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The peatland management handbook

T A Rowell

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THE PEATLAND MANAGEMENT HANDBOOK

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Introduction

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Introduction

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Habitat management is an essential element in the business of nature conservation. Ample information is available on the management of some habitats, notably woodlands and grasslands, but precious little is easily accessible for peatlands. This is odd in many respects because not only have peatlands - like woodlands and grasslands - long been an important element in the rural economy (the Cambridgeshire Fenland provided virtually every necessity for the livelihood of the local inhabitants) but one of Britain's oldest nature reserves, Wicken Fen, is a peatland. It is possible to trace back to the 1890s the intention to manage the vegetation of this site for conservation purposes. During this long history, much has been learned but little committed to print.

Most peatlands have been managed to some extent; many have been highly managed. Fens provided grazing, conserved grass, fuel (peat, sedge and, possibly faggots and small timber), and thatching (reed and sedge), as well as wildfowl, fish and a variety of minor products. Bogs have provided fuel (peat) as well as poor grazing and game. Often, traditional management ceased some time ago.

This handbook is a first attempt to collate information relevant to the management of **bogs and peat-forming fens**. It concentrates on management of the **hydrology** because of its prime importance in peat-forming systems, and on management of the **vegetation** as a secondary but highly significant factor in this habitat. Management of the fauna is clearly also important, particularly as many fens are prime invertebrate sites . More attention needs to be paid to this area in future revisions of the Handbook.

AIMS OF THE HANDBOOK

This Handbook has been produced with three main aims.

* To bring together and review as much as possible of the present knowledge of the management of peatlands, and to derive from this review a series of recommended management techniques.

* To stimulate improved management of peatlands.

* To encourage continued interchange of ideas and experience between peatland managers by providing a Handbook format which is easily updated in response to new information.

RESEARCHING THE HANDBOOK

Relatively little published information exists that is directly relevant to the management of peatlands. As much of this material as possible has been reviewed, and is listed in the bibliographies at the ends of each section.

As published facts on peatland management are so scarce, much of the information contained in the Handbook was culled directly from individuals interested in the habitat, or practicing management for conservation purposes. This survey covered not only the Nature Conservancy Council but also the County Trusts, the National Trust, the Royal Society for the Protection of Birds and some academic institutions.

THE FORMAT OF THE HANDBOOK

As some aspects of peatland management are in a relatively embryonic state, the Handbook has been formulated to encourage and allow for development of management techniques. Three aspects of the Handbook need emphasis.

* While one of the main aims of the Handbook is to recommend techniques for peatland management, some of the techniques discussed are essentially untested; this fact is always made clear in the text. **Feedback** is therefore needed from field practitioners on these and any other novel or otherwise unreported techniques. A reporting form is included in the Handbook to encourage the necessary feedback. In addition, a section on the **evaluation** of management techniques has been included to provide guidance on the testing, adoption and use of novel methods. This section emphasises the need for feedback. Feedback from field practitioners and further research into peatlands and their management will mean that some sections of the Handbook will become out of date quite rapidly. The text of the Handbook is stored on computer disk so that it can be revised easily and quickly in response to new information.

* **Monitoring** is an essential aspect of management. It provides the information necessary to judge whether management goals are being achieved and it is clearly an aspect of the evaluation of techniques. At present, guidance has been provided on the monitoring of vegetation. Guidance on hydrological monitoring should be available in the future.

* Although the Handbook is divided into discrete sections, few of them stand alone. The control of scrub, for instance, is an essential part of the restoration of degenerate mires, of any other activities requiring control over the water table, and of most mowing operations especially the management of *Cladium*. Most Handbook sections make reference therefore to other sections. Sections are referred to by the abbreviated title used in the running heads at the top of each page. References to the sections are always capitalised (e.g. 'see SCRUB CONTROL') so that supplementary reading can be quickly identified.

THE FORMAT OF THE SECTIONS

Each section of the Handbook presents the basic principles underlying each management technique. These are then developed into guidelines for field practice. As necessary, equipment and materials are also covered but only where the items are not likely to be in general use; basic equipment is therefore not included. The literature which forms the accepted basis of the techniques is listed in a bibliography.

ACKNOWLEDGEMENTS

A great number of people gave up their time to acquaint me with their ideas, experience and achievements in the field of peatland management, and thanks are due to all of them. I am grateful also to Wanda Fojt and Mike Clarke who co-authored sections of the Handbook, to Richard Lindsay and Wanda Fojt who commented on every section of the Handbook and to all those who commented on individual sections, to Susan House and Kate Rowell who drew most of the diagrams, and to the NCC's North of Scotland Peatland Survey Team who acted as guinea pigs for some of the practical ideas developed in the section on monitoring.

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Control of water level

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INTRODUCTION

A high water level in peatlands is of paramount importance. Peat forms under waterlogged conditions, and decomposes when exposed to air. The typical plant communities of pristine mires are adapted to a constantly high water table, and are displaced by other communities if the level falls for any appreciable period.

Peat systems are subject to natural water loss by run-off, sub-surface flow, and evapo-transpiration which balances input from rainfall or from ground sources. **Run-off** can be enhanced by cutting ditches through the peat surface. **Sub-surface flow** can be encouraged by cutting into the mire margins, or by the drying out of the surface layers. **Evapo-transpiration** may increase as vegetation changes, especially when it is towards woodland which is assisted by other drying processes.

Where mires are affected by any of these factors to a detrimental extent, management should be directed as a matter of priority towards restoring the water table to its mean level and range. The techniques necessary to achieve this are quite simple to implement, but the scale of the overall operation usually means that considerable planning and resources are required.

If work is to be carried out on restoring bogs that have been affected by drainage, then additional reference should be made to the Handbook section on MIRE RESTORATION.

PRINCIPLES

Site survey

Where any manipulation of water levels is planned, it is essential that any work is preceded by a detailed survey. The survey should aim to cover the following areas:

* Levelling of the site, with particular reference to the falls in the ditches;
* The location of the main outfall(s) from the site;
* The catchment from which water will be impounded;
* The volume of water to be impounded by any dams to be erected.

Water level and fluctuations

A plan to raise or stabilise the water table in a peatland site should take into account the natural regime the particular mire type be formed and maintained under. A raised mire, for instance, would have a water level at or near 5 cm below the surface for as long a period as possible during the year. A flood-plain fen would have a widely fluctuating water level varying from flooding during late winter to 50 cm or more below the surface at the end of the summer or early autumn.

Run-off

Many mire systems contain man-made waterways. These would have been installed for a variety of reasons, sometimes combining the functions of boundary marker and access route, but always having a drainage function, whether intended or not.

Ditches in any condition will intercept overland flow and conduct water relatively quickly off the site. This point is frequently not appreciated, as old, well vegetated ditches appear to be free of water under all situations. Experience with damming ditches in this condition shows that they quickly fill up with water which must have been flowing in the unconsolidated matter in the bottom of the ditch.

Whatever their condition, all ditches in **bogs** should be blocked to reduce the outflow of water from the site. Even when blocked, ditches will still intercept run-off and conduct the surplus over and above the ditch capacity off the site. Ideally therefore, ditches should not only be blocked but should be infilled or be encouraged to infill as rapidly as possible.

For **fens**, the situation is not so clear. On some sites, such as flood-plain fens, large ditches may have been a feature for decades or even centuries. At Wicken Fen in Cambridgeshire, for instance, the system of wide (4 - 5 m) ditches can be attributed to the seventeenth and eighteenth centuries. The aquatic environment in these ditches is well developed, and an important feature of the site. Blocking of the ditches would be an important aid to maintaining the water table, but infilling would be detrimental to other features of the site and could be rejected as an unsuitable management measure on these grounds. Ultimately, a decision must be made over the relative importance of the terrestrial and aquatic habitats, and management planned on that basis.

Many other fen situations are equally unclear, and it is recommended that advice is sought before any ditch blocking is planned.

New ditches should not be constructed on peatland sites. This has been done on occasion supposedly to conduct water into a dry area. Although ditches will act as a reservoir during periods of low water table (if the water table is below the level of water in the ditch), they will intercept run-off during periods of rainfall, reducing the amount of recharge. Where flooding from watercourses is important, they will increase the speed at which the flood withdraws.

The practical solution to the problem of ditches on peatland sites is the construction of dams.

Sub-surface flow

Most sub-surface flow in undamaged peat occurs in the unconsolidated surface layers. Deeper down where considerable compression has occurred, water movement is extremely slow. The amount of sub-surface flow depends on the type of mire and on how it has been treated. In topogenous mires, water collects in a basin and stagnates. Water moves more freely over soligenous and, to some extent, in ombrogenous mires.

Increased sub-surface flow may occur along lines of weakness in the peat which may occur in the following situations:

* When old, deep-cut ditches have become infilled with unconsolidated plant material.
* When the peat boundary has been breached, and a new, steeper hydrological gradient results.
* When part of the peat body is cut away.
* When the peat has dried out, and an attempt is made to re-wet it.
* In peat adjacent to ditches, leading directly to a fall in the water table in these areas.

Sub-surface flow in ditch lines, or as a result of a breaching of the peat boundary, can be halted by damming. Dams result in an increased and more stable water level in ditches so that sub-surface flow in the adjacent peat is reduced and the water table rises. Where part of the peat body has been cut away, a possible solution is bunding. Increased sub-surface flow due to damage to the peat structure following drying out is impossible to remedy, though the water table can be raised by damming, etc.

Dams

Safety

> Legally, no dam may be higher than 15' (4.5 m) nor may it impound more than five million gallons (22.7 million litres) above ground storage capacity, unless built under the supervision of a Chartered Civil Engineer. This includes a pond of less than 5 acres (2 hectares) having 4' (1.2 m) above ground storage capacity, for example.
>
> On-stream dams must be designed to handle runoff both from normal rainfall and occasional storms. M.A.F.F (1977) suggests that a catchment area of 500 acres (200 hectares) be taken as a maximum, because larger catchments require excessively complex overflow arrangements. This figure should be lowered for volunteer-built dams to about 100 acres (40 hectares).

Brooks (1981)

Water pressure

Water pressure increases with depth so that the highest pressure on a dam is at the base. The amount of pressure exerted at the base depends not only on the height of water on the upstream side, but also on the balancing height on the downstream side (Figure 1). It is possible, therefore, to use relatively flimsy structures provided they are relatively close together. Proximity of dams is an advantage in the peatland situation as it results in a more constant water level across the site.

Upthrust pressure

If a non-porous structure is not fixed into impervious substratum, then an upthrust pressure is exerted which is proportional to the water pressure exerted at the base. If the upthrust is greater than the weight of the structure then it may shift or float.

Current

Current should rarely be a problem on peatland sites but, if it is likely to be significant, care should be taken over the choice of materials and structure.

Erosion

Erosion is likely to be a problem on dams made of peat which are overtopped by water. As these are also not water-tight structures they should be avoided entirely. With more stable structures, erosion may occur on the downstream side under the spillway where water strikes or eddies in the bottom of the ditch. Erosion is, in this case, easily avoided by the provision of an apron (Figure 2).

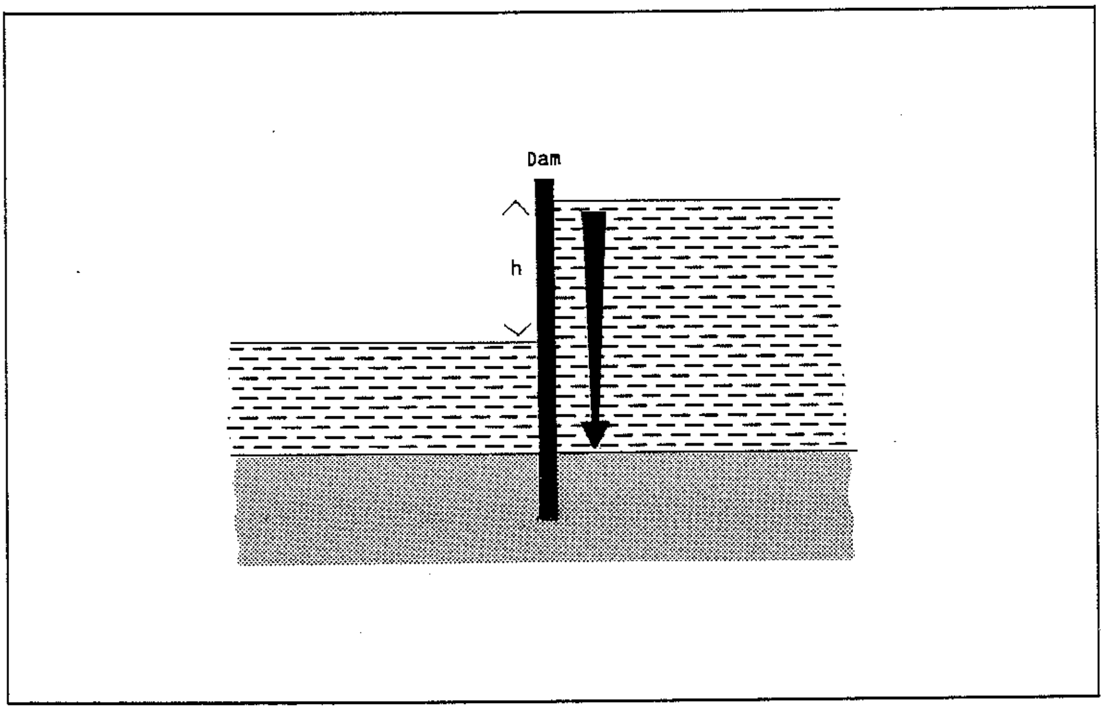

Figure 1: The water pressure at the base of a dam (indicated in this cross-sectional view by an arrow) is proportional to the head of water (h), i.e. the difference in height of water across the dam.

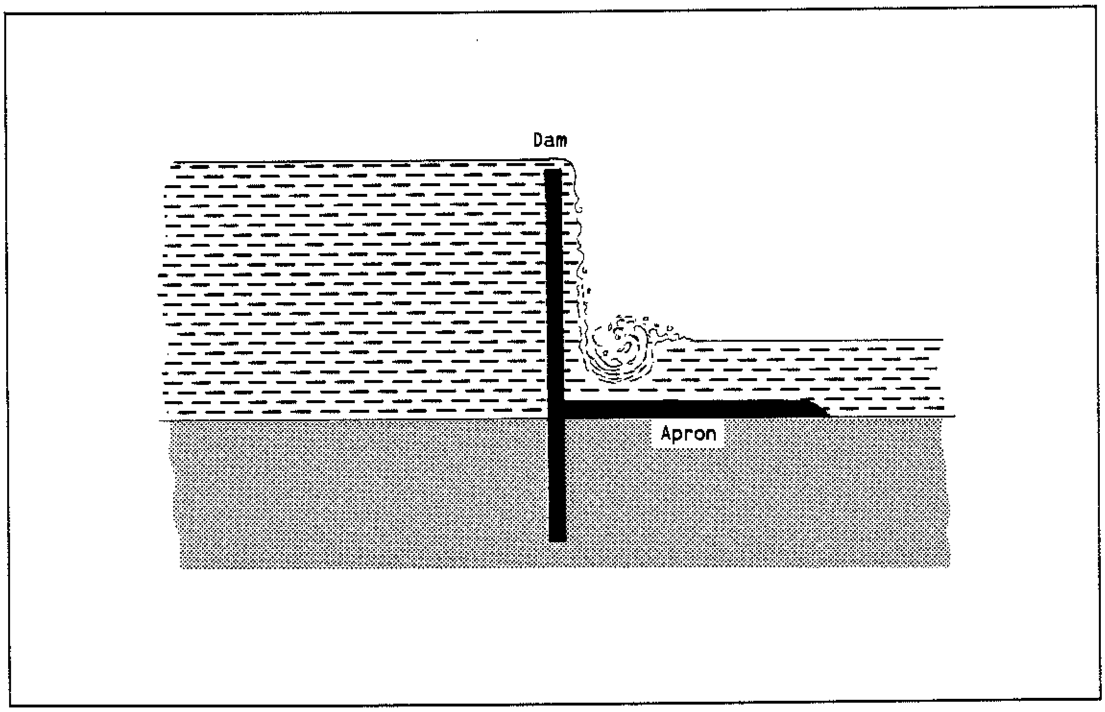

Figure 2: The provision of an apron made, for instance, of brushwood or corrugated steel prevents the scouring of the ditch bottom below the dam (seen here in cross-section).

Seepage

Any operational dam will result in different levels of water on either side. In trying to find its own level, the water will tend to seep through any convenient lines of weakness. Seepage through peat causes instability and slumping, which is another reason for avoiding the use of peat dams. Seepage will also occur around and under a dam structure. To reduce this to a minimum, dams should be keyed well into the bank on either side, and into an impermeable substratum

Requirements for dams on peatlands

The purpose of dams on peatlands is to reduce the loss of water *via* the drainage system. Ideally, dams are impermeable to water, and should remain operational for as long as possible. For maximum efficiency, it is essential that:

* The dam extends well into the banks so as to avoid piping around the ends, and well into the mineral substratum or undisturbed, compacted peat at the base so as to minimise the risk of piping under the dam;

* Installation of dams should be achieved with as little disturbance of the peat as possible, i.e. piling of the dam is preferable to excavation and backfilling;

* A central spillway should be provided if the top of the dam is not flush with the ground, so as to avoid erosion around the ends of the dam;

* An apron should be provided that will prevent erosion of the ditch bottom below the spillway;

These requirements mean that the only suitable methods of dam construction on peatlands involve piling. Piled structures have certainly been the most successful dams examined on peatlands, provided that due care has been taken to key them well into the bank and substratum, and that excavation and back-filling of the peat has been avoided. Less successful structures include peat dams and horizontal board dams; the latter always leak badly.

With these requirements in mind, designs for dams on peatlands are recommended below with guidelines for their construction.

Bunding

Bunding is an appropriate measure for the waterproofing of a peatland perimeter where general damage to the boundary has occurred. The effectiveness of bunding depends on reliable, long term imperviousness of the material used, and on a good seal being achieved at the ends of the bund. The technique may be unreliable if used to attempt the sealing up of an area of seepage without adequate investigation of the exact location of the loss, or of other breaches in the peatland boundary. As the water level rises following bunding, it will tend to find other points of weakness if they exist. Therefore, partial bunding may often prove unsuccessful.

Bunds are usually constructed of impervious soil, i.e. clay. The clay should be laid in a channel cut around the site and should be well keyed into an impervious substratum by compression with an excavator bucket (Figure 3a). If overland flow of water off the site is likely to be a problem, e.g. where the margins of a peat body have been cut away, then the bund can be constructed to protrude above the soil surface (Figure 3b). A problem in this same situation is drying and cracking of the clay where it is exposed to the air, leading to leakage of water from the peat body. A solution is to introduce an impervious polythene film into the full depth of the bund (Figure 3c). Waterproofing of this type has recently been carried out at Wicken Fen, Cambridgeshire, and is awaiting implementation at Wedholme Flow, Cumbria. The water authorities or drainage boards should have the expertise to advise on this type of work.

Once a clay bund has been installed, the area should be kept free of woody species. Their roots will tend to dry out the clay leading to cracking and leakage.

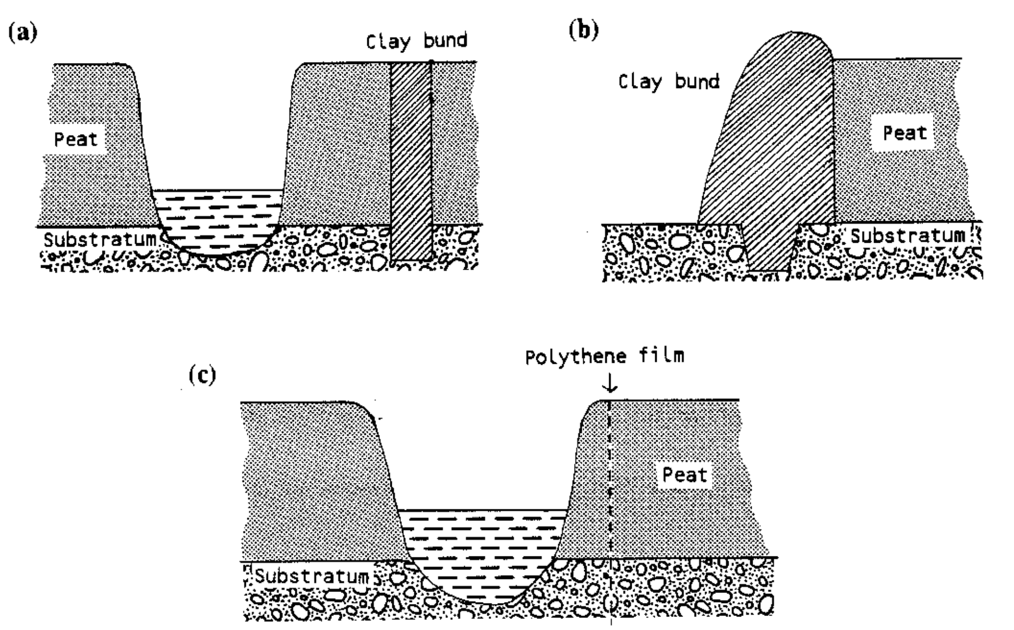

Figure 3: **Bunds can be used to prevent or reduce water loss from a pealand site. They can be constructed of clay (a and b) or polythene film (c). Where a clay bund is not completely buried (b) it can dry out and crack, resulting in leakage.**

Water supply

Once a peatland site has been adequately sealed its original hydrology will eventually be restored. Situations do arise, however, when this is not possible because the original water source no longer exists or because the site has become isolated from it. In the latter case, efforts should be made to reconnect the site to the supply. A degree of unwanted enrichment in the supply could be dealt with by a method outlined in MIRE RESTORATION and involving the ponding of introduced water on-site. Movement of the water out of the pond through the peat reduces the enrichment.

When a water supply has been lost altogether, an alternative must be considered if the site is not to be irretrievably damaged. An independent bore-hole supply has been installed at the RSPB reserve at Strumpshaw Fen, and this is a permanent though expensive solution. The points to be considered with an alternative water supply are:

* Will water quality match the site type?

* How reliable is the supply?

- How will the water be introduced into the site?
- Can the hydrology of the site be maintained? For example, is it possible to maintain the hydrology of a flood-plain fen using water drawn from a bore-hole?

Soil level

Rather than manipulate the water level generally within a site, there are occasions when it is more appropriate to manipulate the soil level. This is a technique that is only likely to be applied over a relatively restricted area within any site, and is dependent on reasonable stability of the water level. A separate Handbook section covers this topic (see SOIL LEVEL MANIPULATION).

PRACTICAL ASPECTS OF DAM-BUILDING

Slit drains up to 0.5 m across

Simple dams consisting of a single sheet of some impervious material such as corrugated steel are suitable for narrow ditches. It is possible to obtain this with a plastic coating on both sides, and this is the recommended material. Square-section material is recommended for strength. For increased longevity, the edges of the sheet can be painted with bitumastic paint.

Slightly wider ditches can be blocked using the same material, but two sheets will need to be joined. This can be achieved easily by overlapping one corrugation (temporary fixing with double-sided tape helps), then drilling through for pop-rivetting. This work can be done on-site using a hand drill.

For safety, steel dams should be capped with a strip of wood, or with a three-sided edging strip which should be available from the manufacturers of the corrugated sheets.

To insert the dam, a starter slot should be cut with a rutter through any turf or tussocks (Figure 4a); there may be some advantage in removing large tussocks first. The sheet, with corrugations running vertically, is temporarily topped with a stout, three-sided piece of angle iron (Figure 4b), and can be rocked into place (Figure 4c), initially by hand, secondly by the weight of a person standing on the angle iron (suitably supported by a helper), and lastly with a wooden tamper if necessary. The difficulty of this operation varies with the nature of the peat. Under amenable conditions it is possible for a two-man team to insert a dam every three minutes or so.

A spillway can be cut into the top of the sheet if necessary - a deep dent from a sledge hammer may suffice.

An apron can be constructed from the dam materials simply by laying a suitable sized sheet in the bottom of the ditch, and anchoring it if necessary. An alternative method is to use brushwood, if available on-site. Two or more stakes should be set deeply into the peat, just below the dam, but should not protrude above the spillway. Brushwood should be laid between the stakes with the cut ends of branches pointing upstream. Layers of brushwood should be trodden down, and wired to the stakes. This type of construction technique is illustrated in the Handbook section on GULLY EROSION CONTROL.

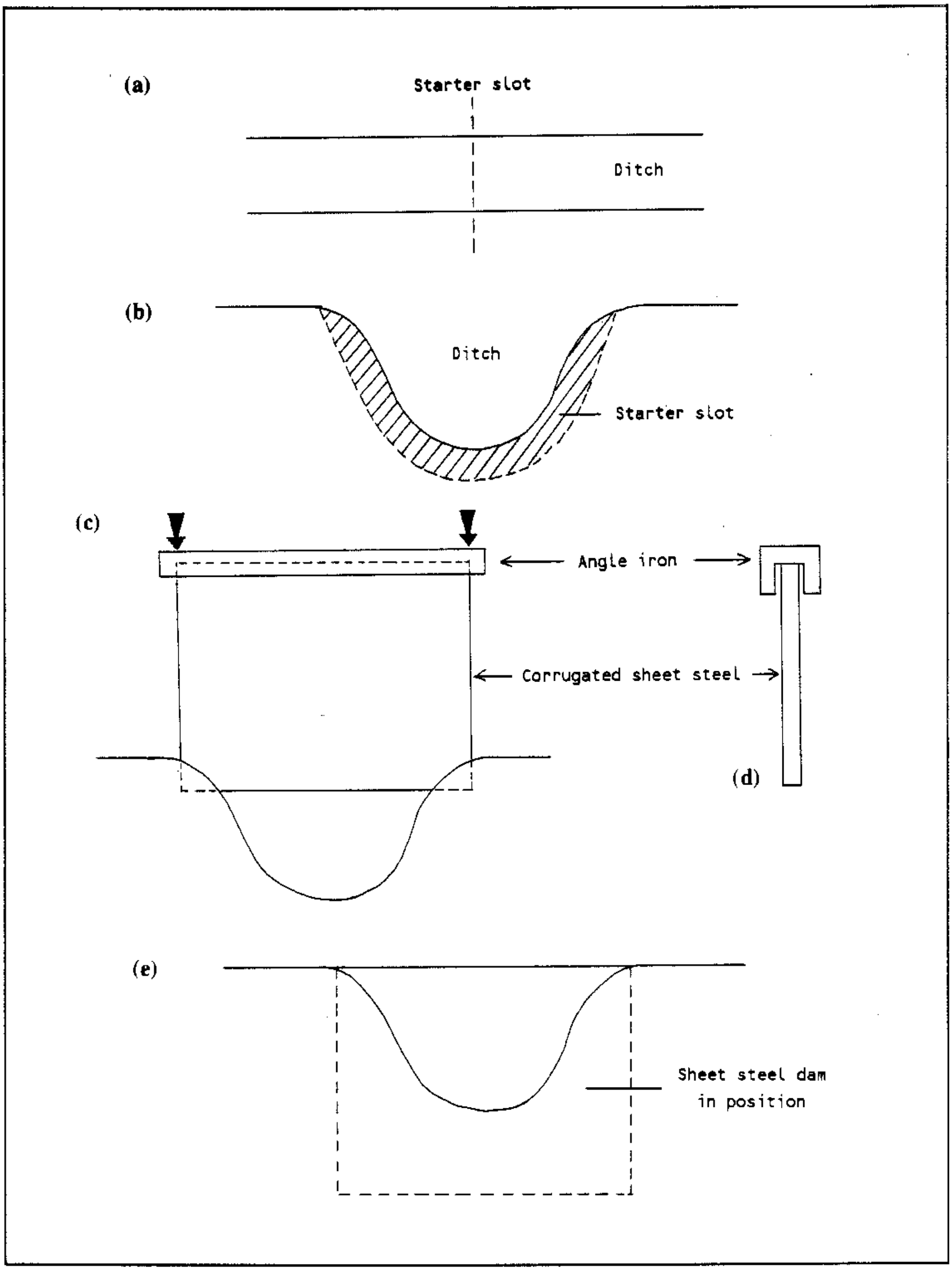

Figure 4: **The procedure for inserting a sheet steel dam. A starter slot is cut across a ditch penetrating any tussocks or tough roots; (a) plan view, (b) cross-section. A sheet of corrugated steel is inserted into the slot and topped with a length of angle iron; (c) front view, (d) side view. When the top of the sheet is flush with the ground the angle iron is removed (e).**

Larger ditches

Larger ditches than about 0.5 m deep require more substantial dams. Two designs are recommended as they fulfil the requirements for peatland dams, and have been used successfully for many years.

Firstly, the vertical board dam (Figure 5) described in the BTCV handbook 'Waterways and Wetlands' (Brooks 1981) has, with the following slight modifications, many excellent qualities.

* Untreated timber, preferably oak or elm should be used.
* The dam should extend **at least** a metre into the bank at either side.
* On the rare occasion that a lower stringer (cross-piece) is necessary it should be inserted with as little excavation as possible. Similarly, excavation for the upper stringer should be kept to a minimum; it can be laid at ground level and secured by stakes if sufficient clearance can be gained above the spillway to avoid blockages.

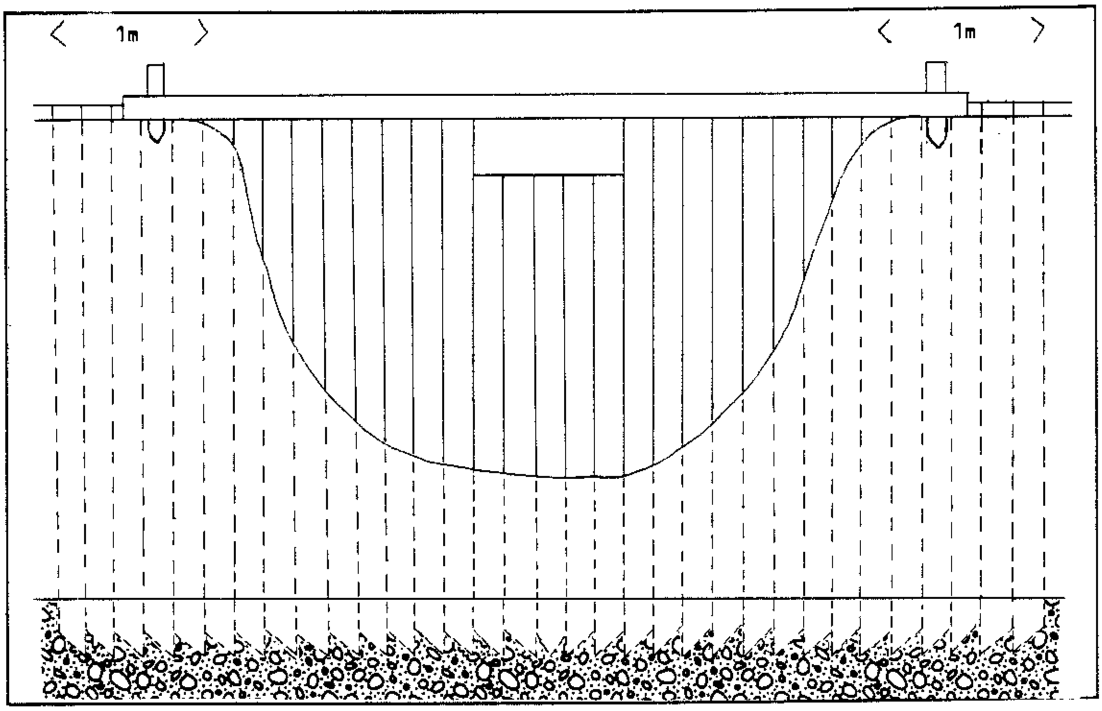

Figure 5: **Dam, suitable for larger ditches and made of pre-cut wooden boards. Note the chamfering of the centre board compared to all other boards, and the alignment of chamfers to right and left.**

The second recommended design involves the use of heavy steel interlocking sheets (M7 sheets) which are piled into position in much the same way as timber boards in the previous design. A stringer should be provided, and could be either timber or steel bolted through the sheets. Again, the dam should extend at least a metre into the bank at either side.

Potential problems with dams

Where ditches are narrow but deep, difficulty may be experienced in installing thin gauge sheet steel. In this case, a heavier gauge steel can be used, or M7 sheet (see below).

A board dam may leak immediately after installation but, as the timber swells and suspended particles lodge in any remaining fissures, it should become watertight.

The dam structures given here cannot be regarded as totally permanent. All dams will need regular monitoring for failure, and will need immediate repair or replacement when failure occurs. A sensible contingency would be to maintain a stock of necessary materials on each site.

MONITORING

Transects of dip-wells will show the response of the water table to damming or bunding. A more or less uniform response would be expected, and dip-wells showing less than average response may indicate local defects in dams or bunds. It is possible, however, for dip-wells to malfunction so that single anomalies should be treated with caution.

All dams should be frequently inspected for faults. Look in particular for water coming directly through the dam, water piping around the sides of the dam or flowing onto the peat surface, water welling up downstream of the dam (indicating that the base of the dam is faulty). Defective dams need immediate attention.

MATERIALS

Timber for BTCV type board dams.

Consult local merchant of home-grown timber on having boards and stringers cut to size.

Example (1987) prices per cubic foot:

oak .... £15 - 00
elm .... £10 - 00

M7 interlocking sheeting in plain steel.

Dimensions: 406 mm wide
3.55 mm thick
1.5 - 6.0 m long in 0.5 m steps

Example prices (June 1987):

4.5 m length....... £24-78 + VAT
5.0 m length....... £27-54 + VAT

Savings of about 10% can be made by specifying used sheets.

Delivery depends on quantity, but is free for 100+ sheets.

Supplier: Mabey Hire Company,
Scout Hill,
Ravensthorpe,
Nr Dewsbury.
W. Yorks.
WF13 3ET

Tel. 0924 460601/464695/460606

Corrugated sheet steel

This material can often be obtained cheaply as offcuts from local suppliers of steel clad buildings. Unfortunately, the readily available material is plastic coated on only one side (the other being painted). Steel sheet with plastic coating on both sides is available, and is the recommended material for peatlands. Specify as double-sided plastisol-coated steel

Dimensions:

900 mm approx. wide depending on profile chosen
0.5 or 0.7 mm thick steel cut to any length

Example prices (June 1987):

0.5 mm thick ...... £4.76 per linear metre
0.7 mm thick ...... £6.05 per linear metre

Supplier: Brohome Ltd,
Bedwas House Industrial Estate,
Bedwas,
Gwent
NP1 8DW

Tel. 0222 869646

Double-sided sealing tape

Supplier: Brohome Ltd (address as above).

Plywood

A possible alternative to sheet steel is a board and polythene sheet 'sandwich'. Some details of exterior grade boards are given below; all prices are for 8' x 4' sheets.

Shuttering grade: constructed from softwoods and moisture-resistant glue. Imported.

Example prices (July 1987):

9mm .... £10 - 18
12mm .... £14 - 67

Exterior grade: constructed from hardwoods and moisture resistant glue (as shuttering grade). Imported.

Example prices (July 1987):

6mm .... £11 - 58
9mm .... £19 - 39
12mm .... £21 - 90

Marine grade: constructed from better quality hardwoods and glue than exterior grade.

Prices: about double that of exterior grade.

Polythene sheet

Example price (April 1988):

1000 gauge sheet, 8 m x 28 m ...... £68 - 35 inc. VAT + del.

Available from:

Lakeland Tufftarp Covers,
Penllan,
Bwlchyffridd,
Newtown,
Powys
SY16 3JW

Tel. 068 687 323

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Manipulation of soil level on peatlands

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Manipulation of soil level on peatlands

T.A. Rowell

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INTRODUCTION

Many peatland habitats began life as aquatic systems with the accumulation organic material eventually leading to terrestrialisation. As the growth of peat progresses, the hydrology of the system changes, and a succession of plant communities follows. These natural processes can be interrupted and diverted by artificial drainage, or they can be set back by lowering of the soil level through peat extraction.

Many peatland habitats existing today have a history of peat extraction, and are therefore a direct result of human interference. However, because peat extraction has been abandoned in many parts of Britain, and successional processes inevitably continue, seral communities will tend to disappear.

One management approach to this problem of ecological succession on peatlands is to raise the water table. An alternative to this undoubtedly expensive measure is to lower the level of the soil. Less technical expertise is required than for control of the water level, and peat digging (which is essentially all that is involved) can be tackled, though only on a relatively small scale. Peat digging is certainly the most sensible method of controlling succession on peatlands where drainage is not to blame for changes in the plant community.

Some practical experience of this management technique has been gained and, in Broadland, a study has been made of the conditions involved in the development of vegetation following peat extraction. Other observations are collated here, and guidelines proposed for the manipulation of soil level on peatland reserves.

Communities

The following communities occur in peat cuttings. Their presence does not imply that regeneration will necessarily occur following extraction, or that the full range of species will colonise in the short or long term.

M1 - *Sphagnum auriculatum* bog pool community

M2 - *Sphagnum cuspidatum/recurvum* bog pool community

M3 - *Eriophorum angustifolium* bog pool community

M9 - *Carex rostrata-Calliergon cuspidatum* mire

M13 - *Schoenus nigricans-Juncus subnodulosus* mire

M14 - *Schoenus nigricans-Narthecium ossifragum* mire

M15 - *Scirpus cespitosus-Erica tetralix* wet heath

S1 - *Carex elata* sedge-swamp

S2 - *Cladium mariscus* sedge-swamp

S9 - *Carex rostrata* swamp

S24 - *Phragmites australis–Peucedanum palustre* fen

S27 - *Carex rostrata-Potentilla palustris* fen

While peat digging destroys plant communities in the immediate vicinity, most communities will be badly damaged by nearby peat extraction through changes in water level.

Examples of the revegetation of peat cuts

Descriptions of the revegetation of real peat cuts, or those made for the purposes of conservation, indicate the potential of this approach.

In the Cambridgeshire Fenland:

> In opening a turf[1] pit, it is usually found necessary to throw off about eighteen inches of the superstratum, which is always cast into the last made pit, by the side of which the new one is formed. This vegetable soil or fen mould is then in a proper state for producing a luxuriant vegetation, and in consequence, a prodigious growth of sedges, flags, reeds and bull-rushes, are immediately produced; the very roots of which contain more vegetable matter, and are far more capacious and bulky than some of the plants which proceed from them.
>
> Vancouver (1811)

The species described above are essentially emergent macrophytes. Another contemporary description indicates the type of succession that might be expected in wetter pits.

