetic features, including clay wayboards, were described from the carbonate successions studied, and the mineralogy and rare earth element geochemistry of the clay wayboards was determined. Palaeoenvironments were reconstructed on the southern part of the Askrigg Block. These were used to interpret geological events on the southern part of the Block in a sequence stratigraphic context. The styles of sedimentation were influenced by glacioeustatically-controlled cyclic changes in relative sea-level, consisting of 5th order parasequences, dominated by highstand carbonate sediments. Local tectonic movements on the Askrigg Block periodically caused reductions or increases in sediment accommodation potential. Some filling of the accommodation probably occurred by diachronous shoaling across the platform, which could account for lithofacies differences close to the Asbian-Brigantian Boundary at different localities, but autocyclicity did not primarily control the style of sedimentation. Glacioeustatic falls in base level were the primary mechanism which caused emergence, with differences in platform geometry controlling the styles and durations of emergence across the platform.

The mineralogy and geochemistry of the kaolinite-rich clay wayboards indicates that they were of volcaniclastic origin. The wayboards are classed as tonsteins, but their original composition would have been close to a trachyandesite/basalt of within-plate origin, which is part of the alkaline suite of igneous rocks. The volcanic ash was likely to have been fairly locally-sourced, say, within 100 kilometres of the study area possibly from the Isle of Man or Derbyshire.

Author: Marion Dunn

WHAT GORDALE BECK CAN TELL US ABOUT THE PAST 2 BILLION YEARS OF EARTH HISTORY

Stromatolites are well known in the geological record as organosedimentary structures and are believed to have formed by the growth of photosynthetic microorganisms, mainly cyanobacteria. The link between these fossils and modern stromatolites was only made in the early 20th Century when modern stromatolites containing cyanobacteria were discovered in the Bahamas and the United States. In Britain, stromatolites are not common fossils since they attained their maximum development during the Precambrian period. Most of the British Precambrian is metamorphosed and contains few fossils. However, less altered rocks of the large cratons of Russia and Canada show that that stromatolites dominated the living landscape from about 1.3-3.6 billion years ago, and therefore for much of Earth's history. Modern stromatolites are now known from many places on Earth. They are widely distributed but uncommon, being restricted to shallow seas with high salinity and to some freshwater environments. The marine forms are mostly densely mineralised while freshwater forms range in their degree of mineralisation.

Modern freshwater stromatolites have been recognised for several decades, but investigating their progress has been slow. In many ways the freshwater forms are a better 'model' than the marine ones because the mineralisation process, initiated by the cyanobacteria is closer to the fossil forms than the modern marine representatives. The senior author recognised the potential of the Malham stromatolites in the 1970's and several studies have ensued.

The streams of the Malham Tarn area contain several stromatolite-forming cyanobacteria, most notable of which is *Rivularia haematites*. This organism forms dark brown nodular colonies on stones in calcareous fast-flowing streams. In Britain, *R. haematites* is uncommon except in some of the Dales streams. One of the best streams is Gordale Beck, about 2km east of Malham Tarn Field Centre.

Rivularia consists of radiating layers of filaments separated by bands of calcium carbonate crystals giving it a strongly zoned appearance when a slice through the colony is examined. The colonies grow slowly, about 2-3 mm per year, and since some of the largest colonies are up to 15mm in thickness, they attain an age of several years.

Several studies of the *Rivularia* stromatolites have been undertaken during the past two decades. These have shown that the growth of *Rivularia* is correlated strongly to temperature and light intensity. Growth almost stops during winter, but during this period, a narrow but dense layer of inorganic calcium carbonate crystals is deposited at the surface. This phenomenon is a purely chemical process akin to the deposition of stalagmite in caves. The 'inorganic' deposition of carbonate continues throughout the year, but during summer, the colony is growing outwards so the carbonate deposits are 'diluted' by the growing filaments. However, during summer, a number of very fine bands of calcium carbonate appear within 2-3 mm within the colony surface. Research within the past two years has shown that these bands are the result of photosynthesis during summer anticyclonic periods. *Rivularia,* although calcified, is sufficiently soft to allow microelectrodes to be inserted within them. Various chemical concentrations can be measured. We found that both dissolved oxygen and pH peaked 2-3 mm below the surface and this provides evidence for maximum photosynthesis in that region. Further work using a porphyrin optrode allowed us to map in two dimensions the distributions of dissolved oxygen within a colony and this confirmed our microelectrode results. Photosynthesis removes carbon dioxide from the surrounding water causing a rise in pH. The pH rise (to 9-10.5) rapidly increases the calcite precipitation rate leading to band formation.

We plan to conclude our study next year when we shall remove water from the colonies and analyse it directly for carbon dioxide concentration. We also plan to run a series of radiotracer studies to determine the proportion of carbon dioxide that enters the Rivularia organic matter and the associated calcite.

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SEDIMENTARY CORES FROM MALHAM TARN: A RECORD OF ENVIRONMENTAL CHANGE

Introduction

Sedimentary cores through lakebeds provide material from which environmental changes over the lake's history may be inferred. The top of a core contains recently deposited sediment while sediments deeper down the core were formed earlier in the lake's history. Certain features of sediment cores may be used as proxies for past environmental changes. Such proxies include: fossil type and abundances, sedimentary structures, sediment composition, and stable isotope geochemistry.

The sedimentary deposits of Malham Tarn are over 6.6 m thick and provide an environmental record since approximately 10,000 years ago. Allan Pentecost (King's College London) and Pietro Coletta have recovered sedimentary cores spanning the entire depositional sequence of Malham Tarn.

Discussion

Absolute dates for the cores are yet to be obtained, but three notable time markers are present in the sedimentary core sequence:

1) Alder pollen abundance increases above the 6.20 m depth horizon of the core. Bartley et al (1990) provide a radiometric date of around 7600 years ago for this alder cover increase at another locality in the Craven District.
2) Elm pollen abundance declines above 3.70 m, probably arising from a catastrophic pathogen outbreak across much of the UK (Roberts, 1998), dated for localities in the Craven District at around 5000 years ago (Barltey et al., 1990).
3) A distinctive change at around 19 cm below the current lakebed from charophyte marl to a top layer of sediment containing abundant *Sphagnum* remains, which marks the 1791 AD man-made deepening of Malham Tarn (Pentecost, 2000).

A detailed stable isotope record for the carbonate and organic carbon fractions of the Malham Tarn sedimentary sequence is now available (Coletta, 2004). The general features of the isotope record are:

1) High amplitude isotope trends at the base of the core (below 5.3 m core depth).
2) A trend toward more positive isotope values from around 4.5 m to 0.2 m.
3) Extreme isotope trends from 0.2 m to the top of the core.

Similarities between the isotope trends in the lower part of the Malham Tarn core and isotope records from other Northern Hemisphere locations suggest that large-scale climate events have been recorded in the Malham Tarn record. For example, a peak in the oxygen isotope record of the Malham Tarn marl at 5.46 m probably corresponds with a peak shown in the oxygen isotope record of the Greenland Ice Sheet Project core 2 (GISP2) documenting a particularly warm period around 6900 years ago.

The trend toward more positive isotope values from around 4.5 m to 0.2 m probably results from lake shallowing and silting up. A smaller lake volume will increase the influence of processes that preferentially remove light isotopes from the lake water (i.e. primary production, surface evaporation and CO_2 degassing).

The isotope records for the top 19 cm portion of the Malham Tarn cores show extreme trends that relate to the artificial deepening of the Tarn in 1791. The oxygen isotope record shows a large negative shift (-1.8‰ per mil) from 11 cm to 5 cm core depth, presumably recording a decrease in the significance of surface evaporation due to deepening. It is interesting to note that this oxygen isotope trend occurs above the 19 cm sedimentary marker, suggesting either a delay in lake deepening or a period of rapid sediment deposition following the 1791 event. The organic carbon isotope record shows an initial negative shift following the 1791 event, possibly recording the influx of isotopically light carbon in inflowing groundwater. This is followed by a positive shift that indicates an increase in lake productivity, perhaps resulting from increased nutrient inflows from erosions of the lakeshore as the Tarn deepened or from the re-establishment of a productive phytobenthos.

Conclusions

The isotope records obtained from the Malham Tarn sedimentary cores provide a solid foundation for future research to build on. It is clear that varied local environmental and hydrological changes have overprinted/masked the isotope record of general climate change at Malham Tarn. Investigations using other environmental proxies will reduce these uncertainties and help construct a more reliable palaeoenvironmental record. Portions of the Malham Tarn core, identified in this study, over which notable trends in the isotope record occur, should be dated radiometrically. Better comparisons may then be made with palaeoenvironmental records from other localities. This will help distinguish whether trends in the Malham Tarn isotope records resulted from local environmental factors or from wider climatic changes.

