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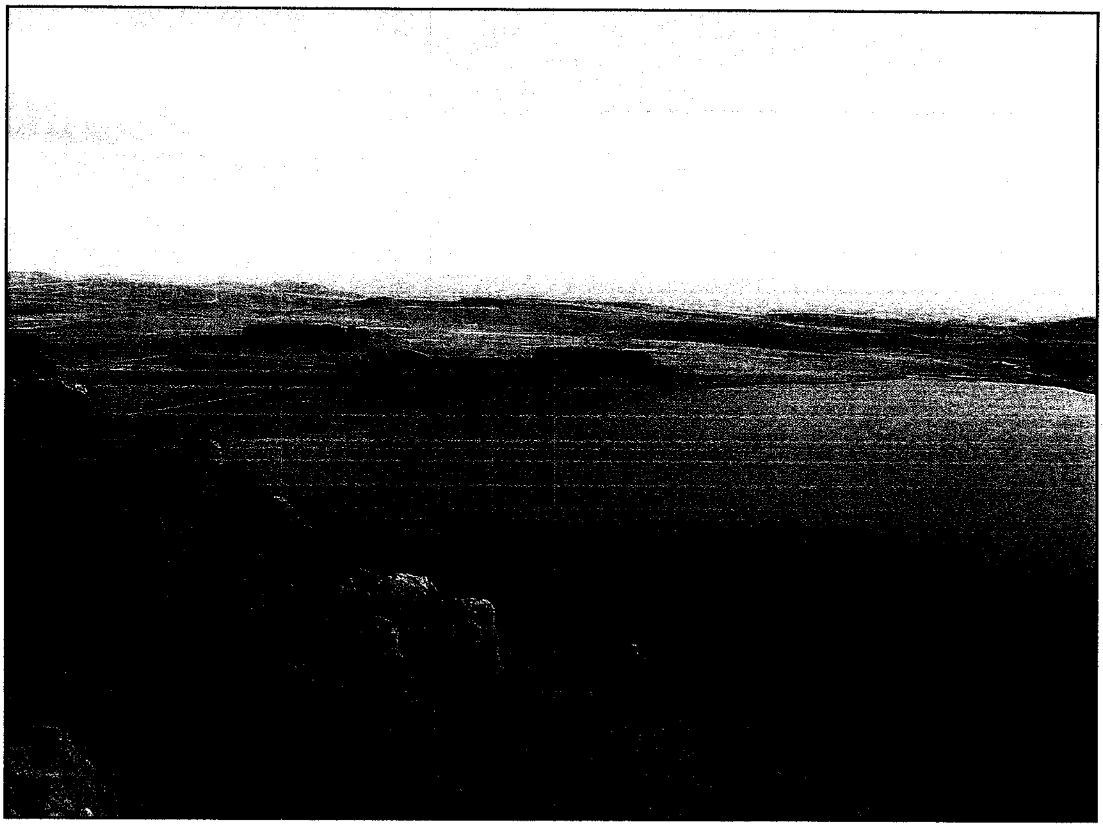
Monitoring and Managing Change at Malham Tarn



The Malham Tarn Research Seminar

Friday 16th – Sunday 18th November 2001

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Foreword

The second Malham Tarn Research Seminar was planned before I took up post as Head of Centre. For me it became the highlight of 2001 as friends of the Centre gathered to share their experience and visions for the future.

As someone returning to the area the Seminar programme was tremendously stimulating; presentations of historic and current research findings lead onto a wide ranging discussion on the future of the landscape and conservation. This was particularly pertinent in a post Foot and Mouth livestock-free landscape. One year later the effects of the virus and the control policy are still evident and the future of the landscape is still open to debate.

This compilation of extended abstracts and short papers is one definite outcome from the Seminar and although it gives a flavour of the discussion there was much more to the weekend than can be fully represented here. Individual authors may publish fuller versions in appropriate publications such as Field Studies.

A second outcome was the establishment of the Cowside Beck Research Group. The idea was proposed by Oliver Gilbert and taken up enthusiastically on a variety of fronts; initial work on water chemistry, lichenology and valley form took place in 2002. The Research Group is an open access body and any further contributions will be most welcome.

There are few sites in the country with as diverse and strong a research history as Malham Tarn. A place based seminar is one way that workers from different fields can meet and share their experience. The 2001 seminar brought together many workers from different areas and the dominant theme was ecological. Ideas for the theme of the 2003 Seminar along with offers to chair sessions, organise proceedings and other hints or tips for the weekend would be gratefully received.

The dates for the next Malham Tarn Research Seminar are Friday 14th – Sunday 16th November 2003. I am sure that the next set of abridged proceedings will be of as much interest as these.

Adrian Pickles
Head of Centre
Malham Tarn Field Centre
November 2002

Acknowledgements

All contributors and attendees.
Cory Jones for setting the process in motion
Paul Evans, Jack Talling and others for guidance on structuring the sessions
Elizabeth Judson for co-ordinating the programme and facilitating the weekend.
Steve Trudgill for being lead-chair person.
Malham Tarn Field Centre Staff: catering, domestic and office staff for a splendid show.
Margaret Marker for being the driving force in compiling these proceedings
Paul Bradley for the front cover photograph.

THE MALHAM TARN RESEARCH SEMINAR 2001

Friday 16th – Sunday 18th November 2001

Past, present, future. Monitoring and managing change at Malham Tarn

Malham Tarn Field Centre is the focal point for research activity in the Malham area. As we move into the twenty first century The Countryside and Rights of Way Act, European Habitats Directive for Special Area of Conservation, and the UK Biodiversity Action Plan will all impact on the area. The 2001 outbreak of Foot and Mouth in the Dales may have long lasting agricultural and economic effects which need to be taken into consideration. The research seminar brought together researchers, external agencies and the managers responsible for the site. This enabled participants to share current knowledge and to consider future research needs and opportunities.

Original Objectives

- Maintaining the profile of Malham as location for research
- A review of research based on Malham Tarn
- Developing a shared understanding of the future of:
  - □ Malham Tarn National Nature Reserve
  - □ The National Trust Malham Estate
  - □ Field Studies Council (FSC) Malham Tarn Field Centre
- To establish priorities and opportunities for research and monitoring based at Malham Tarn

Programme

Friday

Where are we now?