> The principal plants observed first to show themselves in pits from which turf has been dug, and which appear to greatly assist in its formation, are the Chara hispida and C. gracilis, Utricularia vulgaris, Nymphaea alba, Potamogeton (various species), Sagittaria sagittifolia, and Alisma ranunculoides. The Chara and Utricularia especially seem well-adapted for causing a rapid accumulation of vegetable remains by the constant decaying of their stems at bottom, while their upper extremities continue to make fresh shoots. After, however, the accumulation has proceeded to a certain extent, the pits are so far lessened in depth that at the present day the water no longer stagnates there in summer. A different kind of vegetation in consequence then takes place. The above plants make way for various species of Junci, Carices, and other grasses, which tend rapidly to fill the pits up, but which, growing above the level to which the fen is now saturated with water, are not subjected to the conditions under which alone the formation of turf is possible.
>
> Jenyns (1845)

In Cambridgeshire, it was noted that, where peat was dug, a profitable crop of Cladium would frequently be available within a short time. Studies in Broadland have shown that this species has colonised many of the 19th century 'turf ponds' scattered throughout the area, but that the exact pattern of development of the vegetation has depended on factors such as water quality and depth of peat, and that species richness is associated with the looseness of the unconsolidated substrate which tends to move up and down with the water table so avoiding extremes of dessication and flooding. Some species are clearly associated with peat workings, e.g. *Anagallis tenella* and *Liparis loeselii*, and it has been suggested that *Viola persicifolia* only survives in the fen habitat because of disturbances such as peat digging.

Where peat pits have been recently dug in Broadland, terrestrialisation of deep peat slurry has occurred within three years. The main contributor to the firming of the surface has been by the rhizomatous growth of *Juncus subnodulosus*, with abundant *Potamogeton coloratus*, and other species including, *Anagallis tenella*, *Baldellia ranunculoides*, and *Ranunculus flammula*. Deeper, machine-dug ponds contain *Chara hispida*, *C. vulgaris*, and *Utricularia*.

Experimental peat cuts have been made at other sites. At Wicken Fen for instance, a cut made during 1950s produced *Nitella tenuissima*, one of the classic rarities of the Cambridgeshire Fens, and unrecorded since 1922. These artificial cuts clearly have a great deal of potential for

1 Turf = peat.

producing interesting plant communities, especially if they are designed with plant colonisation in mind.

A study of Irish bogs subjected to small-scale peat digging indicates the type of recolonisation that might be expected (White 1930). All phases of peatland communities were noted from aquatic through marsh and fen to bog. Considerable variation was found in the course of recolonisation according to factors such as depth of cutting, former vegetation and extent of extraction. Of particular importance is the observation that, while small cuttings within bog vegetation are relatively quickly recolonised, large areas were recolonised by peatland species only slowly and were greatly affected by invasion of agricultural weeds.

Cleddon Bog in Gwent had pools and good *Sphagnum* cover at the beginning of the 20th century. Afforestation of the catchment and improved drainage caused some drying out and has resulted in almost complete loss of bog species and pools. The site is now an expanse of tussocky *Molinia caerulea*.

Experimental stripping of the tussocks from four small plots at Cleddon has resulted in rapid recolonisation by *Sphagnum* spp, *Drosera rotundifolia* and *Narthecium ossifragum*, contrasting dramatically with the dominance by *Molinia* over the remainder of the site. The sensitivity of this soil level manipulations is demonstrated by one plot which was made a few centimetres deeper than the rest. This tends to retain standing water and has been slower to colonise, infilling mainly with *Sphagnum cuspidatum* (more details are given by Etherington (1983)).

PRINCIPLES

Choice of site

Extraction of peat destroys the stratigraphical record and removes any hope of recovery of an original mire surface. For these reasons, any peat digging for conservation purposes should be restricted to areas known to have already been dug.

Peat extraction is a destructive and unpredictable management tool. Its use should be further restricted to attempted regeneration of rare communities known to be dependent on extraction, and in danger of being lost in the future if drastic management is not undertaken. At present, there are no such communities associated with British bogs.

A potential site for hydroseral regeneration by peat extraction should have the following qualities.

* It should generally be fen rather than bog.
* It should be on deep peat; thin peat and floating mats must be avoided.
* It should be free from the influence of brackish water.
* The target vegetation should be close at hand so that propagules can invade naturally, or be easily introduced by 'shoeing' - the throwing of turves cut, in the past, from the surface of a new peat pit.
* the site should not be in sensitive or valuable vegetation; in practice this is not the sort of site that would be considered, as the object is to regenerate the more interesting communities, not destroy them.

* For the development of species-rich vegetation on Broadland or similar flood-plain fens, the main hydrological influence should be base-rich.

* Water level fluctuations should not be severe, and the mean level should be high; good information will often be lacking, but avoidance of the main draw-down zone should help.

* Access should be available for workers and/or machinery.

* A suitable site should be available close by for the disposal of spoil.

Depth of excavation

Traditional peat cuttings were quite deep, up to 0.8 m for the 19th century Broadland turf ponds. Depending on water table, these will have had a considerable aquatic phase before development of terrestrialising communities (see descriptions of colonisation above). Shallower cuttings could be more useful from a conservation point of view because there will be less spoil to dispose of, and terrestrialisation will be quicker. On the other hand, shallow cuttings will be more easily dried out if the water table fluctuates appreciably, and may be less conducive to the formation of a floating mat which will protect the vegetation against such variations.

It has been recommended that, in the Broadland context, a series of depths of cutting are made, from about 20 to 80 cm, all within one complex of pits. Coupled with this approach, the selection of a site with minimal fluctuations in a high water table, as suggested above, should produce the best results.

Size of pit

While the 19th century Broadland turf ponds were often very large, and elsewhere peat was frequently dug from trenches of no great width but considerable length, small pits are almost certainly better for conservation purposes, as they will colonise and develop faster. Dimensions of about 20 m x 20 m or 10 m x 50 m have been suggested for use in Broadland. Wave action might be a problem in the latter case.

Access to site, and protection of working area

Protected access to the site should be provided (see ACCESS) to avoid damage to surrounding communities by pedestrians and machinery.

The area around the pits is bound to suffer a degree of damage (destruction of vegetation, and compaction of peat) during excavation, but this should be minimised by the use of hinged board track. This is particularly important if an excavator is to be used, but the impact of human feet should not be underestimated.

Methods of excavation

By hand

Traditional methods of peat extraction are a superficially attractive means of creating peat cuttings for conservation purposes (an account of traditional methods of peat digging in the Cambridgeshire Fenland is given in Godwin's *Fenland: its ancient past and uncertain future*). Problems of compaction of peat are minimised, and over-enthusiasm resulting in over-deep pits and large quantities of spoil is likely to be curbed.

In the past, areas to be dug for peat would be drained before work began, or at least the trenches or pits would be regularly baled out. Experience indicates that unskilled volunteer teams armed with standard spades and shovels are likely to produce a pit full of slurry. Considerable nutrient enrichment results from this over-disturbance of the wet peat. Colonisation of the slurry has produced interesting results in its own right, but will not achieve the aim of the exercise; to simulate the communities and succession produced by traditional extraction methods. The use of sharpened traditional tools (the spade and becket) and a pump able to handle slurry would help. Blocks of peat would be removed cleanly, working would be easier, and slurry kept to a minimum.

Working peat pits by hand is most suitable for wetter sites where the use of machinery might cause undue compaction. However, lightweight machinery on properly protected access routes can cause less disturbance than a group of people congregated around an excavation site.

By machine

The sensitive use of a small excavator running on hinged boards has much to recommend it over hand labour for the excavation of peat pits. Peat is removed quickly and cleanly, and there is no need to use a slurry pump. However, clear instruction to the operator, and careful supervision, are essential, with particular attention being paid to the use of protected access, excavation to the specified depth only, and disposal of waste.

Use of explosives

Explosives have been used to create small ponds on peatlands and is a method recommended by the Game Conservancy as a 'quick and easy method of creating good wildfowl habitat in unproductive bogs or wetlands'.

Explosive shock waves are likely to disrupt the stratigraphy of peatland sites which is an important part of their scientific value. **Explosives are, therefore, an unsuitable method for creating ponds/pits on peatlands, whatever the final use intended.**

Timing of excavation

All excavation should ideally take place when the water table is at its lowest. This is particularly important for optimal working conditions when working by hand, but may improve access and reduce the likelihood of damage irrespective of methods.

Introduction of vegetation

Where peat is cut by hand for traditional purposes, the problem of disposal of the useless surface peat with the layer of living vegetation was usually solved by dumping it in an adjacent worked pit. It is likely that this practice ('shoeing') will have accelerated the process of recolonisation, if not from the vegetative parts present, then from viable seed buried in the surface layers. Most, if not all, pits will be dug below the level of the store of viable seed (about 15 cm in many soils), and many will be below the level of existing vegetative parts from which some regeneration would be expected. While there is no evidence that shoeing is advantageous, it will be worth trying. Good quality comparative data is needed to determine optimum techniques.

Introductions of individual species are also worth considering as a means of accelerating development to terrestrialisation. *Typha angustifolia* and *Cladium mariscus* have been suggested for Broadland situations, as they are often major pioneer species.

Disposal of spoil

The peat removed from an excavation must be disposed of so as to cause as little disruption of the site as possible. Heaps of spoil will dry out rapidly, and provide a medium for invasion by opportunist species, many of which will be atypical of the site. Furthermore, the spoil heap will cover and destroy some existing vegetation. Possible solutions to the problem of disposal are:

* If peat is removed in traditional turves, dry them on-site (to reduce weight), and remove from site;

* Remove peat directly from site in a dumper truck using protected access route;

* Select a nearby site suitable for disposal; strip the vegetation in turves - make a low mound ideally no more than, say, 1 metre high - replace turves evenly over the mound, supplementing them with those cut from the surface of the excavation area.

GENERAL PRACTICE

An plan to reduce soil levels on peatlands should take the following general approach.

* Site survey to assess suitability for peat cutting in terms of:

  - peat depth;
  - proximity to target communities;
  - water quality;
  - Water level fluctuations;
  - disposal of spoil;
  - access;
  - sensitivity/value of vegetation on proposed location of excavation;

* Plan timing of work location and dimensions of pits, excavation method, disposal point, source of material for shoeing or species introductions.

* Arrange suitable protected access for men and/or machines.

* Arrange protection of the area around the proposed excavations.

* Organise equipment and labour; in particular, ensure all cutting edges are sharpened and kept sharp throughout the job.

* Prepare both the excavation site, and any on-site disposal site by paring off the living vegetation in turves.

* Dig out pit to pre-determined dimensions; use a portable slurry pump if working by hand; ensure adequate supervision of machine working.

* Using wheelbarrows or a small dumper truck running on hinged boards, transport spoil to disposal point, making a mound of no more than one metre in height.

* When the pit and spoil mound are complete, lay turves over spoil mound to aid colonisation.

* Throw remainder of turves into pit, distributing them evenly over the bottom.

* Cut turves carefully from target community; turves should be taken singly over a wide area, rather than stripping one large patch, so that revegetation of the bare peat is as rapid as possible.

* Distribute turves from target area evenly over the bottom of the pit.

* Obtain any species for introduction, such as *Typha* or *Cladium*, taking the same precautions as for turves (see above), and plant as required in the pit.

* Remove any temporary access reinforcement as necessary.

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Restoration of degenerate and cutover peatlands

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Restoration of degenerate and cutover peatlands

T.A. Rowell

CONTENTS

INTRODUCTION

When a mire is drained, or is influenced by drainage of its margins, perhaps for peat extraction, the vegetation and, eventually, the peat itself are adversely affected. The rapid loss of surface water affects both the vegetation and the peat through its erosive power, and also results in a lower water table because evaporative and other losses are not made good. Species sensitive to drainage and erosion (notably *Sphagnum* spp) are lost or much reduced, and are replaced by more resistant species such as *Molinia caerulea*. The possibility of reversing these trends has been recognised in Germany where a great deal has been written about regeneration, and a certain amount of experience has been gained. There is also a possibility of establishing bog vegetation on cut-over mire surfaces. The principles would be the same as for regeneration of degenerate mires, but would require considerable planning, care and determination during the extraction phase.

In contrast, while Britain has a large number of degenerate mires, many of them managed for nature conservation, little experience of regeneration has been gained. We are at the stage of beginning to learn about the possibilities and techniques for ditch blocking and full integration of all the techniques outlined here has not yet occurred.

Several important points need to be noted before embarking upon any attempt to regenerate a mire surface:

* Restoration of the subtle hydrology of a bog is a difficult feat of engineering;

* Recolonisation of anything resembling a normal bog vegetation is likely to be a long term process, depending on the degree of degeneration of the surface peat (which will release mineral acids and nutrients on resoaking, both inimical to bog vegetation), on availability of sources of plant propagules, and on the amount of effort expended in the management of the hydrology and vegetation;

* Achieving restoration of the hydrology and colonisation by desirable species will be extremely expensive;

* As there has been so little experience in this field to date, there can be no guarantee of success, particularly if the aim is to attain an actively growing mire surface. All work will be experimental to some extent.

* Because of the experimental nature of this type of work, all experiences (successes and failures) should be reported.

PRINCIPLES

Survey and monitoring

To establish the potential of any degenerate site for regeneration, a detailed survey should be carried out. The survey should include attention to the following:

* Vegetation, including abundance and location of desirable species, extent, type and size of trees and shrubs, extent and structure (e.g. tussockiness) of undesirable vegetation;

* Potential for recolonisation/introduction from nearby sites;

* Position, size, and gradient of ditches, and whether and cut into the underlying mineral;

* Extent, depth and nature of the peat;

* Nature of the underlying mineral;

* Availability of freshly cut peat from nearby works;
* Availability and quality of water supply;
* Potential for a buffer zone around the site.

Conditions for regeneration

For regeneration to be a serious consideration on either a degenerate or a cut-over site, the following conditions should be met:

* There should be a large area of peat surface where the drainage does not cut into the mineral substrate;
* There should be an extensive layer of compressed peat in, preferably, a well humified state, and amounting to at least 50-100cm in depth;
* It should be possible to exclude any possible sources nutrient enrichment, either water- or air-borne, from the site;
* There should be a broad buffer zone between the site and any farm land;
* A source for colonisation or introduction of most of the absent desirable species should exist locally.

Tree and shrub removal

Trees and shrubs damage mire surfaces by:

* Shading out light-demanding species;
* Extracting water from the peat;
* Intercepting rainfall;
* Causing eutrophication and smothering of smaller species by leaf fall;
* Causing eutrophication by providing bird roosts.

All woody species other than dwarf shrubs should be removed from the site (see SCRUB CONTROL). Seedlings can be pulled by hand, but care should be exercised if removing them from *Sphagnum* hummocks. All larger trees and shrubs need to be cut down (chain saw or brushcutter) and the stumps carefully treated with chemical. If the site is not too wet and the surface is reasonable even, then it is possible to use a tractor-mounted flail, such as a 'Junglebuster', to break up trees of up to three metres in height. Branches will eventually rot down if left lying, but large quantities are best disposed of.

Clearance should begin in the least wooded and most undamaged areas of the site, and should then progress towards the less immediately important areas. German workers have suggested that leaving a surrounding belt of trees may protect the regenerating site from wind-borne nutrient input, e.g. fertiliser drift, but this should be off the main peat body and, preferably, outside the hydrological unit.

Priorities for tree removal should be as follows:

1. Areas with cotton grasses and bog mosses
2. Areas with *Erica tetralix* and *Calluna vulgaris*
3. Areas with *Molinia*

In general, all timber should be removed from the site. Large amounts can be burnt on site, but ashes should be removed. A certain amount of larger timber can be disposed of by lowering it into deep water-filled cuts and ditches, to reduce water movement and so enhance recolonisation. Care should be taken when packing branches into ditches and peat cuttings that they are not filled to the peat surface. Adequate space should be left for a *Sphagnum* layer to form over the branches. Remember that the sides of ditches are often slightly higher than the average peat surface because of the dumping of spoil. **The packing of ditches with branches does not block water flow and they will still require damming.**

Any regrowth of undesirable woody species (e.g. birch, sallows, pine) should be removed by grazing, burning, cutting or herbiciding (weed-wiping), and over-abundant growth of dwarf shrubs should be controlled, by e.g. grazing, cutting or burning. These practices also have the advantage of rejuvenating heather, though burning should only be undertaken following the guidelines given below (see also BURNING).

When herbicides are employed, care must be taken to ensure that chemical does not contact the peat surface or any vegetation other than that being treated.

Buffer zone

When a site selected for regeneration management is bounded by agricultural land, provisions should be made for a buffer zone to protect the oligotrophic area from fertiliser drift. A zone of 50-200 m has been recommended, and its efficacy will be improved if it is wooded.

Recontouring

Degenerate surfaces

Surface topography results in varying conditions of wetness and, therefore, more variable colonisation; colonisation is also more rapid. Shallow slopes are also more conducive than steep slopes to the formation of a floating mat of vegetation. Floating mats are less prone to damage from a fluctuating water table than terrestrial vegetation.

Where steep-sided drains, extraction pits, or other earthworks cut into the surface of a degenerate mire, advantages ensue from the recontouring of their sides. Peat cut from the sides can be used to reduce depth, and is best cut away and placed in blocks wherever possible. Slopes should be as shallow as possible, not exceeding 1:10.

As recontouring of ditches makes them wider at the top, they will be more difficult to block than in their original state. It is suggested, therefore, that ditches and cuttings are not recontoured about 5 m either side of the points where dams are to be installed (Figure 1).

Cut-over surfaces

Freshly cut-over surfaces should not be levelled flat, but should have some system of baulks and cuttings with overall height differences of < 40 cm. High baulks will dry out, and become a fire hazard and a medium for invasion by undesirable species. Again, slopes should be as shallow as possible, not exceeding 1:10.

If the site has been left flat then an effort should be made to cut it into a system of baulks and hollows.

Small cuttings (perhaps, ideally 10-20 m across) are preferable to large ones (100-200 m) as the extent of marginal peat is increased, and wave action reduced.

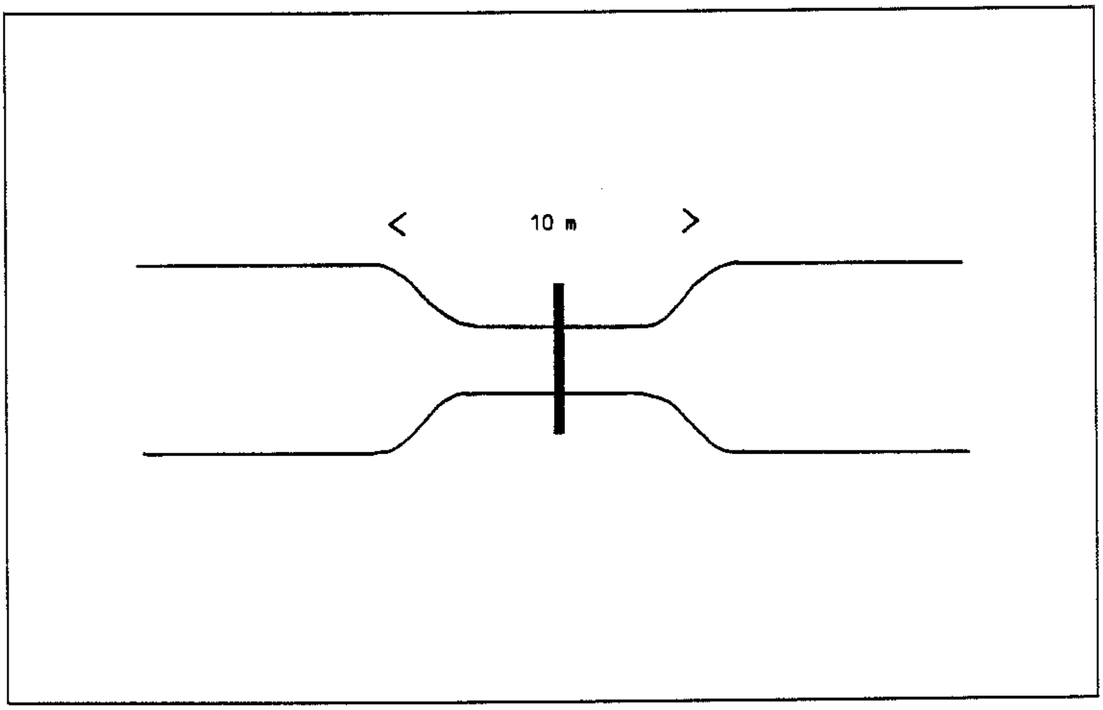

Figure 1: **Plan view of ditch to show how edges should be recontoured to reduce slope and increase the speed of recolonisation. Do not recontour where a dam is to be installed.**

Baulks impound water, thus reducing runoff, but should be wide, i.e. 5-10 m, to effectively prevent lateral seepage.

The surface left for regeneration should be firm undisturbed peat, i.e. not milled or bulldozed, as German workers have found these surfaces unsuitable for colonisation. They do, however, recommend rounding off existing baulks by pushing the more or less right-angled lips of baulks into the angles of the adjacent cutting.

Rendering the site watertight

The objective of making the site watertight is to increase the retention of nutrient-poor rainwater and, in some cases, to prevent the influx of nutrient-rich water. Runoff is reduced by the contouring of the peat surface, the damming of ditches, and the compartmentalisation of cuttings.

Ditches

All internal ditches should be effectively sealed by damming; structures vary according to the size of ditch (see dam construction). Although it will rarely be possible, German workers recommend that ditches should be filled along their entire length with blocks of cut peat which should be consolidated. Dams are still required, however, to prevent seepage along the line of hydrological weakness.

Ditches will need to be dammed at frequent intervals to produce even resoaking of the site. Damming frequency is determined by slope. The aim is to maintain the water level as near to the peat surface as possible along the entire length of the ditch. It is recommended, therefore, that spacing is organised to give a maximum fall of 300 mm or half the dam height, whichever is the lesser, from the top of each dam to the water surface on the downslope side (Figure 2). A smaller fall than this is obviously desirable but will increase costs. If the original spacing does not result in the correct levels, then it should be reduced as soon as possible by the addition of extra dams. If at all possible, the dams should be arranged so that the water comes well up on the downstream side. This reduces the pressure from the head of water and should reduce the likelihood of failure.

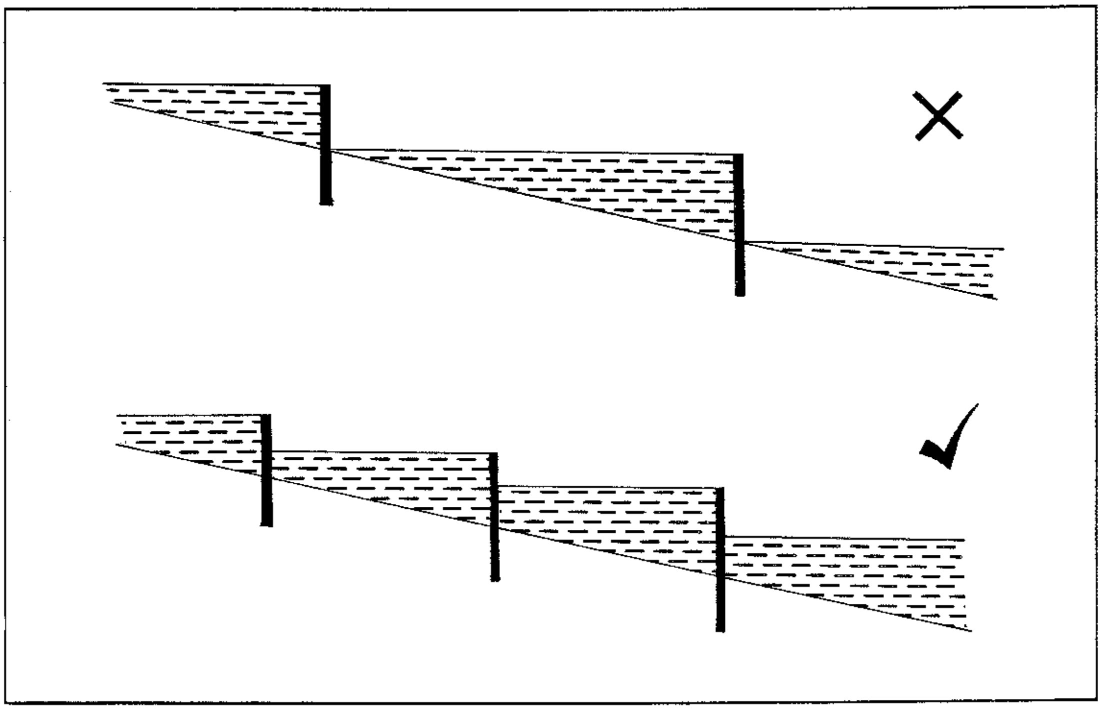

Figure 2: **Cross-sectional view of two series of dams 50 cm high showing correct and incorrect spacing. In the first series the water level is incorrectly maintained at less than 30 cm from the surface of the peat (assuming that the top of the dams are at ground level).**

While the German approach to ditch blocking involves treating large ditches first, followed by successively smaller ditches, there would seem to be some merit in a modified method if the site has a core area of better vegetation. Blocking should logically start in the centre of this area and work outwards in a more or less concentric fashion, particularly if the work is to be carried out in a piecemeal fashion.

If major ditches are cut into the mineral substratum then they may, if not extensive, be caulked. All loose material should be removed from the bottom of the ditches and a caulking layer of 60-100 cm of freshly cut unhumified peat consolidated in its place. Ideally, the peat should be underlain with an impermeable membrane such as butyl sheeting.

Peat cuttings

Linear peat cuttings should be treated like ditches, even if they do not outfall into the drainage system, so that water level is, again, maintained as near the surface as possible. Damming and compartmentalising wide cuttings will be expensive and needs investigation into the best methods.

Use of bunds

Bunding of the perimeter of an upstanding peat block with clay has been attempted, but is unlikely to be successful unless the full depth of clay can be kept moist and the surrounding area kept free of woody vegetation (which will penetrate the seal with its roots). It is possible that this could be achieved by maintaining a water-filled ditch between peat body and bund, which presupposes a reliable source of clean water. It must be stressed that a single period of drought can cause cracking of a clay bund, resulting in loss of water from the peat body, and requiring immediate repair.

Resoaking

If nutrient-poor water is available, either directly or following treatment, it could be pumped onto the site to speed up the resoaking process. This is not, however, an advisable process unless quality can be assured.

Otherwise, it will be necessary to rely entirely on input from rainfall. This is why it is essential that trees are removed and their re-establishment prevented, and that runoff is reduced to a minimum.

The ultimate aim is to raise the water table to within 5 cm of the surface. Response to ditch blocking should be rapid; in a German site, 290 mm of rainfall accumulated in a peat body over a period of three years, with a further 60-80mm over the following three years, giving a rise in water table of 1 m.

Widespread flooding will rarely be desirable because it may lead to eutrophication when existing vegetation dies and decomposes. Good control of water level is therefore necessary, and dams should be set so that surplus water can escape via the drainage system rather than spilling onto the peat surface. The movement of water around high-set dams damages the sides of the dams causing failure, and damages vegetation and the peat surface by erosion. This can be prevented by proper attention to dam design and construction (see DAM CONSTRUCTION).

Short-term eutrophication will almost inevitably occur in newly flooded ditches, which may kill or delay colonisation by *Sphagnum* spp.

Resoaking can be accelerated by pumping water into the site. This can be most easily achieved when adjacent areas are being cut for peat, so that water free of mineral influence is available. A possible method for the introduction of this water into the managed area, and to reduce any degree of enrichment that may have developed, is to cut large circular basins into both the source and target areas. These should be about 50 m across and about 1 m deep (Figure 3). As the basin in the source area fills, water is pumped from it to the basin in the target area. Although water will flow into the peat only slowly from this reservoir, it will be cleaned by the peat itself. If the sides of the basin are shallow sloping, as described above, then the basin itself will colonise rapidly.

Colonisation and introduction

A degenerate mire surface may contain propagules of lost species, in which case recolonisation by these species may proceed without intervention. Some species will not have a persistent bank of propagules and, if a nearby source is not available, will be unable to colonise. Even with a nearby source, some species are relatively immobile and will only recolonise over a very long period.

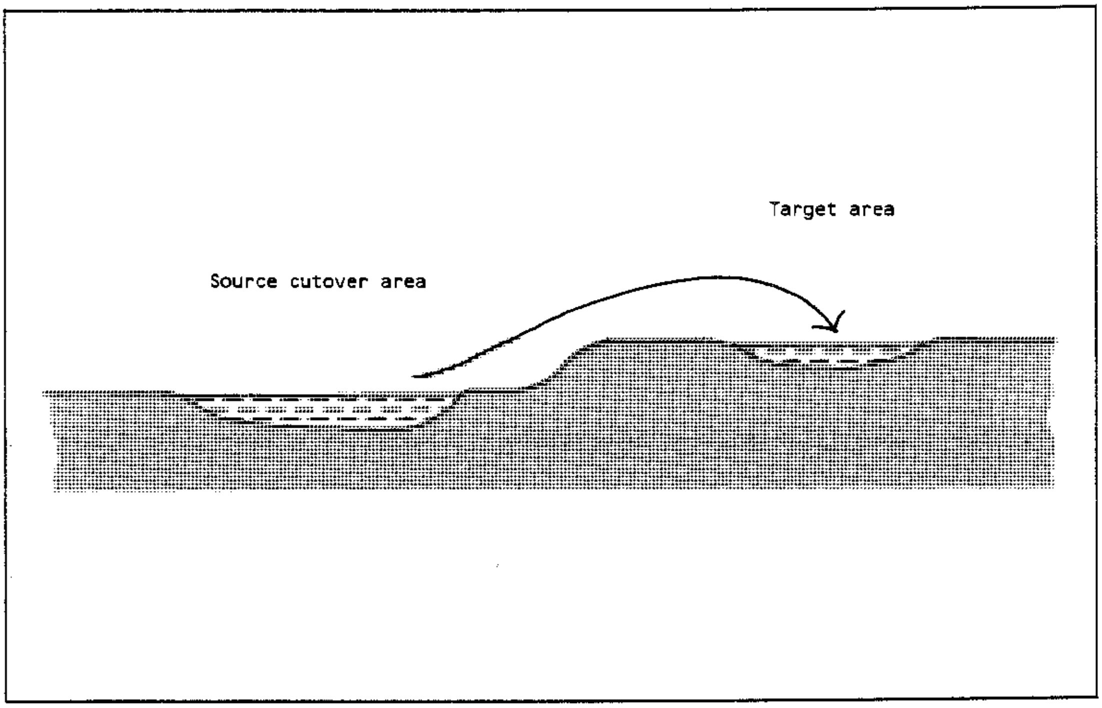

Figure 3: **Cross-section showing the use of specially cut reservoirs to (a) collect water on a cutover area and (b) receive water pumped from the source area to the target area.**

Cut-over peat will obviously be without its own stock of viable plant propagules, and colonisation will proceed with whatever is locally available. Ideally, there will be a nearby source of suitable species for colonisation of the resoaked peat, i.e. a more or less undamaged bog surface. Failing this, colonisation by the full range of desirable species is likely to be slow, and a great deal of effort will have to be expended in ensuring that the desired balance of species is maintained.

An alternative or additional approach to the colonisation of both degenerate and cut-over mires is to introduce species, or vegetation in the form of turves, from a remote site, possibly one where utilisation is about to destroy the mire surface.

Sphagnum has been successfully transplanted in British Columbia, and has regenerated from fragments in Germany. Some small experience of transplanting has also been gained in this country, but the long term prognosis for survival is unclear. Trials and data on introduction of *Sphagnum* in Britain would be welcome, so that methods can be recommended.

Ericoid shrubs and the cottongrasses can be successfully introduced or spread as seed.

As we have so little experience of introducing species, there may be a need for careful experimentation with some species. In any case, careful monitoring of any introductions will provide invaluable information for future use.

Management

Following successful resoaking of a site, considerable management is necessary to ensure that development of the vegetation follows the desired course. Of particular concern will be the control of *Molinia caerulea*. Furthermore, as has already been suggested, upkeep of dams may form a substantial management commitment.

Mowing

Summer mowing (see also MOWING) can weaken *Molinia* by preventing transport of nutrients from leaves to roots prior to winter. Mowing also rejuvenates heathers, and breaks up and spreads existing *Sphagnum* hummocks so encouraging its spread across the site. Mowing can be an alternative to burning prior to grazing. The use of mowing on regenerating mire surfaces depends on wetness, and on evenness of the surface. Where *Molinia* tussocks are a problem on surfaces unsuitable for mowing machinery, brushcutters can be used to remove them.

Burning

Burning may be useful as a (usually) once only measure to aid control of Molinia or woody species. On its own, burning achieves very little. German workers stress that it must be immediately followed by grazing to further weaken and destroy undesirable species.

Burning should be carried out before March, when the ground is frozen but snow-free, and winds are light (some wind is needed to move the fire briskly over the ground. The vegetation must be burned only in very small blocks of about 20 x 30 m (see also BURNING). The object is to avoid a hot and penetrating burn which will damage a developing or established moss layer. Fire retardant foam may be the most practical means of burning in small blocks (see BURNING).

It is not essential and, indeed, may not be desirable or feasible to burn the entire site in one season.

Grazing

Grazing of regenerating mire surfaces is a practical alternative to mowing for the control of undesirable plant species. It has considerable advantages over mowing in that it can be more or less constant, and is not so restricted by conditions on the site.

Grazing (see also GRAZING) must be carried out all year round. German experience is that most breeds of sheep are unsuitable. They use a breed specially suited to bog conditions by its hardy nature and small size. It is, consequently, a poor quality beast, so there is little chance of a good financial return to offset the costs of running the flock.

As animals obviously cause potential problems of enrichment, it is recommended that, to reduce this threat to a minimum, certain precautions are taken:

* The sheep should be penned at night off the site;

* The flock should be driven slowly to the site in the morning, allowing time for defecation before they reach the site. At night, they should be driven quickly off the site;

* While on the site, the flock should be driven constantly forward. This avoids intensive grazing, and ensures that dung is distributed as thinly as possible;

* The recommended breed of German sheep produces dung balls that break up during defecation, and are therefore more widely spread than usual.

This type of grazing plan requires a high input of skilled shepherding, and represents a further considerable commitment of resources to the regeneration programme.

Fears may be expressed that grazing, particularly of this well-shepherded type, will have an adverse effect on populations of ground-nesting birds. The German experience is that this does not occur.

Monitoring and record-keeping

During management for regeneration, water levels, integrity of dams, and botanical development will require regular and frequent monitoring. As part of the monitoring scheme, clear and detailed records should be kept of all management operations.

Transects of dip-wells will show the response of the water table to ditch blocking. A more or less uniform response would be expected, and dip-wells showing less than average response may indicate local defects in the blocking of ditches. It is possible, however, for dip-wells to malfunction so that single anomalies should be treated with caution.

All dams should be frequently inspected for faults. Look in particular for water coming directly through the dam, water piping around the sides of the dam or flowing onto the peat surface, water welling up downstream of the dam (indicating that the base of the dam is faulty). Defective dams need immediate attention.

As we have so little information about the course of recolonisation during these management activities, it is essential that careful monitoring of the vegetation is undertaken. Management for regeneration is an obvious candidate for intensive Level 3 monitoring (see VEGETATION MONITORING), which of course means that monitoring should also be carried out at Level 1 and 2 as well. To gain as much information as possible about introducing species, planned and designed experiments will be preferable to ad hoc monitoring.

GENERAL SEQUENCE OF OPERATIONS

* Survey site.

* Establish suitability for regeneration.

* Remove all trees and non-dwarf shrubs.

* Recontour site as necessary.

* Make site watertight.

* Begin monitoring of dams.

* Resoak.

* Begin monitoring of vegetation.

* When moisture conditions allow, re-introduce species as necessary, and include them in the monitoring scheme.

* Manage species balance by e.g burning, grazing, herbicide, mowing, etc.

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5

Control of gully erosion

T A Rowell

Control of gully erosion

T.A. Rowell

CONTENTS

INTRODUCTION

Drained bogs may develop large erosion gullies around their perimeters associated with the outfall of the drainage system. Erosion may also develop as a result of over-grazing and burning, or may simply be the result of heavy rainfall following a period of drought. The process of erosion of peat on blanket bog is described by Hulme & Blyth (1985).

The depth and width of many erosion gullies makes the use of the dam designs given elsewhere in this volume inadvisable. Indeed, dams intended to bring the water level up to the surface (see MIRE RESTORATION) will probably be out of the question, either because of the expense and level of engineering required, or because the amount and head of water impounded might prove dangerous to adjacent properties.

A more appropriate approach in these circumstances may be to attempt to reduce further erosion and, if possible, to encourage the trapping and accumulation of peat particles on the bed of the gully. Techniques to achieve this (check dams) have, as far as is known, not been tried on peatlands, but those described here have been successful on mineral soils. The techniques are offered as suggestions only, and require testing.

The application of these techniques is of little use unless an attempt is made to reduce the interception and channelling of run-off (see WATER LEVEL CONTROL). Where necessary, attempts should also be made to re-vegetate bare peat surfaces.

PRINCIPLES

The purpose of a check dam is to impede or slow the velocity of water flow, reducing scour and causing suspended material to be deposited in the catch basin behind the dam. When water overtops the dam via the spillway, it falls onto a protective apron. A series of dams reduce the effective gradient of the erosion channel and, as sediment fills the catch basin, the channel becomes a series of long steps.

Impermeable dams in erosion gullies have to be able to withstand high forces. As the main function of a check dam is to reduce the force of the water flow, rather than to impound water permanently, permeable dams are a viable alternative. These are acceptable where high flows are not involved, and can be constructed from brushwood which may well be available on-site.

Many low dams are preferable to a few high dams. A low dam is one of less than 1.2 m high.

Spacing of check dams is most effective if dams are placed at the limit of upstream deposition of sediment associated with the downstream dam (Figure 1). Spacing can be calculated from the following equation.

$$S = \frac{H}{K\,G\cos a}$$

where	S =	spacing between dams
	H =	effective dam height as measured from gully bottom to spillway crest
	G =	gully gradient as a ratio (G = tan a)
	a =	angle corresponding to the gully gradient
	K =	an empirical constant (K = 0.3 for G < = 0.2 or 0.5 for G > 0.2)

Note that a value for K on peat soils needs to be determined, as the values given above are for preliminary guidance only.