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Author: Pietro Coletta

2005 INTERIM RESULTS: YORKSHIRE DALES KARST DEPRESSION SURVEY

This is the 3rd report back to the Malham Research Seminar group on this research. The research began in 1997 around Crummackdale.

The first reports of large/deep/complex karst 'depressions' emanated from researchers working from Malham Tarn House. Academic work was subsequently published of which the best known workers were Marjorie Sweeting and Tony Waltham. 21 depressions were reported by both Clayton and Sweeting and in 1997 Waltham considered there were 57 around Crummackdale. We now have nearly 500 (493) entries on our data base!

This presentation considers only results from the total number. We are awaiting detailed statistical analysis by 12 geographic areas to compare with the total results presented now.

The area with depressions covered extends 36km west to east and 10km north from the Craven Fault System. All data have been recorded by 1km grid squares. Thus there were 360 potential squares of which 125 (35%) contain depressions. This confirms that depressions are localised and clustered.

Field investigation of depressions such as Feizor, noted in the literature, was our starting point in 1997. Our survey mapping utilised stereoscopic air photographic coverage (courtesy of the Yorkshire Dales National Park (Grassington) and English Nature (Leyburn)). Ground control has covered <40% of our sites. Very few depressions have had to have shape or location corrected and only a few have been located on the ground rather than from photos.

The information for every depression is recorded under the following categories: location (grid reference), altitude (of the surface from which it has developed), shape (round, oval, elongate, irregular), orientation, width and length (basis for area calculations by formulae), geology (of the surface), depth and position in the landscape. The data presented here are for the total of all depressions:

Altitude: expressed as a histogram. The range is from 190m to 560m altitude. Frequency is bimodal: 360-400m (the former 1300ft surface) and 500-510m (Malham High Country).

Shape: 80% of all depressions are either round or oval. 16% are elongate, located in structurally controlled valleys trending 135 degrees. Only 4% are irregular and most of these are composite with more than one low point.

Area: Surface area was calculated by formulae from the Width and Length measurements as m^2. The total area histogram is bimodal at 4-8k m^2 and 10-20k m^2. Deep depressions, exceeding 7m depth, (20) and irregular depressions (21) exhibit similar modes.

The spatial distribution of very large depressions (over 30k m^2) has been plotted (Fig). These very large depressions are preferentially located along the Craven Fault System (29%) as faulting increases the potential for solution, and on the Malham High Country (50%) which we now believe was never severely glaciated so allowed greater survival and where the water draw down effect would have been maximised.

Depth: Only 20 depressions (4%) exceed 7m depth. The modal depth is 10-20m. As most contain loess and peat, true depth is difficult to determine.

Geology and Orientation: In every geographic area Gordale Limestone is the dominant surface geology. Orientation is not available for all depressions because round has no orientation. Our data indicates that 135 degrees is dominant with 90 degrees and 40 degrees progressively of lesser importance. Major valleys in which depressions have developed are frequently also aligned 135 degrees following major lineaments.

Conclusions

1. We can confirm the early research that large karstic depressions exist and are localised in distribution. A few are deep. However those reported in the early literature are a small proportion of our total number.
2. All depressions have acted as sediment traps. We have reported previously on decalcified loess underlying peat dating from 9000B.P. The loess is far more significant than the loessic fraction reported by Clayton (1981).
3. The significance of the Malham High Country as a complex ancient karst with a probable polygenetic origin is confirmed.
4. That these large depressions are associated with well-rounded, well-developed limestone pavement indicates that both are palaeokarstic forms. They must pre-date the major glaciations. Glacial erosion was chiefly effective along the dales.
5. The geology and orientation data indicate that the origin of these large depressions was favoured by major inception zones as has already been shown for major cave passages and also karst water movement (Lowe, 1999)
6. Finally we have a statistical data base awaiting analysis by 12 geographic areas to determine whether location affects variance between the sets.

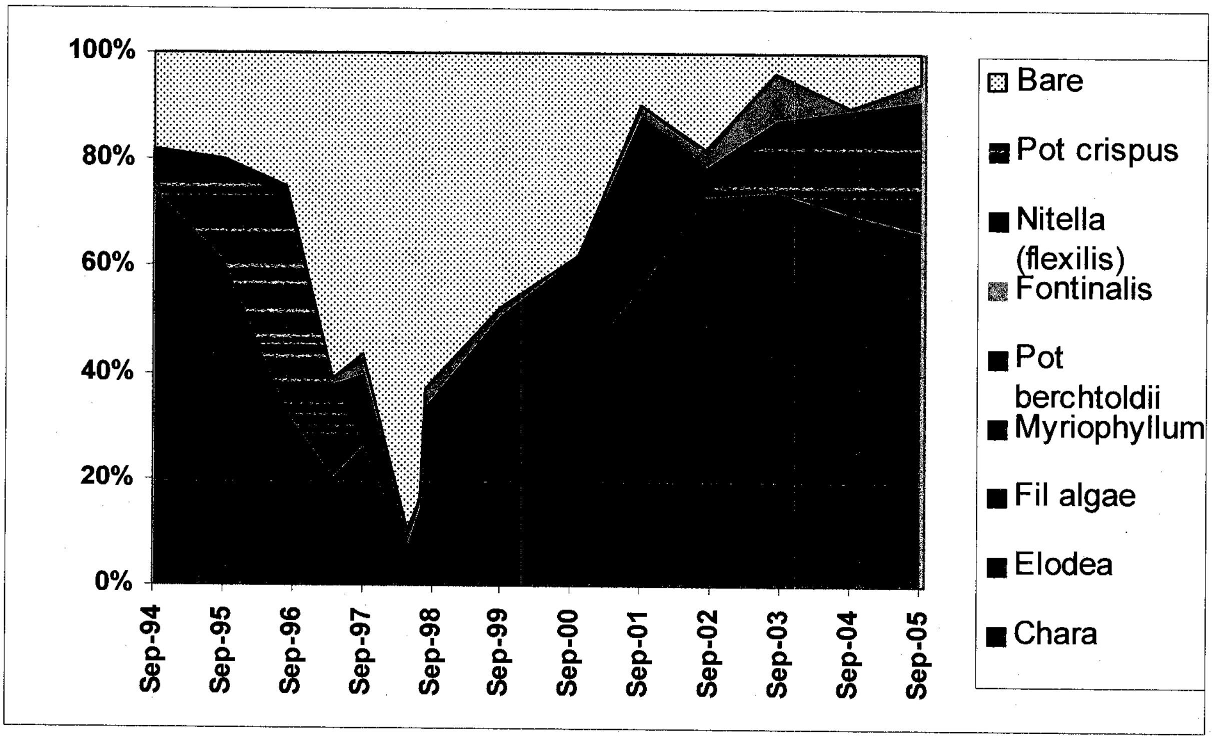
Await the next instalment!

Authors: Margaret E. Marker & Helen S. Goldie

AQUATIC MACROPHYTE ECOLOGY OF MALHAM TARN FROM 1994 TO 2005. POSSIBLE LINK TO NORTH ATLANTIC OSCILLATION.