- Welcome
- Conservation objectives in the Yorkshire Dales National Park, the Craven Limestone Complex Special Area of Conservation and at the Malham Tarn National Nature Reserve. — *Paul Evans*
- The future on the Malham Estate. — *Martin Davies*

Saturday

Past research at Malham

- 30 years of limestone erosion monitoring. — *Steve Trudgill*
- 50 years of climatic monitoring. — *Tim Burt*
- 10000 years of sediment history. — *Allan Pentecost*
- Solutes and seasons: water analysis on Tarn Moss. — *Mike Proctor*
- Carbon cycling in Malham Tarn using stable isotope tracing. — *Pietro Coletta*
- Solute budgets in Malham Tarn. — *Jack Talling*
- Five kilometres around the Centre. — *Allan Pentecost*

Tour of Estate / NNR — *Martin Davies / Paul Evan /Robin Sutton / Adrian Pickles*

Current issues and current research

- Chironimids: fly dipping can measure lake status. — *Les Ruse*
- The future of White Clawed Crayfish. — *Paul Bradley*
- Chara. — *George Hinton*
- Springtails. — *Peter Bruce*
- Lesser Known orders. — *Douglas T Richardson*
- Population Biology and conservation of the nationally rare moss *Zygodon gracilis*. — *Alastair Headley*
- Bats in Upper Wharfedale. — *John Altringham and David Bullock*

Evening Session

- Walter Umpleby's Diary: haytime climate at Newhouse Farm. — *John Rodwell*

Sunday

The Future of research and monitoring at Malham

- North and East Yorkshire Ecological Data Centre - *Lisa Kerslake*
- Yorkshire Dales Biodiversity Action Plan - *Tim Thom*
- Conservation objective and monitoring needs. — *Roger Meade & Chris Maidstone*
- The role of Malham Tarn Field Centre. — *Adrian Pickles*

Poster displays

- Mapping pre-last Ice Age dolines. — *Helen Goldie & Margaret Marker*
- Mounting Diatoms for microscopic purposes - *Steve Gill & Mike Samworth*

- Diptera. *Peter Bruce*

WHITE-CLAWED CRAYFISH *(Austropotamobius pallipes)* AT CRAVEN LIMESTONE COMPLEX SAC, NORTH YORKSHIRE

Introduction

This short paper summarises interim findings of a three-year research project investigating white-clawed crayfish (*Austropotamobius pallipes*) at Malham Tarn, its feeder streams and outfall stream, which together comprise the major wetland component of the Craven Limestone Complex SAC, North Yorkshire. Field investigations have been carried out in 2000 and 2001, and are continuing during 2002, with funding of essential research expenses from English Nature Species Recovery Programme.

The primary focus of this PhD research is concerned with aspects of the pathogenesis of crayfish plague (*Aphanomyces astaci*) in riverine populations of *A. pallipes*. Crayfish plague has not been confirmed at Malham Tarn, but *A. pallipes* have virtually disappeared from this site, and the cause of this is currently unknown. One element of the current research is attempting to establish whether crayfish plague may have contributed to the loss of *A. pallipes* from this SAC site.

The style of this short paper is deliberately brief and omits detailed presentation and analysis of field results at this interim stage. Paul Bradley presented interim findings at the FSC research seminar in Nov-01, and subsequently at English Nature's 10th Anniversary Species Recovery Programme conference in Dec-01. A short article on this work subsequently appeared in the Feb-02 edition of BBC Wildlife Magazine. Paul's thesis is expected to be submitted during Autumn 2003, and further publications are planned to disseminate subsequent findings of this ongoing research. Paul also leads IEEM training courses on '*Working with Crayfish*', which are based at FSC Malham Tarn Field Centre.

Site Description

Malham Tarn is a largely natural headwater lake, situated at an altitude of *ca.* 376.6m. The catchment covers an area of only about 600ha. The Tarn is principally fed by an inflow stream in the northwest corner, and the outflow stream flows only a short distance (*ca.* 500m) above ground, before sinking into the Great Scar limestone in several places, and emerging downstream of Malham Cove as a headwater tributary of the River Aire. The Tarn takes much of its inflow from springs at the base of the limestone to the north, but there are also a number of smaller inflows, including a line of springs emerging along the shallow margins of the northern shore of the Tarn.

The Tarn is a large but relatively shallow upland lake. The Tarn covers an area of 62 ha, but its maximum depth is only 4.4m, with an estimated mean of 2.4m. The surface water temperature rarely exceeds 15^0C, and because of its exposed location and shallowness, thermal stratification is rare and transient. The water of the Tarn is base rich (alkalinity ranges from 62-142 mg.L^{-1} CaCO3), and typically shows pH in the range 8.0-8.6 (Woof and Jackson, 1988). During the summer months, higher water temperatures and increased photosynthesis in the Tarn lead to a reduction in carbon dioxide concentration and subsequent calcium carbonate deposition onto the floor of the Tarn (Pigott and Pigott, 1959).

The water level of the Tarn currently varies by *ca.* 0.15m during the year. The water level would have been much higher in the early Post-glacial, when the outflow discharged over Gordale Scar. The level would have dropped when the outflow took a more southern route towards Malham Cove, but was then artificially raised by *ca.* 1m following construction of an embankment and sluice gate in 1791.

Malham Tarn and its associated wetlands were designated as a National Nature Reserve in 1992. The area is part of the Malham and Arncliffe SSSI, first notified in 1955, and was listed as a Ramsar Site in 1993. The Tarn is the highest and best known marl lake in Great Britain (Ratcliffe, 1977), and is one of only eight upland alkaline lakes in Europe.

Craven Limestone Complex was first submitted as a candidate SAC in 1998. SACs for white-clawed crayfish are those that are considered to:

- give a representation over a wide geographical area;
- cover a variety of habitats, including rivers, natural lakes and some `refuges` of artificial origin that contain large isolated populations with a good chance of remaining free of crayfish plague; and,
- have recent (post-1990) records of healthy, recruiting, white-clawed crayfish populations free of plague.

Research Progress

An historical review carried out for the current research found that white-clawed crayfish were apparently abundant at Malham Tarn until the 1970s. Holmes (1965) commented that crayfish, "*...are plentiful on the stony exposed shores. They attain a good size... Large numbers of crayfish remains have been noted around the edges of the Tarn when otter have been recorded in the area.*" Ratcliffe (1977) stated that white-clawed crayfish are amongst the "*most abundant species*" on the rocky shores of Malham Tarn. But it appears likely that this was based upon collated information, which was out of date when the Nature Conservation Review was published. Fryer (1993) commented that crayfish, "*...have not apparently been seen at Malham Tarn since 1976. Formerly plentiful there, they have obviously declined in abundance and may even be extinct. The reason for the decline is unknown*".

There have been a small number of records of white-clawed crayfish at Malham Tarn over the last 20 years. However, it is clear that a very substantial decline occurred during the 1970s, leaving only a small fragment of the former population at this site. A survey of white-clawed crayfish at Malham Tarn was carried out by English Nature in 1997, to assist assessment of Malham Tarn as part of the Craven Limestone Complex candidate SAC. The survey located a total of seven white-clawed crayfish at only two locations on the margins of the tarn. Malham Tarn is an isolated headwater, and the 1997 survey report considered that, as such, the possibility of a plague outbreak at this site would be very unlikely. However, the survey report recognised that crayfish plague can be carried by fish transfer between waters (Alderman and Polgase, 1988).

Detailed surveys carried out during 2000 and 2001 have located a total of 44 white-clawed crayfish at Malham Tarn. All were found to be mature animals. Biometrics have tentatively aged these from 5 to 15 years of age. However, at this altitude the growing season for crayfish is likely to be shorter than low altitude populations, and it is possible that these animals may be older than biometrics suggest.

Fieldwork carried out by FSC Malham Tarn Field Centre during the 1950s found densities of white-clawed crayfish within the range 1 to 5 crayfish.m^2. The Tarn covers an area of 62ha, and this density range would give population estimates of 620,000 to 3,100,000 at Malham Tarn. Based upon the number of marked/unmarked crayfish recorded during 2000 and 2001, it is estimated that the total population of trappable individuals at this location may now be less than 100 animals.