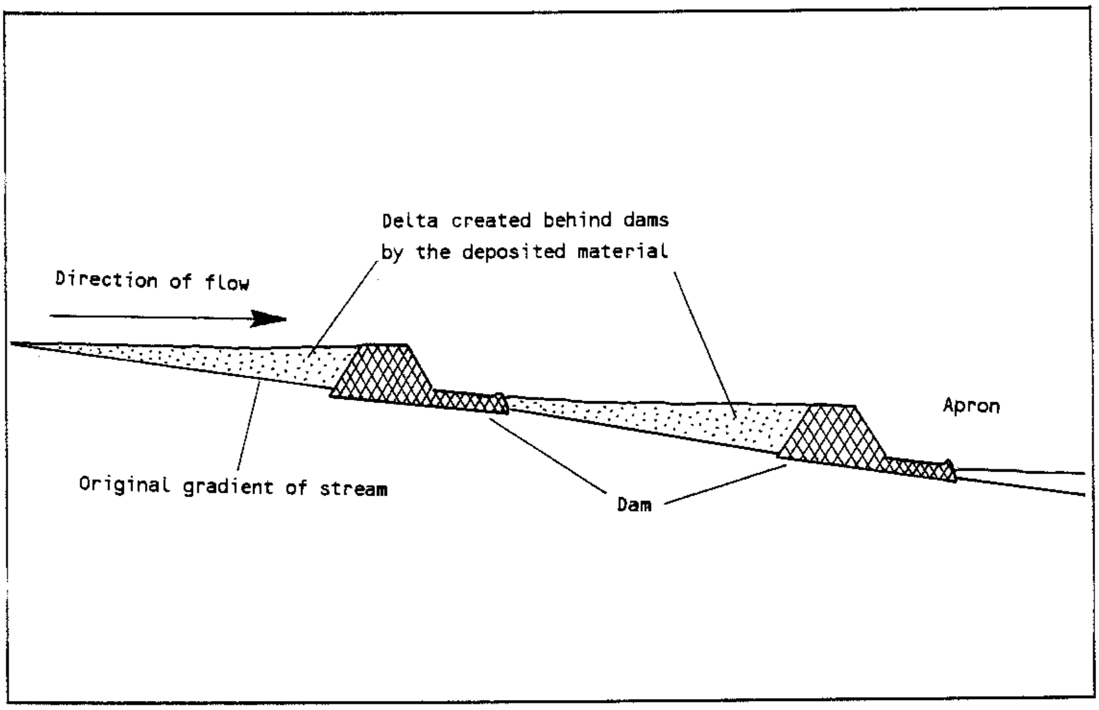

Figure 1: **Cross-sectional view of gully check dams showing how deposited sediment can accumulate behind them. Check dams should he spaced so that the full layer of sediment reaches back to the base of the upstream dam (redrawn from Gray & Leiser 1982).**

Several considerations are involved in the design of effective spillways for check dams. Firstly, they should have sloping rather than vertical sides to discourage the trapping of debris. Secondly, the length of the spillway should be no greater than the width of the gully bottom, to avoid further erosion of the sides. Thirdly, the size of the spillway should be sufficient to accommodate the maximum flow from a 25 year design storm.

Check dam aprons must be installed immediately on the downstream side to avoid undercutting of the gully bottom. Its surface should be roughly level, and it should be embedded so that its surface is about 150 mm below the height of the original gully base. At the downstream end, a sill about 150 mm high creates a pool that reduces the impact of water passing over the spillway.

To construct effective check dams, and to further reduce the erosive power of the water flow, steep-sided gullies require regarding to a shallow batter.

The head of an erosion gully is liable to migrate back into the site, and requires special attention in the form of a plug constructed from brushwood. This slows the movement of water so reducing its erosive power.

Check dams and gully-head plugs are held in place by stakes. In easily eroded soils such as peat there may be considerable advantages in using live stakes of *Salix* spp. These root and have the twin advantages of improved anchoring of the construction, and of providing additional strengthening to the soil itself. Where the species to be used are not a normal component of the local vegetation, then they may be killed off chemically after several years.

CONSTRUCTION METHODS

The methods given here are quoted *verbatim* from Gray & Leiser (1982). As experience is gained on peatlands in Britain, they will probably require modification.

Check dams for small gullies (< 1.5 m deep and < 4.5 m wide)

Materials required

1. Posts: two to four, 4-inch diameter x 6 ft long.
2. Stakes: two to four, 3-inch diameter x 3 ft long.
3. Poles: two, 3-4 inch diameter x 6 ft long.
4. Wire: about 15 ft of no. 9 galvanized wire.
5. "Dam brush", "apron brush", and "litter".[1]

Construction procedure:

1. Slope back the banks, if too steep, as shown in Figure 2. Throw the fresh soil upstream from the dam.

2. Set posts of sound wood with 4-inch tops. The center posts should be long enough that they can be buried 3 to 3.5 ft, and extend up to within 1 or 2 ft of the top of the gully bank. The outer posts need not be set quite so deep but should extend higher, as shown in Figure 3. Space the posts 2 ft apart. Willow posts are recommended.

3. Set two to four stakes 3 inches in diameter and 3 ft long, as shown in Figure 3. Use willow, if possihle, and plant right side up so they will sprout.

4. Place a 6-inch layer of litter between the posts, and on the gully bottom and sides downstream from the posts for about 6 ft, as shown in Figure 4.

5. Place brush or green tree branches as shown in Figures 5 and 6. The long, straight limbs, apron brush, should be placed in a layer across the bottom. For the rest of the dam, the shorter brush should be used. The butt ends should be placed upstream. Usually, the gully can be almost filled with brush, and when the cross poles are placed, the brush will be forced down into a compact mass.

6. Place the cross poles on the upstream side of the posts. One or two men should stand on these poles to compress the brush properly while the poles are being wired to the posts and stakes with no. 9 galvanized wire.

7. Place a layer of litter against the upstream face of the dam, and carefully pack into the openings between the butt ends of the brush.

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1 See below for definitions of these materials.

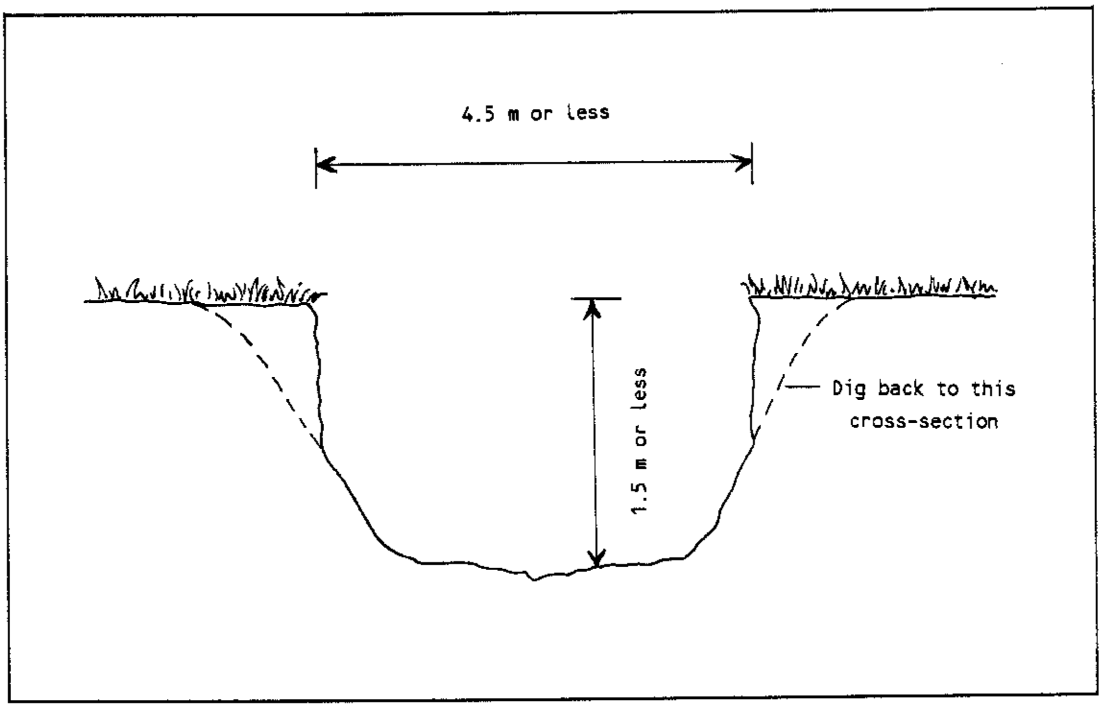

Figure 2: **Cross-section of a gully showing the maximum size for the best use of a single-row post-brush dam (redrawn from Gray & Leiser 1982).**

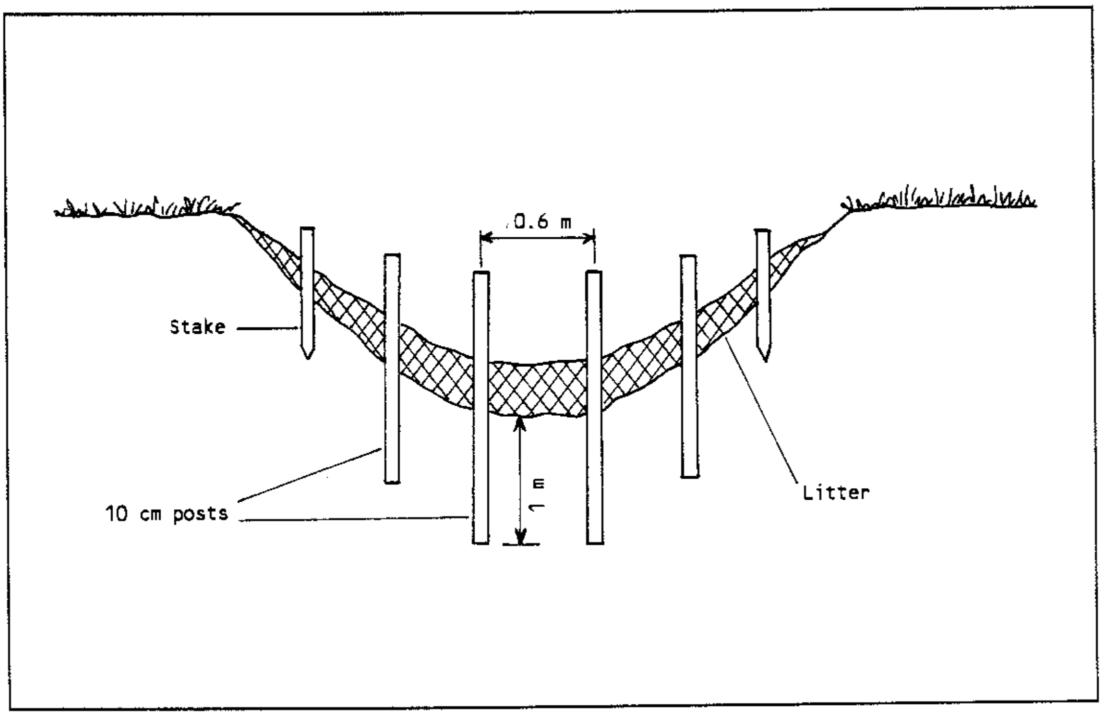

Figure 3: **After the banks have been dug back, the posts are set and a layer of litter placed (redrawn from Gray & Leiser 1982).**

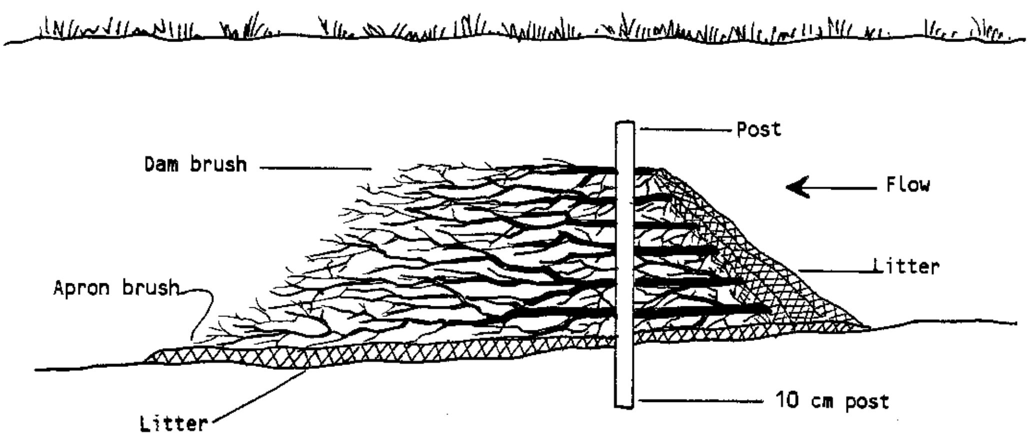

Figure 4: **Side section of a completed dam. Not how the longer brush is placed on the bottom to form an apron (redrawn from Gray & Leiser 1982).**

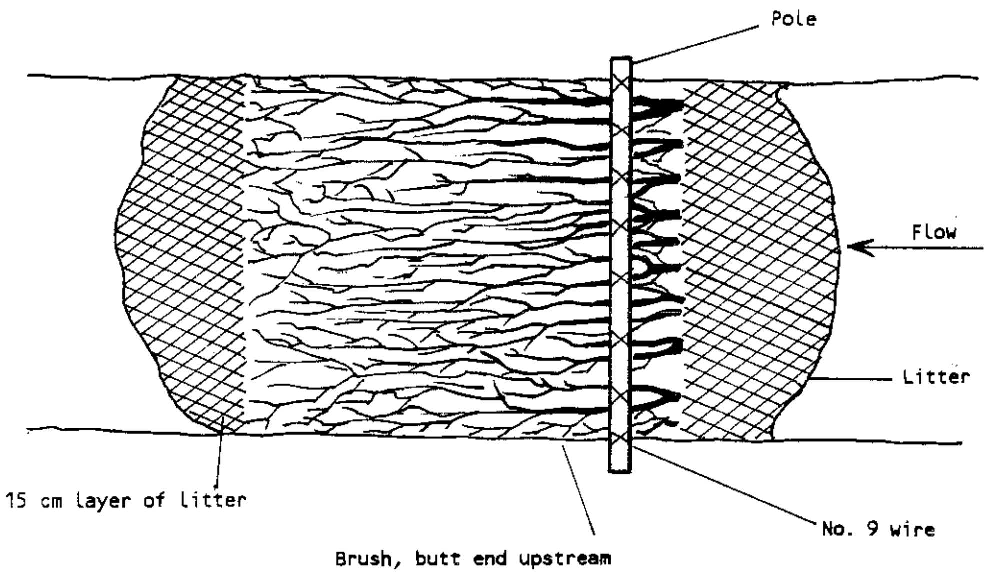

Figure 5: **Plan view of a completed single-row post-brush dam. Note that the brush is carefully piled and trampeled down with the butt ends laid upstream between the posts (redrawn from Gray & Leiser 1982).**

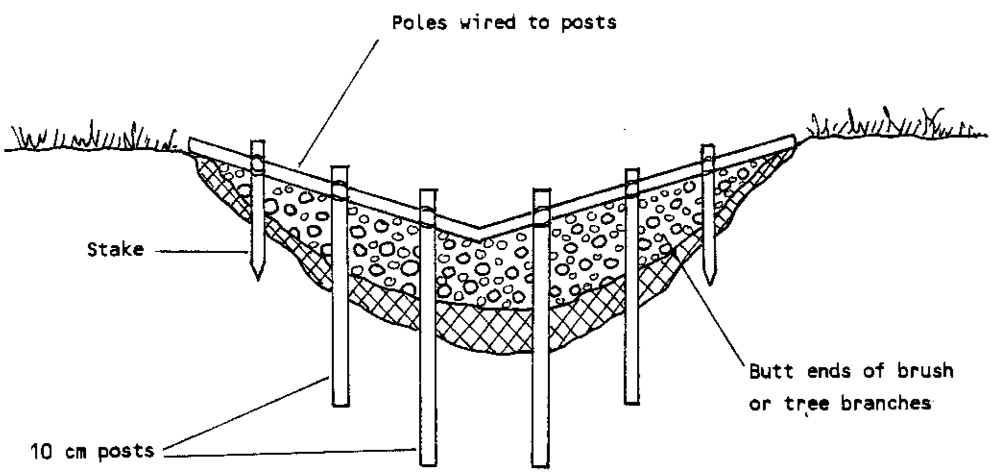

Figure 6: **Elevation of a single-row post-brush dam looking downstream; complete except for litter which should be placed against the upstream face (redrawn from Gray & Leiser 1982).**

Check dams for larger gullies

Materials required

1. Posts: The center posts should be 8 to 8.5 ft long and 6 to 8 inches in diameter, but shorter posts may be used at the side of the ditch and may be only 4 to 6 inches in diameter. Willow posts are excellent.

2. Wire: about 3.5 ft of no. 9, soft, galvanized wire is required for each foot of width of the gully from bank to bank.

3. "Dam brush", "apron brush", and "litter".

4. Stakes: 2 to 3 ft long. Use willow if possible.

Construction procedure

1. Slope banks back, if too steep, as shown in Figure 7. Throw the loose dirt upstream from the dam.

2. Set posts as shown in Figure 8.

3. Place a 6-inch layer of litter on the gully bottom and banks extending about 10 ft downstream from the posts, as shown in Figures 8 and 9.

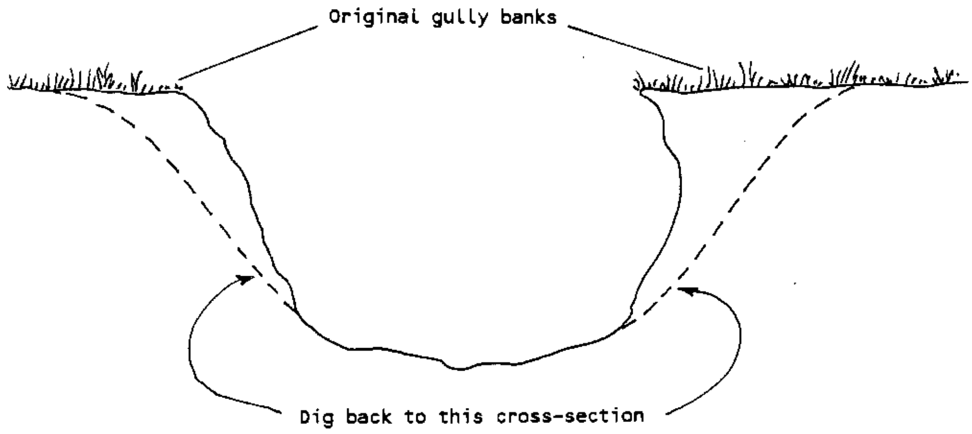

Figure 7: Cross-section of a gully showing how banks should be sloped back prior to constructing a double-row post-brush dam (redrawn from Gray & Leiser 1982).

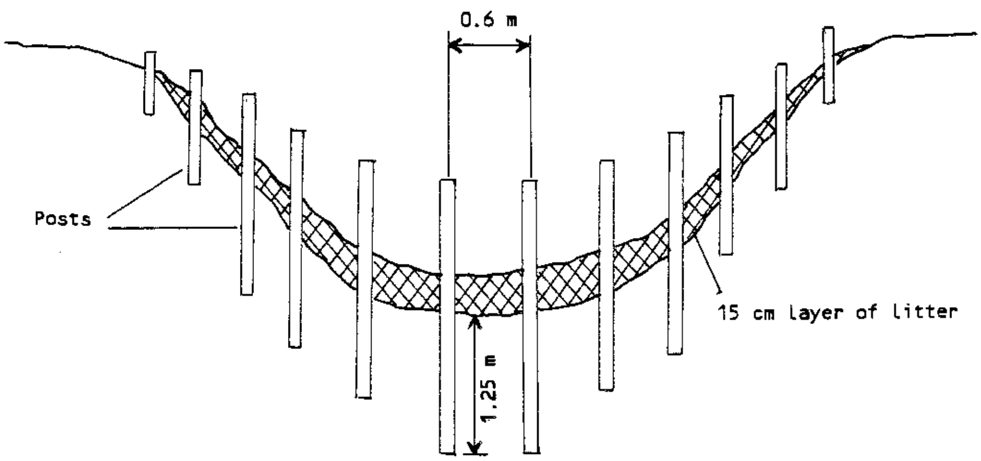

Figure 8: The placing of posts and litter for a double-row post-brush dam (redrawn from Gray & Leiser 1982).

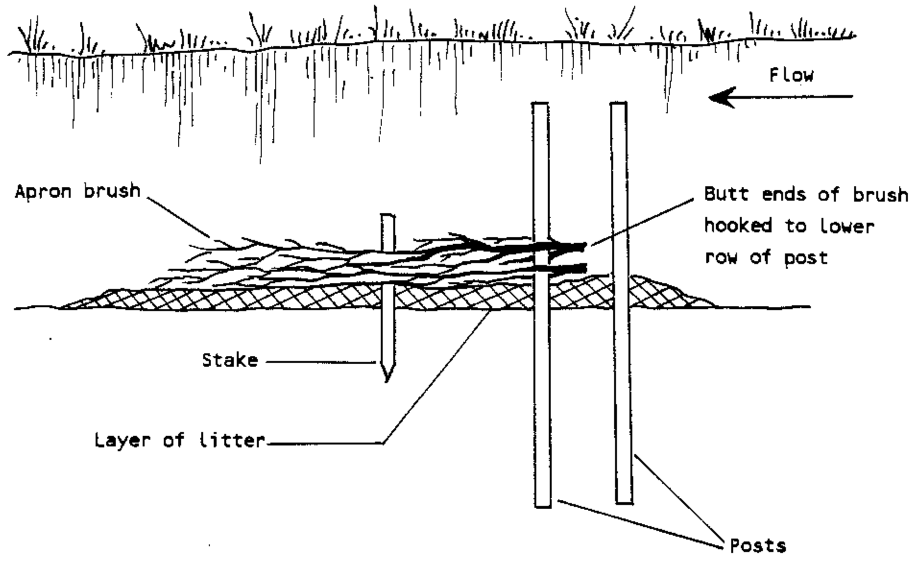

Figure 9: **Side section of a double-row post-brush dam after apron has been placed (redrawn from Gray & Leiser 1982).**

4. Place about a 1-foot layer of apron brush, butts upstream and hooked to the lower row of posts, as shown in Figure 9. This brush should extend downstream about 10 ft or more.

5. Drive a row of stakes across the gully through the middle of the apron and wire the limbs down to form a dense mat. Willow stakes are preferable.

6. Entirely fill the space between the two lines of posts with dam brush laid crossways of the gully. Thoroughly pack it, and pile it above the tops of the posts for a foot or more.

7. Staple wire to a post at one end, stretch it tight, and thread it back and forth as shown in Figure 10. It is usually necessary to have one or more men stand on the brush while wiring to help force the brush into a compact mass.

8. Place litter against the upstream face of the dam, as shown in Figures 10 and 11.

Dam reinforcement

In addition to the live stakes used in the construction of check dams, willow cuttings should be planted around the dam at a spacing of 0.3 - 0.45 m (Figure 12) to reinforce the structure. Larger dams should be supported by more extensive live staking (Figure 12).

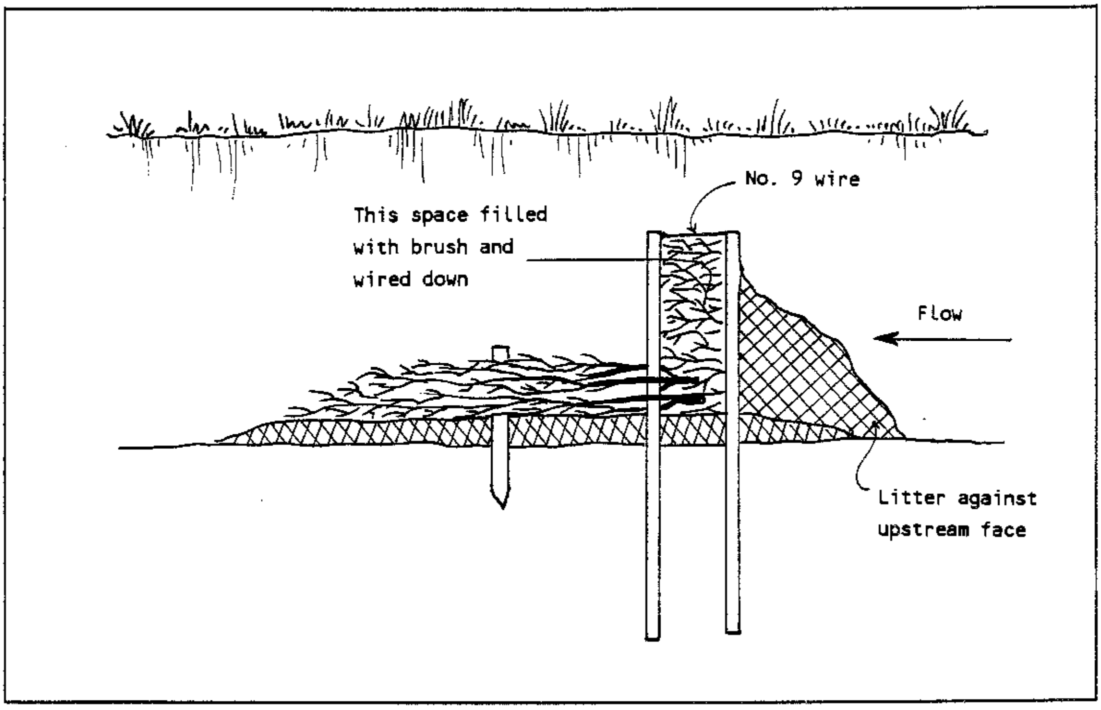

Figure 10: **Side section of a completed double-row post-brush dam (redrawn from Gray & Leiser 1982).**

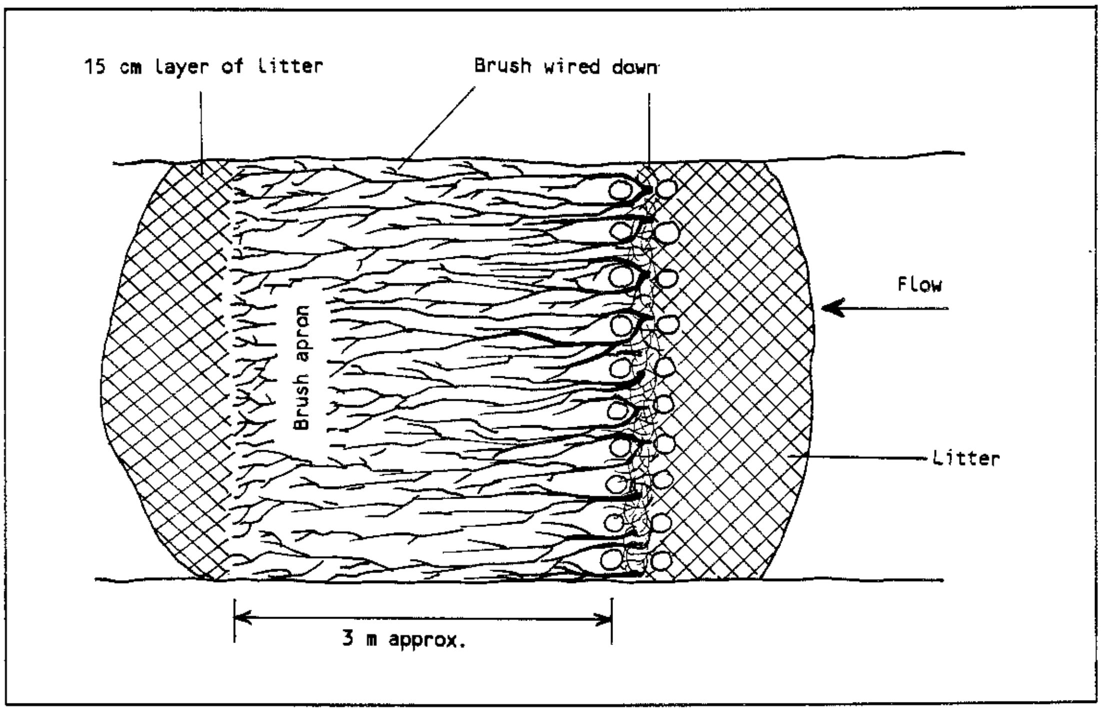

Figure 11: **Plan view of a completed double-row post-brush dam (redrawn from Gray & Leiser 1982).**

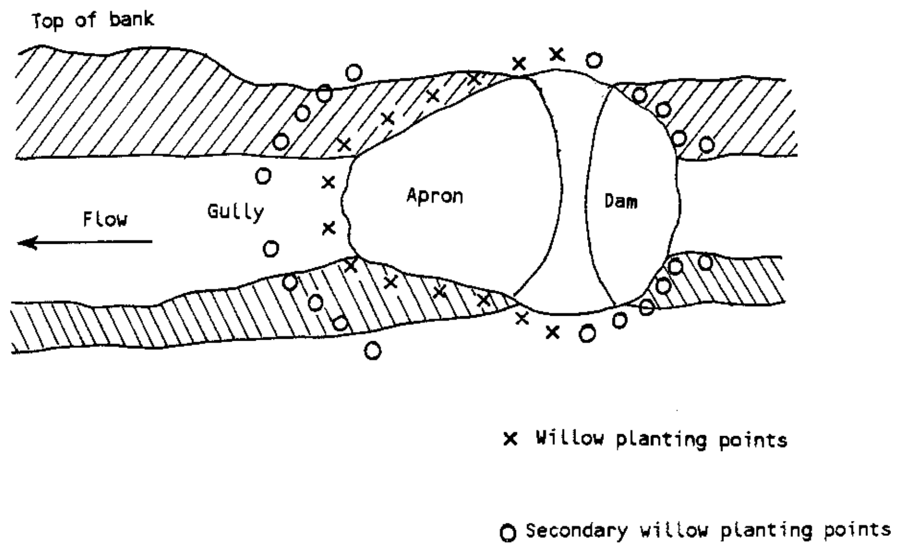

Figure 12: **Plan view of a gully check dam showing planting points for willows (redrawn from Gray & Leiser 1982).**

Once the live willow stakes are well established and have stabilised the structure, they could be killed by treating with a suitable herbicide (see SCRUB CONTROL) if they are regarded as undesirable on the site.

Gully-head plugs

A mattress of brushwood should be placed at the head of all gullies to prevent further headward erosion. Not only should the mattress be staked down, preferably with live stakes, but it should be reinforced with live willow stakes in the pattern shown in Figure 13. Vegetation should be further encouraged to establish in and around the mattress as soon as possible, as it will enhance its effectiveness.

MATERIALS

Dam brush

Flexible, green, and heavily leaved (i.e. not dry and brittle) tree branches of 1.0 - 1.3 m maximum length. Pine, fir, oak, willow, and orchard prunings have all proved satisfactory.

Apron brush

As for dam brush, but longer (i.e. 1.5 - 3.0 m long).

Litter

Fine-textured plant material, e.g. forest litter, straw, or fine, dense brush.

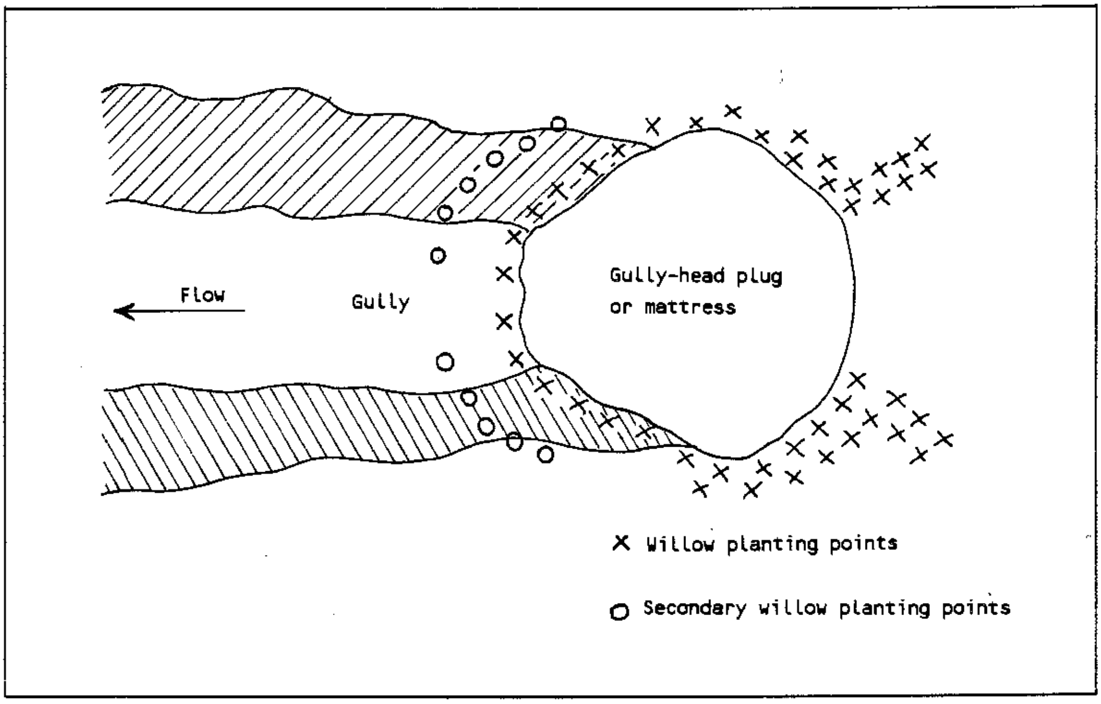

Figure 13: **Plan view of a gulley-head plug or mattress showing planting points for willows (redrawn from Gray & Leiser 1982).**

Posts

Preferably live willow stakes (see below for details of handling these), but any good fence post material is satisfactory. Preserved timber is probably best avoided, so long-lasting hardwoods should be considered.

<u>Live staking</u>

The following guidance for the preparation, handling, and planting of live stakes is quoted *verbatim* from Gray & Leiser (1982)

Preparation and handling of cuttings

> In preparing and handling cuttings prior to planting, the following guidelines will increase the chances for success:
>
> 1. Select healthy wood of reasonable straightness from plant species that root easily and are native to the planting site.
>
> 2. Make clean cuts with unsplit ends. Stems up to 1.5 inches in diameter can be best cut with two-handles brush pruning shears. Several stems of small diameter may be cut at a time with a carpenter's hatchet. Larger branches can be cut with chain saws. The butt end of cuttings may be pointed to facilitate driving.
>
> 3. Trim branches from cuttings as closely as possible.

4. Length: Cuttings of small diameter (up to 1.5 inches) should be at least 18 inches long. Thicker and longer cuttings (up to 3 or 4 ft) are desirable for staking ... on slopes.

5. Diameter: The minimum diameter is 0.25 inch; the thicker the cutting, the greater the food reserves. Cuttings greater than 1 inch are desirable, although their numbers may be limited by the supply.

6. Location of buds and bud scars: Cuttings put out their greatest concentration of shoots and their strongest ones just below an annual ring (formed from a terminal bud scar). Cuttings should be cut so that a terminal bud scar is within 1 to 4 inches of the top. At least two buds and/or bud scars should be above the ground after planting.

7. Handling of stakes between cutting and planting: Cuttings must not be allowed to dry out. They are best planted the same day as prepared. They must be kept covered and moist during transport, storage, and during the planting operation. Cuttings may also be kept submerged in water for one to several days after preparation to ensure that they remain moist. At no time should cuttings be left exposed to the air to dry out prior to planting.

How to plant stakes

In addition to the way in which stakes are prepared and stored, the way in which they are set in the ground is also crucial for success. The following guidelines should be observed:

1. Plant the cuttings the right side up (i.e. with the butt ends in the ground). It is not always easy to tell the top from the butt of a leafless cutting. A good rule is to have the butt end of all stakes pointed or marked immediately by the cutting crew at the time they are made. Alternatively, the tops of bundles of cuttings may be painted with a water-soluble latex paint. The paint also seals the ends and reduces dessication of the cuttings.

2. Set the cutting as deep as possible. Most of the sprig length should be planted in the ground. It is preferable that at least 80 percent of the sprig length be in the ground. Two reasons for deep planting are to minimize water loss due to transpiration, and to lessen the problem of root breakage caused by the relative movement between the cutting and the ground.

3. Avoid stripping the bark or needless bruising of the stakes when setting them in the ground. In fairly soft soil the stakes can be driven with a wooden maul. Do not use an axe or sledge. In hard ground use and iron bar or star drill to prepare holes for the cuttings.

4. Tamp the soil around the cutting. The cutting must be firm in the ground so that it cannot be readily moved or pulled out.

Time to plant stakes

Stakes should be cut and planted when willows or other suitable species used are dormant. This period extends from the time the leaves start to turn yellow in the autumn until the time growth starts again in the spring.

In moist soils, willow stakes can sometimes be planted successfully during the summer season, but usually this should not be attempted. When this procedure is attempted, the cuttings should be defoliated. Additional soaking of cuttings prior to planting may be required for late plantings.

PROBLEMS AND PITFALLS

As we have no experience of these techniques, the likely problems are not known. Feedback from field experience is required.

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6

Access provision

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Access provision

T.A. Rowell

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INTRODUCTION

A single footprint on the *Sphagnum* surface of a raised bog takes 20 - 30 months to disappear (Slater & Agnew 1977). It is not only the sensitive bryophytes that may suffer as a result of being crushed. Damage by trampling to plants such as *Calluna vulgaris* and *Erica* spp. can be compounded by frost, and full recovery by some species after a single trampling event may take as long as eight years.(Bayfield 1976). Some species may be encouraged by trampling, possibly because of reduced competition, or nutrient release from the peat. *Rhynchospora alba* appears to be encouraged in trampled areas, and may represent an increased fire hazard on some sites (Slater & Agnew 1977).

Clearly peatlands are extremely susceptible to mechanical damage from pedestrian and vehicular traffic, and care should be taken to ensure that either damage does not occur, or that it is restricted to selected areas that are to be written off. However, susceptibility to damage will vary according to wetness and type of vegetation cover, so the measures needed to protect sites must be judged in the light of these factors and the type and intensity of traffic expected. There may be a temptation to remove peat down to the mineral ground to provide access routes for vehicles. This (as well as disruption and compaction) will affect hydrology and the techniques discussed here should help avoid such problems.