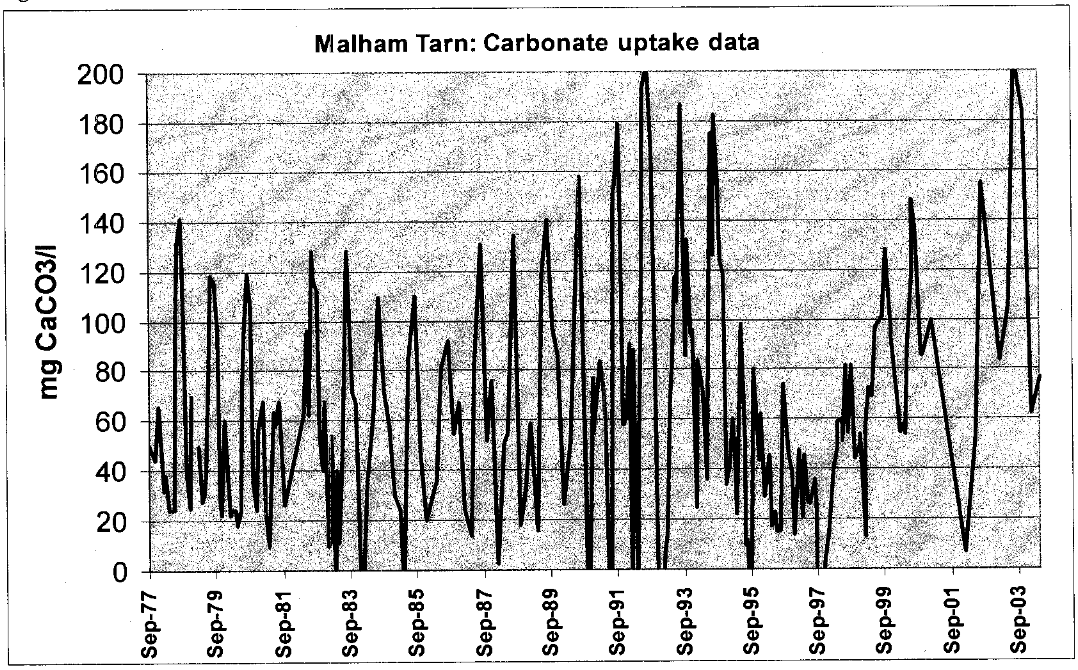
The semi-quantitative study which started in 1994 provides convincing evidence of the dynamic nature of the submerged macrophyte assemblage. The ecosystem productivity appears to be influenced by long term climatic change rather than any water quality factors. The full eleven year coverage (Figure 1) shows periodicity in the abundance of submerged macrophytes and changes in species composition. The temporal sequence shows the initial dominance of charophytes (1994) and gradual west to east displacement by *Elodea* over a two year period. Rapid collapse of the *Elodea* population occurred in 1997, followed by loss of charophytes from the central and eastern tarn. Gradual recovery of *Chara globularis* in 1999 was coupled with increasing abundance of *Potamogeton berchtoldii*. Charophytes re-established dominance in 2002 coupled with the reappearance of *Elodea* and the collapse of *Potamogeton berchtoldii*. The latest survey shows that charophytes probably peaked in 2003 and are now declining as *Elodea* becomes more extensive in the west.

Figure 1: Macrophyte assemblage changes in abundance (frequency)



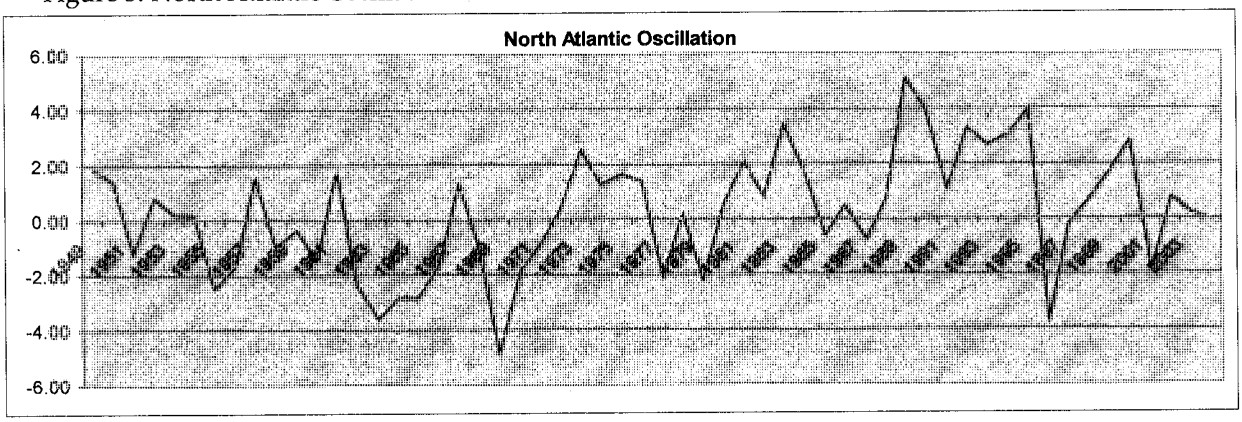
Depletion in alkalinity, resulting from biotic carbon uptake and inorganic carbonate deposition varies seasonally and between years. In situ carbonate uptake (Figure 2) can be calculated from regular (mainly monthly) alkalinity measurements taken at the tarn inflow and outflow by the Environment Agency. Over the period of this study, carbonate depletion was greatest between 1992 - 1994 and 2002 – 2003. These maxima coincided with the greatest abundance of submerged macrophytes. A large drop in macrophyte abundance following the 1995 drought lead to marked decline in carbon uptake.

Figure 2: Seasonal variation in alkalinity depletion in Malham Tarn



Recent papers have shown tentative links between the position of the Gulf Stream (North Atlantic Oscillation – Figure 3) and vegetation dynamics for phytoplankton and terrestrial ecosystems. The present study shows a similar correlation for submerged macrophyte abundance (1994-2005) and in lake carbon deposition (1977-2003). Low carbonate uptake (Figure 2) occurred in 1981, 1986 and 1997 (also macrophyte minimum in Figure 1).

Figure 3: North Atlantic Oscillation Winter Index



For survey methodology and earlier results see: Aquatic macrophyte surveys of Malham Tarn: 1994 to 2001. The Malham Tarn Research Seminar 2001, 'Past, present, future. Monitoring and Managing Change at Malham Tarn': Field Studies Council

Author: George Hinton

MALHAM'S VASCULAR PLANTS – RARITY, VULNERABILITY AND CANDIDATES FOR LONG TERM MONITORING

Introduction

Monitoring of rare species is a common feature of nature reserves. It can help identify quantitatively the effects of habitat management (such as grazing regime), local changes (eg. scrub development) or broader changes (eg climatic effects). A notable success of British conservation has been the Butterfly Monitoring Scheme which has enabled local and national influences on a species to be understood (Brereton *et al*, 2006). By contrast to butterflies long term monitoring of plant species is difficult to standardise. This is due to the various factors that can be recorded (eg. no. of individuals, degree of cover etc.), these in turn being a product of the various growth forms and reproductive patterns of vascular plants. In an attempt to bring some order to plant monitoring Menges and Gordon (1996) identified three basic levels of monitoring; Level 1 identifies species occurrence and the area of occurrence; Level 2 identifies a measure of abundance based and Level 3 involves demographic monitoring of particular individuals such as that employed by Hutchings (1987) on *Ophyris sphegodes.*

With its combination of relative isolation, climate, geology, soils and relatively long history of protection Malham has many vascular plant species of conservation significance, although the dynamics of these species is poorly understood. Hence initiation of Long Term Monitoring (LTM) on at least some of these species is worthy of consideration. Following the mapping of British plant species by Perring and Walters (1962) the degree of rarity of each member of the British flora has been categorised using distribution. Rare plants are present in 15 or less hectads nationally and scarce plants are present in 16-100 hectads nationally. These rare plants have been described by Perring and Farrell (1977, 1983) and Wiggington (1999), while scarce plants have been described by Stewart *et al* (1999). These lists have been recently reviewed by Cheffings (2004).

A different approach has been taken by Cheffings and Farrell (2005), who produced a Red List for the British flora based upon the rate of decline and international distribution. This allocated members of the British flora to IUCN categories of conservation importance. Malham has a number of plant species which are designated scarce or rare or fall into IUCN categories. These species may be appropriate for LTM. The aim of this paper is to confirm which rare and scarce plants are at Malham; to identify which plants with significant IUCN categories are at Malham and from these lists to identify which species could be suitable for LTM based upon the criteria of access, safety, life history and abundance.

Methods

There is no up-to-date vascular plant species list for Malham. A species list was constructed initially using easily accessible published material (Sinker, 1960; Proctor, 1974; Ratcliffe, 1977; English Nature, 1990, 1988, Jones, 2001; Cooper and Proctor, 1998; Abbott, 2005). It should be noted that the areas covered by these various studies are not contiguous and the species list is therefore not specifically restricted to the NNR but encompasses areas such as adjacent SSSIs and locations close to the village that historically have been considered to be Malham.

Using this list and by comparison with Cheffings (2004) a list of rare and scarce species were compiled. Similarly, by comparison with Cheffings and Farrell (2005) an additional list of important IUCN category species was compiled. Species of five IUCN categories are recorded at Malham. Four of these categories are based upon increasing risk of extinction; Endangered (EN), Vulnerable (VU), Near Threatened (NT) and Least Concern (LC). A fifth category, Data Deficient (DD), identifies those taxa where there is insufficient information to accurately identify extinction risk. This group typically involves microspecies aggregates. From these lists suitable candidates for long term monitoring were identified by considering status, abundance, safe access, life history, growth form and potential ease of monitoring. Copies of the full species list are lodged with the FSC at Malham, National Trust regional and central office and local English Nature office.

Results

509 taxa were identified as growing in the Malham vicinity. Of these, 35 were non-natives. The native plants included 6 nationally rare species and 23 nationally scarce species (Table 1a and b). Using IUCN categories ten of these species are identified as Endangered, Vulnerable or near Threatened (Table 2). In addition 11 taxa, which are neither scarce nor rare, are recognised as Endangered, Vulnerable or near Threatened (Table 2a, b and c) and one taxon (*Euphrasia arctica* ssp. *borealis*) is identified as Data Deficient. All other taxa are identified as Least Concern.