White-clawed crayfish are one of the interest features for which Malham Tarn was notified as part of the Craven Limestone Complex Special Area of Conservation. On the basis of these investigations, the condition of the *A. pallipes* population at Malham Tarn is *Unfavourable* (JNCC, 1998). This category allows that recovery may be possible, and may occur either spontaneously or as a result of effective conservation actions being identified and implemented. At this stage, it remains possible that the population may have stabilised at a low level, or may have begun to recover. Studies are continuing during 2002 and 2003 to further examine the status of white-clawed crayfish at Malham Tarn, the possible causes of population decline, and the factors that have enabled this remnant population to survive.

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Author: P. Bradley (March 2002)

CARBON CYCLING AT MALHAM TARN: A STUDY USING STABLE ISOTOPES

Introduction

The seasonal dynamics of the Malham Tarn carbon cycle were investigated through regular fieldwork every 3-4 weeks over three years. This involved the use of stable isotope analysis to monitor seasonal changes of dissolved inorganic carbon (DIC) in the lake's inflow and outflow waters.

There are two stable isotopes of carbon: 12C (global abundance 98.89%) and 13C (global abundance 1.11%). Environmental processes change the ratio of 12C to 13C at various stages of the carbon cycle. For example, plants preferentially take up the lighter isotope (12C) during photosynthesis; for aquatic plants this leads to depletion of 12C in the surrounding water and to concentration of 12C in the plant material. Plants are a source of 12C rich carbon, which is released during respiration and organic decay.

Seasonal changes in stable isotope composition

The stable isotopic composition of DIC was seasonally variable in both the tarn inflow stream (Tarn Beck) and at the tarn outflow:

Tarn Beck

Two sources of carbon determine the stable isotope composition of the spring water DIC that feeds Tarn Beck: 1) Biologically produced soil CO_2, which dissolves into rainwater as it drains through the catchment's soils. This is rich in the 12C isotope and will vary seasonally with biological activity. 2) Carbon derived from weathering of the local limestone.

A strong negative correlation was observed between Tarn Beck DIC stable carbon isotope composition and average temperature 48 to 69 days prior of sample date ($R=-0.7185$ $P<0.01$). If this time lag represents the flow-through time for spring water: The most 12C enriched DIC, which occurred in Tarn Beck during mid September, will correspond with high soil CO_2 production in midsummer. 12C depletion of Tarn Beck DIC occurred in late winter and will correspond to low CO_2 production in the catchment's soil during Midwinter.

Tarn Outflow

Depletion of 12C from DIC was observed during summer. The extent of this depended on the abundance of benthic vegetation (surveyed by George Hinton, English Nature). Summer 12C depletion was greatest when benthic vegetation was abundant. 12C depletion of DIC was minimal during the summer of 1998 when benthic vegetation was sparse.

In wintertime the stable isotope composition of Tarn outflow DIC was closest to that of Tarn inflow, especially when benthic vegetation was sparse (winter 1998-99). Stable isotope composition of DIC was more variable and 12C depleted during winter when *Elodea canadensis* was abundant compared with years when *Chara globularis* var. *virgata* dominated the benthic vegetation. This observation is explained by the nature of the two plants: Chara dies back during the winter while Elodea is evergreen and will contribute more to the removal of 12C by photosynthesis in winter.

Author: P. Coletta

THE LICHENS OF LIMESTONE STREAMS

A survey of the lichens of limestone streams, covering 60 localities in England and Scotland, revealed that those in the Yorkshire Dales are richest in terms of the number of species per site.

Findings

The lichen communities are present as a series of overlapping bands related to length of submergence. These have been named the submerged, fluvial mesic, fluvial zeric and fluvial terrestrial zones. The flora involves about 50 lichens, many of which are rarely recorded specialists restricted to this habitat. The richest sites for submerged species are headwaters, especially around springs: only 4 lichens are involved in this zone. Diversity further downstream is related to the amount of exposed limestone available for colonisation with topographical complexity also important. The fluvial mesic zone is the richest with around 20 aquatic species. In the fluvial xeric zone lichens typical of damp limestone, that are not restricted to stream courses appear. Active tufa deposition and disturbance of the stream bed by farm stock are detrimental to aquatic lichens.

At the start of the survey several of the lichens present were under consideration for Red Data Book status, but once this neglected habitat had been 'de-neglected', they fell into the 'scarce' category (15-100 per 10 kilometre grid squares).

Table 1: The number of lichens in various limestone streams

	Submerged+Fluvial Mesic	Submerged + Fluvial Mesic + Fluvial Xeric
Chalk (6 sites)	2	2
Cotswolds (5)	2	2
Derbyshire Dales (4)	9	14
Ichnadamph (NW Scotland (2)	13	25
YORKSHIRE DALES		
Goredale Beck	4	8
Cowside Beck	11	19
Ghaistrills Strid	12	21
River Wharfe	12	24
Aysgarth Falls	17	29

(Numbers in brackets indicate number of sample sites)

Cowside Beck: future work

Cowside Beck which rises near Malham Tarn and flows 4 km over Great Scar Limestone to join the River Skirfare, is one of the best examples of a small limestone stream in the country. It has springs, a winterbourne section, gorges, rapids, colluvial sections and trout, which show it is unpolluted.

A group of 6 people who attended the Malham Tarn seminar, intend to produce an integrated ecological account of its bryophytes, algae, lichens, cave fauna and flora, invertebrates, water chemistry and geomorphology. This study will include the tufa depositing tributaries descending from Dew Bottoms and also Darnbrook Beck as an example of a stream flowing over the Yoredale Series geology.

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Author: O. Gilbert

AQUATIC MACROPHYTE SURVEYS OF MALHAM TARN: 1994 to 2001

Introduction

Malham Tarn is the highest marl lake in Britain and perhaps the best example of an upland charophyte (stonewort-dominated) lake. It has been the subject of intermittent survey work since the 1930s (Sledge, 1936; Lund, 1961; Holmes, 1965; Pentecost, 1984), which shows that at least a third of the lake is covered by luxuriant stonewort growth. The macrophyte assemblage, although dominated by *Chara globularis* also has significant amounts of other macrophytes including *Potamogeton berchtoldii* and *Elodea canadensis*. On the eastern side of the tarn is a permanent bed of *Potamogeton lucens*, 3 to 6 hectares in extent.

Research commissioned by the Nature Conservancy Council (Talling & Hilton, 1987) during the 1980s raised concerns over eutrophication. The work demonstrated an increase in dissolved N (nitrate) since 1950 (attributed to atmospheric N deposition) and nutrient modelling suggested that the Field Studies Centre was a possible source of phosphorus enrichment.

Methods

Given the sensitivity of charophytes to water quality, work started in 1994 to provide semi-quantitative data on macrophyte cover and abundance (frequency) in the Tarn. Cumulative presence or absence data for each species was recorded from 10 drops of a (10cm diameter) grapnel at each sampling station (see Hinton & Rees, 1989). During a day's fieldwork about 50 stations were sampled on boat transects across the tarn. Sampling points were located by compass bearings (1994, 1995) and from 1996 onwards using a hand held Global Positioning System with a precision of 5 to 20 metres. Fieldwork was carried out when charophyte biomass is at its maximum during August or early September.