Many of the techniques discussed here are untested on peatland sites. Any implementation of these or similar techniques should be well recorded and information disseminated *via* future editions of the Handbook.

PRINCIPLES

The over-riding principles underlying the provision of access facilities on peatlands are the avoidance of compaction of the peatland damage to the vegetation, particularly to any *Sphagnum* carpet.

Access for management

On many sites, access is required mostly for management work and wardening. The former often involves short term intensive use of pathways, while the latter normally requires regular but light use. Emergency access may also be necessary in the event of fire.

Where traffic is very infrequent, then special access provision need not be made, but it is preferable to ensure that damage is kept to a minimum area and level. Some form of footpath reinforcement may be necessary where the route crosses wet depressions such as old ditches. Where only a few pedestrians are involved, briefing on footpath routes plus monitoring of path condition are probably all that are necessary for adequate control. Where larger numbers are to use pathways, briefing plus a path-marking system will probably be required.

Heavy foot traffic over wet peat will necessitate some form of protection, either permanent or temporary. Unprotected paths over wet ground invariably widen as damage occurs and walkers seek out drier, undamaged areas. This widening can be avoided by imposing restrictions on such as ditches or fences, and by improving areas liable to damage.

Vehicular traffic of any sort over peat should be avoided wherever possible. Where transport is necessary, then low pressure tyres should be used. Use of an Argocat or Veepee once or twice a year to access areas of wet peat by unprotected routes is acceptable, but more frequent access must be strictly controlled. Random routeing of vehicles over peat is an approach often advocated on the basis that damage is minimised by being spread. However, given the recovery time of the peat surface and of some peatland species, this is not advisable.

It may be necessary to restrict access to parts of some peatland sites to certain times of the year, other than on a protected pathway such as a boardwalk. Slater & Agnew (1977) recommended that access to the dome of the raised bog Cors Fochno be limited to summer and winter only, when the peat would be at its driest and damage much reduced.

Access for visitors

Visitors to a peatland site require careful control that may involve not only provision of a reinforced route, but also the designation of an area to be used for educational purposes. The latter will normally be in a less sensitive area, but one where the full range of commoner species can be seen. Some of the disadvantages of such restrictions may be partially overcome by the provision of raised viewing-points to allow visual access to restricted areas.

METHODS OF ACCESS PROVISION

Mowing of rides or droveways

On many fen sites, particularly grass-dominated areas, access may be easily provided by mowing droveways through the vegetation. Regular mowing will tend to change the character of the vegetation (see MOWING) which will often knit into a reasonably hardwearing sward. Mown droveways will often support large numbers of visitors provided they are not used in wet conditions. Wet patches, such as defunct ditches or peat pits, will result in a widening of the droveway unless they are repaired and regularly maintained (see below)

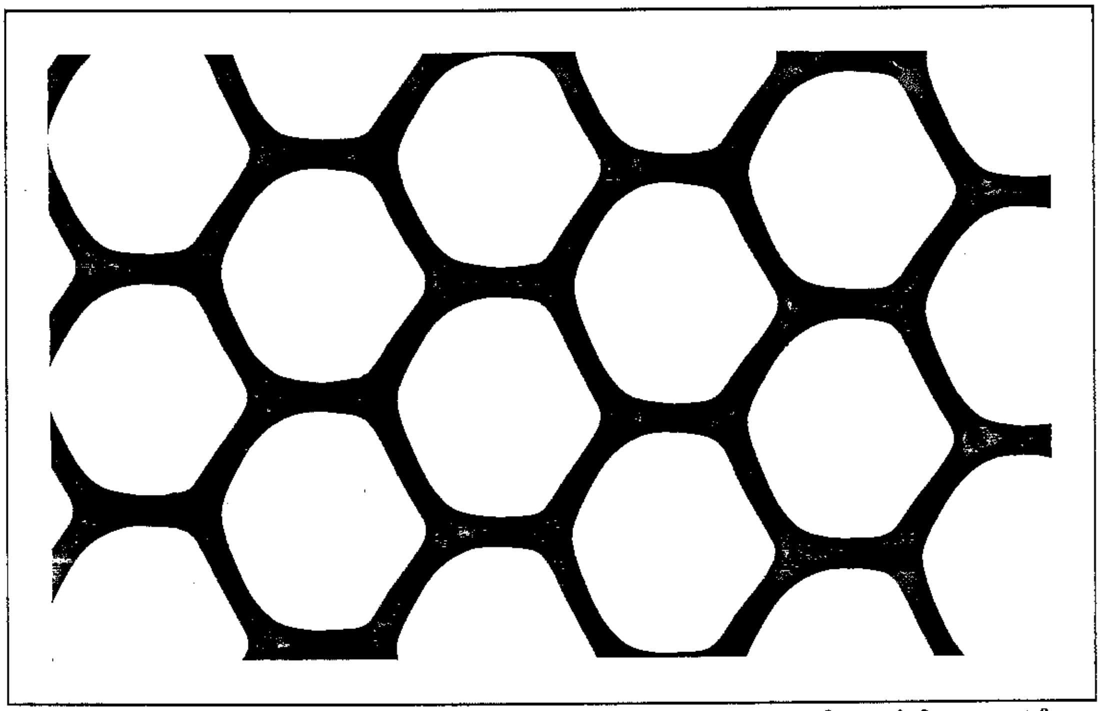

Figure 1: **Polyethylene mesh (actual size) suitable for use as surface reinforcement for patbways or infrequent access by vehicles.**

Control of footpath width and route

Monitoring of footpath condition, repair, temporary closure and re-routeing will all help avoid the tendency for footpaths to widen or shift through pedestrian deviation. More positive control can be exercised by the provision of a good surface along the entire route of the path (e.g. a boardwalk), or by incorporating a deterrent strip along both sides of the path. On some peatland sites this has been achieved by cutting ditches along both sides of the route. The spoil from the ditches can be used to slightly raise the level of the footpath, affording improved views for visitors. This technique has been effectively employed at the RSPB reserve at Strumpshaw Fen, but is only suitable for sites where ditches already form an important part of the hydrology and habitat. To reduce drainage, they should not be connected to the outfall.

Short distance repair and reinforcing of footpaths

New pathways over wet peat will require some form of reinforcement if foot traffic is to be anything more than very infrequent. Simple reinforcement of the surface with polyethylene mesh may prove sufficient for moderate use. A mesh size of about 30 mm (e.g. Netlon C/E 131, see Figure 1) is most suitable. Whatever the product used, it should be manufactured from ultra-violet stabilised and acid resistant polyethylene. Products containing metallic wire should not be used. Mesh used for light reinforcement should be laid on the surface of the vegetation. If the vegetation is long or coarse then it should be cut before laying the mesh so that the mesh can lie as flat as possible and plants grow through and bind it to the surface. This technique can be problematical over uneven ground or where rocks and stones protrude. The mesh can be cut to lie around large rocks but, otherwise, some levelling of the surface may be necessary.

Wet or damaged areas in unprotected footpaths should be regarded as a priority for repair and reinforcing. Possible methods include short lengths of boardwalk, duckboarding, pallets or chestnut paling. Less intrusive materials include sheaves of reed, *Cladium*, or other hardwearing vegetation which will have to be replaced relatively frequently, or longer lasting timber cording or piling. The use of sheaf or cording may be improved by first laying and anchoring a heavy mesh. The longevity and reinforcing capability of cording and piling may be improved by incorporating live stems of *Salix* spp. which will root and bind the peat.

The use of sheaf or cording over very wet ground is often difficult because the repair material is quickly pushed into the wet substrate (Agate 1983). Mesh can be used as a sub-base for gravel paths in such situations, and should also be suitable for use under bundled vegetation. A smaller mesh size should be used of about 10 mm (e.g. Netlon C/E 121, see Figure 2).

To repair a damaged area (see Figure 3):

* Scrape out sloppy peat down to a firmer substrate.
* Level the bottom of the repair area.
* Undercut and fold back sods all round the repair area.
* Lay mesh across repair area ensuring that it will run under the turned back sods.
* Re-lay the sods and anchor the mesh with stakes driven through the sods, preferably with live stakes (see GULLY EROSION CONTROL for live staking techniques).
* Fill the repair area with sheaf, faggots, brashings or bundles of heather, using larger bundles as a base and finer material for the surface.
* An improved surface can be obtained by laying chestnut paling fencing over the bundles.

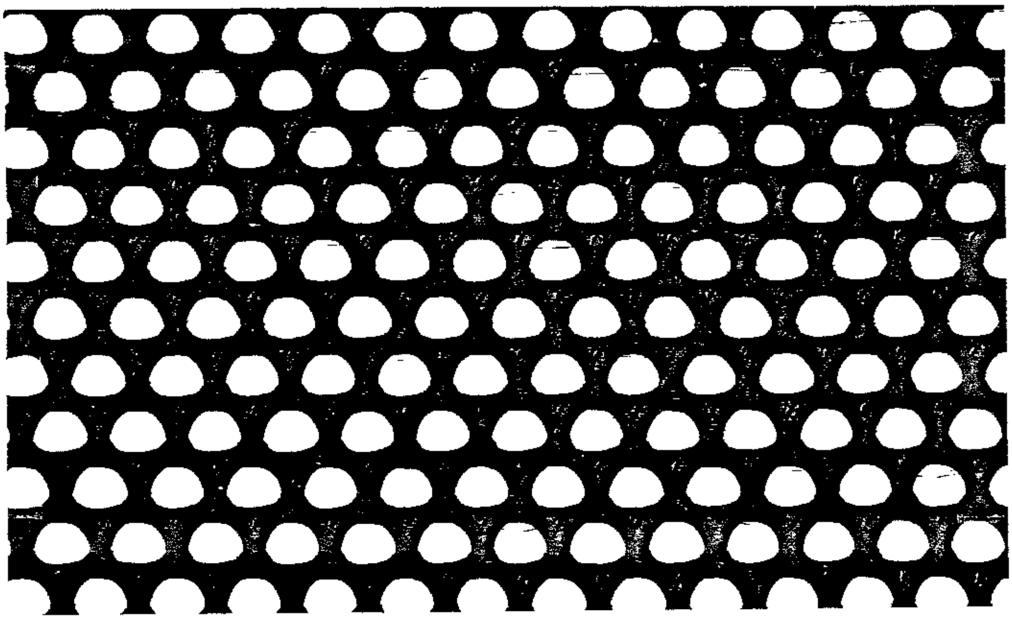

Figure 2: Polyethylene mesh (actual size) suitable for use as a footpath sub-base.

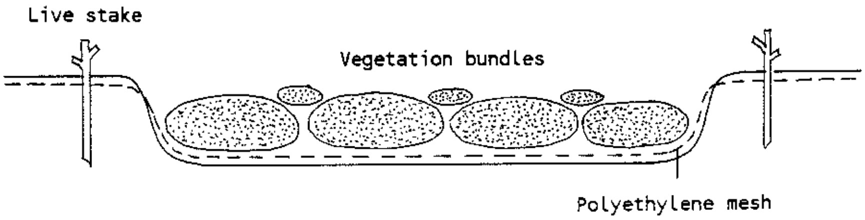

Figure 3: The repair of damaged pathways on peat using mesh and bundles of vegetation (cross-section). The pathway can be finished with strewn vegetation and/or old chestnut paling or more mesh.

Timber piling

Timber piling is a labour intensive but hardwearing method for repairing damaged areas on footpaths, or for traversing wet areas. The technique involves driving in round untreated posts of 5 - 25 cm diameter to a depth of at least 1 m. They can be sawn off flush as the work proceeds, and finally levelled with a sledge and batten. A proportion of live stakes, particularly at the edges of the repair area, may prove advantageous in binding the pathway and in providing deterrent edges

Temporary access

Pedestrians

Temporary access for pedestrians is most easily provided by short lengths of boardwalk which can be laid end to end. To reduce ground pressure and damage to a minimum, these should be slatted on both sides. For safety, they should be linked, possibly by wire fixed with fencing staples. A manufactured alternative is the hinged boarding intended for vehicle use.

Vehicles

A solution to temporary protection for vehicle access is the use of hinged hardwood boards which are available for hire or purchase. These are about 1m wide and need to be laid in a double row to accommodate a vehicle (in a single row they could be used for pedestrian access). The boards transmit a ground pressure of only 4 $g.cm^{-2}$ when in full contact with the ground. Two 2.8 x 0.9 m boards will therefore support up to about 3200 kg before 70 $g.cm^{-2}$ ($1lb.in^{-2}$) is reached, or 6700 kg to equal the ground pressure of an Argocat (but without the shearing forces of the tyres of that vehicle).

Permanent access

Pedestrians

For infrequent pedestrian use on peatlands, surface reinforcement with mesh, as described above, may prove adequate. Under most circumstances however, permanent access on wetter peatland sites is best achieved by the building of a boardwalk. They provide good control of access and may, if well constructed, allow access to difficult areas by the handicapped and infirm. Unfortunately, boardwalks are visually obtrusive and should therefore be kept to a minimum, be carefully and tidily constructed, and be well maintained.

On peatlands, boardwalks should be constructed from untreated timber as preservatives are known to have caused extensive damage to vegetation in at least one instance. This damage may be due to insufficient weathering of the treated timber before installation, but treated timber should be avoided until good quality information is available on suitable preservatives and weathering periods in relation to method of treatment and type of timber. The problem of treated timber has prompted one installation of a boardwalk constructed from African hardwood, giving an extremely long life, complete freedom from preservatives, and suitability for large numbers of visitors. British hardwoods should also prove suitable for this purpose. For less demanding uses, locally available rough sawn timber may be suitable, and this may prove to be a use for waste timber cleared from the site. When constructing boardwalks to a lower specification, care should be taken to ensure an even and safe surface.

The Countryside Commission for Scotland provide specifications for boardwalks (Appendix). These should prove adequate for most visitor access purposes provided long enough piles are used to ensure that the structure does not sink. Where peat is too soft for this design, then serious consideration should be given to re-routeing the boardwalk. If piles are not possible, then the boardwalk should be built in sections and faced with slats on both sides to reduce damage to the peat surface. It is possible to provide visitor access over floating fen by laying standard boardwalk sections over old car tyres, as at Oxwich NNR This may also prove a suitable method for gaining temporary access to quaking bog.

Consideration should be given to the peak volumes of traffic a boardwalk is likely to have to carry. Width and number of passing places should be planned accordingly. Some discussion of this, and a range of alternative designs for boardwalks, are given by Agate (1983).

Vehicles

The problem of provision of permanent vehicular access across peatland sites has not, in general, been properly addressed, but steps must be taken to avoid the extent of damage experienced at Gualin NNR Here, uncontrolled use of Argocats disrupted the surface peat over a wide area. Despite their low ground pressure, these machines can cause damage by shearing the vegetation mat. Several runs over the same wet ground soon results in a quagmire devoid of vegetation.

Route planning must be the basis of vehicular access to peatland sites. Wherever possible, routes should follow mineral ground or shallow peat (i.e. less than 20 cm depth). Any permanent access to areas of deeper peat must be protected. For infrequent use (up to, say, 15 visits a year) surface protection with mesh is probably adequate. This technique is described above. For more intensive use, hinged boards (discussed above for temporary access) probably provide the best long term solution.

Access routes for fire fighting will normally be determined as part of the fire plan and, provided safe access can be assured at all times, can pass through areas normally requiring reinforcement.

MATERIALS

Polyethylene mesh

Netlon C/E 121 and C/E 131 are both available in 30 x 2 m rolls.

Example prices (Jan 1988):

C/E 121 .... £121 - 50

C/E 131 .... £108 - 50

Orders in excess of £2500 are dealt with direct from the manufacturers at about 17.5% discount. Otherwise, a list of local suppliers can be obtained from

Netlon Limited,
Kelly Street,
Blackburn
BB2 4PJ

Tel. 0254 62431

Hinged board track

Flexboards: each board consists of about 20 hardwood (untreated oak, ash, elm or sycamore) strips joined by two transverse mild steel bars. The bars are looped at each end allowing a hinge pin or dowel to be inserted through the loops of two adjacent boards to form a flexible connection. Hinge pins are pierced at each end so that pickets can be hammered through them into the ground.

Standard Flexboards 90 x 280 x 3.8 cm, 101.6 kg, min. ground pressure 4 $g.cm^{-2}$, price at Jan 1988, £39 each.

Heavy duty Flexboards.... 106 x 200 x 5 cm, 101.6 kg, min. ground pressure 4.8 $g.cm^{-2}$, price at Jan 1988, £37 each.

Flexboards can be purchased or hired from:

Sommerfeld Flexboard Ltd,
Doseley Industrial Estate,
Frame Lane,
Doseley,
Telford,
Shropshire
TF4 3BY

Tel. 0952 503737

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APPENDIX: Specifications for boardwalks (Countryside Commission for Scotland

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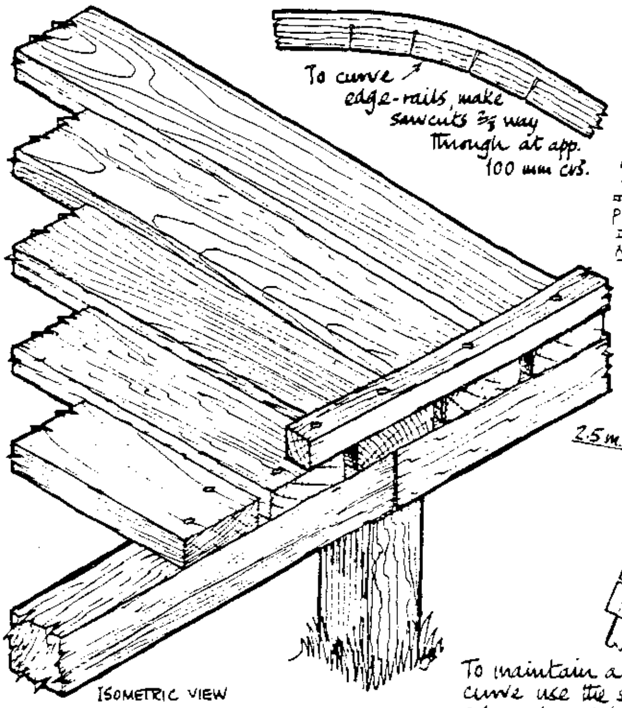
Countryside Commission for Scotland
Battleby Redgorton Perth PH1 3EW
☎ Perth (0738) 27921

INFORMATION SHEET **6.9**

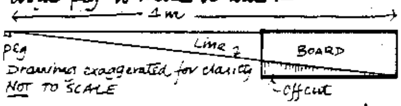
Board Walk

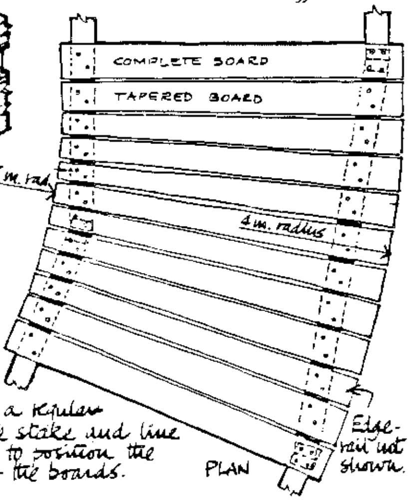
1:25

Order of operation:
1, Set out; 2, Piles; 3, Stringers; 4, Boards; 5, End detail; 6, Edge rail; 7, creosote or tar.

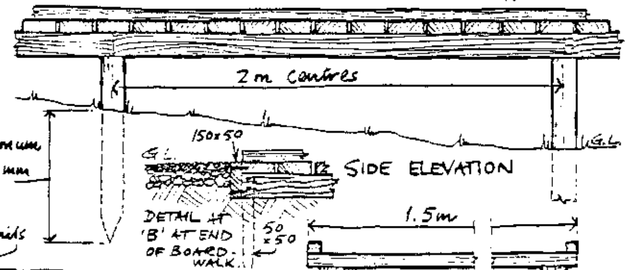


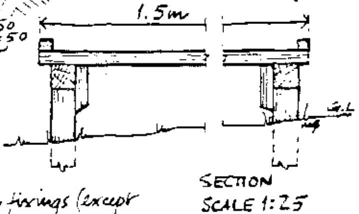
NOTE: For a trim appearance it is essential that the boards at the bend are cut to an even taper - use a line and peg to mark it thus:-

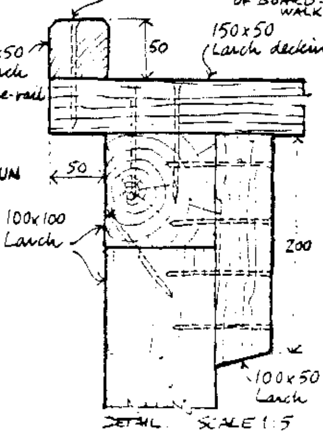




A Board-walk is an obtrusive element in the landscape, and they should therefore be used selectively.
They are most useful for the protection of fragile areas to which controlled access is required, and provide a smooth, firm surface for wheelchair users.
If used as ramps, the maximum declivity should not exceed 1:12.







MATERIAL LIST PER 2.0 m RUN

Piles	2-off	1500x100x100
Boards	13-off	1500x150x50
Stringers	2-off	2000x100x100
Edge rail	4-lin. metres	50x50
Brackets	2-off	200x100x50

FIXINGS
26-off 75 mm galv. nails
60-off 100 mm galv. nails

All fixings (except edge rails) 100 mm galvanised nails.

FINISHES
All timber should be pressure-treated against fungal rot.
After erection two coats creosote should be applied. For a non-slip surface spray boards with hot tar and dust with grit.

Countryside Commission for Scotland
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INFORMATION SHEET **6.10**

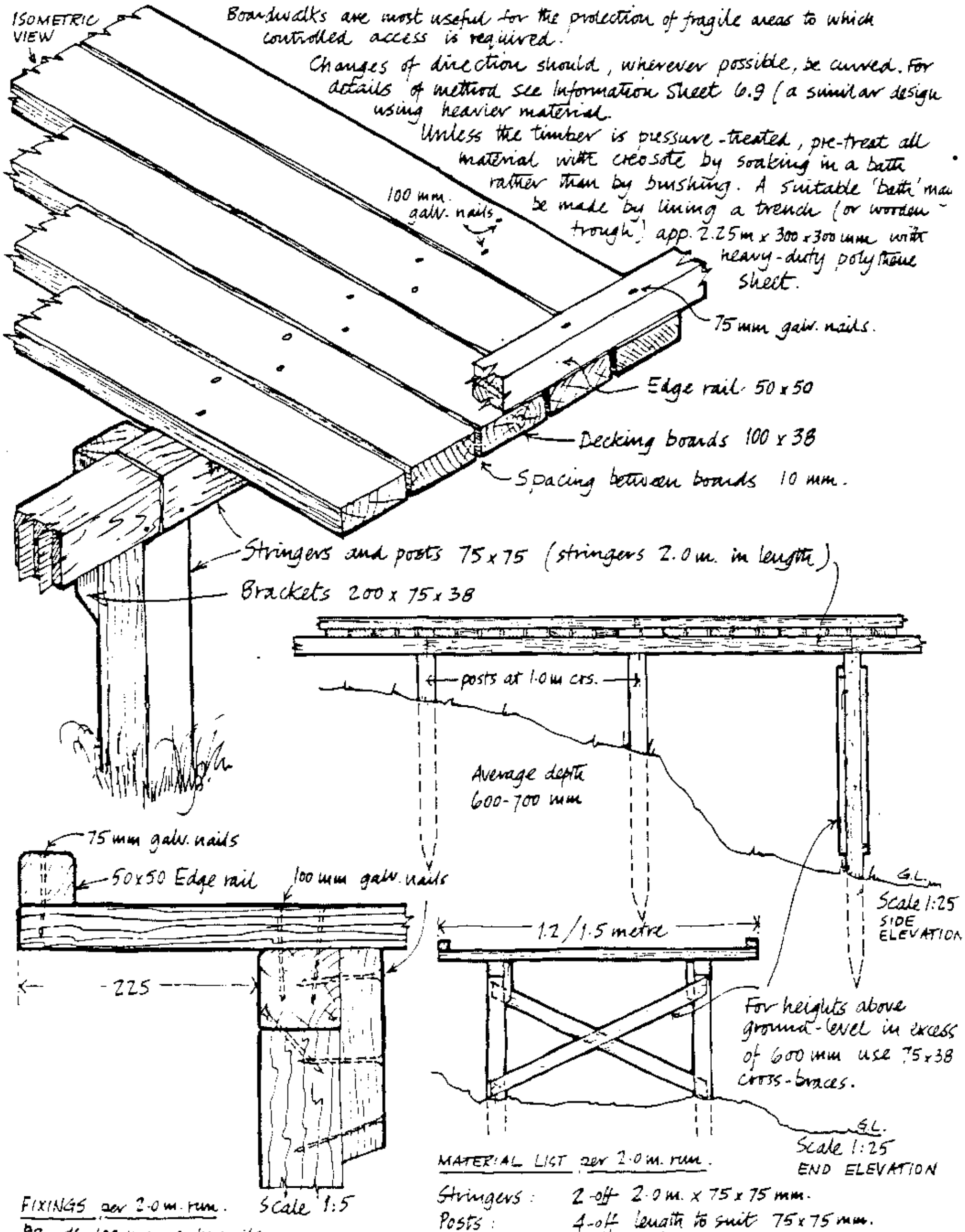
BOARD WALK C.C.S.Design

Scales as marked

Boardwalks are most useful for the protection of fragile areas to which controlled access is required.

Changes of direction should, wherever possible, be curved. For details of method see Information Sheet 6.9 (a similar design using heavier material.

Unless the timber is pressure-treated, pre-treat all material with creosote by soaking in a bath rather than by brushing. A suitable 'bath' may be made by lining a trench (or wooden trough) app. 2.25m x 300 x 300 mm with heavy-duty polythene sheet.



FIXINGS per 2.0 m. run.

92-off 100 mm. galv. nails.
38-off 75 mm galv. nails.
8-off 75 mm g. nails per pair of cross-braces.

MATERIAL LIST per 2.0 m. run.

Stringers:	2-off 2.0 m. x 75 x 75 mm.
Posts:	4-off length to suit 75 x 75 mm.
Deckboards.	19-off 1.2/1.5 m. x 100 x 38 mm.
Edge rail:	2-off 2.0 m x 50 x 50 mm.
Brackets:	4-off 200 x 75 x 38 mm.
Cross-braces:	To suit at 75 x 38 mm cross-section.

CCCS

Countryside Commission for Scotland
Battleby Redgorton Perth PH1 3EW
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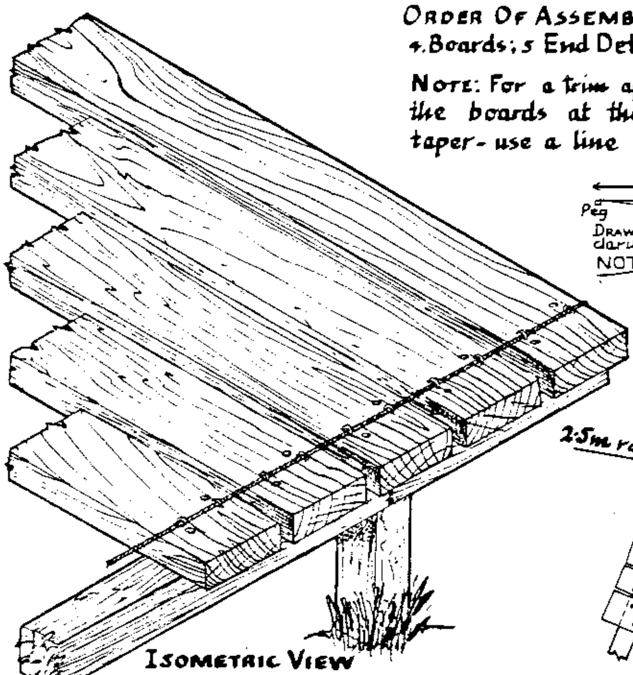
INFORMATION SHEET **6.13**

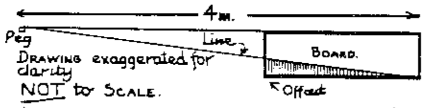
Board Walk

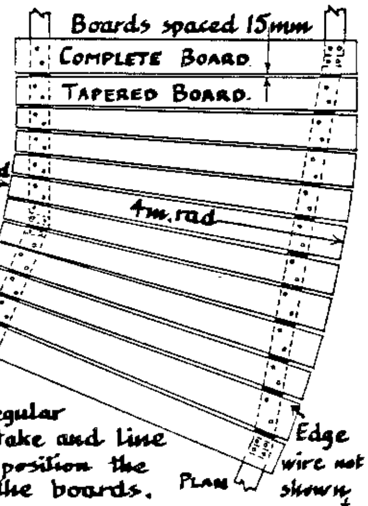
Scales 1:10 & 1:25

ORDER OF ASSEMBLY: 1. Set out; 2. Piles; 3. Stringers 4. Boards; 5 End Detail; 6. Edge wire. 7. creosote or tar.

NOTE: For a trim appearance it is essential that the boards at the bend are cut to an even taper - use a line and peg to make it thus:-

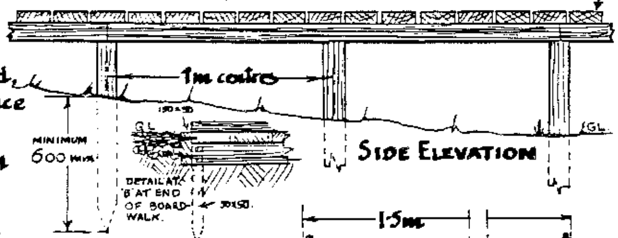






To maintain a regular curve use the stake and line as compasses to position the outer ends of the boards.

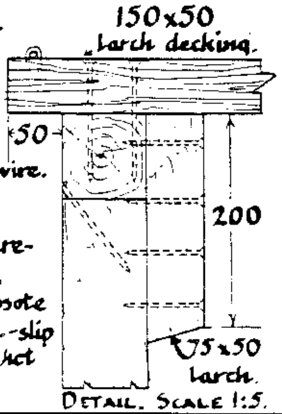
A Board-walk is an obtrusive element in the landscape and they should therefore be used selectively. They are most useful for the protection of fragile areas to which controlled access is required, and provide a smooth, firm surface for wheelchair users. If used as ramps, the maximum declivity should not exceed 1:12.

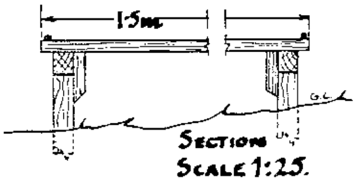


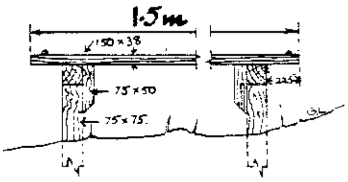
MATERIAL LIST PER 2·0m RUN.
Piles 4-off 1500 x 75 x 75.
Boards 13 off 1500 x 150 x 50.
Brackets 2-off 200 x 75 x 50.

FIXINGS.
26 Galv. fencing staples.
60-off 100mm galv nails.
4 metres, 2mm galv-fence wire.

FINISHES
All timber should be pressure-treated against fungal rot. After erection two coats creosote should be applied. For a non-slip surface spray boards with hot tar and dust with grit.







7

Mowing

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Mowing

T.A. Rowell

CONTENTS

INTRODUCTION

Mowing is a traditional means of managing certain types of peatland, typically flood-plain fens, and is frequently used in habitat management to manipulate botanical diversity, structure, and succession. It is a management technique which offers a very high degree of control over vegetation structure and composition, and has been seen, therefore, as a possible alternative to both grazing and burning in some situations.

In its traditional role, mowing has been the means of cropping single species such as reed (*Phragmites australis*) and sedge (*Cladium mariscus*). So much information exists on these two crops that they are dealt with separately in this handbook (see REED MANAGEMENT and CLADIUM MANAGEMENT). Traditionally, mixed species crops have also been mown from tall fen communities, i.e. marsh hay and litter.[1]

In conservation management, these traditional practices have been continued or resumed, and other techniques are beginning to be developed. These newer techniques include the mowing of short-fen communities to encourage or maintain botanical diversity or some particular sensitive or rare species, and the mowing of heather to re-initiate the building phase without the need for potentially damaging burning.

Communities

The following peatland communities may be maintained or influenced by mowing.

M9 - *Carex rostrata-Calliergon cuspidatum* mire

M13 - *Schoenus nigricans-Juncus subnodulosus* mire

M22 - *Juncus subnodulosus-Cirsium palustre* fen-meadow

M23 - *Juncus effusus/Juncus acutiflorus-Galium palustre* rush-pasture

M24 - *Molinia caerulea-Cirsium dissectum* fen-meadow

M26 - *Molinia caerulea-Crepis paludosa* mire

M27 - *Filipendula ulmaria-Angelica sylvestris* mire

S2 - *Cladium mariscus* sedge-swamp

S24 - *Phragmites australis-Peucedanum palustre* fen

PRINCIPLES

General

Mowing is usually considered to be non-selective in contrast to defoliation by grazing. While animals select species to eat according to palatability and need, a blade cuts all. However, selection does operate in mowing to a limited extent. Selection is governed by the height of the blade above the ground, and may leave unharmed certain species or age classes according to

1 Note that the term 'litter' in this context is a local term for cut and dried vegetation, rather than the plant ecological term for fallen dead plant material.

their morphology. In addition, timing determines which plants in a community are affected by the cut according to their phenology.[2] Frequency of cutting combines the effects of timing with species' and individuals' physiological abilities to withstand defoliation and/or replace lost tissue. The latter will also vary with aspects of the environment such as availability of nutrients and the rigours of climate and hydrology. The stresses imposed by the environment combine with the disturbance caused by mowing to determine the types of species that might survive under a particular regime. Mowing during the growing season reduces the standing crop of vegetation, allowing diversification of the community; this has been confirmed for fen vegetation (Wheeler & Giller, 1982). The range of available species determines the potential species density attainable by the particular management regime and environmental situation, but there can, of course, be no guarantee of the composition of vegetation resulting from a new management regime.

Morphology

When vegetation is mown during the growing season, it is the position of the meristem[3] that is important. Where this is at the tip of the shoot, then the form of the plant may be altered when it is removed (as when you 'pinch out' the growing point of a domestic plant to make it produce more side shoots), or the whole plant may die. Some groups of plants, notably the grasses and sedges, have the meristem at ground level so that it escapes damage during defoliation. These plants survive mowing well, though the loss of tissue may weaken the plant and change its competitive relationship within the vegetation.

Phenology

The timing of life history events varies between species so that flowering, for instance, occurs throughout the growing season within a community but with a different suite of species in flower at any particular time. Species will be affected differently according to time of mowing, and species composition may eventually change accordingly.

Mowing during flowering and before seed development will have obvious consequences in preventing establishment from that year's potential seed production. Alternatively, mowing just before seed-release may aid the dispersal of some species.

The value of phenological observations in conservation management can be illustrated by the case of *Peucedanum palustre*, the fenland Umbellifer that is the foodplant of the swallowtail butterfly (*Papilio machaon*). A decline in the abundance of this species at Wicken Fen is responsible for the extinction of the butterfly at that site, and has been linked to a reduction in the extent of herbaceous vegetation and to a fall in water table (Dempster, King & Lakhani 1976). Examination of the life history calendar of the plant (Figure 1) reveals potential conflicts over the time of cutting of the vegetation within which it formerly flourished. Late summer mowing removed the flowering stem, not only reducing seed input (important for this short-lived perennial) but also resulting in the death of a large proportion of individuals (Harvey & Meredith 1981). The calendar suggests that earlier cutting might possibly stimulate germination, but more importantly would avoid cutting the flowering stem with its attendant problems. A change in the time of cutting appears to have achieved this, and populations of *Peucedanum* appear to be much larger than formerly.

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2 Phenology refers to the timing of life history events such as germination, flowering, seed setting, etc.

3 The growing point of a plant.

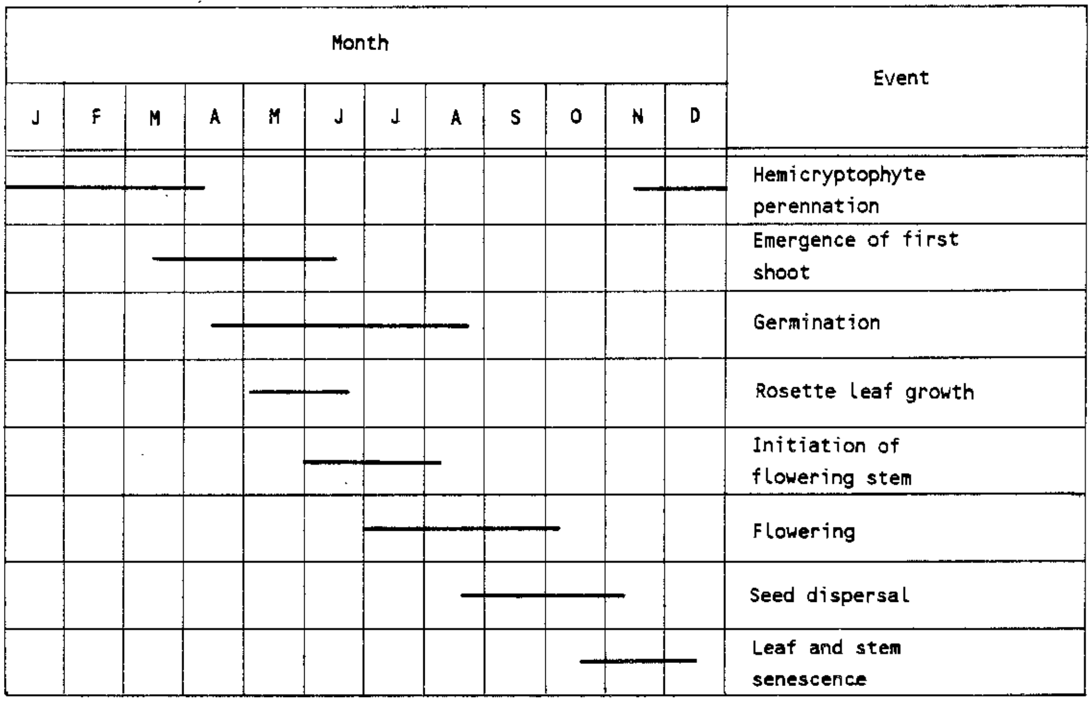

Figure 1: **The life history calendar of *Peucedanum palustre* (Harvey & Meredith 1981). Mowing during June - December will prevent or reduce seed production and can kill the plant. Mowing before June does not have this effect (only the rosette leaves are damaged) and may open up the canopy thus stimulating germination.**

Two important components of fen vegetation are easily manipulated by timing of mowing. Reed (*Phragmites australis*) is eradicated quite rapidly by summer mowing, while *Cladium* can be badly affected or killed by mowing followed by flooding (see REED MANAGEMENT and CLADIUM MANAGEMENT).