Table 1a Nationally Rare vascular plant species at Malham Tarn and environs.

Polygala amarella	Dwarf milkwort
Bartsia alpina	Alpine bartsia
Eleocharis austriaca	Northern Spike-rush
Carex flava	Large yellow sedge
Carex muricata subsp. muricata	Large-fruited Prickly-sedge
Calamagrostis stricta	Narrow Small-reed

Table 1b Nationally Scarce vascular plant species at Malham Tarn and environs.

Equisetum variegatum	Variegated Horsetail
Dryopteris submontana	Rigid buckler-fern
Minuartia verna	Spring sandwort
Hornungia petrae	Hutchinsia
Primula farinosa	Bird's eye primrose
Ribes spicatum	Downy currant
Sedum villosum	Hairy Stonecrop
Potentilla crantzii	Alpine cinquefoil
Dryas octopetala	Mountain Avens
Alchemilla glaucescens	Ladies Mantle
Alchemilla glomerulans	Ladies Mantle
Alchemilla wichurae	Ladies Mantle
Sorbus rupicola	Rock whitebeam
Polemonium caeruleum	Jacob's ladder
Melampyrum sylvaticum	Small cow wheat
Euphrasia rostkoviana subsp. montana	Eyebright
Juncus alpinoarticulatus	Alpine Rush
Carex appropinquata	Fibrous Tussock-sedge
Carex capillaris	Hair Sedge
Sesleria caerulea	Blue Moor-grass
Polygonatum odoratum	Angular Solomons seal
Epipactis atrorubens	Dark red helleborine
Corallorhiza trifida	Coralroot orchid

Table 2a. Endangered species at Malham tarn and environs based upon IUCN criteria. (Species in **bold** are not nationally Scarce or Rare and so do not feature in Table 1).

Alchemilla wichurae	Ladies Mantle
Galium pumilum	**Slender bedstraw**
Crepis mollis	Northern Hawks beard

Table 2b. Vulnerable taxa at Malham tarn and environs based upon IUCN criteria. (Species in **bold** are not nationally Scarce or Rare and so do not feature in Table 1).

Polystichum lonchitis	**Holly fern**
Primula farinosa	Bird's eye primrose
Saxifraga hypnoides	**Mossy saxifrage**
Gentianella campestris	**Field Gentian**
Euphrasia rostkoviana subsp. montana	Eyebright
Groenlandia densa	**Opposite leaved pondweed**
Blysmus compressus	**Flat sedge**
Carex flava	Large yellow sedge
Calamagrostis stricta	Narrow Small-reed
Allium oleraceum	**Field garlic**
Corallorhiza trifida	Coralroot orchid

Table 2c. Near threatened taxa at Malham tarn and environs based upon IUCN criteria. (Species in **bold** are not nationally Scarce or Rare and so do not feature in Table 1).

Minuartia verna	Spring sandwort
Cardamine impatiens	**Narrow leaved bitter-cress**
Sedum villosum	Hairy Stonecrop
Gentianella amarella subsp. septentrionalis	**Northern Felwort**
Carex diandra	**Lesser Tussock-sedge**
Carex muricata subsp. muricata	Large-fruited Prickly-sedge

Discussion

Malham and its environs is extremely rich in vascular plants holding almost a fifth of the UK flora. Although the species list is unlikely to be exhaustive, by concentrating on published data it is likely to have a full list of species of conservation importance given the breadth of the literature and the tendency of authors to focus on such species.

There are 40 species that are of conservation importance either because of restricted distribution, marked rate of decline or both. It is anticipated that candidates for long term monitoring will come from this list. It is suggested that all of these species (Table 3) could be the subject of Level 1 monitoring at a five-year interval. It is also considered that while many of these species are suitable for a Level 3 type monitoring, the extensive time demands of such work render it impractical when time for conservation work is limited and it is discussed no further here. However such work would be suitable for individual research projects.

The most useful form of LTM given time constraints is therefore anticipated to be Level 2 type monitoring. The most useful form of LTM is where a reliable body of information accrues over a period of time using the same method for a single species. Consequently the methods used need to be robust enough to be reliably compared between different recorders over a prolonged period of time.

A candidate list of species for Level 2 monitoring is presented (Table 3). Species groups such as *Euphrasia* and *Alchemilla* require basic identification and mapping and are possibly not suitable for LTM because of their taxonomic difficulty. Beyond these two groups of species the list is drawn up taking into account ease of identification, safe access and conspicuousness. The list is also aimed to include various levels of conservation designation, life history, growth form and taxonomic group.

Different methods and time intervals will be appropriate for different species. For instance those species represented by a few individuals (eg *Carex muricata* ssp. *muricata, Bartsia alpina*) can be counted in their entirety. Species which are more extensive (eg *Primula farinosa*) will require some sampling approach. Similarly short-lived species (eg the biennial *Gentianella campestris*) will require more frequent recording than longer lived species (eg the perennial *Saxifraga hypnoides*).

The fifteen candidate species for LTM at Malham is presented for further consideration rather than any pretence to be definitive. It is hoped that this will stimulate further discussion leading to a refined candidate list of species, choice of suitable methods for each species and subsequent initiation of level 2 long term monitoring.

Table 3. Candidate species for Long Term Monitoring at Malham Tarn and environs.

Species Name	**Conservation status**			**Comment on suitability for LTM**
	Rare	Scarce	IUCN	
[redacted]				
Carex muricata subsp. muricata	x		NT	
[redacted]				
Carex flava	x		VU	Tussock forming
Polygala amarella	x			Grazing sensitive
Bartsia alpina	x			Small population
[redacted]				
Minuartia verna		x	NT	Possible fluctuations due to drought
Sedum villosum		x	NT	
Primula farinosa		x	VU	Abundant
[redacted]				
Corallorhiza trifida		x	VU	Inconspicuous. Nos may fluctuate
[redacted]				
Hornungia petrae		x		
[redacted]				
Dryas octopetala		x		
[redacted]				

Carex capillaris		x		Species unobtrusive
Sesleria caerulea		x		Species dominant
Polygonatum odoratum		x		Large discrete individuals
Epipactis atrorubens		x		Large number of vegetative individuals
Euphrasia arctica subsp. borealis			DD	Taxonomic difficulty
Galium pumilum			EN	Species unobtrusive
Cardamine impatiens			NT	On scree, access difficult
Gentianella amarella subsp. septent.			NT	Easy ID. Endemic. Poorly understood
Carex diandra			NT	Identification difficulty
Polystichum lonchitis			VU	Identification difficulty
Saxifraga hypnoides			VU	International responsibility
Gentianella campestris			VU	Easily identified
Groenlandia densa			VU	Counting difficulties - aquatic
Blysmus compressus			VU	
Allium oleraceum			VU	Difficult to locate after early summer

Potentially suitable species are unshaded, unsuitable species are shaded. Summary of reason for decision is given in right hand column. For IUCN status explanation see text.

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GRASSLAND SUCCESSION AT MALHAM TARN NNR – PRELIMINARY FINDINGS

Background and Methodology

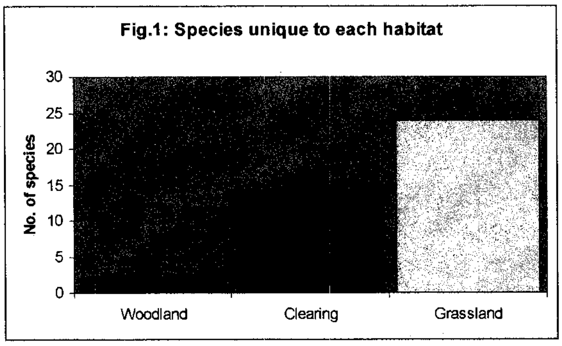
The aim of this project was to investigate an area at Malham Tarn where felling of a patch of secondary woodland took place in October 2004. This was a National Trust Management Plan with the objective of extending the species-rich limestone grassland westwards from Tarn Close. The project involved setting up permanent quadrats and measuring the vegetation post-felling in 3 areas:

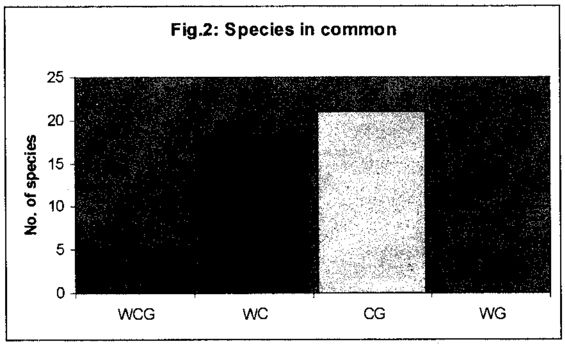
- Woodland - This plot is also secondary woodland, situated adjacent to the cleared area. It was used to approximate the vegetation composition of the Clearing, pre-felling.
- Clearing - The area (approx. 80m x 80m) were trees have been removed.
- Grassland - This is the 1.6 hectare, diverse calcareous grassland known as Tarn Close.