Survey results

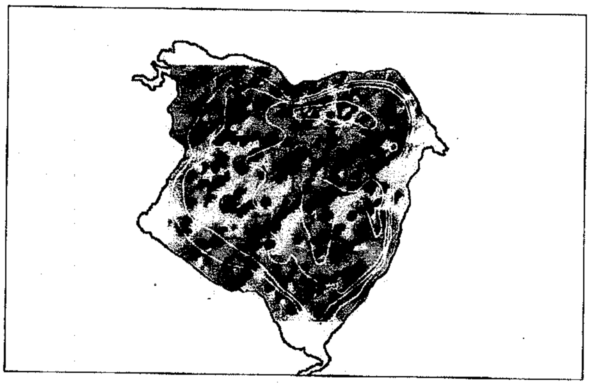
The submerged vegetation is very dynamic with submerged macrophytes changing in extent and quantity from year to year. In some years charophytes are dominant and extensive (1994, 1995 and 1999), in others *Chara globularis* is co-dominant with either *Elodea canadensis* or *Potamogeton berchtoldii*. Cumulative distribution maps for the eight year run of data (Figure 1) show that pondweeds favour shallow water (<2.5 metres deep) predominantly on the western shelf and lake centre. Charophytes tend to favour deeper water (2.5 to 3.5 metres deep) but are largely absent from the deepest points.

The year to year sequence of macrophyte spatial change shows the initial dominance of charophytes (1994) and gradual west to east displacement by Elodea over a two year period (Figure 2). 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* (the two species are now co-dominant). The small amount of seasonal data for 1997 and 1998 show that charophytes do not always have permanent over wintering swards. Charophyte abundance (frequency) was lowest in 1997 and 1998 (30%) and highest in 1994, 1995 and 2001 (>65%). Newly recorded species from this study include *Potamogeton crispus* and *Nitella sp.*

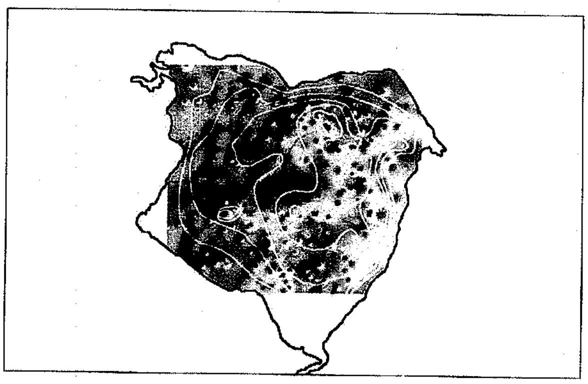
Figure 1 MALHAM TARN MACROPHYTE SUMMARY DATA

All data 1994-2001: highest abundance (dark), lowest (light)

Chara globularis



Elodea canadensis



Potamogeton berchtoldii

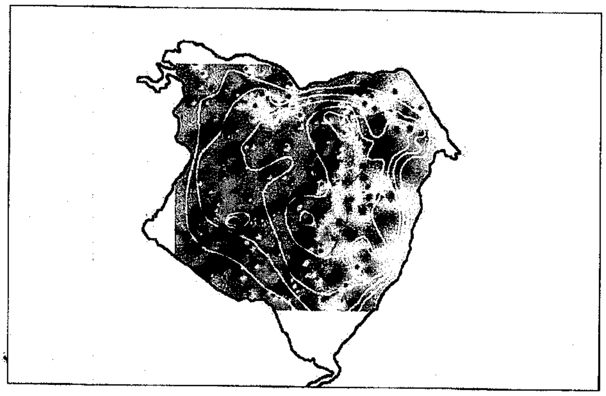
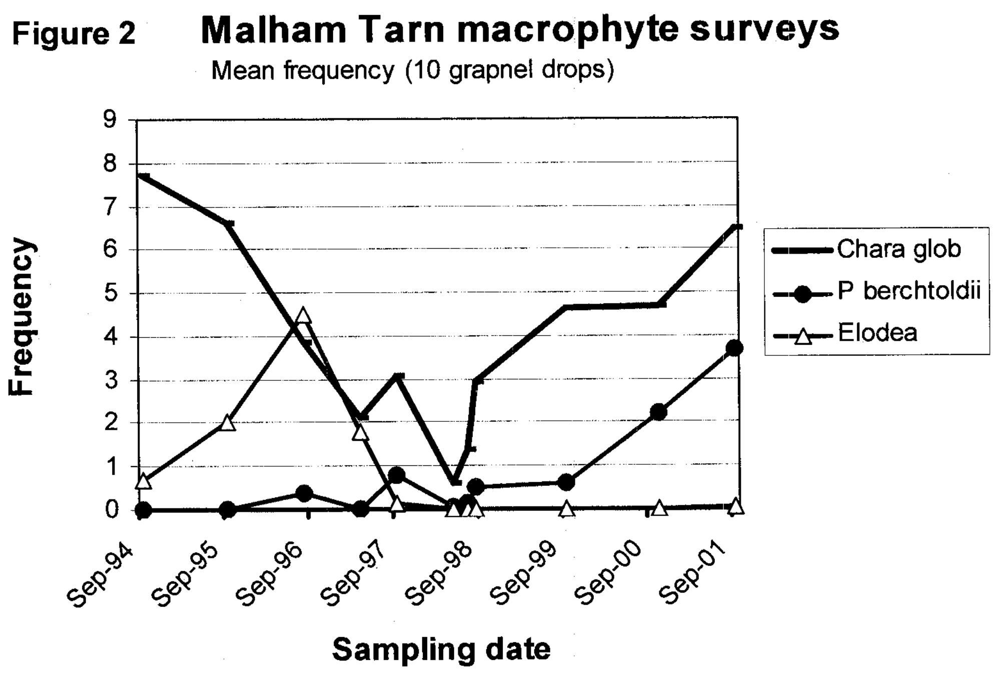
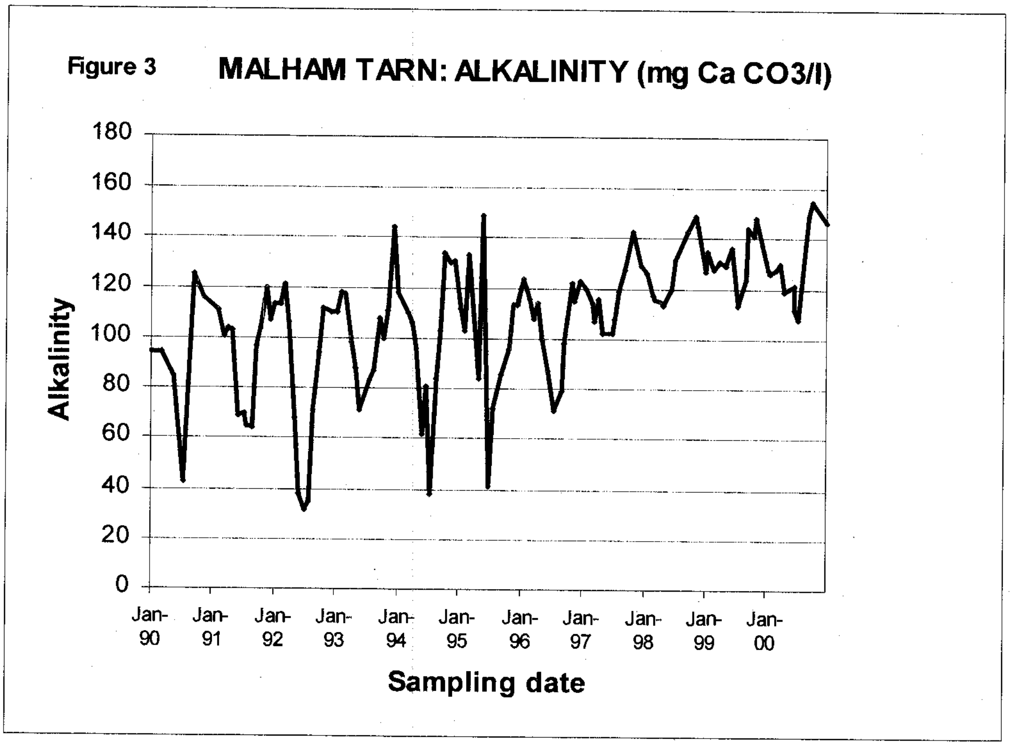