Time of mowing is often manipulated in conservation management to avoid critical periods in the life histories of animals, particularly birds and insects. Taken to its apparently logical conclusion, this has occasionally led to avoidance of mowing altogether, with consequent loss of habitat through invasion by scrub. Where mowing is important then some faunal losses must be accepted. Where space permits, adoption of a range of mowing times may provide the best solution to animal management by providing a wide variety of habitats.

Standing crop

A clear association exists between high above-ground biomass (standing crop plus litter[4]) and low species-density, as demonstrated by studies of fen vegetation in Broadland (Wheeler & Giller, 1982). The amount of standing crop and litter can be reduced by mowing (or may be naturally low through infertility), and this may result in an increase in species density. Survey data show that this is not always the case (Wheeler & Giller, 1982). Experimental data indicate that increases can occur rapidly, being detectable within two or three years (Rowell, Guarino & Harvey 1985). Summer mowing will reduce standing crop most effectively, as it removes biomass at the peak of the growing season. Late season or winter mowing will have

4 In this context, 'litter' is fallen dead plant material (see footnote 1).

little or no effect because only dead material (potential litter) is removed, unless evergreen species are involved (e.g. *Cladium*; but there are other reasons for not mowing this species in the winter; see CLADIUM MANAGEMENT).

Frequency

In general, the frequency of mowing should match the productivity of the vegetation, i.e. highly productive vegetation can be cut relatively frequently while unproductive vegetation should be cut infrequently, if at all. Unless dealing with intractable, tall vegetation, mowing more frequently than once a year should be unnecessary. Cutting twice in the first year of a newly managed site, for instance, may be damaging because it could create too many germination sites, allowing invasion by unwanted species.

Sometimes, infrequent mowing is adopted, either out of regard for animal populations or because of lack of resources. This often leads to a build up of litter or standing crop, with a consequent reduction in species density and, possibly, of flowering performance. If more frequent mowing has been the rule in the past, then some animal populations may suffer, and new species may invade to utilise the new vegetation structure. As with timing, it may be useful to adopt a range of mowing frequencies so as to create a wide variety of habitats.

Planning for mowing management

Prior to any new mowing management, a survey should be undertaken with the following aims.

* Establish access routes (see ACCESS) and, where necessary, disposal points for waste cut material.

* Classify vegetation on the basis of ease of access, and removal and handling of waste.

* Classify vegetation on the basis of probability of development of desired vegetation.

* Classify vegetation on the basis of suitability for mechanised or hand mowing.

Any past mowing regimes should be researched, and any available information assembled on community structure and composition. The possibilities for disposal of waste should also be examined.

Selection of areas for mowing management

When sites are being selected for diversification by mowing management they should, whether or not they contain scrub, already contain the desired herbaceous species as vegetative plants. Other species may be present as seed but, unless a study to determine the composition of the seed community is undertaken, these must be discounted. Their later appearance in a newly-managed site will be counted an unlooked-for bonus.

Scrub with a high proportion of alder may prove to be difficult to diversify following clearance because of eutrophication resulting from the breakdown of nitrogen-rich leaves. High fertility of such areas tends to result in rapid growth of species with a high relative growth rate such as *Urtica dioica*.

Experience in Norfolk suggests that communities with large amounts of *Epilobium*, *Eupatorium*, and *Calamagrostis canescens* may prove unresponsive to mowing. It has proved possible elsewhere, however, to diversify communities containing large proportions of *Calamagrostis canescens* and *C. epigeios* (Rowell, Guarino & Harvey 1985).

Mechanisation vs hand mowing

Compaction and nutrient release can be caused by the use of wheeled machinery on wet sites. The possibility of these problems on any species-rich peatland, wet or dry, should be avoided by restricting the use of machinery to drier areas of low conservation value.

Damage to tussocks should be avoided as they are important habitat for many invertebrates and some other plants. Hand tools and powered brush cutters are the only suitable equipment for use amongst tussocks.

Many mechanised tools will be damaged by contact with stumps of trees and shrubs. The cutting and chemical treatment of any woody species encountered during mowing should be routine practice.

Past mowing regimes

Information about past mowing regimes may be fairly easily available from local sources, notably past owners or tenants of the land in question. Other sources are likely to be documentary; sources and methods are discussed by Sheail (1980). The use of documentary sources to establish past mowing regimes has been a successful approach for at least one peatland site (Rowell 1987).

Disposal of waste vegetation

Unless the amount of cut material is very small, all mown vegetation should be removed from the site. Material left lying will become litter and large amounts will tend to suppress species density. Removal of cut material requires a level of organisation and equipment above that of straightforward mowing. While mechanisation is not possible on wetter sites, as discussed above, equipment such as hay turners and buckrakes can simplify the task where conditions allow. Otherwise, labour will have to be organised to rake, pitch and carry cut material.

A variety of alternatives exist for the disposal of waste cut material.

* Use on-site (e.g. footpath repair).
* Use off-site (e.g. marsh hay).
* Dumping on-site ('habitat piles').
* Dumping off-site.
* Burning on-site.
* Burning off-site.

Burning on-site involves consideration of site protection against fire, eutrophication and the consequent ingress of undesirable species.

GENERAL PRACTICE

Planning

* Survey site for vegetation types, and possible access routes and disposal points.
* Determine appropriate mowing regimes for available vegetation.
* Determine availability of equipment and labour.
* Determine means of disposal of waste.
* Select areas for mowing treatments.
* Select access routes and disposal points, ensuring suitability for available equipment.
* On large sites, most effective deployment of labour and equipment may be achieved by devising a mowing plan involving a range of timings and frequencies.

Access

Reinforce access routes, where necessary, before damage occurs (see ACCESS).

Restoration to mowing management

Sites which have been abandoned to succession usually need special treatment before mowing management can be resumed. The build-up of litter and/or the development of woody plants will prevent safe operation of most mowing equipment. If sensitive species are still known to exist within the vegetation, then the vegetation will have to be cut carefully, probably using brushcutters. Otherwise, it can be burnt off (taking appropriate precautions, see BURNING), or mown with a flail and the debris raked off. Flailing is only appropriate when scrub development is relatively minor; equipment specifications will indicate the size of stem that can be cut.

Woody stems will foul and damage mowing equipment. They should therefore be cut off at ground level and treated before any mowing management is undertaken. Annual mowing will generally suppress woody species so that they do not continue to cause problems to mowing equipment. Any less frequent regime will necessitate further cutting of woody stems to ground level, followed by chemical treatment.

Mowing

Mowing is generally a trouble-free operation provided that equipment is well maintained, the ground surface is fairly level, and mowing areas are kept free of stumps and other obstructions. Care should be taken to mow as close as possible to the boundaries of the managed area to avoid scrub development and encroachment.

Timing of mowing should be strictly adhered to, particularly if changes in the vegetation are being monitored. It has proved useful to establish firm dates within which operations must be completed. This circumvents the common situation of, for instance, a June/July operation becoming an August operation, and eventually moving to September. The establishment of firm dates does, of course, require high standards of effective management of labour and equipment.

Handling of cut vegetation

Where hay is to be made from the cut vegetation, then normal hay making practice should be followed. In all other cases, handling of the cut vegetation will be made easier by allowing it to dry and knit together in swathes for a period. While raking-up can be done by hand, this may be more easily achieved where the ground is relatively dry and firm by a vehicle-mounted buckrake. Burning of swathes should be resisted, and they should not be allowed to lie for longer than absolutely necessary.

Cut material will often be carried off by tractor and trailer, but on wet or species-rich sites other means will have to be found. One possibility is the use of a 'stretcher', with heaps of vegetation being carried on two poles between two workers. Once the material has left the sensitive area, vehicular transport can be employed.

Disposal

The ideal means of disposal of cut vegetation is where it can be put to some positive use, such as hay. Fen vegetation can have a reasonable feed value, so that it may prove possible to organise mowing by an outside agent who takes the crop as the only payment. In this situation, attention will have to be paid to specifying how and when work is to be done, and to the provision of an adequate level of supervision.

A próportion of cut vegetation can be left on-site in piles to rot down and, in so doing, provide habitat for small mammals, reptiles, and invertebrates. All such piles should, however, be sited away from the main area of interest, possibly on the edge of areas of scrub.

A small proportion of cut vegetation may be usefully utilised on-site in the repair of damaged footpaths (see ACCESS).

If other means of disposal are not available, the option remains of burning waste in piles (burning in swathes on the ground is not acceptable). Bonfires should be constructed away from the main area of vegetation or other interest. Peat, being organic, is easily combustible, and the greatest danger associated with the burning of mown vegetation is a peat fire. These are notoriously difficult to extinguish and various methods have been adopted to allow burning with a minimum of danger.

At some sites, burning of cut vegetation is carried out during the winter when the water table is high. Some burning into the peat is inevitable using this method. The vegetation is destroyed and the soil enriched, making the fire-site a focus for invasion by atypical species. More sensitive approaches have been developed for the burning of scrub waste, and could also be used for mown material. These involve placing a non-inflammable break layer at the base of the fire, e.g. sheets of corrugated iron. The more successful methods incorporate additional layers to keep the source of heat further from the peat.

- Lay down a layer of brushwood, followed by a layer of corrugated iron, then the material to be burned.

- Alternatively, lay down a layer of overlapping sheets of corrugated iron, place bricks or other building blocks in a grid pattern suitable for supporting a further layer of corrugated iron; burn on the top layer of iron. Further similar layers would afford extra protection.

A certain amount of ash is bound to drop from the protective structure, and will cause enrichment of the immediate surrounding area. It is important, therefore, to establish a series of permanent bonfire sites so that this type of damage is restricted.

Where peat fires have been inadvertently started, they have been successfully dealt with by isolation with a trench dug down below the water table.

The amount of ash produced by mown waste is limited compared with scrub waste. It should, nevertheless, be disposed of carefully. Dumping on-site is not acceptable because of possible problems of nutrient enrichment. Similarly, disposal in ditches is also unacceptable. Ash needs to be transported off the site in suitable containers along the established protected access route, and dumped where it is unlikely to cause harm.

Scrub management

Any significant woody stems found in the mown areas should be treated following mowing. Where mown areas are bounded by scrub, this should be cut back occasionally (say one year in three) to avoid gradual encroachment and damage to communities of interest through shading.

MOWING OF HEATHER

Burning of heather is a traditional practice for rejuvenating *Calluna* to provide new growth. In some conservation situations, burning is undesirable either because of damage to other species (e.g. on wetter blanket bog), or because of danger to nearby forestry. Cutting is also a means of providing a firebreak.

The NCC has experimented with swiping heather with a chain flail. This chops heather into smaller pieces than with a solid blade, and does not break. Use of this equipment on heather requires that the tractor unit has an independent PTO and a creeper gear.

Tests by the North York Moors National Park showed a swipe to be ineffective on old heather compared to a Turner flail which operates in a vertical plane (North York Moors National Park, 1986). The most effective cutting height was found to be about 7 cm.

The vast amount of litter produced by cutting heather (about 15 cm depth from 90 cm tall heather) means that it is not an effective long term replacement for burning. Where the aim is to produce a firebreak, the material can be rowed and burnt. On dry, flat ground, a double chop forage harvester has been used, and this solves the problem of litter, at least in the short term, by blowing it over the adjacent ground.

Cut heather can be disposed of by rowing and baling for use as a seed source and mulch in areas requiring revegetation following erosion. There is now considerable trade in seed of native plants for restoration projects, and it is possible that this trade could provide an outlet for cut heather.

EQUIPMENT

Hand mowing

Wet or tussocky areas should be cut with a scythe. Some use may be made on such sites of a mechanical brushcutter, though these tend to cut unevenly and are best reserved for restoration work.

Mechanised mowing

The ability to mechanise mowing on peatland sites is firstly dependent on having a relatively even terrain free from tussocks. Degree of mechanisation depends largely on wetness. On areas of medium wetness, self-propelled reciprocating mowers can be operated effectively; models made by Ferrari and Iseki are the most popular and appear reliable. The drier sites can be managed using tractor-mounted tools, provided the tractor is lightweight, has four wheel drive, and is fitted with low ground pressure tyres. Only the very driest sites can support the heavier tractor-drawn equipment and, in general, its use should be avoided on peatland sites.

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Management of Cladium mariscus (sedge)

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Management of Cladium mariscus (sedge)

T.A. Rowell

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INTRODUCTION

Cladium mariscus, great fen sedge or saw sedge, is commonly known simply as 'sedge' in the Norfolk Broadland and the Cambridgeshire Fenland. In the past the cut and dried leaves of sedge have had a wide variety of uses, principally as fuel and thatch and for strewing floors, paths and cattle stalls. Sedge is still saleable, being used entirely for ridging thatched roofs, as it is more flexible and hardwearing than reed. Though regionally plentiful in Britain in the past, saw sedge is relatively uncommon today.

Sedge has been used by thatchers recently in Kent, Surrey, Sussex, Hertfordshire, Bedfordshire, Leicestershire and the East Anglian counties. Outside East Anglia, its use is not traditional, but has been introduced by East Anglian thatchers. Because of a reduction in the availability of sedge in recent years, its use has become less common, particularly where it has to be transported for any distance. Its place is being taken by wheat straw. All growers of sedge report that they can still sell all that they can produce. The prospect for re-expansion of the sedge market is, however, uncertain and is likely to depend on the relative prices of sedge and other competing products.

Cladium is a plant of calcareous fens; while this link is clear, we have no good indication of the effects of water quality on this species. In the wettest conditions it may be found in more or less monospecific stands, but otherwise, depending on water level and management, it coexists with many other species. Sedge is harvested from sub-communities of the NVC community S24 - *Phragmites australis-Peucedanum palustre* tall-herb fen.

Management of sedge beds, unlike management of reed beds, tends to increase species richness. Abandoning management, however, allows the *Cladium* to smother other species, and richness declines.

Management of areas of sedge should be considered wherever there is a history of management, but neglect is allowing scrub encroachment. Where there is no such history, the same symptoms may indicate a lowering of the water table, though, of course, natural accretion of peat may also be implicated.

PRINCIPLES

Water level

Cladium thrives best when the water level is in the range +0.4 m to -0.15 m in relation to the soil surface. When the water level is low enough for woody species to become established and flourish, then *Cladium* is not at its most vigorous and tends to be reduced through competition for light. This situation can be tackled either by raising the water table or by instigating management by mowing. Increasing the water level to the point where the woody component of the vegetation is ousted will almost certainly result in dominance by *Cladium* to the detriment of many other species.

Mowing

Timing

Cladium is an evergreen plant which is capable of growing all year round. Low temperatures, however, reduce growth effectively to zero, and the growing point at the base of the leaves is frost-sensitive. Therefore, if the plant is cut late in the season or during the winter, the growing point no longer has the protective benefit of a canopy and may suffer some damage from frost. This does not appear to be fatal.

Cut shoots of *Cladium* also appear to be damaged by flooding. Indeed, there is plenty of anecdotal evidence that this is a major cause of the loss of the species from some parts of Norfolk fens and is a result of mowing sedge late in the season or during the winter. There is no information on the period of flooding that can be detrimental, but it is clear that cut shoots can be damaged or killed in this way at any time of the year.

Late season or winter cutting may favour *Phragmites*, while early to mid season cutting will suppress it and reduce any tendency to compete with *Cladium*.

Obviously, the timing of mowing operations is very important in the maintenance of sedge. Published sources indicate that cutting should be done in the months of May-August or June-August. Current practice is to cut between March and early autumn, but historical evidence and anecdotal information indicates that May and June are probably optimal months for the sedge harvest and that mowing should cease by the end of July so as to allow good growth before the winter.

Earlier mowing may benefit other species which can be damaged by later mowing, e.g. *Peucedanum palustre*. Breeding birds may be disturbed, but a certain amount of disturbance may be necessary to maintain the habitat. Individual decisions will have to be made on this point. With sedge, of course, only a portion of the vegetation is disturbed during each season.

<u>Frequency</u>

Experiments and experience indicate that too frequent cutting of *Cladium* can also damage it by reducing its vigour and allowing invasion by other species. Overcutting is characterised by reduced shoot density and size. On the other hand, the longer a sedge bed is left between cuts, the more difficult it is to cut and the more unusable material has to be stripped out and disposed of. Normally, sedge is cut every third or fourth year, but every second year is occasionally possible if it is growing very vigorously. Vigour is almost certainly associated with water level, but field observations suggest that susceptibility to frequent cutting may depend on timing. There is too little objective information to be totally clear on this point, and it would seem safest to retain a frequency of three or four years.

<u>Pattern of mowing</u>

As sedge is not cut annually, it is usual to mow a portion each year. This has advantages in planning the deployment of labour and reduces damage to associated plant and animal populations. Observations suggest that, where there has been a tendency to leave poor-quality sedge uncut (e.g. at the edge of fields or patches), the overall area of sedge has been reduced. Although this is not profitable, efforts should be made to cut sedge areas beyond the limits of the *Cladium* itself.

<u>Post-harvest</u>

If cut sedge, whether in swathes or bundled, is left lying on the ground for long periods, it may damage the regrowing shoots by causing them to rot or to become etiolated. The growing points may be damaged by trampling, so all movements of people and machinery over the newly cut areas should be kept to a minimum.

<u>Scrub</u>

Cladium suffers from two essentially different forms of scrub encroachment. First, woody species may become established in a sedge field and put on considerable growth during the period between harvests. These inevitably reduce the amount of harvestable sedge and, if not removed, will replace the *Cladium* altogether in time. All woody material should, therefore, be removed at each harvest either by cutting and poisoning or, preferably, by pulling. Secondly, where sedge fields are surrounded by carr, *Cladium* can be lost by gradual, often imperceptible, encroachment from the side. This can easily be avoided by 'facing-up' scrub - i.e. cutting back all overhanging branches and removing all rooted encroachment. Facing-up should be a routine post-harvest practice.

Establishment of *Cladium*

Until recently, no records of the germination of *Cladium* in Britain were known, and it was thought that once the species had been eradicated from an area, recolonisation was unlikely. Vegetative spread is slow and has been estimated to cover about one metre in ten years.

The seed of *Cladium* is viable, at least in some seasons. Investigations of its germination in the field indicate that it will germinate in bare peat where relatively high temperatures are reached. The seedlings are very small and appear to be sensitive to frost and, possibly, to shading. Protection against frost is afforded by winter flooding.

Cladium produces prolific quantities of seed in some seasons. It would be interesting to use seed to try and introduce the species to new peat cuttings of the type described elsewhere in the Handbook (see SOIL LEVEL MANIPULATION). The technique is, however, untried and any results achieved should be reported. A more certain method of establishing *Cladium* is to transplant mature plants. This appears to be successful provided the plants are introduced into a wet situation, and the roots are not allowed to dry out.

GENERALISED PRACTICE FOR SEDGE-CUTTING

- Cut sedge by either scythe or reciprocating mower at either three or four years old. Start cutting as early as possible (e.g. April), taking into account local flooding and ground conditions and avoiding severe frosts. Complete cutting by the end of June if possible - certainly no later than the end of July.

- Either leave the cut material in swathes to make (i.e. dry), or bundle immediately and stook to make. If the latter method is followed, then it is essential that air can circulate to prevent a build-up of heat.

- See below for standards and specifications of sedge bunches.

- If sedge is left to dry lying in swathes, bundle after not more than one week.

- Remove non-sedge material and dead sedge from the bundle as it is made.

- The making of bunches of sedge is aided by the use of two stakes inserted into the ground the same distance apart as the intended diameter of the bunch. These act as a crude measure between which bunches can be constructed.

- No material, swathed, bundled, stooked or stacked, should be left lying on the fen surface for more than one week as this may jeopardise the growing sedge.

- Any rubbish (non-sedge material and dead sedge) is usually burnt in small bonfires, preferably off the sedge field.

- Any bushes growing amongst sedge should be pulled if possible (this is standard practice with *Myrica* which is difficult to treat with chemicals and responds vigorously to being cut), but should otherwise be cut and chemically treated.

- Where a field is bounded by scrub, face up after sedge harvesting (i.e. cut back all overhanging woody vegetation as far as possible). This prevents gradual shading-out and encroachment, which slowly reduce the size of the field.

STANDARDS AND SPECIFICATIONS FOR REED AND SEDGE

This section is taken *verbatim* from Norfolk Reedgrowers' Association (1972).

1. The standard bunch

The standard to be aimed at is a bunch which, at the time of cutting and tying, measures 2 ft 4 ins (70 cm) in circumference at the bond, and the bond will normally be at least 12" from the butt.

It must be realised that sedge, being cut green, will dry and shrink after cutting and tying, and a stacked bunch will, in time, seem very loose at the bond.

[Thatchers prefer to use sedge when it is partially green and approximately 3 ft 6 ins (1.07 m) in length (Cooper 1972).]

2. Units of quantity

With sedge a commonly used unit is the "score", i.e. 20 bunches.

After that 600 bunches (sometimes referred to as a "load") is a convenient unit, and is in line with the "100 fathom" often used for reed.

3. Quality

A bed of sedge will never consist of a pure stand of the true sedge plant itself (Cladium mariscus), but will usually contain an admixture of other marsh vegetation - grasses, rushes, young shoots of sweet gale (Myrica), milk parsley and probably some reed. The main requirement is that it should be suitable for use by thatchers in making the ridge or capping to a thatched roof.

It hardly seems possible, therefore, to suggest definitions of various qualities, but in general it should be over 3 ft (90 cm) in length of leaf, and may of course be up to 5 ft (1.5 m) if left uncut for many years.

4. Bond

As a guide to growers, the bonds for tying sedge should consist of binder twine cut to lengths of 3 ft 4 ins (1 m). After tying a small loop at one end the length will be reduced to 2 ft 10 ins (85 cm). This enables the marshman to make a bond of 2 ft 4 ins (70 cm), leaving a loose end of 6 ins (15 cm).

REHABILITATION OF SEDGE BEDS

Where sedge beds have been neglected for long periods, the sedge is frequently unusable or unharvestable because of the amount and size of woody material and the dense, matted nature of the vegetation. To get a bed back into condition, it needs to be cleared of all vegetation and the normal rotation reinstated.

The most rapid method of achieving this clearance is to burn off the vegetation. This allows easy access to the remaining woody plants, which should be removed by pulling if possible, but otherwise by cutting as close to the ground as possible (so as not to foul cutter blades in future) and treating chemically (see SCRUB CONTROL). Care should be taken to ensure that the cleared area extends beyond the limit of dense *Cladium* growth, to encourage spread.

Burning precludes any possibility of utilising any of the sedge and may be considered undesirable from a faunal point of view. An alternative, but more labour-intensive approach is to cut the vegetation with brushcutters, remove it from the site and burn it in heaps (see MOWING for methods of disposal). All stumps must be treated.

It may be possible to get a contractor to take on a sedge field in poor condition, but it must be understood that a contractor will normally only take the viable sedge crop. Any other work must be tightly specified (clearing unusable sedge, cutting beyond the limit of *Cladium* growth, treating of stumps, etc) and will have to be paid for.

POTENTIAL PROBLEMS IN SEDGE MANAGEMENT

* Time of cutting: cutting outside the prescribed months of May to July is potentially damaging, though reference should always be made to the local flooding regime (see above).

* Frequency of cutting: too frequent cutting can damage sedge (see above).

* Contractors: sedge is commonly cut by contractors, both on and off reserves. They seem to have been responsible for two particular problems:

    (a) They frequently do not carry out the work when required, often arriving on site in October, when mowing may result in damage to the sedge;

    (b) They do not carry out subsidiary operations that ensure the continued health of a sedge field, e.g. removal of bushes; this work must therefore be carried out by the site manager.

Contractors must not be allowed to cut sedge outside the periods recommended above. They must be adequately supervised to ensure that undue damage is not caused, e.g. by bonfires or by leaving sedge lying too long. Subsidiary work must be carried out simultaneously or immediately after sedge has been removed.

EQUIPMENT FOR SEDGE-CUTTING

* Scythe: probably the most frequently used tool in the Norfolk Broadland; needs experience.

* Reciprocating mower: the mechanical alternative to a scythe. Preferences vary; most reserve experience is at Wicken Fen, where the large offset of the Mayfield is preferred to the smaller offset of the Ferrari. The offset allows the sedge to fall to one side in an easily manageable swathe.

* Brushcutter: this machine cuts unevenly and is therefore unsuitable for routine harvesting, where mowing of a swathe is necessary. The brushcutter is, however, an ideal tool for restoration work.

THE BRITISH REED GROWERS' ASSOCIATION

This organisation concerns itself not only with reed but also with sedge. Anyone considering harvesting sedge commercially should find it a useful contact.

The British Reed Growers' Association,
c/o Francis Horner & Son,
Old Bank of England Court,
Queen Street,
Norwich
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Tel. 0603 629871

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Management of reed

T A Rowell & W J Fojt

THE PEATLAND MANAGEMENT HANDBOOK

Management of reed

T.A. Rowell & W.J. Fojt

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INTRODUCTION

Phragmites australis (reed) is a species of grass which is widely distributed in Britain. In some regions, notably southern England, the dead stems of *Phragmites* are harvested for use in thatching. While commercial harvesting of reed has provided the impetus for management in the past, conservation interest - principally in birds and insects - has added a new dimension and further criteria for management decisions.

Phragmites can tolerate a water table from 2 m above the soil surface to 1 m below and, although it may respond adversely to rapid fluctuations, this tolerance allows it to flourish in a wide variety of situations. It may be found, therefore, fringing water bodies as an emergent macrophyte or forming a floating mat, or in seasonally flooded or wholly terrestrial conditions. Freedom from competition and its own vigorous growth result in virtually monospecific stands under very wet conditions. Under progressively drier conditions, degree of dominance tends to lessen unless management intervenes to reduce competition or to invigorate the *Phragmites*.

COMMUNITIES

Phragmites can be the principal species in several communities, all of which might be considered for management for the encouragement or suppression of reed. The main communities dominated by *Phragmites* are:

S4 *Phragmites australis* swamp and reed-beds

S24 *Phragmites australis-Peucedanum palustre* fen

S25 *Phragmites australis-Eupatorium cannabinum* fen

S26 *Phragmites australis-Urtica dioica* fen.

Only S4 is normally mown for reed commercially. The importance of commercially cut beds is such that they comprise more than 45% of stands in England and Wales greater than 2 ha in extent.

Where *Phragmites* predominates in S24, a history of management for reed is unlikely. Litter or fodder harvesting are more probable alternatives, and resumption will result in the suppression of reed to the advantage of other species.

S25 is generally unmanaged, according to information collected for the NVC.

S26 is normally unmown, but it may be accessible to stock which add further nutrients to an already eutrophic system.

Phragmites is also found in, and may physiognomically dominate, several other communities where management to encourage it would be inappropriate but where suppression might, on occasion, prove necessary. These include:

M9 *Carex rostrata-Calliergon cuspidatum* mire

M10 *Carex rostrata-Calliergon cuspidatum* mire

M13 *Schoenus nigricans-Juncus subnodulosus* mire

M14 *Schoenus nigricans-Narthecium ossifragum* mire

PRINCIPLES

General principles of management by mowing are discussed in the MOWING section of this handbook. Principles specific to the management of *Phragmites* are examined below.

Commercial reed harvesting, or management for conservation?

Reed-beds do not have great botanical value for nature conservation. The most valuable are the wetter examples which include *Cicuta virosa* and *Sium latifolium*. As moderate summer water levels are sufficient to resist invasion by scrub, these sites are not in any immediate danger. Management should therefore not be necessary to retain their value. Some other nationally scarce species are associated with reed, e.g. *Peucedanum palustre* and *Symphytum officinale*. Some, such as *Peucedanum*, are important food-plants for invertebrates, as is *Phragmites* itself.

Reed-beds are, however, considered important for their insect and bird populations. Birds include marsh harrier, bittern, bearded tit, and Savi's and Cetti's warblers. The requirements of these birds suggest that both managed and unmanaged reed-bed may be important to them, e.g. bitterns in drier unmanaged reed-beds require water as a food source, and populations can be improved by reinstating or opening up ditches within the bed. Insects form an important aspect of the diet of many of these birds of reed-bed. In particular, populations of stem-boring insects are adversely affected by cutting and mowing, though some birds such as bearded tits can obtain a bumper feed when reed is harvested and old stems containing over-wintering invertebrates are exposed.

Management of reed for conservation purposes frequently follows a somewhat illogical pattern, based on preserving reed-bed and open water as immutable. Reed encroachment into open water is controlled by the spraying of Dalapon or by dredging, so preventing the formation of new reed-bed. The drier end of the reed-bed sere, which would ultimately develop, especially under a summer mowing regime, into species-rich fen, is flooded artificially and expensively to prevent the development of scrub. This truncation of the succession ensures that there will be no development of the next successional stages, and no development of new reed-bed.

An alternative approach is to manage the succession at stages earlier and later than the reed-bed itself, by increasing the amount of open water (see SOIL LEVEL MANAGEMENT), and bringing dried-out reed-bed under mowing management or allowing it to progress unmanaged to scrub. The wetter areas of reed-bed do not require management, and can be left to provide the undisturbed habitat required by birds and insects. Greater habitat diversity is ensured by this approach, which also obviates the need for continual management of the water-table.

Commercial management of reed-bed can be considered on reserves under certain circumstances:

* The bed has been managed up to the present.
* The site is very large, and the cutting of reed would constitute justifiable diversification of the habitat if maintained alongside unmanaged reed.
* No more than 20% of the site is cut in any one year.

Reed-cutting has certain benefits, including checking invasion by woody species, habitat diversity, provision of suitable breeding habitat for birds such as redshank and snipe.

The resources required for commercial management mainly involves heavy commitment of labour. An alternative is to sell standing reed to a thatcher who would then cut it himself. Management by a third party requires careful supervision to ensure that methods do not conflict with aspects of conservation management. Furthermore, to protect the quality of the reed-bed, all reed, not just the best, should be taken from the let area. Any scrub should be cut and treated, and any encroachment of scrub into the borders of the bed must be similarly dealt with. In practice, these tasks will fall to the site manager.

Water regime

Water level

Phragmites is reputed to be able to withstand flooding to a depth of 2 m, and a water table as low as 1m below soil level. A recent survey showed an actual range in British rich fens to be between 100 cm below the soil surface to 28 cm above.

Erratic variation in water level can disrupt growth patterns and allow other species to establish.

A high water level during spring protects the young shoots from damage by frost, but a high level during the period following cutting can damage a reed-bed by preventing aeration of the rhizomes *via* the dead stems.

Damage of cut stems through flooding is avoided by lowering the water table prior to cutting. Lowering the water table also facilitates operations in the reed-bed.

A water level maintained within about 20cm above and below the soil surface during the autumn, winter and spring deters invasion by woody species.

Maintenance of aerated conditions is regarded as beneficial to reed. In commercial beds, water flow is encouraged by the construction and maintenance of ditches and grips. Too strong a current may prove detrimental.

Water quality

Phragmites is supposed to perform best in relatively eutrophic conditions, although a recent survey suggested it is normally found in rich fens under conditions of moderate fertility. The study recorded a wide range of fertility, however, varying from about 4% to as much as 765% of the mean for all fens sampled. Algal blooms resulting from eutrophication may, according to some suggestions, lead to the emerging shoots being deprived of light and oxygen resulting in reduced density.

Tolerance of pH is similarly broad, with values between 4.8 and 8.3 being recorded, but tending to cluster closely around the median of 6.6.

Phragmites can tolerate up to 1.2% chlorinity, but not sudden increases that might result from a redirection of salt water into a previously freshwater area.

Mowing

Timing

As with other species (see MOWING), the life history calendar of *Phragmites* determines its response to being mown, particularly in relation to timing.

The young shoots of *Phragmites* usually emerge between late March and late April, and grow rapidly until June/July. During the period of emergence, which can continue until June, replacement of cut stems is possible, though the probability of complete replacement decreases with time. Full to partial replacement of the crop following mowing is therefore possible up to June; harvesting is therefore commercially possible as late as May, but will cause considerable disturbance to wildlife if done any later than mid-March. Replacement of cut stems is less likely following mowing during the post-emergence period. Growth of rhizomes, storage of nutrients, and formation of new buds are all affected to the extent that, if the crop is mown in July, the vigour of the stand is greatly reduced. The later the stand is mown, the less vigour is affected. Mowing during the winter has no adverse affect at all other than to expose emerging shoots to frost which can increase density. Mowing in July is so detrimental that repeated treatment can eliminate *Phragmites*.

Frequency

Annual cutting of *Phragmites* during the winter produces dense, thin-stemmed reed with very little admixture of other species, i.e. a species-poor stand. In time, productivity may decline under this regime if the bed has a low nutrient status.

Biennial cutting during the winter is generally the favoured management regime for commercial reed production, as problems of productivity are less likely. Associated species remain infrequent under this regime. Post-emergence cutting, as discussed above, can reduce the vigour of *Phragmites*, and can be used to control or eliminate the species. Increasing the frequency of cutting speeds the decline of *Phragmites*, but the most efficient control will be achieved by combining annual cutting with optimal timing, i.e. July.

Grazing

Phragmites is naturally grazed by deer, water voles, and some wildfowl. The impact of feeding geese, which take succulent, young shoots in the late spring (when they are unlikely to be replaced), is considered to have contributed greatly to the recent decline of reed-swamp in Broadland. Coypu have also caused considerable damage, but are no longer a problem.

Grazing by sheep tends to be light, is concentrated in the spring, and is not considered damaging. Cattle can be more damaging, with the combination of grazing and trampling turning a reed-bed within only two years into rough grazing marsh with dwarf *Phragmites*. As long as suppression of the *Phragmites* has not proceeded too far, the former dominant should re-assert itself once grazing ceases.

Burning

The degree of damage caused to *Phragmites* by burning is dependent on the developmental stage of the shoots at the time of the fire, and on the moisture content of the litter around the stem bases.

Burning a reed-bed during the normal period for mowing is believed to result in increased density of stems. A light burn during the early spring is a recommended technique for encouraging dense, even growth in an uneven and sparse reed-bed. A severe burn will delay emergence by up to two month, and the crop will mature late.

Where a reed-bed has been neglected for a long period, it will be overgrown and possibly invaded by woody species. Restoration to commercial use, or clearance for improved conservation management, is a difficult and laborious task to achieve by cutting alone. All material cut during clearance has to be disposed of, probably by burning in heaps. Burning the standing vegetation is a more convenient means of clearance, and a legitimate operation if carried out only once. Burning-off must be followed by removal of the remains of woody plants by either uprooting or cutting and treating with chemical (see SCRUB CONTROL).

The effects on the plant community of repeated burning of reed-beds are not known, and caution should be exercised in the use of this management technique. Reed-bed managed by burning tends to have a much lower species density (less than 17%) than areas managed by mowing. Burning will kill all insects resident in or on the standing vegetation (e.g. stem-boring moths) and, depending on timing, can affect bird populations by destroying either nests or sites for nest-building. Clearly, there will be a divergence of opinion and practice between management of reed-beds for commercial reed and management for conservation purposes.

GENERAL PRACTICE

It is not the purpose of this handbook to give full details of the management of reed for commercial purposes, though guidance is given on accepted standards and specifications. Where site managers are determined to establish or reinstate reed-cutting, they would be best served by consulting the British Reedgrowers' Association. Otherwise, information is given here that should help maximise the conservation value of reed-beds together with information about restoration and establishment of reed-beds.

Water

Establish the sources of water flowing into the site and ensure that they are not polluted. Try to divert polluted water away from the site and replace with a clean source.

Determine the locations of the outfalls from the site. Ensure that water levels are maintained as far as possible; block the outfalls if necessary but remember that reed requires a flow of water.

Sluices are useful in an embanked reed-bed for taking advantage of the tidal rise of adjacent rivers, and holding a high water table for much of the year. For complete control, and the working of a dry marsh at harvesting time, a pump system needs to be installed.

Mowing

If mowing is to be used as a technique for managing reed, then establish a rotation, preferably reserving some areas on a long rotation or, if sufficiently wet, maintaining them uncut.

Mowing should begin in December or January and should be completed by the middle of March to avoid disturbance to bittern, marsh harrier and bearded reedling, all of which breed or establish territories in the early spring.

In sensitive situations, e.g. where the soil is very wet or where rare species are present, mowing should be by hand-scythe. In most other situations, mechanisation is possible. Reciprocating mowers are modified for reed-harvesting by the addition of a reed-box around the blade. The alternative machine is the Olympia reed-harvester.

Remove cut reed from the field as quickly as possible; do not leave bunches lying on the ground for longer than necessary.

Scrub control

Scrub encroachment is probably an indication of falling water-levels. If this cannot be rectified easily, then one or more of the following options should be considered.

* Clear and treat scrub on a regular basis (see SCRUB CONTROL).
* Mow in winter for reed, or in summer for a more diverse vegetation with less reed (see MOWING).
* Allow succession to proceed.

Disposal of waste

Dispose of waste cut material off-site (see MOWING).

Burning

Avoid burning as a management tool, other than for the one-off clearance of abandoned and overgrown reed-beds.

Reed clearance and management of succession

While the clearance of reed from the edges of watercourses and water bodies is necessary management, some development of reed-bed should be encouraged, to replace that lost through terrestrialisation and peat accumulation. To balance this, open water will have to extended, or totally new areas created (see SOIL LEVEL MANIPULATION). This type of approach is, of course, only suitable for large sites.

Productivity

Reed-beds can yield as much as 400 bunches per acre (1000 per ha) when cut annually (single wale), and 400 - 500 bunches (1000 - 1200 per ha) when cut every other year (double wale). At Hickling Broad, where three men and an Olympia rice-harvester are employed on the reed-beds, a crop of 13000 bunches needs to be taken before the operation starts to make a profit.

Productivity of commercial reed-beds can be affected by snow and bird (starling) damage. Soft reed is a condition that has affected reed-beds in many areas of the country and, as the reed is useless for thatching, also reduces productivity. The causes of this condition are unclear, and research is currently being carried out in an attempt to rectify the problem.