Permanent 20m x 20m plots were established in each of the 3 areas standardised, as far as possible, for gradient, proximity to Tarn, aspect, trampling and timing of the sampling. 2-metre square quadrats were used to survey the area as these are deemed appropriate for sampling low level vegetation (Gibson, 2002; Rodwell, 1992). In addition 0.5m grids (giving 25 point samples per 2m quadrat) were used to estimate percentage cover of plant species within the larger plots. All plant species in 10 randomly positioned 2m quadrats were identified. Moisture, pH and shade levels were also recorded.

Preliminary Findings

There were twice as many species in the cleared area (22 +/- 5) as in the woodland (11 +/- 2). Grassland had the highest species richness (mean of 29 species +/- 3.9 per 2 metre square). There was a significant difference in median species richness between the three habitats (Kruskal Wallis, H (adjusted for ties) = 20.36, df = 2, P<0.001). The grassland is classified by MAVIS (Modular Analysis of Vegetation Information System) as CVS community 38, the woodland as 39 and clearing as 28.





Figures above indicate species unique to each habitat (Figure 1) and species that habitats have in common (Figure 2) respectively, (W=Woodland; C=Clearing and G=Grassland).

Shannon Wiener Diversity Index was used to compare between sites with Pielou's Test for evenness. There was a significant difference in mean species diversity between all 3 sites (Table 1. ANOVA, $F_{2,27} = 26.83$, P<0.001). It can be seen that the grassland is the most diverse site, 2.3 (+/- 0.2), and it has species which are the most equally abundant, 0.93 (+/- 0.02), where a score of 1 for evenness means that all species are equally abundant. A full species list can be found in the undergraduate dissertation report to be submitted to Malham Tarn Field Centre.

SITE	Mean diversity (s.d.)	Mean evenness (s.d.)
Grassland	2.3 (0.2)	0.93 (0.02)
Clearing	1.8 (0.3)	0.87 (0.05)
Woodland	1.5 (0.3)	0.83 (0.11)

Table 1. Mean diversity and evenness (with standard deviation) of the study sites.

Similarity between plots was investigated using PRIMER (Plymouth Routines In Multivariate Ecological Research) (Clarke & Warwick, 2001). Results were ordinated using Multi-dimensional scaling (MDS) of a Bray-Curtis similarity matrix to assess the similarity between the 3 habitats (Fig. 3; Clarke & Gorely, 2001).

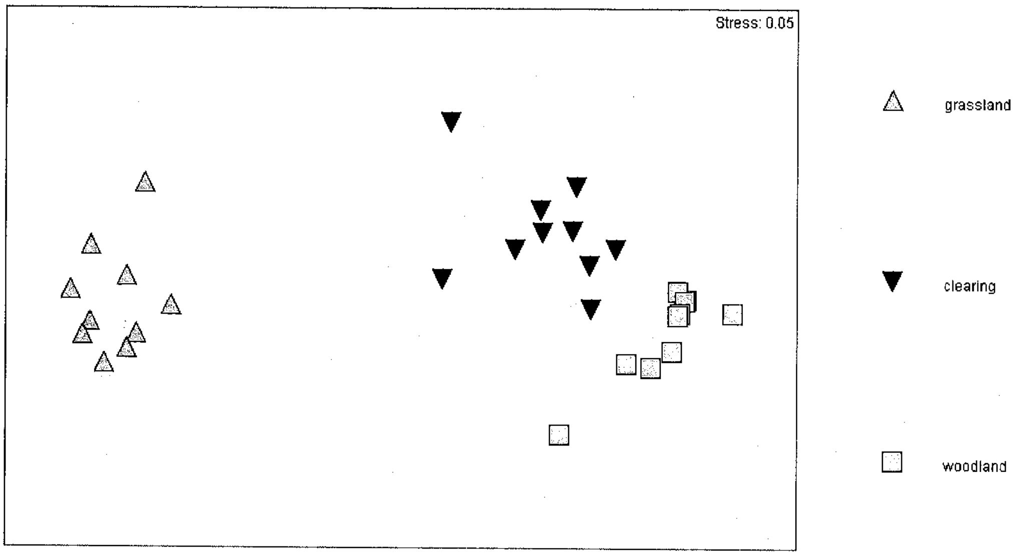


Figure 3. MDS plot of plant species data from the three habitats.

A stress factor of 0.5 indicates that this is a good representation of the similarity between habitats (Clarke & Warwick, 2001). The clearing was most similar to the woodland, but was more similar to the grassland than the woodland was.

Conclusion

This study has shown that the cleared area is botanically distinct from the adjoining woodland and grassland, though its plant community more closely resembles the woodland. The work presented here will provide a baseline for long-term monitoring of the cleared area to establish whether the desired conversion to species-rich limestone grassland is taking place.

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NEW RESEARCH ON THE DARK GREEN FRITILLARY(ARGYNNIS AGLAJA LINN.)

Introduction: The status of Argynnis aglaja

The dark green fritillary, is encountered in rough grassland with abundant violets, especially *Viola riviniana* (the common (dog) violet), in a variety of situations from the early seral stages of woodland, to heathland, moorland and grasslands. Its populations have fluctuated during the past century but mainly it has declined. It was quite well distributed in Yorkshire until the 1850's but probably mainly on uplands. Within Yorkshire, *Argynnis aglaja* is now rare, recorded in only 50 out of 2377 tetrads (Frost, 2005). Recent records 1996-2004 are mainly from North York Moors National Park (NYMNP) and the Yorkshire Dales National Park (YDNP) but a scatter of records and unconfirmed sightings of large fritillaries are from the eastern Pennines in west central Yorkshire where the species has had a long history of solitary records and occasional colonisation but it is only proven resident in the NYMNP and the YDNP. (Clough 2005, Whitaker 2004). Since those publications more has been discovered about its distribution in the West of Yorkshire where a total of five breeding sites all associated with calcareous grassland (NVC CG9) (Rodwell 1992) have been located in the YDNP (Table 1). Currently the species has been recorded in 1 10km square in VC63; 7 10km squares in VC62 in the NYMNP and 16 10km squares in VC64. The species is only common on Scar Close NNR but it was observed in a total of eleven other 1km squares around the Ingleborough Nature Reserves complex during 2005.

Table 1. ***A. aglaja*** **Breeding Sites in the YDNP 1995-2005**

Site Name	NGR	Total No 1995 - 2005	Max No. Seen	Alt. m	Site Area ha	Comments
Duckstreet Quarry NR	SE11 64	2+	2	385	4.0?	Extinct Small Colony
Scar Close NNR	SD75 78 SD75 77 SD74 77	1000+	100+	325-350	*ca* 30	Very Large Colony
Nr.Malham Tarn	SD89 66	23	4	338	20+	Small Colony
Kettlewell Park Gill	SD98 74	16	8	300-390	2	Small Colony
Swarth Moor SSSI	SD81 96	16	2	220	11	Small Colony
Rise Hill	SD76 88	10	3	380	0.75	Small Colony
Southerscales N.R.	SD74 76	12	5	345	15?	Probable Colony
Austwick; Wharfe	SD77 70	7	3	240-250	<2	Probable Colony
Nr Cautley Spout	SD68 97	4	3	270-300	-	Unlocated Colony
Buckhaw Brow	SD80 65 SD81 63	2	1	300	-	Unlocated Colony
Grass & Bastow Wood	SD99 64	5	1	200-290	40?	Unlocated Colony
Ribblehead Quarry NR	SD76 78	11	3	315	5?	Possible Colony
Salt Lake Quarry NR	SD77 78	5	4	315	1	Possible Colony
South House / Sulber	SD77 73	4	2	350	?	Possible Colony

Estimation of *A. aglaja* population on Scar Close NNR, Ingleborough in 2005

The intention was to undertake a trial of field methodology to make absolute estimates of population size of *Argynnis aglaja* during its peak flight period in July-August on Scar Close NNR. The ultimate purpose is to incorporate calibrations of population estimates into the simpler procedure of transect monitoring (Thomas 1983, Whitaker 2005). This can then be used on a wider range of fritillary sites than is possible using the time-consuming mark release recapture (MMR) methodology. Several different MMR methods were tried and it was confirmed that population parameters could be estimated from recapture data of a single day's MRR using Craig's (1953) frequency of capture method.