Figure 2

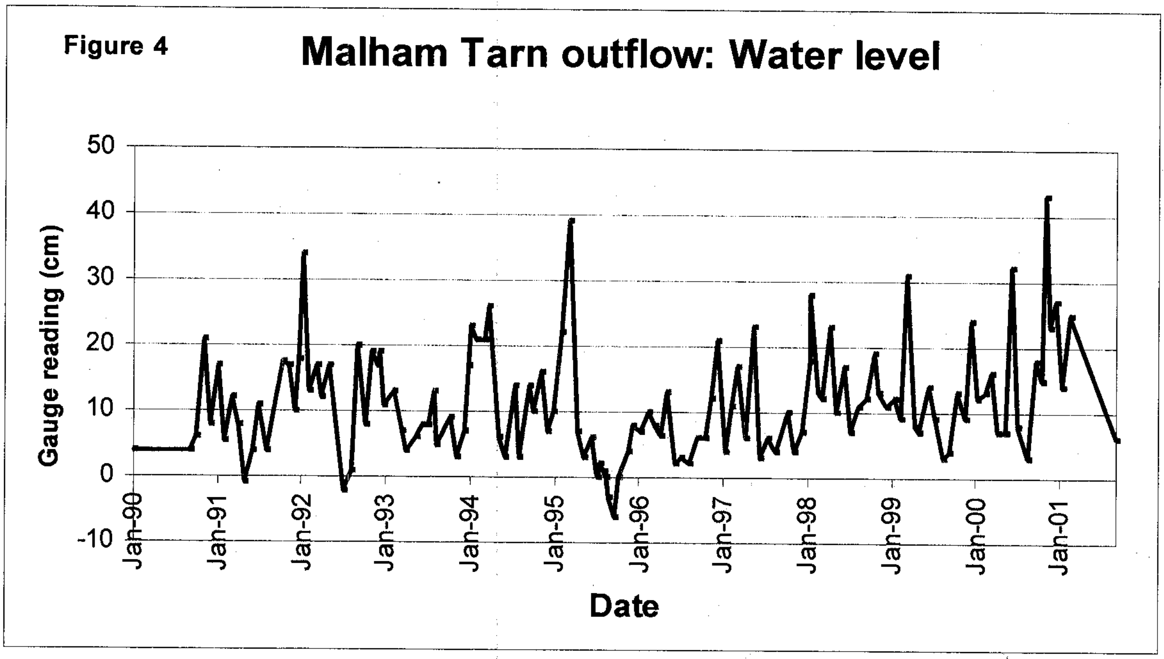


Open water characteristics

Water transparency is often poor during late summer, when blue green algal blooms reduce Secchi disk visibility below 1.5 metres (data from Coletta, P., 1997 & 1998, pers. comm.). Sporadic chlorophyll a data collected by the Environment Agency between 1995 and 2000 show peaks around 20 mg/l in late summer. The mean value for this period (c 7 mg/l) shows little change from the 1980s data (Talling & Hilton, 1987). Annual macrophyte growth in the tarn is reflected in seasonal changes in alkalinity (Figure 3: data from Environment Agency). Biotic carbon uptake and inorganic carbonate deposition cause seasonal declines in alkalinity, which have become more subdued since the 1995 charophyte collapse. Although there are insufficient data to make mass balance calculations, the halving of inorganic C uptake suggests a large fall in ecosystem productivity in recent years. There is no evidence for raised orthophosphate levels in the water column. Means are still around 5 ug P/l, which is still well below the P levels which have an impact on charophyte growth. Mean nitrate levels are unchanged since the 1980s at 0.5 mg N/l and mean pH is 8.4. The water quality data, chlorophyll a values and phytoplankton characteristics show that the tarn is mesotrophic.



Water levels recorded at the tarn outflow by the National Trust (Figure 4) show that there was a prolonged draw-down during the dry summer of 1995. During this period, *Elodea canadensis* began to colonise the shallow western shelf of the tarn, and established dominance during the following year (Elodea is known to prefer shallow water). In the absence of other evidence, this climatic event appears to be the most likely factor in the subsequent collapse of charophyte cover.



Conclusions

Other studies (Talling & Hilton, 1987; Johnes, 1996) have shown little impact of catchment changes on the trophic status of Malham Tarn. Recent water quality data show that the tarn is still mesotrophic and not suffering from eutrophication. The present study provides new evidence for the dynamic nature of the submerged macrophyte assemblage and shows a possible decline in productivity. Changes appear to be influenced by climatic events rather than any measured water quality impacts.

Future work required

The semi-quantitative submerged macrophyte survey work needs to continue (at least annually)

Monthly sampling of orthophosphate, total P, nitrate, ammonia, pH, temperature, alkalinity, oxygen, suspended solids and BOD

Monthly chlorophyll a analysis

Accurate stage gauging and calibration of the tarn outflow

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Acknowledgements:

The field work for this study would not have been possible without the assistance of National Trust, Malham Tarn Estate staff, particularly Tony Bullough and the former warden Alistair Clunas. Pietro Coletta (King's College London) has kindly provided me with some of his research data and carried out additional field surveys.

I would also like to thank English Nature staff who have helped in the field (Paul Evans).

Author: G. Hinton

PRE-LAST GLACIAL KARST DOLINES: DISTRIBUTION AND DIFFERENCES

The poster paper indicated progress of on-going karst research. The significance of Pre-Last Glacial large dolines, which may even have originated as early as the Tertiary Period, is that they contain Holocene sedimentary sequences.

Doline dimensions and distribution

These large dolines are oval or near circular in plan and may be up to 750m in diameter. They are usually shallow so are rarely delimited by contours. However in some localities dolines with depths greater than 30m have been reported. Post-Last Glacial dolines, termed shakeholes, are quite distinct, being only 2-5m in depth and 10 to 15m in diameter.

The research commenced with a pilot study on the plateau above Crummackdale Head, east of Ingleborough. Air photos were used to locate the dolines. In that area most large dolines occur within or adjacent to limestone pavement and are shallow.

As the number and distribution of these large karst features was largely unknown despite localised reports, largely dating from 1960-1975, mapping was a priority. An air photo survey was carried out which concentrated on the southern limestone area immediately north of the Craven Faults using stereoscopic air photography made available by English Nature and Yorkshire Dales National Park. All dolines identified were plotted onto 1:25 000 topographic maps. The map overlay shows the location of all large dolines between Ribblesdale and Wharfedale, a portion of the area surveyed. Ground control of approximately 25% of the dolines identified, has shown that air photo mapping is accurate. All dolines identified from the photos exist, but some have been missed particularly where the surrounding vegetation and that within the hollow are the same. Then there is no tonal contrast. This usually occurs where they lie within glacial drift.