Standards and specifications for reed

Good reeds are hard, straight, tapering, uniform in length and width, resistant to decay, and have sparse feather (inflorescences). Poor reeds have opposite characteristics with particular dislike amongst thatchers for fragile, soft, and uneven reed.

The following recommendations for quantity and quality of reed are given by the Norfolk Reedgrowers' Association (1972).

The fathom

The fathom is the traditional unit for the quantification of reed. A fathom is as much reed as can be bunched together to measure six feet (1.8 m) when measured one foot (30 cm) above the butts of the bunches.

The standard bunch

The fathom is too large a unit for handling and is therefore composed of bunches of reed. The recommended specification for a standard bunch is a circumference of 2 feet (60 cm) measured 1 foot (30 cm) above the butt. This standard bunch will contain almost exactly 2000 reeds if of medium length and quality. Six standard bunches measure, when stood together, six feet (1.8 m) in circumference, i.e. one fathom.

Reed-cutters use ready-cut strings as a rough guide to achieve a standard size of bunch. Alternatively, three hand spans is roughly equivalent to the circumference of a standard bunch.

Larger units

Beyond the fathom, reed may be sold in units of 100 fathoms, which is equivalent to 600 standard bunches, and is often referred to as a "load". A "long hundred" is sometimes used, containing 120 rather than 100 fathoms.

Quality

Most aspects of the quality of reed are difficult to standardise. The standards of the Norfolk Reedgrowers' Association (now British Reedgrowers' Association) are given below.

Length

Reed is measured in the bunch from the butt end to the point at which the majority of the reeds are feathered. Grades are:

* "Short reed" up to 4'6" (1.35 m) in length
* "Medium reed" 4'6" to 6'0" (1.80 m)
* "Long reed" over 6'0"

Purity

"Clean reed" has no clearly visible admixture of other vegetation.

Age

"Single wale reed" is a year's crop cut at the end of its growing season. It should be quite uniform in length. Most commercial reed is cut "double wale", i.e. after two years' growth. About half the crop has therefore stood dead for a year, and will therefore be more brittle than the more recent growth.

PLANTING REED

Phragmites colonises quickly and becomes dominant under suitable conditions provided it can invade vegetatively. In Britain, many clones do not have fertile seed so this is often the only means of colonisation. Occasions may arise when there is a need to establish reed-bed, for example where protection from wave action is needed at the edge of a water body.

Three methods of establishing *Phragmites* have met with success (Lewis & Williams 1984), though it is generally thought difficult.

> 1. From clumps: Large 20 cm square clumps of rhizome are cut with a spade from a healthy reed-bed, and planted in the same sized holes *above* the mean water level. Rhizomes planted below water level will usually rot. Once established, the reeds will gradually colonise downslope into the water. The best season for using this method is October to March, and it has usually proved successful. Great care should be taken not to damage the new swollen terminal stems when firming the clump in. Care also needs to be taken to minimise trampling of the reed-bed when extracting the clump in the first place; damage to emergent shoots will be caused otherwise.
>
> 2 From cuttings: Non-flowering green shoots are cut when about 1 metre high (May or June), and planted a handful at a time in angled slits made with a spade. They must be planted at water level, and firmed so that at least three leaf nodes are buried. This method is usually successful. If the substrate is shallow, horizontal insertion will ensure that the maximum number of nodes are buried - at least one-third of the stem should be left exposed, however.
>
> 3. By seed: Although the common reed very rarely has fertile seed, some clones do, so this is a method worth trying. The best germination conditions are in the mulch of tide-line detritus that accumulates on lakeshores and some river edges. Mature seed heads are pegged down in this mulch, and, if fertile, they will readily germinate. since the seed is late ripening, this is best done in December: the success of this technique is, however, variable. In Holland, fertile seed is grown in peat blocks and individually planted out.

In addition to the difficulties posed by the infertility of *Phragmites* seed, the seedlings require very particular conditions such as a wet but not flooded habitat of relatively high nutrient status that remains open for at least two years following germination.

THE BRITISH REED GROWERS' ASSOCIATION

This organisation is a useful contact for anyone considering harvesting reed on a commercial basis.

The British Reed Growers' Association,
c/o Francis Horner & Son,
Old Bank of England Court,
Queen Street,
Norwich
Norfolk
NR2 4TA

Tel. 0603 629871

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10

Grazing

T A Rowell & M J Clarke

THE PEATLAND MANAGEMENT HANDBOOK

Grazing

T.A. Rowell & M.J. Clarke

CONTENTS

INTRODUCTION

Grazing has been a significant and often formative influence on many types of peatland vegetation, particularly grass and sedge dominated mires, and blanket bog. Consequently, there is frequently a need to employ grazing as a means of maintaining these communities. Traditional methods, if they are known, will often result in good results from the conservation point of view but, for most peatland communities, there is little information available on optimum grazing regimes. This section of the handbook therefore serves as a short summary of available information, and is intended more as stimulus to further work rather than a prescription for grazing management on peatlands.

While it is recommended that grazing is used as a management technique on peatlands only where it is a known traditional practice, there are circumstances where it can be introduced. For instance, grazing by sheep is a useful technique for controlling the dominance of *Molinia* during the restoration of cut-over bog (see MIRE RESTORATION).

Communities

The following peatland communities are affected in some way by grazing. For details of the nature and effects of grazing in these communities see the appropriate sections of the National Vegetation Classification.

Created and/or maintained by grazing

Although the following communities may be maintained by grazing, they are still liable to damage through over-grazing.

M10 - *Carex dioica-Pinguicula vulgaris* mire

M11 - *Carex demissa-Saxifraga aizoides* mire

M15 - *Scirpus cespitosus-Erica tetralix* wet heath

M16 - *Erica tetralix-Sphagnum compactum* wet heath

M19 - *Calluna vulgaris-Eriophorum vaginatum* blanket mire

M20 - *Eriophorum vaginatum* blanket mire

M22 - *Juncus subnodulosus-Cirsium palustre* fen-meadow

M23 - *Juncus effusus/Juncus acutiflorus-Galium palustre* rush-pasture

M24 - *Molinia caerulea-Cirsium dissectum* fen-meadow

M25 - *Molinia caerulea-Potentilla erecta* mire

M29 - *Hypericum elodes-Potamogeton polygonifolius* soakway

Grazed on occasion

The following communities are sometimes grazed and are not necessarily adversely affected if grazing is light.

M13 - *Schoenus nigricans-Juncus subnodulosus* mire

M14 - *Schoenus nigricans-Narthecium ossifragum* mire

M26 - *Molinia caerulea-Crepis paludosa* mire (easily damaged)

S7 - *Carex acutiformis* swamp

S11 - *Carex vesicaria* swamp

S26 - *Phragmites australis-Urtica dioica* fen

S27 - *Carex rostrata-Potentilla palustris* fen

S28 - *Phalaris arundinacea* fen

Damaged by grazing

The following communities are easily damaged by grazing, often through the destruction of *Sphagnum* carpet and the increase of *Juncus* spp. Nevertheless, light grazing may aid the maintenance of drier examples of some of these communities by inhibiting the establishment of woody species.

M4 - *Carex rostrata-Sphagnum recurvum* mire

M5 - *Carex rostrata-Sphagnum squarrosum* mire

M6 - *Carex echinata-Sphagnum recurvum/auriculatum* mire

M17 -*Scirpus cespitosus-Eriophorum vaginatum* blanket mire

M18 -*Erica tetralix-Sphagnum papillosum* raised and blanket mire

M27 -*Filipendula ulmaria-Angelica sylvestris* mire

M28 -*Iris pseudacorus-Filipendula ulmaria* mire

S4 -*Phragmites australis* swamp and reed-beds

PRINCIPLES

Many of the principles relating to grazing are identical to those for mowing, i.e. phenology and life form, and therefore to a certain extent, timing, frequency and intensity (see MOWING). Grazing is more complicated than mowing, involving the added effects of the animals themselves, e.g. redistribution of nutrients in dung and urine, treading, selection of species by the grazer, method of defoliation, and variation in all these is dependent on the species and breed of grazer. The principles of grazing as applied to grassland are discussed by Duffey, Morris, Sheail, Ward, Wells & Wells (1974).

Primary considerations

The following points need to be considered for any site in relation to the effects of grazing on the present wildlife interests and conservation objectives.

* What is the management history of the site in terms of grazing levels, stock types, season and duration of grazing? Quite small changes to a grazing regime can cause appreciable impacts on the vegetation and, as a consequence, on the associated fauna.

* Would changes in the present grazing regime (or the introduction of grazing) damage or improve the wildlife interests of the site? Where a current regime is known to be damaging then efforts should be made to modify it. If grazing has ceased recently on a traditionally grazed site, then its re-introduction may be the optimum management strategy.

The relative grazing value of peatland species and communities

Whilst it will be argued later that determination of grazing levels for conservation purposes should be vegetation-based rather than grazer-based, it is useful at this stage to recognise the quality of the communities involved in terms of their ability to support animal production.

Plant species can be arranged on a ten point scale according to their grazing value (Table 1), essentially an expression of their productivity, nutritive value, and palatability (Bibby, Douglas, Thomasson & Robertson, 1982). Highly productive agricultural species such as *Lolium perenne* or *Phleum pratense* score 8 on this scale. Those species scoring 0 or 1 do not contribute significantly to a positive energy balance, even though they may form a substantial portion of an animal's intake. Those with a relative grazing value of -1 are poisonous to some degree.[1]

The value of species to grazers varies through the year (Table 2). For instance, *Molinia* is well known for providing an 'early bite', but its litter is of little or no value during the winter.

Grazing values for species can be used to calculate an arbitrary relative grazing value for plant communities (Bibby *et al*, 1982). While rye grass-crested dog's tail leys score very high values in excess of 1000, many bog communities (Table 2) score as low as 50 (this is the lowest score given by Bibby *et al* 1982).

Selection of plant species

Grazing animals exhibit preferences for certain of the range of plant species on offer to them. Where grazing pressure is low, only the more palatable species will be grazed, resulting in an uneven structure in the vegetation. Many ground-nesting birds require this type of structure, so that light grazing will be an effective tool for certain grass-dominated communities.

Where pressure is higher, the less palatable species will be closely grazed as well, leading to a smaller scale and more even structure.

As pressure is further increased, some species may be eaten out all together and this, combined with treading damage, may initiate erosion or allow invasion by or increase of undesirable species.

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1 Despite a rating of -1, indicating a degree of toxicity, *Menyanthes trifoliata* appears to be favoured by sheep on blanket bog.

Table 1: **Grazing values of some peatland species (abstracted from Bibby *et al* (1982))**

Species	Value	Species	Value
Anthoxanthum odoratum	3	Luzula spp	2
Arctostaphylos uva-ursi	0	Lychnis flos-cuculi	1
Calluna vulgaris	1	Lythrum salicaria	2
Caltha palustris	-1	Mentha spp	0
Cardamine spp	-1	Menyanthes trifoliata	-1
Carex spp	1-2	Molinia caerulea	2
Cirsium spp	0	Myosotis spp	2
Deschampsia cespitosa	3	Nardus stricta	2
Deschampsia flexuosa	3	Parnassia palustris	1
Drosera spp	-1	Pedicularis spp	-1
Eleocharis palustris	2	Phalaris arundinacea	5
Eleocharis quinqueflora	1	Phragmites communis	2
Empetrum nigrum	0	Pinguicula vulgaris	0
Epilobium spp	2	Polygala spp	1
Equisetum fluviatile	-1	Potentilla erecta	2
Equisetum palustre	-1	Prunella vulgaris	2
Erica cinerea	1	Ranunculus flammula	0
Erica tetralix	0	Rhinanthus spp	0
Eriophorum spp	1	Rhynchospora alba	1
Euphrasia spp	-1	Schoenus nigricans	0
Filipendula ulmaria	3	Succisa pratensis	2
Galium spp	3	Trichophorum cespitosum	1
Glyceria fluitans	4	Triglochin spp	0
Hydrocotyle vulgaris	-1	Vaccinium myrtillus	1
Iris pseudacorus	-1	Vaccinium uliginosum	1
Juncus articulatus	2	Vaccinium vitis-idaea	0
Juncus effusus	1	Valeriana dioica	1
Juncus squarrosus	1	Viola spp	1
Listera ovata	1		

Physical disturbance

The most significant forms of physical disturbance caused by grazing animals are defoliation itself, and treading.

Defoliation

The process of grazing damages plants in differing ways, dependent on the animal species involved, and the intensity of grazing (intensity is dealt with below).

When a grazer removes an aerial growing point of a plant, the plant will be damaged, and may die. Grasses have their growing points at ground level, and are not affected adversely by a loss of leaf; indeed, tillering may be stimulated by grazing.

Table 2: Time of contribution of various peatland species to the diet of hill sheep (from M.A.F.F 1983).

Species	Part eaten	Main time of contribution
Calluna vulgaris	Tips	Late summer and late winter
Vaccinium myrtillus	Leaves	Spring
	Green stem	Late summer and late winter
Molinia caerulea	Green	Early summer
Juncus squarrosus	Green	Winter
Nardus stricta	Green	Late winter and spring
Eriophorum vaginatum	Young heads	Late winter and early spring
	Leaf butt	Spring
	Green leaf	Spring
Empetrum nigrum	Green	Autumn and early winter
Trichophorum cespitosum	Green	Spring

Sheep tend to bite off the upper parts of plants first, and the height of the vegetation is reduced gradually as the flock move backwards and forwards across it. Cattle graze by curling their tongues around tufts and pulling, producing a mosaic of tall and shorter vegetation that contrasts markedly in structure to the even sward that results from sheep-grazing.

The opening up of vegetation caused by grazing may allow diversification, either by the establishment of species new to the community, or by allowing species density to increase.

Treading

The pressure exerted on the ground by a grazing animal's feet has two basic effects on vegetation:

- Damage to plants through breakage of stems and leaves, and by burial. Plants may actually die as a result of this treatment. On peatland sites, trampling disrupts *Sphagnum* carpets and damages the larger lichens.

  Creation of gaps in the vegetation and, possibly, depressions in the soil, provide 'micro-sites' (with differing substrate, microclimate and, on occasion, hydrological conditions to the surrounding area) in which new plants may establish. Establishing species may be desirable, i.e. typical of the habitat, or undesirable and potentially invasive.

Table 3: Relative grazing values of a range of mire communities (abstracted from Bibby *et al* 1982). Communities follow Robertson (1984).

Plant community	RGV
Flying bent grassland	390
Marsh marigold meadow	360
Star sedge mire with sharp-flowered rush	353
Meadowsweet meadow	330
Flea sedge mire	261
Common cotton-grass bog	236
Flying bent bog	223
Star sedge mire	212
Star sedge mire with bog myrtle	184
Blaeberry heath	175
Flying bent-bog myrtle bog	172
Bog moss water track	165
Yellow flag swamp	149
Upland blanket bog	108
Northern bog heather moor	105
Northern blanket bog	105
Lowland blanket bog	95
Bog heather moor	90
Mountain blanket bog	90
Cotton grass bog	87
Few-flowered spike-rush mire	81
Bog rush mire	80
Blanket bog terminal phase	50

Clearly, treading can contribute to the increase or maintenance of species richness that often accompanies grazing. The need for careful control is equally obvious; concentrated treading can result in the total loss of vegetation, though usually from relatively small areas. Management of the usage of gates, and of watering and supplementary feeding sites can help avoid damage.

Enrichment

Enrichment of oligotrophic sites is likely to occur in three ways.

* By the import of nutrients when animals also feed off the site. These nutrients may then be deposited on the site as dung, urine, or carcasses. Import may be balanced to some extent by export, but sites with low productivity are likely to suffer a net gain in nutrients, particularly if supplementary feeding is practised.

* By the uneven return of nutrients to the ground as urine and dung patches, and decomposing carcasses. Behaviour of the grazing animal may tend to concentrate urine and dung patches in certain areas. This patchy distribution of returned nutrients will affect plants on a local basis, even if the amount returned is no greater than total intake. The uneven return of nutrients may be the most significant form of enrichment in some mire systems.

* Through nutrient release from peat as a result of poaching.

For sites of higher nutrient status, grazing is likely to result in a net loss of nutrients although localised enrichment may occur through poaching or the deposition of dung, urine or carcasses.

Sheep are used in the management of vegetation during restoration of mires in Germany. As oligotrophic conditions are being aimed for, the following recommendations have been made.

* The sheep should be penned at night off the site.
* The flock should be driven slowly to the site in the morning, allowing time for defecation before they reach the site. At night, they should be driven quickly off the site.
* While on the site, the flock should be driven constantly forward. This avoids intensive grazing, and ensures that dung is distributed as thinly as possible.
* The recommended breed of German sheep produces dung balls that break up during defecation, and are therefore more widely spread than usual. Efforts should be made to use breeds that will cause as few management problems as possible.

This type of grazing plan requires a high input of skilled shepherding, and represents a further considerable commitment of resources to the regeneration programme.

Setting grazing levels

Grazing levels for conservation purposes must be set with reference to the vegetation. It is essential, therefore, to set clear objectives for any grazing regime, that incorporate measurable vegetation criteria.

Where animals range freely across an area that includes peatland, levels will clearly have to be set with reference to the proportion of each community present. The very reasonable assumption implicit in this approach is that the grazing animals will be largely self-regulating in their use of the forage available, only using the poorer areas when pressed. Considerable skill has to be exercised in maintaining, for example, blanket bog where very low levels of grazing are considered beneficial, but where overgrazing can easily occur.

Initial grazing levels should be set with reference to available guidelines developed by generalisation from a range of sites (see below for blanket bog, valley fens and grass- and sedge-dominated peatlands). Until expertise in the resilience or otherwise of local vegetation is well established, frequent monitoring of the vegetation and adjustment of grazing levels will be necessary.

BLANKET BOG

For convenience of discussion, blanket bog can be divided into three categories, drier peat deeper than 30 cm and dominated by *Calluna vulgaris*, similar ground dominated by some other higher plant species, and wetter ground with a *Sphagnum*-rich vegetation and relatively little cover by dwarf shrubs. As *Calluna vulgaris* confers some economic value on blanket bog, it has been ground dominated by this species that has received most of the attention. Consequently, little information exists relating to the effects of management regimes on other types of blanket bog.

The literature relating to the grazing management of *Calluna*-dominated blanket bog has been reviewed (Mowforth & Sydes, in draft). The review highlights the paucity of information on a national level. As a result of the review the following recommendations were made:

> Density: Recommended numbers ..... on blanket bog are 0.25 to 0.37 sheep/ha.
>
> Time of year: summer grazing is preferential as it relieves pressure on the *Calluna*. *Calluna* is generally winter grazed so an all year stocking regime would require a reduction in numbers.
>
> Raking by shepherds which ensures even distribution of the sheep over the moor.
>
> Access to improved pastures, using the two pasture system, especially when the quality of grazing is important in the sheep diet.
>
> Knowledge of the proportion, type and production of *Calluna* and the associated graminoids in a given area.

In relation to the recommended stocking rate, the following should be noted:

* These are intended to be management practices that do not lead to a decline in *Calluna vulgaris*. Other species of equal or greater conservation importance would be expected to suffer decline earlier than *Calluna*, but useful information on this point is not easily available. In particular, changes in the complement and cover of *Sphagnum* spp, and damage to lichens would be expected where sheep numbers are too high.

* The recommended stocking rate is based on only 21 observations at five sites in three locations in mainland Britain. The locations are southwest Scotland, central Wales, and the North Pennines. Clearly, the number and spread of observations are unlikely to give an adequate guide to suitable stocking levels on a sensitive and variable substrate such as blanket bog.

* The observations listed indicate that while stocking rates of up to 1.37 sheep/ha may result in no damage to *Calluna vulgaris*, damage can occur at a lower stocking rate than the recommended 0.25 to 0.37 sheep/ha. As so little good quality information is available on the responses of blanket bog to grazing, serious consideration should be given to downgrading this value.

While Mowforth & Sydes' review indicates an urgent need for further study of the problem of grazing of *Calluna*-dominated blanket bog, it is also clear that the there is a similar urgency for this to be extended to the wetter blanket mires. Difficulties arise not only from the complex nature of grazing, but also in determining exactly what should be regarded as beneficial in the context of blanket bog vegetation. Possibly, some guidance may be derived from the conclusions of a further literature review (Hodgson 1985; my emphasis):

> The research problem is to design grazing experiments which can be used to provide an adequate framework within which management decisions can be made, and this requires the definition of management in terms which allow vegetation responses to be generalised and which are sensitive enough to allow effective fine 'tuning' of vegetation changes to desired objectives. On all of these counts <u>stocking rate is inadequate</u> as an experimental variable and <u>as an objective guide to management</u>: <u>it is</u>

more appropriate to relate experimental treatments and management decisions to defined sward characteristics.

On blanket bog, the defined vegetation characteristics should clearly include as a priority the maintenance and (in some cases) the development of the complement of peat-forming species, primarily the *Sphagna*. Incorporation of this vegetation-based approach into a formalised process of evaluation (see EVALUATION OF MANAGEMENT TECHNIQUES) would provide a working framework that should lead to practical solutions to the problems of grazing on blanket bog. At present, the evaluation process is in an early and rudimentary phase with an obvious requirement for a great deal of survey and monitoring work (and, possibly, experimentation) before adequate recommendations can be made. As there is little information available for other types of blanket bog and for raised bog, the same evaluation process must be initiated.

It is considered that very light grazing will be beneficial to blanket bog vegetation in many cases. This is obviously so if a site has a long history of grazing. Special efforts should be made to continue grazing if such a site becomes isolated from free-range grazing, e.g. by fencing or forestry.

Burning of blanket bog

Mowforth & Sydes (in draft) recommend a 20 year burning cycle 'if at all' for the maintenance of heather. Rawes & Hobbs (1979) suggest that fire may not be necessary at all, and that light grazing by sheep is all that is required; for instance *Calluna vulgaris-Eriophorum vaginatum* blanket mire (M19) will support 0.37 sheep/ha without burning and still provide food for both stock and grouse. A computer model of heather moorland model, recently developed by the Hill Farm Research Organisation, assumes that heather on blanket bog will not be burnt.

It is known that the damage done by fire to bogs varies enormously with timing, wetness of the ground, weather conditions, species composition, etc. Recovery, particularly by many of the bryophytes, is slow, and erosion may be initiated. It is recommended, therefore, that burning of blanket bog is avoided (see BURNING for more information).

VALLEY FENS

This section is applicable to lowland valley mires of the New Forest type, which are dependent on groundwater but vary from very acidic bog vegetation to calcareous fen, and are generally poor in nutrients. In the ungrazed situation, the principal plant community may be the *Molinia caerulea-Potentilla erecta* community (NVC community M25), but the valley mire habitat centres on the *Narthecium ossifragum-Sphagnum papillosum* community (M21). Grazing is also applicable related vegetation types such as wet heath zones (*Erica tetralix-Sphagnum compactum*, M16), or base-rich seepages or water tracks (e.g. *Schoenus nigricans-Narthecium ossifragum*, M14).

The main aim of grazing in this habitat is to reduce the dominance of tussock-forming graminoids, especially *Molinia*, thereby increasing plant species richness (e.g. Cyperaceae and bryophytes) and habitat diversity.

Most of the information available on grazing of valley mires is based on cattle and horse/pony grazing within the New Forest. Ponies are most easily supported by the forage available from valley mires, and are the preferred option. In all cases, grazing of valley mires is likely to be most successful if adjacent habitats, such as acid or alluvial grassland, heathland and grass-bracken communities, are included in the range.

The ecological success of sheep grazing in this situation is unknown but, historically, some valley mires were almost certainly under sheep. Comparative information from analogous situations is limited, but suggests that this may also be a feasible option.

Principles

The grazing of valley mires revolves around its relationship with *Molinia*. The re-introduction of grazing on *Molinia*-dominated areas may lead to an increase in species richness of 75% or more. The cover of sedges, *Narthecium*, etc is increased, and grazing allows the invasion of less shade-tolerant bryophytes, including an assemblage of leafy liverworts characteristic of the valley mires (e.g. *Odontoschisma*, *Lepidozia*, *Cephalozia* spp.). *Molinia* is favoured by flushing and water table fluctuation. It has a deciduous habit and nutrients are resorbed before leaf fall in October, so that the forage value of the straw is very low. *Molinia* is the main source of 'early bite' in spring (late April/May) when it has a high nutrient content. Before this time, the main forage sources are *Juncus*, *Calluna*, and *Carex*.

The effects of grazing on the invertebrate fauna are less well understood, but invertebrate diversity in mires is dependent on hydrological factors (e.g. humidity, water table) as much as on the complexity of vegetation architecture. Many species are dependent on open areas, pools, etc which are often only maintained by management in lowland valley mires. The main aim of invertebrate management should be a variety in habitat structure, which is often maintained by the uneven pattern of grazing which usually develops.

Assessment of potential grazing levels

The greatest increase in diversity will be derived from grazing tussocky *Molinia*-dominated communities, often with *Myrica gale* and *Erica tetralix* scattered between and above the tussocks. Shade-tolerant *Sphagna* may occur at the bases and on the sides of tussocks, notably *S. recurvum* (var. *mucronatum*) and *S. palustre*. In some cases, with the continued absence of management, succession may proceed to *Salix cinerea* and *Betula pubescens* scrub.

Areas of *Sphagnum* lawn and pools which have persisted at sites in the absence of grazing are probably dependent on groundwater stagnation and low nutrient levels (low rates of throughflow and little fluctuation in the water table), which limit productivity. The effects of introducing grazing on these communities are essentially neutral, but monitoring should be directed at nutrient levels (possibly by simple bio-assay techniques) and the effects of trampling, especially where locally high grazing pressure develops (e.g. around gateways, etc).

Controlled levels of grazing

In terms of the vegetation, the grazing intensity in these valley mire systems should be sufficient to reduce the standing crop below about 350-550 $g.m^{-2}$ (dry matter) for oligotrophic or mesotrophic sites (pH less than about 6.5), and about 750-1500 $g.m^{-2}$ for more flushed or tall fen vegetation. The cover of *Molinia* should be reduced from near 100% to around 25% on average. Enhanced species diversity is associated with standing crops in the range 100-250 $g.m^{-2}$ (values at the higher end of the range, and possibly as high as 350-400 $g.m^{-2}$, are obtained when woody species such as *Erica tetralix* are present. However, species-rich communities (including calcareous seepage mires) can be maintained with very high offtake rates so that, with winter dieback, there is virtually no standing crop left by the next spring except for a bryophyte layer. The limiting factor is not so much the vegetation as the animals in these cases.

It is possible to calculate stocking rates from the New Forest, but these are necessarily crude since the stock are able to range freely between different habitat types. The calculations are based on total stock density, and observations on patterns of habitat occupancy and forage utilisation. In addition, stocking rates are complicated by the different behavioural traits of individuals and groups. This factor will create greater variation in the effective grazing pressure on smaller sites using necessarily smaller herds. The growing season starts relatively early in southern valley mires, growth commencing in early February at low levels. The major flush of growth occurs in late April-May, when the forage quality is at its highest. Growth remains high into late summer because of the continued availability of water, which rarely becomes a limiting factor. In some instances, valley mire fragments have survived in unintensive agricultural situations because the forage value of this habitat during drought is recognised. The main decline in growth is during September.

Approximate stocking rates calculated for the New Forest are as follows:

Average stock density	Total grazing pressure
Feb-April 0.2/ha (12 weeks)	2.5 weeks/ha
May-Sept 0.3-0.35/ha (22 weeks)	7-8 weeks/ha

This is based on 1 grazing unit = 1 pony. Unless the valley mire lies in a larger, semi-natural, grazed management unit, or there is fall-back land, then it is advisable to confine grazing to a short period rather than extending across most of the season. For valley mires in isolation, a grazing unit is taken to equal one cow (not dairy), but if other habitats are also available, then 1 cow = 0.5 grazing units because cattle will make less use of the mire vegetation.

Problems and pitfalls

Nature conservation interest

In certain circumstances, there may be a risk of nutrient transfer from surrounding agricultural land leading to eutrophication of mire habitats. This would depend on the nature of the management unit, particularly in relation to cattle. However, the probability of such an impact is low, especially with the suggested stocking rates. The potential impacts from supplementary feeding outside the main growing season should be considered, as this may form a significant source of enrichment. Stock feeding not really a desirable approach as the object of grazing management is to encourage consumption of vegetation, often of poor quality, and feeding will tend to discourage this.

Poaching is not necessarily as severe a problem as it first seems, since some mires are not invaded by many ruderal plants, and many mire species have a high capacity for vegetative spread. Some mire species are favoured by micro-sites provided by poaching. The historical value of peat deposits for pollen analysis, etc, may be reduced by heavy poaching, but this can be preserved by enclosing a small area over the deepest deposits.

It is also necessary to consider the impact of grazing on adjacent communities. this should not be a problem for heathland or grassland (for example, with grazing some M15 communities develop into species-rich lawns with abundant sedges and herbs). However, grazing may be deleterious in adjacent woodland unless, perhaps, it is derived from wood-pasture. The associated alder carr and willow thicket of valley mires are generally richer in plants and invertebrates if ungrazed, unless there is an open canopy.

Sites where grazing is to be introduced may suffer from a build-up of litter and the development of large tussocks. Over time, the litter will decompose and, with continued heavy grazing, the tussocks will evolve into low, species-rich hummocks. Other management options include burning, but this must be followed by grazing early in the year since burning preferentially favours *Molinia*. Burning should be done when the water table is high in late winter. Tussocks can also be physically cut, e.g. by brushcutter, and this should also be followed by early grazing.

Livestock

The condition of stock should be monitored closely, especially outside the May-June spring flush of *Molinia*, and on mires grazed in isolation. The provision of shelter (early spring), shade and water (summer) is important. the performance of hardy pony breeds is thought to be better (e.g. New Forest or Exmoor types). Mires are traditionally regarded as sources of worm infection, but this is not well substantiated and dry grassland can carry an even higher parasite load, depending on stock movements, etc. However, antihelminthic drugs (which will combat this problem) could be another management cost.

The soft sediments of valley mires are a potential problem to stock, especially cattle, but the risk of trapped animals tends to be over-emphasised. In practice, areas less than about 0.75-1.0 m deep are unlikely to prove a problem. Localised, high risk areas can be easily fenced to deter stock.

GRASS AND SEDGE DOMINATED PEATLANDS

Communities in these categories include the fen meadows and pastures of the Norfolk Broads and the Somerset Levels. Essentially, these are wet grasslands which, in addition to any botanical interest, may also be important habitat for waders.

These areas are usually grazed by cattle for at least part of the year, and may also be cut for hay either annually or biennially. A feature of species-rich vegetation of this type is that it receives little or no fertiliser, and any that is applied is usually in the form of manure.

When such sites are in good condition, grazing is kept 'light' so as to create a suitable structure for waders. Light aftermath grazing on the Somerset Levels produces structure suitable for snipe and redshank, while heavy aftermath grazing coupled with applications of manure will encourage lapwing and probably exclude redshank.

As in other habitats, the effects of grazing on individual species varies. *Phragmites* can be eliminated by cattle grazing, while *Calamagrostis epigejos* and *Elymus repens* can be effectively controlled, allowing the vegetation to diversify (Williams, Wells & Wells 1974). *Juncus*, although apparently taken by cattle (Williams, Wells & Wells 1974), tends to be avoided and increases generally (Pullin & Woodell 1987). Opinions differ as to whether this is a problem, and these tend to be linked to how traditional or continuous grazing has been on the site (where grazing is traditional, high levels of *Juncus* are commonplace and regarded as normal). Attempts to control *Juncus* in grazed areas at Wood Walton Fen by topping in summer and autumn have apparently failed (Pullin & Woodell 1987).

GENERAL PROBLEMS AND PITFALLS WITH GRAZING ON PEATLANDS

Where peat dams have been used for blocking drains on peatland reserves, there have been problems of erosion of the dams by grazing stock using them as bridges. A simple stake and wire fence at both ends of the dam would avoid this problem.

While grazing can be used as a control measure for unwanted species, there always remains the possibility of eradication of desirable species. Grazing should therefore only be introduced as a management regime after careful analysis of the existing vegetation and the setting of clear objectives. The same applies where grazing is to be re-introduced after a period of some other form of management.

Ideally, grazing management for nature conservation will be carried out by a local farmer either under contract or management agreement. The other alternative, grazing management by a conservation organisation, involves a great deal of investment, not only in the livestock themselves, but also in management effort, particularly as such active shepherding is required.

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11

Burning

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Burning

T.A. Rowell

CONTENTS

INTRODUCTION

Burning has long been used as a tool for the management of vegetation in Britain, principally for stimulating new growth of grasses or heather. The use of fire seems to be particularly associated with peatlands and heathlands. One often finds a conviction that a local bog or fen ought to be fired, even though it is no longer used for anything. The adoption of burning for conservation management is warranted where it is a traditional practice **and** has shaped and maintained the plant community. On peatlands in general, however, the use of burning should be considered carefully; it is potentially harmful and on SSSIs will have been notified as a Potentially Damaging Operation. It is a tool to be used only in very specific circumstances. Generally, some other technique will be a more suitable means of managing the vegetation.

Recommendations for burning management on peatlands are developed below with reference to the general and specific effects of the practice.

PRINCIPLES

Effects of fire on plants

The effects of fire on plants depends on the temperature of the burn. A light burn will remove easily combustible material such as dry litter, leaves, and thin stems. A hot burn removes all herbaceous vegetation down to ground level, and can kill seeds and shallow roots in the surface layers. Woody vegetation will lose all or most of its above-ground buds. Some plants have adaptations which render them relatively resistant to fire, e.g. growing points at or below ground level. *Molinia caerulea*, *Trichophorum cespitosum*, *Eriophorum vaginatum* and *Calamagrostis canescens* are examples of species encouraged by burning of peatlands.

Some plants are killed outright by fire. A potentially disastrous effect on peatlands is the death of *Sphagnum* following a fire. Fire virtually eliminated *Sphagnum pulchrum* from Glasson Moss NNR, and reduced the number of *Sphagnum imbricatum* hummocks on 16 ha of Cors Fochno (Borth Bog) NNR from 169 to 39. In each case, a single fire event was to blame. Recolonisation by *Sphagnum* following fire appears to depend on water table, being slow or non-existent if levels are low.

Damage to bryophytes is largely avoided if a quick fire occurs when the ground is frozen.

A fire during the growing season may prevent the setting of seed, which will have a particular effect on species with only short-lived seeds. If vegetative plants of such species are killed by the fire, then recolonisation of the area will be a slow process.

Such species will be able to exploit gaps in the vegetation opened up by fire. Other species may have a large proportion of their seeds killed by high temperatures, reducing the opportunities for expansion of populations or recolonisation of damaged areas.

The aerial portion of vegetation contains a large store of nutrients which are normally released into the system quite slowly by such processes as leaf drip and decomposition; the latter is aided by grazing. Fire releases all or at least a large proportion of this store instantaneously. Fortunately for the immediate habitat, much of the store of nutrients is lost as gases and blown ash. Despite this, ash that falls to the ground will contain some readily available nutrients, particularly phosphate and cations such as calcium and potassium. Unless burning is very frequent or the surface of the peat becomes impervious, most minerals lost from oligotrophic sites are likely to be replenished from natural sources such as atmospheric deposition. Short term enrichment resulting from fire is most likely to be significant on oligotrophic sites. Bryophytes such as *Polytrichum* spp, *Aulacomnium palustre*, and *Campylopus introflexus* are encouraged by the enrichment, and tend to replace damaged *Sphagnum* spp.

A further effect of deposited nutrients is to increase the pH of the peat surface, improving the conditions for bacterial decay. Other factors resulting from burning, such as an increase in surface temperature because the dark peat surface absorbs heat from the sun, tend to enhance the rate of surface decomposition.

Little agricultural advantage is gained in burning many of the wetter peatlands, especially bogs, as stocking densities are so low. Offsetting any apparent advantages is the strong likelihood of erosion resulting from burning. This will remove the vegetation and, eventually, the soil leaving no agricultural value whatsoever.

Natural fires occur once in, perhaps, every 500 years. The frequent burning adopted sometimes adopted as an agricultural management practice does not allow the vegetation to recover from the damage outlined above, and can cause rapid change in the plant community.

Burning is recognised as affecting peatland communities by causing shifts from *Sphagnum*-richness, through dominance by *Calluna*, to a distinctly heathy vegetation. Often in combination with grazing, burning is a major factor in the development of several NVC mire communities, notably

M14	*Schoenus nigricans-Narthecium ossifragum* mire
M15	*Scirpus cespitosus-Erica tetralix* wet heath
M16	*Erica tetralix-Sphagnum compactum* wet heath
M19	*Calluna vulgaris-Eriophorum vaginatum* blanket mire
M20	*Eriophorum vaginatum* blanket mire
M25	*Molinia caerulea-Potentilla erecta* mire

Fire has, as noted above, a drastic affect on *Sphagnum*, particularly in the following NVC communities;

M17	*Scirpus cespitosus-Eriophorum vaginatum* blanket mire
M18	*Erica tetralix-Sphagnum papillosum* raised and blanket mire

A recent survey has shown that species-rich fen communities can survive despite occasional burning (in February when the water level was high). Fen communities have, with a lack of demand for their natural products (formerly obtained by mowing), frequently been under-managed in recent decades. Burning appears to have some potential as an alternative means of management, and has been adopted as such on some sites in Broadland. At Broad Fen, Dilham, for instance, mowing of tall fen is being replaced by burning in February or March on a five year rotation. The first burn resulted in an increased density of flowering *Peucedanum palustre* compared with mowing in June-August; but this can be explained purely in terms of timing, as the later defoliation damages the flowering stem. More information is needed on the effects of burning in these fen habitats before it is adopted as a standard practice. In the meantime, it could be used once in, say, ten years to prevent total loss of a community.

Effects of fire on animals

A fire sweeping through vegetation will kill all of the less mobile animals living above ground and, depending on temperature, many of those inhabiting the surface layers of the soil. Where fire is used deliberately for management purposes, damage to some animals can be avoided by reference to their phenology; it is commonsense, for instance, to avoid the nesting season of all birds utilising the habitat. It is, however, impossible to take all faunal groups into account. Pupating insects, for instance, are always badly affected by winter burning. A solution is to burn small isolated patches of habitat in rotation (or, where burning is to be a once-only treatment, staggered over two or more seasons), so that whole populations are not destroyed.