Results

The population peak observed on transect walks was around day 16 from first sighting on 22nd July (in 2004 the peak was around day 31 on 2nd August) Fig. 1. The first butterfly was observed on the 7th of July and the last on 2nd September, a flight period of 57 days. In preceding years there are few observations available. The 2004 flight period was 46 days between 6th July and 21st August. For the years 1999-2003 only 35 casual records are available between 12th July and 1st September giving 44days. Despite unfavourable weather and the inability of the limited number of workers to capture large numbers of animals on a single day, it was possible to make absolute population estimates for males of up to a maximum value of 707 (±768.4 s.e.) (or 742 (± 369.8 s.e.)) including females) for the period 3-5 August (days 27-29) at this time the relative estimate of population from the transect, had declined to approximately 1300 from an estimated maximum of 1949 on the 22nd July.

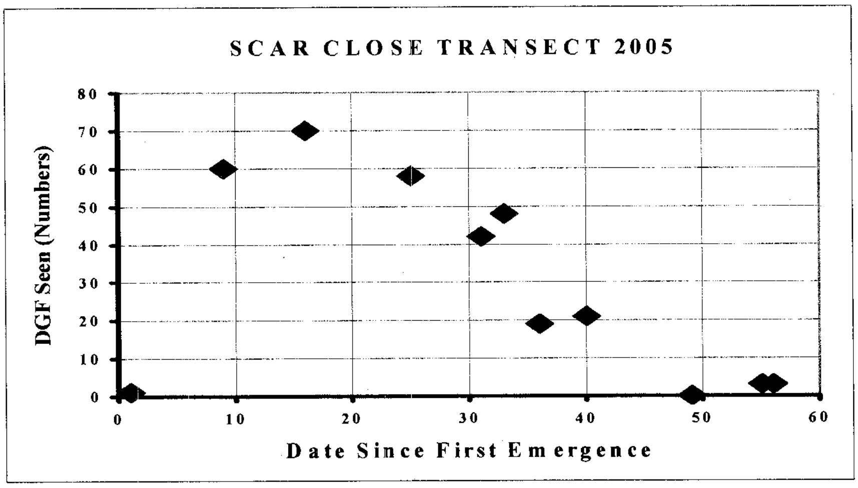

Figure 1 *A. aglaja;* **Totals on transect walks (Day 0 is 7th July, day 60 is 4th September 2005)**

The population was at least 50% larger at peak, placing the population firmly in the 'large' (>1000) classification of Barnett and Warren (1995), one of the largest populations in the country. Female dark green fritillaries were found to be behaving in a very different manner from the males. These differences were supported by observed differences in wing wear. The number of females captured was very small and the only available estimates of the female population is 171(± 117.8) on 2nd August and 86 (±42.7) for the period 3-7 August; about a third (27.1% and 33.2% respectively) of the male population estimate.

A trial timed count experiment was undertaken simultaneously at 7 locations in Scar Close compartment 28 (33.25ha) to observe densities of the butterfly. These counts could be related to differences of densities observed in various sections of the transect route, and are probably related to vegetation differences.

Although *A. aglaja* is popularly considered to be wide ranging e.g. Clough (2005), this is a partial interpretation of its behaviour; where powerful flight is equated with mobility. Little is known about how butterfly species move through the landscape and this is a critical factor in influencing the population dynamics of organisms with fragmented distributions. Ries and Debinski (2001) have demonstrated that, the Regal Fritillary (*Speyeria idalia* Drury), can show strong responses subtle differences in vegetation and was less likely to cross such boundaries than the migrant generalist the Milkeed Butterfly (*Danaus plexippus* L.) It seems probable that *A. aglaja* is behaving in a similar manner to *S. idalia* and this may tend to restrict it to a currently favourable habitat patch but render it vulnerable to stochastic processes which can cause local extinction. If this is the situation an urgent re-assessment of its behaviour is needed to put landscape scale conservation policies into place aimed at re-establishing meta-populations (networks) of this habitat specialist species.

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THE MOLLUSCA OF THE NATIONAL TRUST ESTATE AT MALHAM

Please Note: For the purposes of this paper the study area is an area within the boundaries of the following National Grid references; Westerly - SD34/86; Easterly – SD34/93; Southerly SD34/62 and Northerly SD34/73: a total of 77 one-kilometre squares. Traditionally, the area known as Malham includes some areas which are not owned by the National Trust and are not officially part of the estate, such as Malham village, Malham Cove and Gordale Scar. It does however exclude some areas outside the estate which are regularly visited by study groups based at Tarn House.

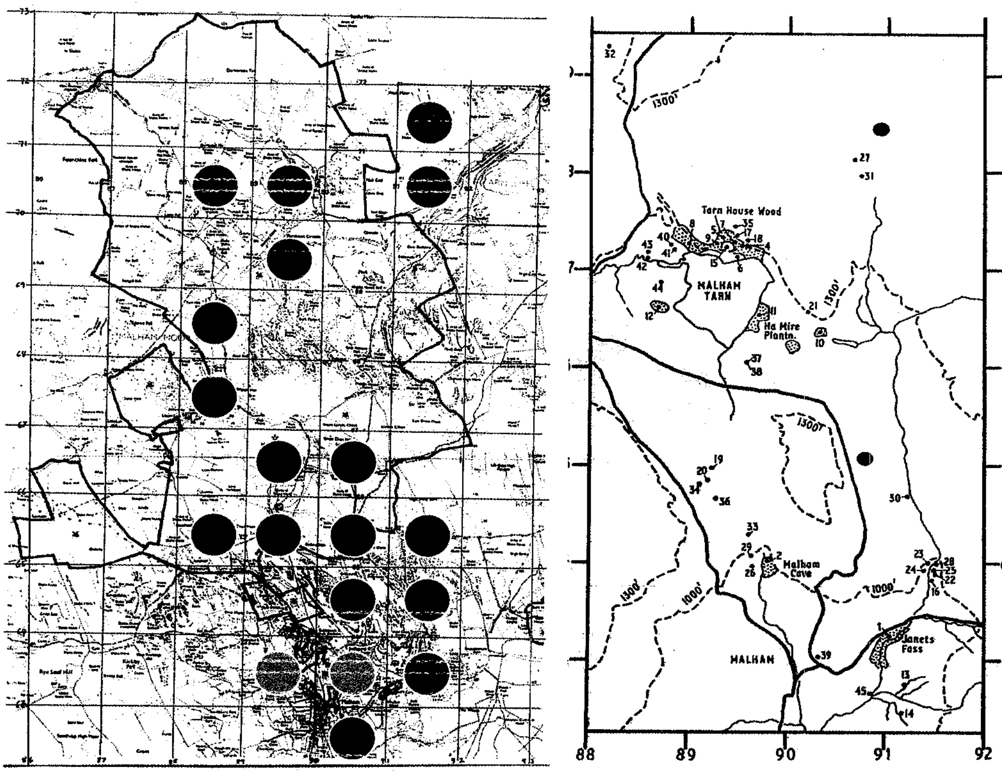
91 species of mollusc are presently recorded from the Malham Estate, with a further 3 species having been recorded as fossil only, *Leiostyla (Leiostyla) anglica* (W.Wood, 1828), *Spermodea lamellata* (Jeffreys, 1830) and *Zonitoides (Zonitoides) nitidus* (O.F.Muller, 1774), (Keen, 1989), bringing the total to 94 species. *Columella aspera* Walden, 1966 occurs just outside the estate but within the study area.

In 1956 L.W.Stratton published "The Mollusca of the Malham Area" (Stratton, 1956), in which he listed 77 species, 3 of which, *Abida secale secale* (Draparnaud, 1801), *Vertigo (Vertigo) pusilla* O.F.Muller, 1774 and *Helicella itala itala* (Linnaeus, 1758) have not been re-found post 2000, and of these only *Vertigo pusilla*, has not been re-found since 1956.

The paper by Cameron and Redfern, on "The Terrestrial Mollusca of the Malham Area", published in 1978 added several additional species to the list, bringing the total at that stage to 82.