All the dolines investigated in the field contain sediments. Even though investigation of the sediments within these dolines is at a preliminary stage, auguring to a depth of 1.3m shows that peat or oxidised peat commonly overlies silty fine sands, either yellow in the aerobic zone or grey at depth. These silty sands apparently overlie glacial drift. Investigation to a greater depth is now necessary.

Summary of the Findings

1. Mapping shows that the large Pre-Last Glacial dolines are clustered in distribution (Fig.). Crummackdale Head has a cluster of shallow dolines associated with limestone pavement. The plateau immediately north of Malham Tarn Field Centre has a high density of deep, rocky dolines. Clusters also occur east of Langcliffe and south of Malham Tarn.

2. Fieldwork suggests these dolines can be classified on morphological grounds:

2.1 Shallow rock rimmed dolines adjacent to or within areas of limestone pavement e.g. Crummackdale Head.

2.2 Deep aligned dolines with steep rocky sides e.g. on High Mark-Hawkswick Clowder.

2.3 Large shallow dolines with limestone floors within glacial drift e.g. Middle House area.(GR 9068)

2.4 Buried dolines indicated by high shakehole density e.g. east of Malham Tarn (GR 9065)

2.5 Large dolines aligned along the North Craven Fault e.g. Feizor (GR 8067) Thwaite (GR7569).

2.6 Deep large funnel shaped holes such as Gaping Gill (GR 7572) or Braithwaite's Wife's Hole (GR 7476) may be a further type.

3. Mapping of old karst features in the Ribblesdale-Wharfedale area suggests that high densities of large dolines are associated with caves with ancient phreatic passages, areas of mature limestone pavement showing rounded forms and tufa deposits pre-dating the present day.(Figure). This is scarcely unexpected since all these landforms require active karst solution over a long period. The fact that clusters occur along the southern edge of the Askrigg Block above the Craven fault system further suggests that karst development may have been enhanced by a steep hydraulic gradient.

4. All the dolines investigated contain similar sediments. The basal peat dates from 9000 B.P.implying that peat growth began only after the Loch Lomond ice advance. No scree has been found within the dolines perhaps indicating that periglacial soliflual movement during that cold phase was insufficient to move scree from the minor scars into the dolines. Preliminary analyses of the silty sands, which appear to be widespread, suggest that they may indeed be loess as hypothesised by Vincent (1995). He believes the limestone pavements developed under a loess cover.

Authors: M. E. Marker and H. S. Goldie

Figure

THE POSTGLACIAL HISTORY OF MALHAM TARN AS RECORDED BY ITS SEDIMENTS

Methods

Malham Tarn has been chosen for a detailed geochemical and palaeontological investigation of a Holocene marl lake. Two cores were taken from the Tarn sediments. One (1996/2) was taken close to the centre of the Tarn and penetrated 6.6 m marl. The other (99/1) was taken on Tarn Moss, close to the Tarn shore and penetrated 3.1 m peat followed by 2.6 m marl and clay.

Results

The marls of 1996/2 contain >95% calcium carbonate consisting of calcified fragments of *Chara, Potamogeton,* bivalve molluscs and ostracods. Organic matter amounts to about 2% of the dry weight and acid-insoluble silts and clays about 3%. In the upper 0.3 m however, the calcium carbonate declines to about 60% with a corresponding rise in organic matter and silt. This change is attributed partly to the damming of the Tarn in 1791 leading to increased erosion within the catchment.

The older marls present in the Tarn Moss core (1999/1, were dated by palynology to ca. 8ky B.P. These grade into a grey marly grit including quartz and shale particles. This gives way 1.1 m below the peat to a layer of stones. Below the stones, the clay is darker and is varved at 1.9 m. The marl of core 1999/1 is only 0.8 m thick and is similar to that of the core 1996/2 but plant fossils are not so abundant. The calcium content of core 1999/1 declines rapidly below 1.55 m where it reaches a minimum of 3-5%. Below 1.7 m the carbonate content begins to increase again to about 40% of total dry weight. The stable carbon isotope ratio is about -5 per mil VPDB in the 1996/2 core but shows a number of significant fluctuations especially near the surface of the sediments and in the deepest layers. A similar ratio is observed in the 1996/2 marls but there is an abrupt increase when the grey marly grit is approached to around +1.5 per mil. These values are maintained within the clays.

Discussion

The 1999/1 core represents a period in the Holocene from the beginning of the Younger Dryas cold stage (10 800 yr B.P.) to about 8 500 yr B.P.The varved clays mark the cold conditions which prevailed in the Younger Dryas and the layer of stones at 1.75 m may be caused by summer ice-melt suggestive of partial reglaciation. The calcium carbonate present in the clays is glacial rock flour. The marly grit, which contains charcoal, may have been deposited rapidly towards the end of the Younger Dryas when air temperature was starting to rise. The succeeding marls developed in a shallowing embayment when the amount of clay entering the Tarn was rapidly diminishing, probably as a response to revegetation of the catchment. The isotopecomposition of these marls demonstrates that they were precipitated within the lake, partly as a result of aquatic plant growth. Core 1996/2 taken near mid-lake shows evidence of shallowing from the stable isotope record and with an increase in aquatic vegetation. It is noteworthy that the stonewort *Chara globularis* or a closely related species has colonised the Tarn floor more or less continuously for the past 9000 years.

Author: A. Pentecost

WATER ANALYSIS ON TARN MOSS: SOURCES OF SOLUTES AND SEASONAL CHANGES

Introduction

Tarn Moss is an ombrotrophic bog: that is, its water and solutes come entirely from airborne sources - rain, intercepted cloud droplets, windborne dust and dry deposition of atmospheric gases. For most of the major metallic cations and mineral-acid anions (Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2}) the average composition of water in pools or shallow water-sampling pits on Tarn Moss is similar to the average composition of Malham Tarn rainwater, but more concentrated by a factor of c.1.7. A major exception is the hydrogen ion where the factor is nearer 4. However the sum of ionic charge on the cations in Tarn Moss water exceeds the sum of ionic charge on the strong-acid anions (as is generally true for other ombrotrophic bogs). The balance is made up by weak acids of the dissolved organic matter (DOM) which is an important constituent of Tarn Moss water.

Multivariate analysis of published chemical analyses over either sample sites or time shows that solutes in rainwater fall into two main groups. Na, Mg and Cl are derived mainly from wind-entrained sea spray and they form a closely correlated group. The other major ions are mainly of terrestrial origin. A group whose current concentrations are largely due to pollutant gases (SO_4^{2-}, NO_3^-, NH_4^+) and reflect human activity (power stations, vehicle exhausts, intensive agriculture) also tend to be fairly closely correlated, while Ca^{2+} (mostly from airborne dust and K^+ (airborne dust, pollen, movement of insects, birds etc. and recycling within the bog ecosystem) behave more independently.