Effects of fire on peat

Peat is organic and therefore combustible. The burning of vegetation over relatively dry peat can result in a peat fire which can burn for months or years, and penetrate to a surprising depth.

The removal of vegetation by fire is usually more complete than when well-controlled mowing or grazing is employed for management purposes. Vegetation intercepts rainfall before it reaches the surface of the soil, but an unvegetated soil must absorb the full impact of the falling droplets. Burning followed by heavy rainfall will result in erosion of the peat surface and, in some circumstances, this will be sufficient to eat through the binding root layer at the surface into the main peat body (the catotelm). The ease with which burning can induce conditions suitable for severe gully erosion is well recognised, and is known to increase sediment loads in previously clear rivers and lakes. Natural revegetation following this degree of erosion is likely to be extremely slow and may be preceded by further erosion.

A hot burn can cause water to evaporate from peat, resulting in irreversible drying of the surface and, because the water is replaced by air, decomposition of the peat is encouraged. The dried out peat can only be replaced by fresh growth and will also form a barrier to the penetration of water to the lower peat body.

Fire can cause surface crusting of peat through deposition of bitumens formed from the combustion of peat waxes. The penetration of the radicles of germinating seeds is made difficult so that establishment is reduced. Run-off is increased, and with more water running off the site, the water table will fall, and erosion increase. Damage to the surface also includes the formation of small 'pock-marks' in which water collects, encouraging very small-scale recolonisation by *Sphagnum*, particularly *S. tenellum*.

Statutory regulations

The burning of heather and grass in the UK is governed by the Hill Farming Act, 1946. Rules are slightly different for Scotland compared with England and Wales. Rules for Scotland are laid out in a comprehensible form in *A Guide to Good Muirburn Practice.*

The burning of heather, grass, gorse, bracken and vaccinium is governed in England and Wales by the Heather and Grass, etc (Burning) Regulations 1986. Aspects of burning vegetation are also controlled by the Highways Act 1980, the Clean Air Act 1956 and the Health and Safety at Work Etc. Act 1974. Advice in relation to these regulations are given in the MAFF/WOAD leaflet *The Heather and Grass Burning Code.*

Remember that:

* Burning is allowed only between 1st November and 31st March in the lowlands, and between 1st October and 15th April in the uplands.
* You must give 24-72 hours written notice to neighbours of intent to burn.
* The local NCC office must be consulted about intended burning on or adjacent to an SSSI

RECOMMENDATIONS FOR THE USE OF BURNING ON PEATLANDS

Burning is an appropriate management tool on peatlands managed for conservation purposes in a few clearly definable situations.

Heather on dry blanket bog

A difference of opinion exists on the need to burn heather-dominated blanket bog. Mowforth & Sydes (in draft) recommend a 20 year burning cycle for the maintenance of heather. Rawes & Hobbs (1979), on the other hand, suggest that fire may not be necessary, and that light grazing by sheep is all that is required. A computer model of heather moorland, recently developed by the Hill Farm Research Organisation, assumes that heather on blanket bog will not be burnt.

Restoration of cutover and dried-out mire

Burning is recognised as an important means, in combination with a prescribed system of grazing, for controlling the development of vegetation during the restoration of cutover mires. Burning is not intended to be used alone, and can achieve little or nothing unless it is followed by grazing and the raising of the water table. It is normally used only once during the restoration process. More details are given in the Handbook section on MIRE RESTORATION.

Restoration of reed and sedge (*Cladium*) beds

Where reed and sedge beds have been neglected for long periods, and become overgrown and invaded by woody species, they are not easily amenable to normal mowing methods. A technique for rapid restoration to mowing is to burn off the overgrowth, and then uproot or cut and treat shrubs and saplings (see SCRUB CONTROL). Once the herbaceous vegetation has regrown to the point when it is suitable for cropping, the normal mowing rotation is resumed (see REED MANAGEMENT and CLADIUM MANAGEMENT). This method of restoration to a mowing regime is also suitable for other tall fen vegetation. This technique should be used only once, and is not intended as a regular management practice. There may be a case for burning once in, say, ten years to maintain a habitat that would otherwise be lost through lack of resources.

Other communities

Burning should not be used as a regular management practice in any other peatland situation other than those mentioned above, unless there is clear evidence that the community has developed under, and is only maintainable by, burning. If good evidence exists, there may be a case for using burning to develop new areas of similar vegetation.

Burning must not be used as a management tool in NVC communities M17 and M18, in any other *Sphagnum*-rich community, and particularly not in any bog system with pools and ridges. While steps should be taken to prevent any accidental fires in these communities, it seems likely that occasional fires will have played a part in the history of all types of terrestrial vegetation, and are essentially unavoidable.

GENERAL PRACTICE

Safe methods of burning vegetation are outlined in *A Guide to Good Muirburn Practice*, and it is recommended that these are followed. A small amount of supplementary information is given below.

Vegetation and property are best protected by the use of firebreaks and firefighting equipment. A high water table or frozen ground affords protection to the surface of the peat, and the latter can also protect bryophytes from damage.

Reference to phenological information during the planning of burning management, and the staggered treatment of small blocks, will ensure the best protection of the fauna.

Firebreaks

For maximum control (and therefore minimum risk to habitat, personnel, and surrounding land), burning of vegetation should be done in small blocks of approximately 20 x 30 m. In taller vegetation, firebreaks should be mown around blocks prior to burning. **Do not place any reliance on mown firebreaks.** Instances have occurred where fires have crossed mown firebreaks of 30m width, even under careful supervision. Adjacent vegetation and property is easily destroyed. Caution is particularly required when highly inflammable litter, such as that of *Molinia*, is present in quantity. In the NCC's Southwest Scotland Region, where there is considerable experience of heather burning, it is considered that only a ploughed firebreak can provide reliable security against the spread of fire.

An alternative permanent firebreak, which is mainly intended for controlling accidental fires but which can be used as the side of a block if management by burning is undertaken, is the lagoon. This type of firebreak has been installed at Glasson Moss NNR. They are a series of shallow cuts about 2 m wide, 60 m long and 0.3m deep, laid out so that the ends overlap. The lagoons have stopped one fire, but have been problematical. The lengths and levels were not properly constructed so that water tended to run from one lagoon to the next causing erosion channels. Some were cut across old peat trenches which were not sealed, and these subsequently drained the lagoons. Some are infilling and revegetating with *Eriophorum*, and require early maintenance. Some remedial work has been undertaken, involving compartmentalising the lagoons with corrugated steel dams, and closing off any intersecting peat trenches, but more expert design and implementation would have avoided these problems in the first place.

Firebreaks should obviously be supplemented with sufficient staff armed with firebeaters. A more technical, and reportedly highly successful approach, is to use fire-retardant foam laid in a metre-wide trace around a mown firebreak. In short vegetation, the foam alone may suffice to demarcate the block.

Fire-retardant foam

Fire-retardant foam is made by adding a small percentage of synthetic detergent to water, and spraying it through an expansion nozzle. It is considerably more effective than spraying water alone. The foam acts by cutting out oxygen from the fire, and by ensuring the wetting of all surfaces of both plant and soil.

The foam can be used as a 2-3% mixture of detergent to water for directly fighting a fire. In burning heather, 450 litres (100 gallons) of water can, as foam, dowse up to 150 metres of fire front.

As a 1-2% mixture, foam can be applied ahead of a fire provided it can be applied 15-20 minutes before the arrival of the fire front; at this concentration it can lose its effectiveness in 30-45 minutes. Using this method, four people have safely burnt 45 ha of heather in 4 days. A trace of foam about 1 metre across is laid around the area to be burnt. It has been virtually 100% successful in stopping the spread of fire. 450 litres of water will lay a trace 1-2 metres wide and approximately 100 metres long on heather. The foam is 75% biodegradable in 5 days.

Trials carried out on NNRs in southwest Scotland have resulted in the recommendation of the following equipment for the application of fire-retardant foam; low ground pressure vehicle (Argocat or VeePee), fibre-glass water container of at least 350-450 litre (80-100 gallon) capacity, Hathaway Mk V pump, and various hoses and couplings. The recommended detergent is Expandol, supplied by Angus Fire Armour in 25 litre drums.

Essential reading on this technique is the Forestry Commission Leaflet by Ingoldby & Smith (1982). Specific details regarding its use on nature reserves can be found in a draft technical note, 'Fire Fighting with Water/Foam Equipment' by J.H. Theaker, available from NCC Southwest Scotland Regional Office.

Peat fires

If fire gets a hold in a peat soil, its spread can be prevented by the digging of a two metre wide ditch down to the water table.

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Control of scrub

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Control of scrub

T.A. Rowell

CONTENTS

INTRODUCTION

In Britain, trees and shrubs (other than dwarf shrubs) are not regarded as a normal element of mire vegetation. They belong to marginal communities, for instance along the areas of draw-down next to watercourses. The appearance of trees and shrub species on mires is symptomatic of damage to the hydrology. The water table is no longer high enough to prevent the establishment of these species. The first priority must always be to determine the cause of hydrological change, and to raise the water table to its original level (see WATER LEVEL CONTROL). Well-established scrub will need to be removed, and its re-growth prevented.

Many of the general aspects of dealing with the felling and disposal of trees and scrub are dealt with in the BTCV handbook, *Woodlands* (Brooks 1980). It is recommended that this section of the Peatland Management Handbook, which deals only with scrub management as it particularly affects peatlands, is read in conjunction with that publication.

PRINCIPLES

Damage to mires by trees and shrubs

Tree and shrub species damage a mire's surface and hydrology by:

* shading out light-demanding species;
* extracting water from the peat;
* intercepting rainfall;
* causing eutrophication and smothering of smaller species by leaf-fall;
* causing eutrophication by providing bird roosts.

Problem species

Major problem species on mire reserves are *Salix* spp., *Betula* spp. and *Rhododendron ponticum*. Other possible problem species include *Alnus glutinosa*, *Myrica gale* and *Pinus sylvestris*.

Access

The need to get people and equipment regularly to any site of scrub control and to remove waste material means that adequate access needs to be planned, implemented and maintained (see ACCESS).

Survey

The first priority in any scheme to remove scrub from a site, or part of a site, must be to survey the areas in question to determine the most effective approach to the task. The survey should cover the following points.

* Establish access routes and, where necessary, disposal points.
* Classify scrub on the basis of ease of access, removal and handling.
* Classify scrub on the basis of probability of recolonisation by desired vegetation.

<u>Classification of scrub</u>

During survey, make notes on the species, density and morphology (height, girth, degree of branching, etc) of woody stems. This allows planning of the method of removal, type of chemicals, etc, and should allow an assessment of ease of removal and handling. With experience, this assessment can be made directly.

Notes should also be made in the field of the locations of sources of recolonisation and the range of desirable species still surviving under the scrub. On occasion, the peat may be well dried out, and the woodland old and have developed an understorey of species such as *Rubus* and *Pteridium*. Such areas are best treated as woodland rather than attempting restoration to mire vegetation.

<u>Buried seed</u>

An additional factor that could be considered during survey is species available in the peat as viable seed, and so effectively invisible. These species may be desirable, but the seed community may also include large quantities of seed of undesirable species. An assessment of the species likely to appear directly from the peat after disturbance can be made by taking samples during May of the first 15 cm of peat. These should be spread about 2 cm thick in seed trays. Place these trays in an unheated greenhouse ensuring that they are protected from stray seed. Germination will continue for some considerable period, but a reasonable assessment should be obtainable after about six months. Obviously, this approach can be time-consuming, but it may provide very valuable information. Muller (1978) provides an excellent guide to seedling identification.

Scrub removal

The object of scrub clearance on mires, particularly on bogs, should be to remove cover and halt the influence of trees and shrubs as quickly as possible, and with as little disturbance as possible. Scrub can be dealt with in a primary fashion by:

* pulling;
* cutting;

* cutting and treatment with herbicide;

* killing *in situ*.

Pulling

Pulling is a useful routine method for dealing with low-density establishment of scrub species from seed, before the individuals have grown too large. Pulling removes most of the living plant material and results in relatively little regrowth. It is usefully employed where the use of chemicals is undesirable, e.g. when using volunteer labour. *Myrica* is routinely pulled from sedge fields (see CLADIUM MANAGEMENT); it responds vigorously to being cut and is difficult to poison.

Large trees and shrubs are usually only pulled where mowing is to be the subsequent management because otherwise stumps can foul and damage mowing equipment. If stumps are simply cut off at ground level, they tend to rise up later as a result of the reduced load. Stump removal, which commonly requires the use of a winch or tractor, inevitably causes a great deal of damage to the surface of the mire, resulting in large hollows. Where the mire surface has little variation, this may be undesirable. The disturbance caused may allow invasion by undesirable species.

At Wicken Fen, where all scrub is pulled, the ideal timing is considered to be November-December, when the ground is relatively dry and firm and the vegetation at a minimum, dry and brittle and relatively easy to clear. Actual timing is governed by the availability of labour, i.e. during summer and early autumn.

Cutting of scrub without chemical treatment

Cutting of scrub without chemical treatment of stumps is a suitable approach for dealing with species that cannot regenerate vegetatively (e.g. *Pinus*), or where regular mowing or grazing is to be the subsequent management policy. Where invasion is not very extensive, it is possible that treatment of species with regenerative ability could be neglected and any regrowth managed by cutting on a rotational basis. It is generally unrealistic, however, to assume that regrowth can be dealt with on a regular basis by hand-cutting or the use of brushcutter, unless the area involved is very small and the problems of removal of the cut material are solved.

Some managers have reported trying to cut larger woody plants without any treatment, but this has proved counter-productive, so now stumps and regrowth are treated.

Cutting followed by chemical treatment

Main treatment

Most effective control of woody species capable of regenerating vegetatively after cutting is gained by treatment of stumps with herbicide immediately after cutting (see p 7 for details of the use of chemicals on peatlands). If this is carried out properly, regrowth should be minimal, but all regrowth should be dealt with promptly in the following season. If the site is not to be mown or grazed, then chemical treatment is the best approach. The method used should avoid contamination of any other plant species; use of a weed-wiper seems most effective.

Stumps should be cut as low as possible, and inexperienced teams should be supervised closely to ensure that height of cut does not increase as the task proceeds; this is a common problem. It is often helpful to have a main team to cut as they find most convenient, and then have a subsidiary team trimming stumps to the ground and treating them.

For maximum effectiveness, stump treatment needs to be carried out during the winter and immediately after cutting. Winter clearance of scrub is frequently not possible on wet sites. Operating during other seasons can still be effective, provided that the period is avoided when sap is rising, as this will prevent herbicide from being absorbed by the stump.

Stump treatment will need to be repeated if rain falls soon after the initial treatment, as the herbicide will be washed off the stumps.

Short cut stumps are difficult to find, particularly in long vegetation, so it is bad practice to separate the processes of final trimming and chemical treatment. It is useful to adopt the following practices.

- The chemical mix should be coloured so that it is easy to identify whether a stump has been treated.

- The chemical should be carried by each work team, and should preferably be the responsibility of one worker who ensures that each stem is treated.

The particular problems of cutting and treating *Rhododendron* are dealt with in a separate section below.

Treatment of regrowth

Chemical treatment of regrowth should be carried out in the season following cutting (and in subsequent seasons as necessary), usually when shoot extension is completed, i.e. during July-September.

Spraying is generally undesirable as, even if a cone is used to restrict the spray, the surrounding vegetation is bound to be affected. A weed-wiper is the favoured method of applying chemical to scrub regrowth, as only the target vegetation is affected, but there may be more risk that not all the regrowth is treated so a commitment to re-treatment is necessary.

<u>Killing trees *in situ*</u>

Seedlings

On occasion, particularly after removal of birch scrub, seedlings may appear in such abundance that pulling is impossible. Spraying with Krenite may be an alternative, as this chemical is relatively safe for non-woody species. However, this should be done on a trial area before being applied on a larger scale.

Larger trees and shrubs

Killing trees *in situ* quickly removes much of the influence of the canopy. This approach needs, however, to be well planned, because the dead timber still has to be removed eventually.

Rapid treatment can be achieved by notching the stem and applying a measured dose of herbicide. Painting-on of chemical may not be adequate. Safe and effective application can be made with a drench-gun (see p 11).

Disposal of waste

The large quantities of waste generated by scrub clearance are a major problem in any conservation work. Dealing with the waste on a peatland site poses particular problems relating to the difficulties of working and transport on soft ground and the danger of setting fire to peat. Some of the possible alternatives for waste disposal are:

* dumping on-site;
* dumping in water-filled ditches or peat cuttings;
* burning on-site;
* use of timber on-site;
* chipping on-site for easy removal;
* off-site disposal.

Dumping on-site

This is not a desirable practice on bog sites. The underlying vegetation will be killed, and the surrounding vegetation may be altered.

On some fens, habitat piles of timber and brushwood of varying size undoubtedly have some conservation benefits, but go only a small way towards solving the disposal problem. Any such piles should be placed outside any areas of special interest.

Dumping in water-filled ditches or peat-cuttings

On cut-over or drained bogs where the aim is to reduce water loss by blocking drains and allowing them to infill, the placing of cut branches and other timber into ditches is a useful method of disposal. It has the added advantage of reducing surface water movement, and thus encouraging colonisation (see MIRE REGENERATION).

Care should be taken when packing branches into ditches and peat cuttings that they are not filled to the peat surface. Adequate space should be left for a *Sphagnum* layer to form over the branches. Remember that the sides of ditches are often slightly higher than the average peat surface because of the dumping of spoil. **The packing of ditches with branches does not block water flow and they will still require damming.**

Burning on-site

The most obvious method for disposing of cut timber and brushwood is to burn it on-site after allowing a period for drying. Unfortunately, this is not always as straight forward a method as it appears.

Peat is easily combustible, and the greatest danger associated with scrub waste burning is the starting of peat fires which are notoriously difficult to extinguish. Various methods have been adopted to allow burning with a minimum of danger. At some sites, burning is carried out during the winter when the water table is high. Some burning into the peat is inevitable using this method. The vegetation is destroyed and the soil enriched, making the fire site a focus for invasion by atypical species. More sensitive approaches involve placing a non-inflammable break layer at the base of the fire, e.g. an asbestos fire blanket, or sheets of corrugated iron. The more successful methods incorporate additional layers to keep the source of heat further from the peat, e.g.:

* Lay down a layer of brushwood, followed by a layer of corrugated iron, then the material to be burned;

* Lay down a layer of overlapping sheets of corrugated iron, place bricks or other building blocks in a grid pattern suitable for supporting a further layer of corrugated iron; burn on the top layer of iron. Further similar layers would afford extra protection.

A certain amount of ash is bound to drop from the protective structure, and will cause enrichment of the immediate surrounding area. Consequently, it is important to establish a series of permanent sites so that this type of damage is restricted.

If a peat fire is inadvertently started, they have been successfully dealt with by digging a trench dug down below the water table to isolate the fire.

After the scrub waste has been burnt on-site, the problem remains of disposal of the ash. Dumping on-site is not acceptable because of possible problems of nutrient enrichment. Similarly, disposal in ditches is also unacceptable. Ash needs to be transported off the site in suitable containers along the established protected access route, and dumped where it is unlikely to cause harm. Wood ash makes a useful garden fertiliser and a certain amount could be disposed of in this way.

<u>Use of timber on-site</u>

A proportion of scrub waste might be used on-site for construction purposes, particularly where straight-stemmed pines are being removed. However, experience suggests that poles and rough-cut timber are unsuitable for use in the recommended dam structures or for boardwalks, as they and variable in length and girth.

<u>Chipping</u>

As far as is known, machinery for reducing timber and brushwood to chips has not been used on peatland reserves in this country. Machines are available that can be tractor mounted or drawn, and that run off the tractor PTO. Wood chips are potentially easier to handle than unchipped material, and are potentially saleable or usable as fuel or for paths. *Rhododendron* chips should not be used or sold for footpaths as regeneration is possible from fragments with whole buds attached.

Limitations on the use of chippers are access facilities for the tractor, and restrictions on the size of material the machine will handle. The latter is not too serious a problem, as most scrub waste will be within the range of the smaller machines.

<u>Off-site disposal</u>

If timber can be got off-site, then there is a certain amount of potential for use or sale. Details of preparation for sale are given by Brooks (1980). Otherwise, it can be burnt.

Use of chemicals

The use of herbicides to control scrub on peatland sites should be in accordance with the guidance given in the NCC's *Focus on Nature Conservation No. 14 - The use of herbicides on nature reserves* (Cooke, 1986) and in any safety handbook provided by the user's employer. Note, however, that methods given by Cooke (1986) by which 'terrestrial' herbicide may be applied have been updated, and this updated information has been incorporated into the recommendations given below. In any case, the product label should be the ultimate guide to approved practice. Under the Control of Pesticides Regulations 1986 it will be an offence to use a chemical in an unapproved fashion from 1 January 1988. Users of pesticides should ensure that they familiarise themselves with the new regulations which are outlined in MAFF leaflet UL79 (*Pesticides: Guide to the New Controls*). A wide range of useful information relevant to scrub control is given by Sale, Tabbush & Lane (1986) and McCavish (1980).

The use of herbicides on peatlands requires the following considerations:

* any remnants of desirable vegetation may be adversely affected by chemicals, either directly through spray drift, or indirectly through translocation between root systems ('flashback') or movement through soil or in water. Choice of chemicals and method of application should avoid these possibilities as far as possible;

* peatland sites are usually closely connected to the ground-water system. The use of chemicals unsafe for application close to water bodies should be avoided if possible. Only ten chemicals are approved for use in or near water (MAFF 1985).

Recommended chemicals and application methods

For most approved chemicals, application by sprayer is not recommended for peatlands. An exception is fosamine ammonium which is selective for woody species and some perennials. Spraying this herbicide may be acceptable, but its effects on peatland species need to be determined. Otherwise recommended methods are brush painting of cut stumps, stump application by drench gun, and weed-wiper application to foliage of regrowth.

The accounts below of herbicides suitable for use on peatland sites mentions only those species likely to be present as scrub. For more detailed information consult Cooke (1986)

Fosamine ammonium (Krenite)

Fosamine ammonium is approved for application by knapsack sprayer and by drench gun (though not to cut stumps). Knapsack sprayers should only be used for general treatment where the non-target vegetation is known to be resistant. It may prove useful for tackling large areas of *Myrica gale*.

Fosamine ammonium may only be applied during the period August to October. It is approved for use on banks near water according to the guidelines laid down by MAFF (1985).

The following scrub species can be controlled by fosamine sulphamate:

Alnus spp
Betula spp
Frangula alnus
Myrica gale
Salix spp (susceptible only - label states 'may not be controlled')

Note that all evergreen species including *Rhododendron ponticum* are resistant to fosamine sulphamate. *Calluna*, *Erica*, and *Vaccinium* spp are also resistant.

Glyphosate (Roundup)

Glyphosate is approved for application by brush to cut stumps, and by drench gun and weed-wiper. Product label information indicates that it can also be used for notch application to standing trees (injection).

Glyphosate is a non-selective herbicide, so great care must be exercised in its application, but difficulties should not arise if knapsack sprayers are avoided. Use against *Rhododendron ponticum* regrowth is enhanced if 'High trees mixture B', a surfactant, is added to the glyphosate solution; details of the use of 'Mixture B' are given by Forestry Commission (1987).

Glyphosate is approved for use on emergent and bankside vegetation including trees.

The following scrub species can be controlled by glyphosate:

Alnus glutinosa
Betula pubescens
Pinus sylvestris
Rhamnus catharticus
Salix spp

Triclopyr (Garlon)

Triclopyr is approved only for brush application to cut stumps. It is toxic to fish and is not approved for use in or near water. Seven days should be allowed after application before stock is allowed into treated areas. Triclopyr is volatile, and can affect plants downwind from the area of application during hot weather.

The following scrub species can be controlled by triclopyr:

Alnus spp
Betula spp
Rhododendron ponticum
Rhamnus catharticus
Salix caprea (variable)

Note that *Calluna vulgaris* and *Erica tetralix* may also be affected by triclopyr.

Control of ***Rhododendron***

Rhododendron is an alien species of such invasive powers that it has aroused national concern. Unfortunately, it flourishes on drained bogs.

The success of *Rhododendron* in Britain has been ascribed to the following ecological features (Shaw 1984):

* prolific seed production and effective dispersal;
* unpalatability to grazing animals;
* shade tolerance;
* response to cutting - coppicing power;
* longevity;
* freedom from pests and diseases.

However, the following weaknesses have been identified, and may be usefully exploited in the control of the species (Shaw 1984):

* short life of seed;
* seed-bed requirements for germination;
* conditions for early growth (up to 5 years);
* inability to sucker;
* climatic limitations;
* edaphic limitations.

Unfortunately, bog surfaces often provide optimal conditions for *Rhododendron* germination and establishment, i.e. a mat of pleurocarpous mosses on drained bogs, or on *Sphagnum*. Edaphic conditions provided by drained bogs are also ideal for the establishment and growth of *Rhododendron*. Shaw suggests possible control measures, based on ecological analysis.

Survey and planning

Define all areas of *Rhododendron* differentiating reproductive units and populations of young non-flowering plants. Devise a plan to destroy those reproductive units most likely to contribute to a rapid spread of the species into hitherto unpopulated areas. At the same time, a high level of priority should be given to destroying young populations before they reach flowering age (10-12 years old for shoots derived from seed), and before they do too much damage to the underlying vegetation.

Holding measures

Remove all young (i.e. non-flowering) plants by pulling. Ensure that the divot is replaced to avoid creating a new site for germination. De-heading of the largest flowering plants, the main contributors to the establishment phase, prevents flowering and seed production for about 3 years, and reduces the size of the bush prior to eventual removal.

Eradication measures

Cut and treat stumps; treat regrowth. See above for details of special glyphosate mixture for use against *Rhododendron* regrowth.

Prevention of further invasion

Seeds travel up to about 100m, so steps should be taken to remove and control all *Rhododendron* in a belt of at least 100m width around the site. This should prevent any further invasion.

GENERAL PRACTICE IN SCRUB CONTROL

The number of variables involved in scrub control preclude the setting down of any general guidance to cover the whole operation. However, the following points should always be observed.

* Scrub removal should only be undertaken if there is to be some permanent means of preventing woody regeneration, i.e. water level management, mowing, grazing, etc. If the resources are not available for this continuing management, then scrub removal should not be started;
* If an access route is to be used with any consistency, then steps should be taken to protect it before any damage is done;
* Work should be carried out carefully causing as little damage to any areas carrying sources of recolonisation;
* If at all possible, chemical control should be avoided. This is only feasible, however, if scrub is pulled, or if there is to be some regular grazing or mowing regime calculated to prevent regeneration of scrub;
* Cut stumps should always be treated, and treatment should be carried out immediately after cutting;
* Disposal of cut material should operate, as far as possible, in tandem with cutting so that there is not a large build-up of material inhibiting recolonisation and destroying any existing vegetation.

PROBLEMS AND PITFALLS

Scrub control is largely a straightforward operation with few opportunities for failure. Most problems that do arise appear to be related to the use of chemicals to prevent regrowth, and are probably linked to improper use. Good quality feedback is needed on the level of success of chemical-based scrub control operations. This needs to include exact information on method and results.

EQUIPMENT

Most of the equipment for scrub control is commonly used in conservation management and is well documented elsewhere[1] Two more unusual items require further details.

Drench-guns

The drench-gun is a veterinary drench which has been modified for herbicide application by the addition of a lance, check valve and spray nozzle. It is a precise instrument allowing exact delivery of a small quantity of liquid. Herbicide can thus be applied in a reduced amount of diluent so that more trees can be treated per knapsack fill. The precision of application means that overspray is likely to be less of a problem than with conventional sprayers.

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1 For general equipment see Brooks (1980); for chain saws see Brooks (1974); for knapsack sprayers see British Agrochemicals Association (undated).

Drench-guns are likely to prove most useful for spraying cut stumps (using a TG3 nozzle with a 50° cone) or for injection of herbicide (using a solid stream nozzle).

At present, only glyphosate and fosamine ammonium have clearance for application by drench-gun.

Drench-guns are available as the Selectokil Spot Gun from:

Selectokil,
Abbey Gate Place,
Torvil,
Maidstone,
Kent
ME15 0PP

Tel. Maidstone (0622) 55471

Price (1987): £85 + VAT approx.

Chippers

Chippers reduce forestry thinnings to small chips suitable for fuel, cattle bedding, foot paths, etc, or for mulching after screening. Three basic types of chipper are available, drum, disc, and screw cone. The size of chip produced can often be altered by varying the number of knives, screens, etc.

No experience has been gained in the use of chippers on peatland conservation sites. It seems likely, however, that tractor-drawn units will be most useful, as tractor-mounted units are likely to prove heavy and unstable. Other forwarder- or truck-mounted units will also be too heavy for soft ground. Feedback on use and effectiveness is required.

Many types of chipper are advertised in the forestry journals. Two agents are:

Jonco Sales & Marketing Ltd.,
6/7 Romar Court,
Denbigh Industrial Estate,
Bletchley,
Milton Keynes,
MK 1RH

Fuelwood Harvesting Ltd.,
Clochsmill,
Duns,
Berwickshire
TD11 3QH

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Evaluation of management techniques

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Evaluation of management techniques

T.A. Rowell

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INTRODUCTION

The Peatland Management Handbook suggests a range of techniques aimed at more effective management of peatland conservation sites. The status of the recommended techniques varies enormously. Some have a good basis in scientific or historical fact, or are well-tested in the field, and can be confidently expected to produce the required results. Others are well-tested in other situations, but need evaluation on peatlands. In a few cases, suggested techniques are little more than ideas that require full testing and, probably, considerable modification in the light of field experience.

Frequently, management techniques are accepted or rejected on appearances. For example, horizontal board dams have been used in attempts to seal ditches in peatlands because they are relatively easy to install, despite the fact that they are known not to work. The structure itself always leaks and the area of weakness introduced into the peat by excavations for their installation results in seepage and eventual wash-out. The most promising design, vertical board dams, have been rejected or inadvisedly modified on occasion as a result of misinterpretation of a single failure. Seepage under the dam due to water pressure has been misinterpretation of a single failure. Seepage under the dam due to water pressure has been misinterpreted on occasion as a washing out of the base of the dam by eddies on the upstream side. The problem arises from incorrect installation and modifications based on this misinterpretation are unlikely to provide a solution. The design could eventually be rejected as a result. Here we see management problems caused by *ad hoc* unscientific evaluations and by failure to communicate information about previous evaluations.

If the standards of conservation management are to be maintained and improved, then the most effective available techniques must be identified and correctly implemented. Several processes and concepts are involved here:

* Identification of current **field techniques**, i.e. those techniques currently in use;
* Recognition that field techniques are modified during implementation into **actual practice;**
* Identification of **recommended techniques**, whether currently practiced or not. These have achieved their status as a result of rigorous scientific testing.

Recommended techniques undoubtedly account for a proportion of the techniques that are employed in the field, but not all recommended techniques are routinely used. An appreciable proportion of field techniques have not undergone testing and could not, therefore, be regarded as recommended. Whatever the status of the techniques employed, the vagaries of implementation (resulting from field conditions, personal preferences, etc.) mean that actual field practice may be substantially different from that implied by the technique employed.

Implementation clearly affects evaluation of a technique. As a simple example, consider the chemical poisoning of cut stumps. Regrowth from 50% of cut stumps might be regarded as unsuccessful. If sloppy implementation had resulted in the non-treatment or inadequate treatment of, say, 45% of stumps, then as a result a technique with a success rate of about 90% could be rejected.

The relationships between recommended and field techniques, and actual field practice are shown in diagrammatic form in Figure 1. The arrows show the flow of information between the boxes. This paper will show how evaluation of management techniques can be carried out in a scientific way. The methodology used was developed for use in the field of vegetation management in land reclamation and restoration but, with modifications, it is equally suitable for conservation management. As the method is developed here, it will become clear that **feedback of information** plays an important part in the process of evaluation. The Peatland Management Handbook is part of this feedback mechanism, but the process is also dependent on feedback from practitioners using the techniques in the field.

The approach to evaluation discussed below may appear to be a process that happens naturally. In practice it doesn't. The formalised structure of the model developed here ensures that the process of evaluation is complete, that the results of research are incorporated into actual practice, and that innovations are fully appraised in the field.

METHODS FOR EVALUATION OF TECHNIQUES

Current management techniques

The level of success achieved by current techniques being used in the field can be evaluated by **survey and monitoring** methods. As already discussed, the relevance of information collected at this stage must be assessed in the light of implementation. Information about implementation can only be collected by direct **observation.**

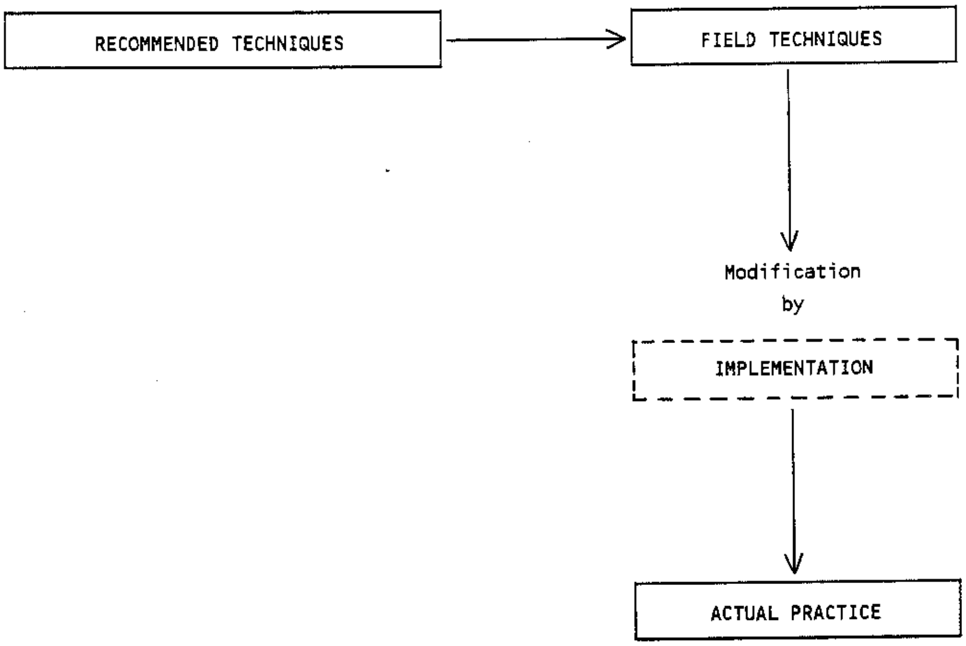

Figure 1: **The relationship between management techniques and practice showing the modifying influence of implementation. Arrows indicate the flow of information.**

Survey and monitoring

Habitat management is aimed at some defined goal. This goal forms the basis for the evaluation of management techniques. It should be possible, therefore, to establish the standard of **performance** of a management technique by survey of a range of representative sites where the technique is employed, followed by comparison of achievement with the standards set by the management goal.

Care should be taken when devising a survey method to ensure that all parameters are measured in a way which gives repeatable results. A professional approach to this type of survey is imperative if spurious acceptance or rejection of management techniques is to be avoided.

When a new management technique is undergoing field trials, it may be necessary to undertake periodic re-assessment of performance, i.e. monitoring. If the approach involves comparison with a standard, then the above precautions apply. If an attempt is to be made to track changes in vegetation then a suitable monitoring method should be adopted (see VEGETATION MONITORING).

Once survey or monitoring indicates satisfactory performance of a management technique, then the major role of the evaluation process is over. It is only continued as a means of ensuring that standards are maintained, and for testing techniques that may improve efficiency.

Satisfactory or unsatisfactory performance of a management technique must be judged in the light of standards of implementation. The results of survey or monitoring should be the subject of feedback, and should be reflected in future recommendations for management (Figure 2).

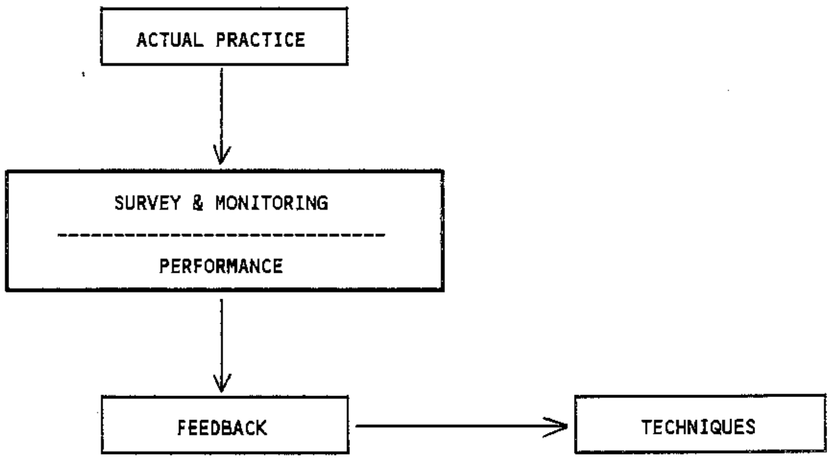

Figure 2: **Evaluation of the performance of management practice by survey and monitoring followed by feedback of information.**

Observation of implementation

Observation in the field is the only method of establishing whether management techniques are being properly implemented. Observation involves careful documentation of each stage of the field implementation of a management technique, and of deviations from specified procedures and materials.

At the simplest level, observations of this sort will result in corrections to local practice to bring implementation in line with established and successful methods. In more complex cases, and providing sufficient observations have been made, then generalisations and hypotheses about techniques and their implementation may be made and subsequently tested.

Observation often provides useful information about the effectiveness of equipment. This should be linked with data on the capability of equipment, and should lead to tighter specifications for conservation management operations. For instance, we know from the specifications of low ground pressure vehicles such as Argocats and Vee-pees that they are capable of travelling over very wet peatlands where other transport would fail. Observations indicate, however, that in many circumstances the shearing action of treads and tracks causes substantial damage to the vegetation and the peat surface. While a single pass of such vehicles can be seen months later, multiple passes can denude the ground and totally disrupt the peat. So while the capability of the equipment indicates its suitability as transport over peat, observation indicates its unsuitability. Solutions to this problem are suggested in the ACCESS section, but still require evaluation.

All results from observation of implementation should be fed back into the evaluation system (Figure 3), bearing in mind that they may modify conclusions based on any survey or monitoring. When observations indicate that poor implementation is producing unsatisfactory results from a management technique, steps should be taken to make changes to field practice. An increased level of supervision will often be all that is required. In some cases, e.g. where the capabilities of equipment are in doubt, a need for research and experimentation may be indicated. When observations indicate that implementation is satisfactory, this should also be reported to encourage the maintenance of existing standards.