An intensive survey of the Malham Estate has taken place since 2000, the intention being to produce an atlas of the mollusca fauna of the area, with up to date nomenclature (Anderson, 2005). As a result of this survey we have re-found all but 9 of the species recorded for the estate: { *Physa fontinalis* (Linnaeus, 1758), *Abida secale secale* (Draparnaud, 1801), *Vertigo (Vertigo) pusilla* O.F.Muller, 1774, *Cecilioides (Cecilioides) acicula* (O.F.Muller, 1774), *Helicella itala itala* (Linnaeus, 1758), *Pisidium (Cyclocalyx) obtusale* (Lamarck, 1818), *Pisidium (Henslowiana) lilljeborgii* Clessin, 1886, *Pisidium (Hiberneuglesa) hibernicum* Westerlund, 1894 and *Pisidium (Pseudeupera) pulchellum* Jenyns, 1832}. This survey has also produced 5 additions to the list post 2000: *Aplexa hypnorum* (Linnaeus, 1758), *Vertigo (Vertigo) genesii* (Gredler, 1856), *Euconulus (Euconulus) trochiformis* (Montagu, 1803)(= *E. alderi* (Gray, 1840)), *Deroceras (Deroceras) panormitanum* (Less. & Poll., 1882) and *Cornu aspersum aspersum* (O.F.Muller, 1774).

The discovery of the internationally rare Round-mouthed Whorl-snail *Vertigo (Vertigo) genesii* (Gredler, 1856) in Great Close Mire Field is perhaps the most important record for the area for many years. A detailed study of this site will take place over the next year or so, with the results being compared with the site at Widdybank Fell in Upper Teesdale (Killeen, 2005).



Maps showing the distribution of ***Vertigo (Vertigo) pygmaea*** (Draparnaud, 1801). Left post 2000 map. Right original L.W.Stratton map

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DROUGHTS, FLOODS AND TRYING TO CONSERVE NATURE: RECENT NATIONAL TRUST INITIATIVES IN THE MALHAM AND UPPER WHARFEDALE AREA AND THE GAPS WE SEE

Current priorities for the National Trust include a strong emphasis on catchment management and climate change (National Trust 2005 a and b). A Water Resource Risk Assessment (Haycock et al, 2005) has been carried out for the Trust. All these are of particular relevance to the 6500ha of National Trust land at Malham and Upper Wharfedale.

What is at risk?

Risks from drought and risks of flood are particularly severe due to the extent of vulnerable ground water and aquifer, erodible lithomorphic soils, flood zones, extent of peat and water-dependant SACs. Increased river erosion, sedimentation and low flows could occur in channels already compromised by engineering. Karst features are at risk from floods and pollutants. Water-dependant habitats, or those with northern species at the southern edge of their range include limestone grasslands, calcareous mires, blanket mire, hay meadows and upland tarns. Well over half the rare vascular plants in the Malham area are northern species, many of which may be vulnerable to higher temperatures and lower summer rainfall. Soils such as rendzinas, rankers, peaty podzols, peaty gleys, blanket peat and alluvium are vulnerable to loss of organic matter, erosion, drying and oxidation.

Management to mitigate impacts of drought and flood

Many initiatives are already under way. The Upper Wharfedale Best Practice Project (Environment Agency, undated), developed by Lane (2005), has identified priority grips for blocking to address run-off rates. Blanket bog is being restored by grazing reductions, and heather burning has been stopped. Surface peats are indeed becoming wetter. 'Sediment hot-spots' have been identified for stabilisation with trees. There is a broad-leaved woodland regeneration programme for gills, and stock reductions for heathland restoration should aid soil stability. Substituting light cattle grazing for sheep should reduce the compaction and erosion which occur on heavily sheep-grazed swards. Progress in re-naturalising river channels is being made with fencing set back from the river banks, and identified flood break-out points have been installed.

Pollution and eutrophication are being addressed by stock reductions, new buildings to house cattle, new manure stores, re-locating and re-designing sheep handling facilities and installing a reedbed for dirty water treatment.

Finally, to tackle climate change at source, the National Trust has an Energy Policy which includes commitment to energy efficiency and development of small scale renewables. There are initiatives in the Malham area to develop renewable energy schemes, plastic re-cycling schemes, and a shuttle bus between Settle and Malham. To protect peat the Trust has ceased burning on its properties here, which, with moor gripping, will help reduce CO_2 output. Peat is a huge carbon sink - each hectare of oxidising peat is equivalent to the vehicle emission from 200,000 km of travel.

The knowledge gaps

It is clear that climate change is affecting the Malham and Upper Wharfedale Estates already. Climate records at Malham show a 1.5°C warming of air and soil in 50 years (Sutton); the water in Malham Tarn is warming by 0.4°C per decade and peaks in ammonia in the tarn could be linked with hot summers; ringlet and speckled wood butterflies have arrived in the Yorkshire Dales and spread (Sutton). Plant species at Malham are susceptible to climate change too - Rodwell describes the example of wood cranesbill, and suggests that a shift in species composition of the Pennine hay meadows might occur. The rare snail *Vertigo genesii* which occurs in Great Close Mire is an arctic-alpine relict and rising temperature of soil might have a severely deleterious effect - we currently have little information on its biology (Norris). The link between flooding events and climate change has been made.

What will happen to whole plant communities when faced by warming and flooding? What vegetation types will result? Will there be a 'northern limestone' equivalent of 'coastal squeeze'? Where will the montane communities go? There is little or no 'available' limestone, without drift, at more northerly latitudes, nor any higher ground not already exploited.

If nearby sites are identified which could be restored to release further available sites, how would the species move?

The Trust's Climate Change position states there is a "need to recognise that we can't always conserve things exactly as we might once have. This goes for species, habitats, coasts, gardens or buildings". Can we change land-use to free up floodplains for river flooding? Can we do this on farms where the 'bottom land' along rivers is the only land available for hay and silage? Can we allow wall patterns to change which might have been in existence since medieval times?

Using Malham and Upper Wharfedale as a case study, it would be informative to review these questions, and others, in partnership with the many individuals and organisations currently making great contributions to conservation in this part of the Yorkshire Dales.

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This seminar: Norris A, Rodwell J, Sutton R.

A fuller version of this paper is available from the author.

Author: Katherine Hearn

SOME THOUGHTS ON HOW TO MAKE RAW DATA AVAILABLE TO A WIDER AUDIENCE

During the course of my work on, in particular, Cowside, Darnbrook, Thoragill and Malham Tarn West Fen Springs I have accumulated a large amount of basic data which I have constantly had to refer to. It has struck me how valuable data of this kind could be to workers be it as a base line for future work on a related site or as an example of how to approach work.

If we are to promote interest, encourage even the most elementary forms of investigation, research, call it what you may, it would appear to me that data of this nature should be openly available in as inexpensive form as is possible.

I print out data in A5 format for consumption by co-workers extra copies being inexpensively made by photocopying.

Someone is, I know, going to chip in and say "put it on the web", "put it on disc" - yes this is becoming present day norm but I find this tedious and time consuming and not as convenient as hard copy which I find much easier to consult and compare.

It is up to us as individuals to list our data and pass it on to establishments such as our own beloved Malham Tarn Field Centre with no strings attached so that they can make it available to anyone who is interested and/ or use it to the best advantage of the Centre.

I would like us all to give consideration to the idea.

Author: Douglas T. Richardson

THE EFFECT OF GRIKE ORIENTATION AND DEPTH UPON MICROCLIMATE

(Poster Display)

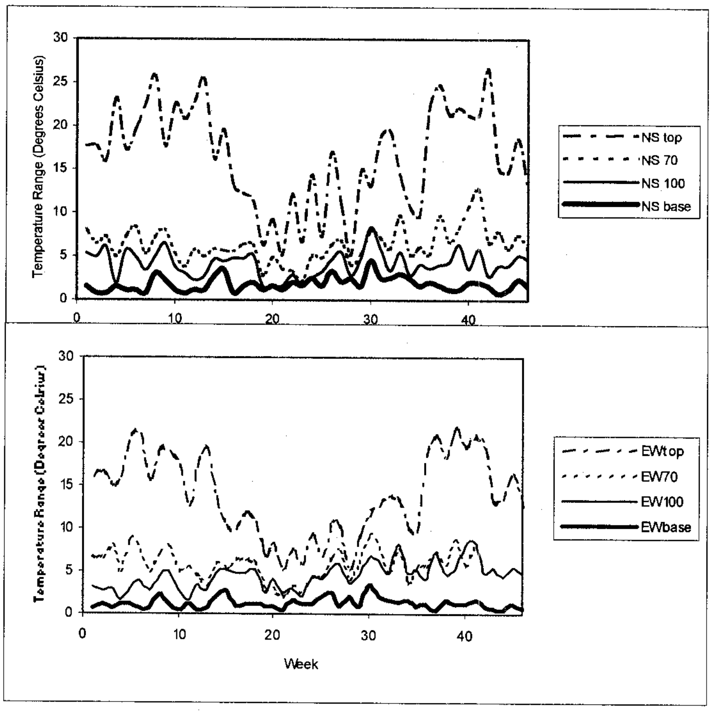
Detailed long-term monitoring of the microclimates of limestone pavements is scarce. Previous studies have generally emphasised the flora and fauna of limestone pavements, with a mention of microclimate as a contributing factor. A 46-week (July, 2002 to May, 2003) record of microclimate from Cumbria is presented. The wider implications of the microclimate upon biodiversity of grikes, using data from other pavements, are also considered.