Results

Water samples were analysed for pH, Ca^{2+}, Mg^{2+},Na^+,K^+, Zen_2^+, Cl^-, SO_4^{2-}, NO_3^-, $H_2PO_4^-$, Fe, Mn and optical absorbance at 320 nm (A_{320}: a measure of water colour and DOM) at roughly monthly intervals from 6 sampling points across Tarn Moss from 1992 to 1997; NH_4^+ was included from Dec. 1993 to Nov.1994. Viewing the sequence of measurements as a whole, a degree of seasonality was apparent in many of the variables measured, but inspection often showed that peak values did not show a close relationship with a simple summer-winter pattern. A_{320} showed a simpler and regular seasonal pattern than any other variable. The ratio SO_4^{2-}/Cl^- usually broadly in line with that in rainwater, showed occasional peaks coinciding with low water levels and oxidising conditions. Levels of NO_3^- were generally much lower than the rainwater average, approaching it only in freezing weather or immediately following heavy rain. The ration $Na^{+}/Cl^{-}$was variable, and generally higher than in seawater, reflecting effects of ion exchange and of the more rapid movement of Cl^{-} through internal generation of negative ionic charge by the DOM.

In terms of monthly means, water level was highest from January to March, and lowest from May to August. Ca^{2+} and Mg^{2+} showed a weak maximum in late summer. K^{+} was at a maximum in early May, falling through the growing season to a minimum in September. There was a slight tendency for pH to be highest in spring (c. 3.9 to 4.0)with a weak minimum (c.3.8) in July. The ratio SO_4^{2-}/Cl^{-} showed a strongly marked peak (to c. 1.1) in late summer, superimposed on a broader trend (c.0.4) in spring, highest (c.0.7 to 0.8) in autumn and winter. Data from Malham Tarn and a wide range of sites in England and Wales suggests that acid deposition of pollutant origin has reduced the surface pH on the Tarn Moss by about 0.4pH units.

Author: M. Proctor

SOME LESSER KNOWN ORDERS:

ISOPODA, CHILOPODA, DIPLOPODA, OPILIONES, HIRUDINEA & PORIFERA

Summary

Details of the 8 species of woodlouse, 6 centipede, 13 millipede, 5 harvestman, 6 leech and 1 freshwater sponge recorded for the Malham Tarn House Reserve were given. Attention was drawn to additional species found in areas adjacent to the reserve for which a search should be made. Species abundance within the very diverse habitats which occur within the reserve were discussed and suggestions put forward as to how research could be conducted, including involvement of student as well as professional groups, and methods of verifying records prior to inclusion in a data bank.

Isopoda (woodlice)

Eight species of woodlice are recorded: *Oniscus asellus, Philoscia muscorum, Porcellio scaber, Trichoniscus pusillus, Trichoniscus pygmaeus, Porcellio spinicornis* (which favours limestone wall tops), *Androniscus dentiger* (a synthantropic species) and *Armadillidium pulchellum* (found in tilth beneath stones particularly those of scree).

Britain's rarest woodlouse, *Armadillidium pictum* is found at Stainforth just over the hill to the west. It is found in association with *Armadillidium pulchellum* in some parts of Great Britain so any specimens of *A.pulchellum* must be looked at very carefully, and if doubts arise, the specimens should be submitted to an expert for assessment.

We have as yet, no sitings of *Haplophthalmus sp.* perhaps the only other woodlouse that will be found in the area.

Chilopoda (centipedes)

Six out of the 12 species so far recorded for the 10 km grid square SD 86 are recorded. These are: *Geophilus insculptus, Lithobium forficatus* (ubiquitous but tends to favour synthantropic sites), *Lithobius melanops, Lithobius variegatus* (looks like *Lithobius forficatus* but has very distinctive purple-banded legs), *Necrophloeophagus flavus* (a species favouring wetter sites), and *Strigamia acuminata* (another species with synthantropic tendencies). *Lithobius crassipus,* one of our commonest centipedes has not yet been found within the Nature Reserve but is quite common at Dean Scar in adjacent SD8865. A further 5 ubiquitous species are recorded from adjacent areas.

***Diplopoda* (millipedes)**

Thirteen species of millipede: *Archiboreoiulus pallidus, Boreoiulus tenuis, Cylindroiulus punctatus* (a subcortical species), *Glomeris marginata* (confused by some for the pill woodlouse *Armadillidium pulchellum*), *Julus scandnavius, Melogona scutellare* (only around from October to March), *Nanogona polydesmoides, Ommatoiulus sabulosus* (notable for its orange-red striped body, is apparently confined to the lawn in front of Tarn House), *Ophyiulus pilosus, Polydesmus angustus, Proteroiulus fuscus* (another subcortical species), *Stygioglomeris crinata* (a single record from 1987) and *Tachypodoiulus niger.*

Of the further 7 species found in similar habitats in adjacent areas *Cylindroiulus nitidus* is of particular interest. It is found at an altitude of 100 to 150 m O.D. in Wharfedale. Will it be found at Malham Tarn at 300 to 400 m O.D. or is altitude a limiting factor?

***Opiliones* (harvestmen)**

Only 5 out of the 8 species of harvestmen recorded for SD 86 as a whole have been found on the Reserve. These are *Lacinius ephippiatus* (which is not particularly common, with most records for Yorkshire being pre-1969). Is it on the decline? *Megabunus diadema, Mitopus morio, Nemastoma bimaculatum* and *Paroligolophus agrestis.* These last four are common and widely distributed.

Of the 6 other species recorded from adjacent 10 km squares, there are the rare *Trogulus tricarinatus* and *Anelasmocephalus cambridgei.* There is a record from High Scree Wood for *Opilio saxatilis* by W.Falconer, dated 1916, which has never been confirmed. It is found at lower altitudes in South Yorkshire. Is altitude again a limiting factor?

The Reserve with its contrasting habitats provides an opportunity for those inclined to carry out detailed habitat preference studies with the added advantage of not having to travel very far. The poster display showed that few species have come to light on Ha Mire compared to those found in the calcareous woodland behind Tarn House. Little work has been done on the Fen, Tarn Moss. Being alkaline one would expect a diversity of species but it is waterlogged which will probably have adverse effects.

Two aquatic orders: leeches and sponges

Six species of leech are recorded from the Tarn, Malham Water and Ha Mire: they are *Erpobdella octoculata, Glossiphonia complanata, Haemopis sanguisuga* (the Horse Leech, a single record from Ha Mire) *Piscicola geometra* (the Fish Leech) and *Theromyzon tessulatum* (the Duck Leech). The abundance of *Piscicola geometrica* may well have been affected by the recent decline in fish stocks. One sponge, *Ephydiata fluviatilis* is found from Malham Water. The sponge could be at risk as the stones in the stream are regularly disturbed by visitors to the area. Not much is known of the freshwater sponges of the area as a whole and for this reason alone, it should be carefully monitored.

Recommendations

Investigation of these orders is not beyond the capability of student groups and involves a number of techniques e.g. hand searching, pitfall trapping and sweeping. Identification is easily carried out by means of pocket lens and low power stereoscopic microscope and there are up-to-date keys available.

Workers should be encouraged to make detailed records using Biological Records Centre or similar type record cards. These should be kept separate and only entered in the Field Centre's permanent record system after being checked by referees.

On the terrestrial side, a word of caution: Continual sampling from fallen logs in places like High Scree Wood could prove a threat for subcortical species and some system of replacing logs and using different sites on a rotational basis should be budgeted for. If logs are to be imported, avoid conifers as they are shunned by most invertebrates, especially millipedes and woodlice.

The poster display provided a visual representation of the distribution of species within the Reserve.