Two adjacent grikes of differing orientation (0° - 180° and 120° - 300°) on the limestone pavement at Clawthorpe Hall Fell in Cumbria were chosen. A rig was constructed upon which sensors were attached and connected to a data logger. The climatic variables of photosynthetically active radiation (PAR), relative humidity (RH) and temperature were measured. Temperature was measured at the surface, 70cm depth, 100cm depth and just above the grike base. PAR was measured at 50cm depth and RH at 70cm depth. All measurements were taken within the atmosphere. Each variable was measured for a period of four minutes at three-hour intervals, with the average reading recorded.

The effect of orientation shows that north-south grikes are better lit, warmer, less humid, but with a greater range of temperatures and PAR (Figure 1 and 2). East-west grikes are darker, cooler, more humid, and have more frost events (Table 1 and Figure 2).

Temperature ranges are at a maximum at the surface and show attenuation with depth. Ranges reduce markedly by 70cm depth, and temperatures are very stable at the base of the grikes where no frost occurred throughout the recorded period (Figure 1 and Table 1).

Figure 1: Weekly Temperature Ranges



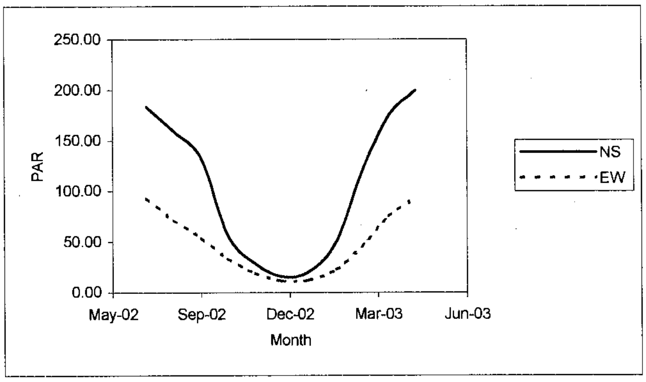
North-South Grike

East-West Grike

Table 1: Number of times below 0° C through Winter

Depth	North-south	East-west
Top	23	23
70	7	10
100	1	4
Base	0	0

Figure 2: Average Monthly PAR



Biodiversity data are not available for the monitored pavements but comparisons can be made with sites in North Wales.

More snails seem to be present in north-south grikes. Lloyd-Jones (2001) found this at Bryn Alyn and Y Taranau and Swindail (2005) found that snail distribution at Y Taranau was significantly influenced by the orientation of the grike ($p = 0.033$) in winter, but not in summer ($p = 0.637$).

Similarly, plants seem to be more abundant and more diverse in north-south grikes. This has been shown in plant surveys at Bryn Pydew (Burek and Legg, 1999 and Inman, 2000), Y Taranau (Lloyd-Jones, 2001) and Bryn Alyn (Inman, 2000 and Lloyd-Jones, 2001).

These data would appear to indicate a positive response to PAR levels by the plants, whilst abundance of snails may be in response to food availability. Given the very different diurnal and seasonal temperature regimes with depth, further work could usefully focus on examining diurnal and seasonal patterns in the distribution of invertebrates within grikes.

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ART AND SCIENCE: IS THERE SURFACE TENSION?

An illustrated talk

The programme this weekend is science based; I thought that I would put an artist's point of view, and give you a picture show. I am speaking from my own point of view, not on behalf of artists or tutors generally. Conference objectives are 'Sharing a baseline of understanding how the landscape has evolved', and identifying gaps in our shared understanding of this landscape'. That understanding, for me, includes our perceptions and interpretations, arts and sciences. I am going to speak generally, but I'll return to Goredale Scar.

What do we share as Scientists and artists? Apart from an abiding interest in the physical world? We both live within and play active roles in constructing human, mental and physical landscapes. In particular, we share process: we share observing, investigating, researching, reference to similar and past experience and examples, analysing, interpreting, structured speculation (based upon recognition of forms or assumed recognition from one point of view), visualization, exploitation of analogy and metaphor, experimental testing, and presentation of remade experience, with a 'style' or method of presentation. We work in both field and laboratory, which, for us, is not always a studio. Perhaps scientists look to explain why, through submitting theories, hypotheses; whereas artists can play imaginative visual music without being accountable. Mind you, the lack of determinism in art is similar to chaos theory, or the self-organised criticality of advanced maths. Most artists think deeply about their work, from philosophy to technique. For us both, good work comes out of vision and good technique.

The Process: It is important to visit the site, get down on the ground and actually get out of the car and to explore the site on foot, if it is possible, though it's not always hospitable. I collect information by sketching, photography, reading, trying to understand the formation of the land, and interpret the 3Dimensional qualities. Not the landscape view. This can mean going into areas where there is rather more to be learnt. Where there is a lack of current information, artists will pursue their own investigations; Constable painted a series of Cloud Studies, noting appearance, time, wind direction, temperature etc. Piper, examined glaciated rocks. Of course, there is also a conceptual stage to our work, beyond the perceptual. This introduces the different ways of presenting information, perspective ways of showing and seeing, orthoganal drawings like these architectural drawings by Richard Rogers.

Presentation can take many forms: Constable was painting The Haywain as a great picture for a grand presentation, the Royal Academy. But this painting was still revolutionary, recording ordinary life, from men fishing to labourers cooling the cart-horses, to the reapers in the background. Heaton Cooper worked mainly in the Lake District, often recording rock formations. John Nash, who taught for years at Flatford Mill, was a passionate countryman, a great gardener, whose art was always focussed on the land, and plants; he was a good plant illustrator. He wasn't much interested in talking about art, only country matters. His brother Paul, on the other hand, an aesthete and intellectual, looked for other messages in the landscape, surreal and spiritual experiences. Christo wraps buildings, and re-interprets the spatial qualities of solids and voids. He prepares proposals like an architect, raising funding and approvals to realise such works as 'Walking Fence' in California, even for a short period. A small sculpture of mine, very much with land in mind. Photography: Robert Davies took a superb midnight view of El Capitan, in the Yosemite. Gerhard Richter, a superb painter uses photography.

There are some artists whose work is based upon the experience of being in the landscape; their time spent there is the art. How, they say, can any painting, a view, express the experience? Richard Long records a walk in Dartmoor; as does Hamish Fulton. Of course, there remains a small question of the images presented; isn't it art also? With Andy Goldsworthy there is a material art object, created from the material on site (the site is his studio, workshop), always short-lived and rarely making any lasting mark on the land. The photograph is all that remains.

Those are different ways that artists present their own experiences and investigations. I am just starting work on Gordale Scar. My work is involved in analysing the spatial qualities of particular places; these are steps that I have taken already.

I photograph and use 1:25,000 and 1:5,000 OS and geological maps. It is this business of translating a 2D drawing into 3D information and vice-versa, a process that we all here have to tackle. Some forms are less accessible; if the ground has a depth, above base rock, how does one show all the anticlines and synclines?

Looking at the work of others: there is a famous painting Ward, with miniature cattle. Piper was also taken by the awe of the place, but with some nice description of the rock face. Karl Weschke is more interested in the volumes of the rock walls, a more architectural aspect. He argues that the land has fashioned and shaped the mind and body of our species; however, he visited Goredale because he had seen Ward's picture, dismissed it, and then wondered whether he was missing anything. I have no more on Gordale Scar, yet.

I am a painter, so are most of the people on my Courses. It is important to me, and others, to understand how the landscape is formed, and I always appreciate the knowledge that I have gained from the field centres, including this one. Like scientists, we also produce our findings. We need this exchange of information.

In the art world now, there is a richness of diverse directions and products. Don't be blinded by 'state' art; every now and then, the 'minor' players, artists hardly heard of who do not seek publicity, emerge, like John Virtue, who has been working in the Devon countryside for years, and who was brought to London last year to draw the city. There are many others: Michael Porter, Philip Hughes, who is particularly interested in rock formations, Sarah Gillespie, painting Slapton Ley, and Tabner who works outdoors, sometimes on the Humber, returning repeatedly to a hawthorn, a record of growth and seasons. The avenues of exploring landscape through painting and drawing remain very much alive, desired and desirable, even if not publicly fashionable. Like yourselves, artists are full of enquiry.

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