Author: D. T. Richardson

FLY-DIPPING TO MEASURE LAKE STATUS

Method

Thirty lakes in England and Wales were characterised by the distribution and abundance of 275 chironomid (non-biting midges) in correlation with chemical and physical measurements. A 250 micron mesh net was used to collect floating pupal chironomid skins found at leeward lake shores. These skins float for about two days before they sink. A sample will be representative of recent adult emergence from across the lake. Species identification of these transparent, well-ornamented pupal skins are relatively easy to identify. The lakes varied in surface area from 5.2 ha to 1255 ha and included Malham Tarn. Three lakes were surveyed twice.

Results

A survey consisted of four sampling visits in a year. Using multivariate regression, alkalinity and lake volume were the best predictors of chironomid species distributions among lakes. Conductivity, lake volume and altitude were the best variables discriminating lake classes based on species distribution. A biological classification, influenced by lake conductivity, was used to calculate indicator species scores. The relationship of indicator species assemblages to a gradient of conductivity was used to demonstrate how past lake conductivity could be inferred from mud core samples of subfossil chironomid head capsules.

Conductivity, lake area and catchment area were the best predictors of profundal species distribution. Within multivariate regression the potential depletion of lake oxygen increased in explanatory importance after exclusion of littoral species. Alkalinity, catchment area and lake area significantly explained distribution of genera. Compared with a classification derived from 208 littoral and profundal species, discriminant analysis of best regression subsets of indicator taxa found 97% of lakes were correctly classified using 15 profundal species and 94% were correct using a combination of 10 genera and species. It was concluded that the pupal skin technique provided representative samples of littoral and profundal lake habitats and that generic-level identification was sufficient for characterising lakes, as required for implementation of the European Water Framework Directive (WFD). It was recommended that high status reference lakes should only be compared with lakes of similar conductivity.

Recommendations for WFD requirements

For the purposes of the WFD, the ideal biotic reference state for a lake would be those fauna present prior to recent (~200 yr) human perturbations. Core-samples of undisturbed lake sediments provide compositional data for chironomid taxa that can be accurately dated. Relationships between relative taxa composition and contemporary environmental characteristics of lakes can be used to infer historic conditions of lakes. The relationship between conductivity and chironomid species composition among the 33 lake surveys was tested for its predictive ability on newly constructed lakes. The Environment Agency (England and Wales) has constructed a flood relief channel through gravel substrata for the River Thames to bypass the towns of Maidenhead and Windsor. As they were dug, sections of channel flooded with groundwater to create a series of lakes. Chironomid pupal skins and conductivity were sampled from six of the new lakes, four times each during 2000. Lake age at the time of the first sample ranged from four months to 3.3 years, with surface area from 0.2 to 7.0 ha. Despite a contiguous groundwater source, the lakes exhibited significant chemical differences. Sixty-eight species were identified, including some atypical of the region. Weighted average regression and calibration of chironomid data from established lakes provided good estimates of conductivity for the new lakes except for the youngest lake. These results were taken as a validation of the use of chironomid pupal skin data for inferring reference environmental conditions of a lake.

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Author: L. Ruse

SOLUTE BUDGETS OF MALHAM TARN

Some progress has been made towards a chemical budget (mass balance) for the Tarn, based on work during 1985-1987. As most components are water-borne, knowledge of the water budget is a pre-requisite. It was here constructed from an estimated relationship between Tarn water level and outflow discharge obtained by dilution gauging, on-Tarn rainfall recorded at the nearby Field Centre, and rough estimates of seasonal evaporation from the Tarn. Total inflow was obtained by difference, allowing for variable Tarn storage: most enters by a single large stream. Its annual magnitude corresponds to catchment rainfall (adjusted for altitude) and a mean run-off factor of c. 0.8.

Water Budget

Estimates of the budget quantities, in 10^6 m^3/year for the year March 1986-7 are:

Outflow	10.0
Evaporative loss	0.5
Surface inflow	9.5
On-Tarn precipitation	1.0

Chemical Analyses

Chemical analyses of the major surface inflow and outflow (at 2-weekly intervals), and of rain water, included Ca^{2+}, K^+, soluble reactive Si, NO_3-N, and total P. Their concentrations were combined with the corresponding water fluxes, and very rough estimates of some contributions from domestic sewage and field fertiliser, to estimate seasonal and annual inputs, outputs and retention in the Tarn.

Findings

The ions Ca^{2+} and K^+, were subject to a spring-summer drawdown of concentration in the Tarn. In consequence their concentrations in inflow and outflow water diverged and there was a considerable net retentention on the seasonal and (for Ca^{2+}) the annual basis. The main biological agent responsible was the stonewort *Chara globularis* that is known to reach the very high density of 1.4 kg dry weight/m^2 and to contain 213 + 3 mg Ca/g and 8.0 + 0.9mg K/g.

Silicon is another plant nutrient subject to seasonal depletion in Tarn water, in this case mainly by benthic diatoms in early spring. The concentration in outflow water was well below that of inflow most of the year and there was a corresponding net retention of Si, presumably on the sediments.

Nitrate-nitrogen provides another major summer depletion in Tarn water, well below inflow levels, caused by a combination of autotrophic plant growth and bacterial denitrification. There is a sizeable input from rain water, both on the catchment and on Tarn. Incomplete information on other forms of N prevents the construction of a full N budget, but there is an annual net removal of total inorganic nitrogen between Tarn input and output. This is a general feature of lakes with moderate to high biological productivity.

Total phosphorus is with similar concentrations in major inflow and outflow - although *en route* there is a shift from soluble reactive phosphorus (PO_4-P) to organic and particulate phosphorus. Other P inputs from rainfall, domestic sewage and field fertiliser are poorly quantified, but collectively are probably of the magnitude of an annual Tarn net retention of P (c. 50 kg/year) that could be an influence for further enrichment (eutrophication).

The long-tern retention of several elements in the Tarn can be viewed from the accumulation in the bottom sediments. Here there are considerable known contents of Ca (especially as *Chara* marl), K and P in the 0-4 cm layer. If this layer represents a time period of 60 years - a plausible estimate - its annualised chemical content would equal the flux-estimated annual Tarn retention for P but would be much less than the corresponding retention of Ca.

A fuller account of this work is in preparation for publication.

Author: J. Talling

RESEARCH REPORTS

THE NEW 5 km RADIUS FLORAS OF THE MALHAM TARN AREA

The Malham Tarn area is a site of major botanical research within the British Isles, but the literature is widely scattered and often difficult to access. These new floras provide detailed information on plant groups to be found within 5 km of Malham Tarn Field Centre. The aim is to provide mordern floras with up-to-date nomenclature which will assist teaching and research groups using the Centre. To date, two floras have been produced: *Freshwater Algae* (over 600 species including several endemics and notable rarities); *Lichens* (346 species and a number of rarities). In each flora the important bibliography is also included. Plans are underway to prepare a bryophyte flora, followed by fungi, flowering plants and ferns.

Author: A. Pentecost

COWSIDE BECK RESEARCH

Five visits have been made to Cowside, Darnbrook and Thoragill becks and their associated tributaries. During these visits some 30 water samples have been collected and analysed. Amongst the aquatic invertebrates that have been found, there are 6 species of *Ephemeroptera* and 10 species of *Plecoptera.*

I wish to thank both Dave Hodgson and Alan Heaton for the unselfish help and the farmers who have given us permission to walk their properties. As I write a further batch of invertebrates has been passed over to me.

Author: D. T. Richardson (May 2002)

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