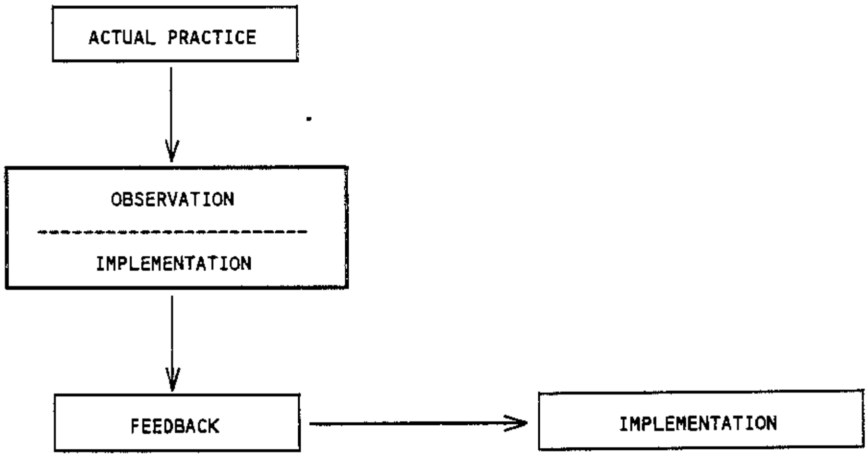

Figure 3: **Evaluation of implementation by direct observation followed by feedback of information.**

New or unestablished techniques

If survey and monitoring indicate that a management technique is achieving the desired goal, then there is no need for further investigation unless financial constraints require that a cheaper alternative is necessary. When standards are not achieved, or new techniques available, then a degree of research must be incorporated into the evaluation process.

Techniques which under-perform may simply be inappropriate to the task in hand. Alternatively, they may have been improperly derived from their scientific basis, or that basis may have been modified since the technique was first established. Before such techniques are abandoned, it is worth re-examining their scientific basis. In the case of traditional techniques, then their historical basis should also be re-examined. Examination of the scientific basis should also be done for any new techniques so that their background is fully understood before implementation in the field. Both scientific and historical bases are established by **literature reviews**.

In certain cases, comparisons of techniques will need to be made. This is best done by **experiment**. Experiments might also be carried out to obtain information about how particular techniques operate. This is not strictly part of the evaluation process, but will provide additional scientific background.

Literature reviews

Literature reviews are used to evaluate the basis for existing techniques, or to aid development and evaluation of new techniques by experimentation (Figure 4).

As far as possible, all literature, published and unpublished, relating to a management technique under investigation should be amassed and reviewed. The aims are:

* to establish the scientific basis of a technique;
* to obtain an overview of the background of the technique;
* to establish the nature of other techniques in the same field.

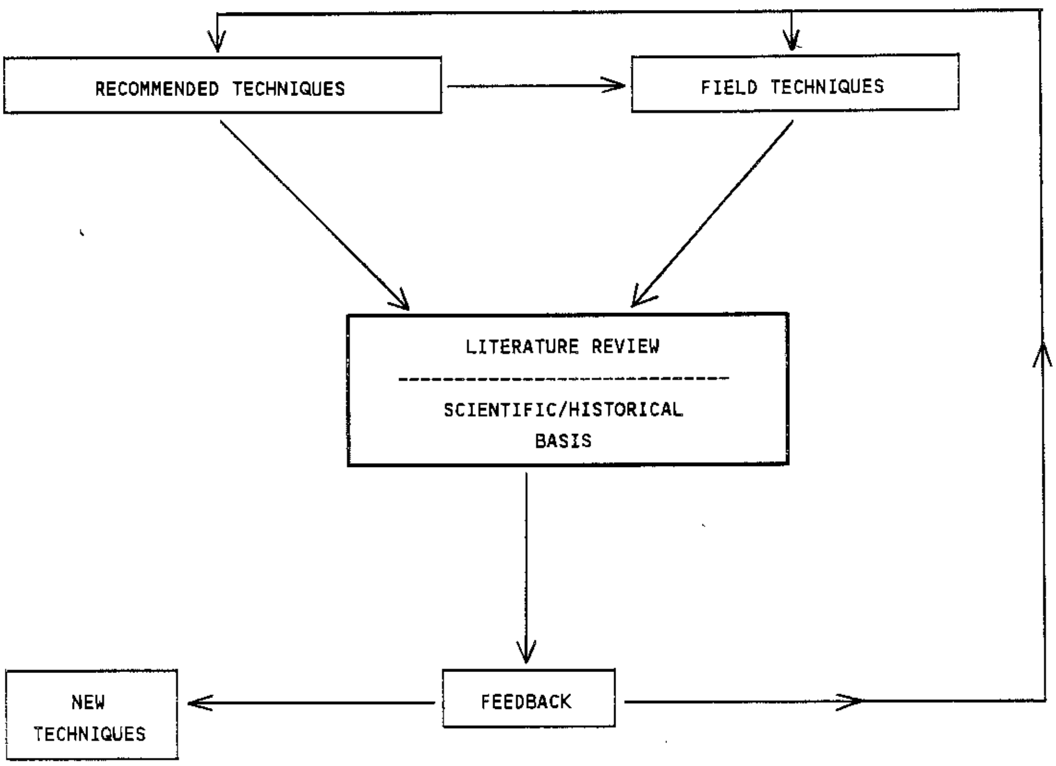

Figure 4: **Evaluation of the scientific and historical basis of management techniques by critical literature review followed by feedback of information.**

To carry out an effective literature search, make good use of the skills of trained library staff, abstracting journals, reference lists in known literature, on-line databases, and the personal knowledge of experts in the field.

Many literature reviews consist simply of summaries of findings. For effective evaluation, however, reviews must be critical of the available literature; this is particularly important where conflicting ideas and advice are offered on a particular technique. The need for critical scientific ability must not be under-estimated. The following aspects of the scientific literature should be examined.

* Assumptions
* Relevance
* Methodology
* Conclusions, particularly in the light of assumptions, relevance and methodology

Some techniques may be regarded as traditional in nature. They may still have a scientific literature, but a review of their historical basis may also be required. It may be possible to achieve this by a literature review, but some recourse to primary historical material may also be necessary. The interpretation and critical appraisal of historical literature and material is very different from the assessment of scientific literature, and the need for evaluators with these different abilities should be recognised.

When a literature review indicates that the benefits of an individual procedure are well-established, and performance in the field matches the published claims, then there may be a case for the technique being accepted or maintained as 'recommended'. When the literature forms an inadequate basis for a technique, the case should be judged on its merits using additional information from field evaluation by survey/monitoring and observation. If alternative techniques exist, or there is a possibility of improvement, then experimentation may be required to establish any advantages.

Literature reviews are clearly not without their limitations. Techniques may be based on unpublished work, and it may prove difficult to locate all the relevant material. Consequently, unlike the other stages in the evaluation process, the quality of evaluation obtained at this stage is not entirely dependent on the expertise of the evaluator. There is a need, however, to ensure that evaluators have experience not only in locating and summarising scientific and other literature, but also in all other aspects of scientific method including experimental method, data analysis, and interpretation of numerical and other types of information.

The value of literature reviews is indisputable. Critical review has shown-up, for instance, not only faults in the basis for the management of sedge at Wicken Fen, Cambridgeshire, but also flaws in the appreciation of the development of the site. The literature review led to research into the pattern of previous land-use, and resulted in a new framework for ecological interpretation of the site, with important implications for management.

The feedback of information from a literature review may lead to modification of existing techniques, and may provide sufficient evidence for the experimental development of new ones (Figure 4).

<u>Experimentation</u>

Experiments are a means of testing hypotheses about the effects of management techniques or 'treatments' on, for example, vegetation. They are an excellent means of comparing the performance of two or more techniques under similar conditions. Often, it will be possible to use the findings of other evaluation methods, literature review, survey and monitoring, and observation, to generate hypotheses for testing by experiment (Figure 5).

Proper design of experiments is essential if observed effects are to be attributed with any confidence to a treatment or combination of treatments. Design, replication, sampling methods, types of data to collect, and analytical techniques all require considerable care before experiments are set up. This is not the place to discuss these in any detail, but the example of replication will show their importance.

Most people would accept that to generalise from a single result would be foolhardy. Thus, if a new management technique is tried once on a patch of vegetation and fails, it would be unreasonable to reject it out of hand. Any one of the following could apply.

* The patch of vegetation could be unusual.
* The patch of soil (including its water regime) could be unusual.
* Assessment could have been carried out inappropriately.
* Any of these factors could have interacted with each other, or with the management technique, to produce the result.

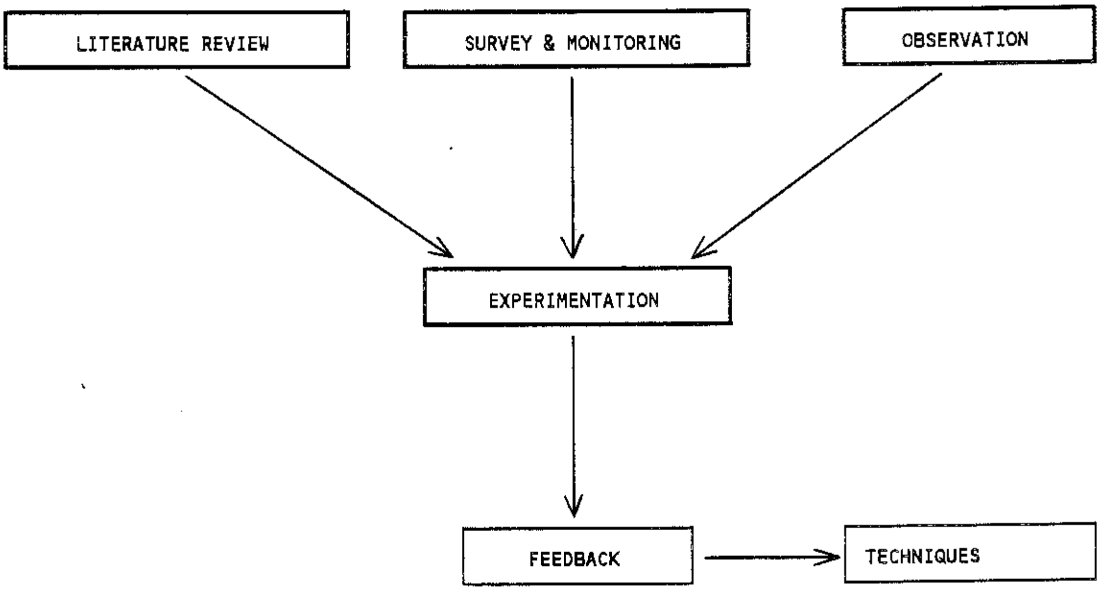

Figure 5: The relationship between experimentation and other methods of evaluation. Experimentation clearly has a secondary role, requiring information from earlier evaluations.

So, the result of the single trial might indicate what would happen if it were tried elsewhere or it might not, we have no way of knowing which. A perfectly good technique could be rejected as worthless, or a poor technique could be accepted because it produced the desired result on a single occasion. This problem is accentuated with biological material and with soils because they can both be very variable. The solution is to do the experiment more than once; to replicate it. The whole experiment must be done several times; replicating sampling within each treatment is not good enough (though it provides a more precise estimate of the plot than a single sample), the experiment has still only been done once (Figure 6). If there is any doubt as to how an experiment should be designed or analysed then consult a biometrician or statistician, but be very clear what you wish your experiment to tell you.

While the technical requirements of good experimentation effectively outlaw the unreplicated trial or 'look-see' experiment, there may be some value in this approach under certain circumstances. A preliminary, unreplicated, field-scale trial can be extremely useful in establishing the capabilities of equipment and revealing any operational and assessment difficulties, thus highlighting any problems that can be prevented or allowed for in the fully replicated experiment.

The majority of experimentation needs to be carried out in the field to ensure that the effects of treatments are assessed in the context of operational constraints, full-scale equipment, site conditions, etc. However, field-scale experiments involve considerable commitment of land, time and finance. Consequently, experimentation should only be undertaken when the other evaluation methods indicate a real need.

The results of well-designed experiments should influence management techniques (Figure 5). However, the real test of any technique established by experiment is its general performance in the field where it may be subject to a wide range of modifying influences. This can only be determined by observation of field practice, and monitoring of field performance.

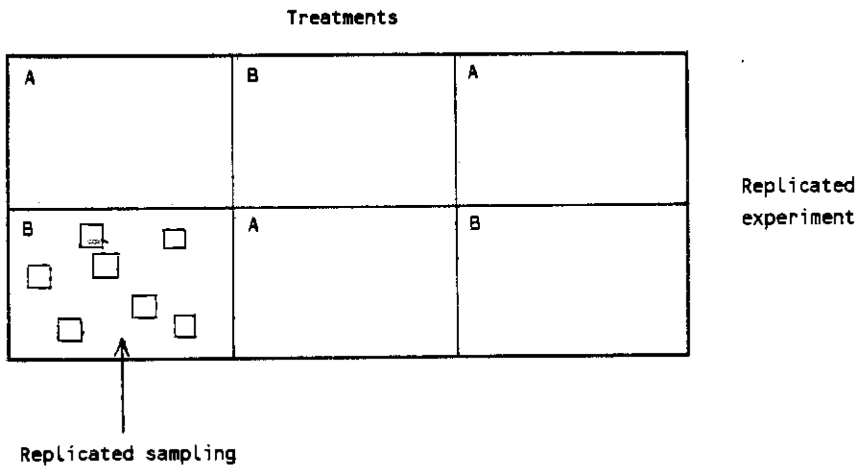

Figure 6: **A simple experimental design with two treatments A and B contrasting the replication of experiments and the replication of sampling.**

INTEGRATION

The four methods outlined here for the evaluation of management techniques can be divided into two groups. Primary methods are those that should be employed in the evaluation of currently-used techniques, and for obtaining background information prior to using the secondary method, experimentation. Experimentation is expensive and technically demanding. Its use should be reserved for those occasions when management innovations are required, and all other possibilities for evaluation have been exhausted.

The relationships between management techniques, practice, evaluation methods and feedback are summarised in Figure 7. The flow of information is purposely shown as circular and therefore never-ending as, even when a particular technique is known to be satisfactory, a certain level of monitoring and supervision (observation) has to be maintained.

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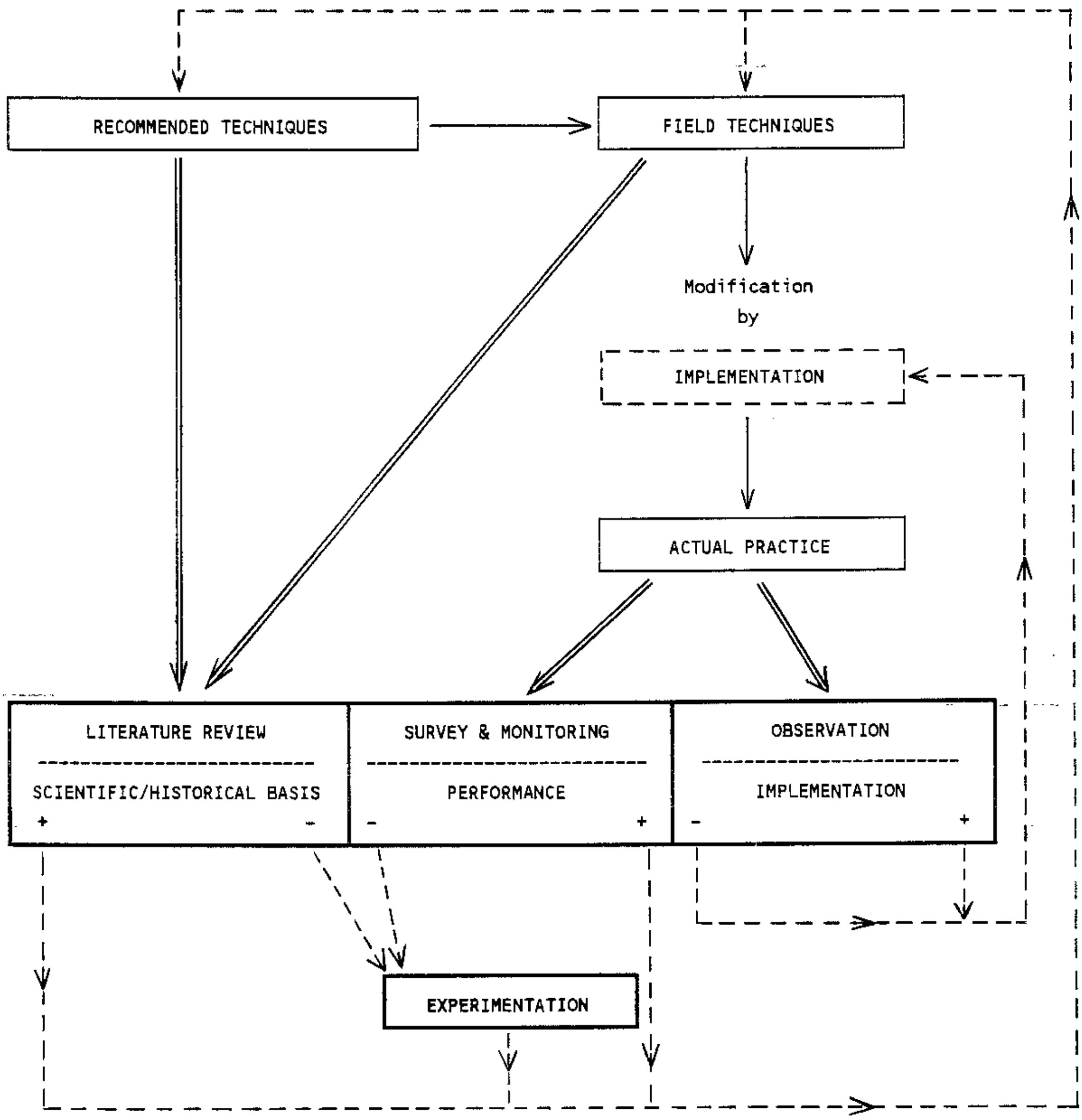

Figure 7: **Integrated model of the relationships between management techniques, practices (light boxes), implementation (broken box) and evaluation methods (heavy boxes). Arrows represent the flow of information:**

⟶ establishment and modification of techniques

⟹ evaluation

- - - -> feedback

+ and - represent satisfactory or unsatisfactory outcome of the evaluation.

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Monitoring of vegetation

T A Rowell

THE PEATLAND MANAGEMENT HANDBOOK

Monitoring of vegetation

T.A. Rowell

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INTRODUCTION

Monitoring of vegetation is the repeated recording of some relevant aspect of the constituent species, such as relative abundance, with the aim of detecting change.

Monitoring is normally carried out for one of several purposes within the context of nature conservation.

* As a routine 'alarm system' (Smith, Wells & Welsh 1985) to alert the site manager to any sudden change in vegetation that may require investigation into cause, and/or remedial management action. This type of monitoring requires comparisons of data with some established standards.

* To identify changes related to known interference, whether it be a planned alteration in management practice, or some newly perceived threat. Again, established standards are required if useful comparisons are to be made.

* As a means of detecting the normal pattern of background change.

While monitoring is necessary in any habitat, there are some special problems involved in monitoring vegetation on peatlands. This part of the Handbook provides solutions not only to these particular problems, but also tackles some of the more general difficulties of monitoring vegetation. Some simple statistical techniques are given which allow basic analysis of monitoring data.

Minimum requirements of a monitoring scheme

Monitoring schemes provide overviews of the condition of a site at points in time. These overviews should be accurate enough for conclusions about change to be made with confidence. It seems needless, therefore, to have to state that **any monitoring scheme must be capable of detecting change**, but the point needs to be made strongly, and heeded. In many past schemes, great difficulty has been experienced in determining whether apparent changes are real rather than due to error. An aim of this document is to develop methods which give the greatest possible chance of achieving this on peatlands, and many of the points discussed will have equal relevance in other habitats.

Further desirable qualities of most monitoring schemes are:

* The results of the monitoring should be applicable to the wider vegetation.

* It should be possible to relate observed change to some probable or known environmental change.

* A chain of communication should be established before any monitoring work is done so that effective responses can be made to any significant changes as and when they are detected.

LEVELS OF MONITORING

Much of the monitoring of vegetation that is done at present is based on assessment and re-assessment of permanent quadrats. As will become clear in the discussion below, to execute this type of monitoring properly requires considerable resources and attention to detail. In many cases, the required level of resources is not available, and simpler methods will be more appropriate. Rather than attempt to implement a cut-down version of permanent quadrat monitoring, which will not be able to give a good overview of a site, other approaches are recommended. Less resource-hungry methods are suggested below (termed 'Level 1' and 'Level 2' monitoring), but the main body of this document is concerned with developing an approach to sample-based methods of the more exacting kind ('Level 3').

The levels of monitoring recognised and discussed below are, in order of resource requirement:

Level 1: Frequent and regular fixed-point photography and site notes (including damage, loss, and evidence of Potentially Damaging Operations), supplemented by 'opportunist' aerial photographs.

Level 2: Infrequent but regular aerial photography and vegetation survey to determine community boundaries.

Level 3: Detailed examination of vegetation at frequent and regular intervals by rigorous sampling to obtain suitable for statistical comparison with previous datasets or some agreed standard. This level also includes monitoring of populations of individual species where necessary.

These levels of monitoring are not intended to be mutually exclusive. All conservation sites should receive Level 1 monitoring, whether or not they are being examined in more detail at a higher level. So, for example, a site where detailed Level 3 monitoring is being done, presumably for some special purpose, should also be monitored at both Level 1 and Level 2.

Level 1

Basic information

Any obvious environmental factors likely to influence the site should be included in records made during Level 1 monitoring. Important factors are grazing, burning, mowing, water regime, and any possible sources of pollution. Some guidance on recording these factors is given below (see p 40).

Any damage to the site, any loss of habitat, or any evidence of a potentially damaging operation (these are notified for SSSIs) should be noted. Any incidence of these should be reported. Records should always be made of visits where no adverse factors were noted.

Although this type of monitoring provides only very basic information about the status of a site and its vegetation, it does provide an opportunity to maintain contact with site owners and occupiers.

Fixed-point photography

Where resources are severely limited, a restricted level of monitoring can be achieved quite simply by taking fixed-point stereo-pair photographs. The value of fixed-point photographs in detecting change in the landscape has been proven (e.g. Sheail, 1980), and stereo-pairs aid interpretation to a remarkable degree. The photographs should be views of the site taking in all its major features, covering as much ground as possible. Elevated vantage points are particularly useful.

The taking of stereo-photographs requires no special equipment other than a camera, though a wide-angle lens and motor drive are useful. These are available cheaply as they are built into many compact cameras. Stereo-photographs are simple to take, and techniques are detailed below (see p 39). Fixed-point photography is discussed by Smith, Wells & Welsh (1985). The marking and relocation of fixed points is discussed below (see pp 29 - 31). An important aid to interpretation of fixed-point photographs is the inclusion in the frame of some standard item, such as a building, as a reference point. If a permanent reference point is not available, then a temporary one in the form of a ranging pole can be placed at each visit in the same position in relation to the fixed-point.

Photographs should be developed as quickly as possible, carefully labelled with site, code number of fixed-point, time, and date. Some cameras will record the date onto each frame of a film, and this feature could be useful in reducing both the burden of labelling and the possibility of error.

As with all monitoring records, two copies of each photograph should be made, each set being stored under cool, dry, dark conditions at two separate locations. The cheapest means of obtaining two sets of prints is to take advantage of processors' offers on reduced price second sets. For slides, it is cheaper to take duplicate frames rather than make copies.

Sets of photographs should be examined immediately after receipt from the processor. For maximum contrast, comparison should be made between the most recent set and the earliest, noting any relevant changes such as relative vegetation height (the reference point is important here), relative amounts of identifiable species, and community boundaries. The resources required to make these regular comparisons should be recognised and built into the work program alongside the monitoring visits themselves. Any obvious changes on the site should be reported to the site manager or other designated authorities.

Aerial photography

Level 1 monitoring should be supplemented whenever possible by the purchase and examination of aerial photographs covering the site. Regular contact with organisations that either fly or commission aerial surveys should provide some cover for the cost of prints alone.

Frequency of Level 1 monitoring

Level 1 photography and recording should be carried out at least annually. For SSSIs basic recording should be done on an interval of less than six months, allowing time for action if the site has been damaged or if there is evidence of a potentially damaging operation.

Review of Level 1 schemes

The findings and progress of Level 1 monitoring schemes should be reviewed and reported on every five years. Copies of the reports should be lodged with the photographic and other records.

The review should include not only the information collected during formal monitoring, but also any other records made during the five year period, including visits by any officers for purposes other than monitoring. Also of relevance will be the opinions of any other knowledgeable and regular visitors to the site. The object of the review should be to **re-assess the status of the site** from all the available evidence.

The value of such a review is limited unless a pre-planned chain of communication has been established that will ensure that action will be taken if the review (or, indeed, any individual monitoring visit) indicates adverse trends on the site.

Level 2

The aim of Level 2 monitoring is to attempt some degree of direct recording of vegetation so as to determine community type and boundaries, without the detail required at Level 3. Level 2 monitoring should therefore allow the logging of gross changes; these will tend to lag well behind environmental changes so that remedial action will have to follow directly upon the detection of significant change if it is to have much chance of success.

The problems of defining significant change will be a recurring theme in this document. There are no clear guidelines for Level 2 monitoring of peatlands, but the following are offered on a provisional basis.

* Gross and indisputable boundary changes should be acted upon.
* Suspected boundary changes should be reported and investigated further.
* Large community shifts (e.g. from one NVC sub-community to another) should be acted upon.
* Where difficulty in interpretation arises, consult the NCC's Peatland or Fen Specialist.

Level 1 monitoring is an important supplement to Level 2 monitoring, providing important supporting information particularly on the structure of vegetation. It also creates an opportunity for an essential annual link with the site that would be missing if monitoring was at Level 2 only.

Many of the aspects of organisation and record keeping discussed below under Level 3 monitoring also apply to Level 2.

Ground survey

Level 2 monitoring on peatlands is basically the repetition of an NCC Phase 2 type survey at regular (though not necessarily frequent) intervals. Organisations outside the NCC might prefer to follow some survey technique of their own, or the National Vegetation Classification method. Whichever method is selected, the primary aim is to determine the types and boundaries of plant communities. Community type should be determined to, for instance, NVC sub-community level. Particular attention should be made to the determination of boundaries as one of the major features identifiable at this level is the movement of vegetation boundaries.

Air photography

In addition to ground survey, regular air photography, is also necessary for Level 2 monitoring. Ideally, infra-red film should be used, and the timing of the aerial survey should coincide as closely as possible with the ground survey. Community boundaries should be plotted onto photograph overlays. The photographs provide support for the findings of the ground survey, and a visual basis for later review.

During each survey, community types and boundaries should be compared with those determined on the previous survey. Resources for this must be allowed for during the field visit so that any apparent changes can be verified in the field. After the survey, photographs from the aerial survey should be examined for evidence in support of the findings of the ground survey.

Frequency of Level 2 monitoring

Level 2 monitoring should be carried out at relatively infrequent intervals of, perhaps, five to ten years. While fixing intervals for Level 1 or Level 3 monitoring depends on considerations other than resources, the frequency of Level 2 monitoring is likely to be influenced by the availability of funds for aerial photography and ground survey.

Review of Level 2 schemes

A review of each site under Level 2 monitoring should be made immediately after every visit. The review should take the same form as the Level 1 review discussed above, and should include all Level 1 information. The main aims should be to re-assess the status of the site and to examine the effectiveness of monitoring, recommending changes if necessary.

The results of the review should be reported *via* the chain of responsibility established to ensure that they are acted upon. Copies of the report should be lodged with the monitoring records.

Level 3

The remainder of this document discusses Level 3 monitoring, the frequent and regular examination of samples of vegetation to detect the details of directional change and background fluctuations, and to detect ecologically significant change from some pre-determined standard.

PROBLEMS IN LEVEL 3 MONITORING

The problems of Level 3 monitoring receive considerable casual discussion, but it is not easy to find detailed, practical guidance in the literature. Peterken & Backmeroff (1988) provide a most useful review of some real woodland schemes, drawing a series of conclusions from the problems encountered. These are often equally applicable to peatlands. While they recognise that the data from many schemes are difficult or impossible to analyse in a statistical sense, the important point is made that they do provide information about real pieces of vegetation, which can be related to the remainder of a site by modern sampling methods. For many purposes, however, it is preferable to have a method that provides reliable data immediately referable to the site as a whole.

Pre-determined standards

If the quality of conservation sites is to be maintained, then not only must the attributes of quality be recognised but the problem of what constitutes a significant change in those attributes must also be tackled. Simple techniques for detecting statistically significant change are dealt with here, and these help us avoid the mistake of making incorrect deductions from information we have collected. Ecologically significant change is completely different and requires some definition within the context of nature conservation (e.g. the loss of features which made the site worthy of conservation; change other than normal successional or background change; etc). Notwithstanding definitions, from a practical standpoint we need to know when a change is great enough to require expenditure of resources to halt, reverse or re-direct it, and when it is too great to be amenable to intervention.

At present, solutions to these problems do not exist. Information needs to be gathered from monitoring and management projects before they can be formulated. Ideally, studies should be made that compare damaged with undamaged sites, preferably beginning before damage occurs. Any queries over the interpretation of changes noted during Level 3 monitoring can be addressed to the NCC's Peatland and Fen Specialists.

Consistency of method

A variety of methods are used for assessing similar peatland vegetation across the country. On occasion, variation in method even exists within groups of sites monitored by the same individuals. An inconsistent technique makes comparison of results between sites difficult, and so reduces the chances of developing generalisations from a group of similar studies. A standard method for Level 3 monitoring of peatlands would have obvious benefits.

Methodology and interpretation

A standard method for monitoring grassland vegetation has been discussed and developed by Smith, Wells & Welsh (1985). While a wide range of problems are addressed and useful solutions found to many of them, a number of items remain unresolved and, of course, peatlands present special problems of their own. Some of the problems arising from the account of grassland monitoring, and from the special problems of peatlands, are listed below.

* The difficulties of defining ecologically significant change in vegetation require urgent attention.

* The analysis and interpretation of permanent quadrat data receives little attention in the grassland method. The possibility of analysis of data by the use of multivariate techniques is mentioned, but no guidance is given. Similarly, the problem of detecting and differentiating directional and cyclic change, i.e. long term increases or decreases, and short term fluctuations, is not addressed.

* Permanent quadrats have the advantage that they virtually eliminate sampling error (provided a repeatable quantitative approach is taken), but they have two, linked, disadvantages.

    (i) They cannot provide an unbiased estimate of change in the wider vegetation.

    (ii) Changes observed during different time periods may be correlated, so inviting spurious interpretations (see below).

* Permanent quadrats on wetter peatlands are subject to an excessive amount of repeated damage by the observer, which may cause changes in the vegetation that will be difficult to distinguish from other changes. The installation of permanent markers and boardwalks (for the protection of permanent quadrats) can also induce change .

* Cover-abundance scales (e.g. DAFOR, Domin) are often recommended for the assessment of monitoring samples. More detailed techniques are frequently rejected as too time-consuming. Cover-abundance scales are, however, useless if they are incapable of detecting change that can be differentiated from apparent changes due to error. They have consistently been shown to be inaccurate (e.g. Grieg-Smith, 1983; Kennedy & Addison, 1987; Sykes, Horrill & Mountford, 1983), and require a heavy input of training, calibration and monitoring of observers.

- The complement of assessors frequently changes from season to season, so there is likely to be significant inconsistency in application of the monitoring methodology. This will be particularly so where subjective assessments are made (e.g. deciding whether a borderline species is in or out of a quadrat; application of cover-abundance scales). Smith Wells & Welsh (1985) indicate that observer bias is 'smoothed out' after several records have been made. This means that it takes several years to obtain a reliable record of the vegetation. A similar period would also have to elapse before deciding if an observed change is real rather than due to bias. In any case, observer errors due to misidentification and failure to spot small plants are systematic rather than random, and are therefore little reduced by averaging (Kennedy & Addison 1987).

- The one metre square quadrat appears to predominate in monitoring schemes, and is recommended for grasslands. Unfortunately, it is unsuitable for monitoring sensitive or tall plant communities on a permanent quadrat basis, as either the vegetation will be damaged by the observer, or all sides of the quadrat will be damaged, or the far side of the quadrat will be inadequately recorded. It is also difficult to log all the species in a large quadrat unless it is well sub-divided.

In reviewing some recently established monitoring schemes, several potential problems become obvious. Frequently, the monitoring method is based on survey techniques, with quadrat size based on National Vegetation Classification methodology, and assessed by cover-abundance scales. Survey techniques are usually designed to census, as far as possible, all species, and to gain a reasonably accurate, but not necessarily precise, estimate of relative abundance. Fine differences are often not important in survey, and experience plays a large part in evaluation of the results. **Level 3 monitoring need not involve all species in a community**, and must provide very precise estimates of relative abundance so that changes can be identified with confidence. Estimates need not necessarily be accurate assessments of the wider community, although clear advantages result if they are.

Within this framework of problems and constraints, an attempt has been made to devise a standard methodology for Level 3 monitoring on peatlands that will produce useful results. Most of the conclusions have been based on past experience but, inevitably, some of the decisions leading to recommendations have been somewhat arbitrary. Future experience within these guidelines will help resolve any difficulties.

INITIAL CONSIDERATIONS IN LEVEL 3 MONITORING

Survey

The establishment of an alarm system type of Level 3 monitoring system should be preceded by a full Phase 2 survey. Establishment of the Level 3 monitoring system should follow immediately.

Monitoring for management

Where management changes are planned, it is essential that a suitable Level 3 monitoring system is set up before they are implemented, to establish the initial condition of the vegetation. Any existing monitoring scheme will rarely be adequate as it will be designed to monitor across a site, rather than be concentrated in new management areas.

Monitoring of vegetation following management changes is not an adequate substitute for a pre-planned and properly designed experiment. Any changes noted in a monitoring scheme must be regarded as particular to that individual area of vegetation, and more general conclusions cannot be drawn without considerable additional evidence.

Monitoring for changes due to new threats

Monitoring schemes to trace possible damage from newly perceived threats will often have to be established in haste. The Phase 2 survey and any alarm system monitoring scheme will obviously form a good basis, but additional Level 3 monitoring will need to be established with reference to the nature of the threat and the probable extent of its influence.

Different types of threat can be recognised and need separate consideration for monitoring. Some, such as grazing, may have quite even effects but others will have a distinct gradient of effect spreading either in all directions from a point source, or in one direction perhaps on a prevailing wind or following water movement. Location of samples should reflect this.

Key species

For any particular site, or section of a site, a small group of species is likely to be indicative of the general condition. There is little reason, in many cases, to monitor the full complement of species found in quadrats. For example, *Sphagnum* spp will be important on bogs; their relative abundance being an indicator of wetness and nutrient status. Changes in species abundance will, however, tend to lag behind environmental changes and observers should be aware of this point.

The following notes on potential indicator species for bogs have been provided by R.A. Lindsay. Some information for fens should be available at a later date.

Aulacomnium palustre: increases suggest enrichment (in a permanent quadrat, this may be due to very local deposition of dung).

Betula spp: increases suggest drying out.

Calluna vulgaris: increases suggest drying out of the site or, on occasion, reduced grazing.

Carex panicea: increases suggest that more bare peat is being exposed (often somewhat flushed) probably resulting regular or bad burning in a wet climate.

Cladonia spp: increases suggest drying of the surface.

Deschampsia flexuosa: increases suggest regular burning in N. England.

Drosera spp: decreases suggest a falling water table.

Erica tetralix: increases suggest a rising water table if the dwarf shrub layer was originally dense, or a falling water table if the dwarf shrub layer was originally absent.

Eriophorum angustifolium: increases suggest a rising water table.

Eriophorum vaginatum: in England and S.W. Scotland increases result from regular burning or drying out of the site.

Hypnum cupressiforme: increases suggest drying of the surface.

Molinia caerulea: increases suggest increased water movement, more flushing and less stagnation.

Narthecium ossifragum: increases suggest increased water flow/oxygenation.

Odontoschisma sphagni: increases over *Sphagnum* suggests drying out.

Pinus sylvestris: increases suggest drying out.

Pleurozium schreberi: increases suggest drying of the surface.

Polytrichum commune: increases suggest enrichment.

Polytrichum juniperinum: increases suggest burning.

Racomitrium lanuginosum: increases suggest drying of the surface.

Rhynchospora alba: increases often result from trampling as it shows a preference for wet, bare peat.

Sphagnum compactum: increases suggest drying out and burning.

Sphagnum cuspidatum: decreases suggest drying out of hollows and pools.

Sphagnum imbricatum/Sphagnum fuscum: decreases suggest burning.

Sphagnum papillosum/Sphagnum magellanicum: decreases suggest drying out.

Sphagnum recurvum: increases suggest enrichment or recovery from peat cutting.

Sphagnum rubellum: increases at the expense of other species suggest drying out.

Sphagnum subnitens: increases suggest flushing.

Sphagnum tenellum: increases suggest recovery from fire or from a dry surface.

Trichophorum cespitosum: increases (particularly of the tussock form) suggests increased burning.

Vaccinium oxycoccos: decreases may suggest drying out.

PLANNING FOR LEVEL 3 MONITORING

Considerations

Before establishment of a Level 3 monitoring scheme, a great deal of planning is required. Aspects to consider are listed in Tables 1, 2 and 3. These tables can be used as check lists for the planning of monitoring projects.

Table 1: Aspects of monitoring schemes that require consideration during planning and at various other stages (* indicates items to be considered at the beginning of a monitoring study; ** indicates items that need to be considered prior to each site visit).

*	Aims of the study.
*	Range of the study (e.g. species/communities to be included. whether some species are to be lumped into genera).
*	Levels of change regarded as undesirable if 'alarm system' is to be set up.
*	Variability of the populations to be monitored.
*	Type of data to be collected, and method of collection.
*	Method of data analysis and interpretation.
*	Pattern and approximate location of samples.
*	Appropriate number of samples required to detect significant change.
*	Appropriate size and shape of quadrats.
*	Frequency of sampling.
*	Timing of sampling.
*	Methods of marking and re-registering quadrats.
*	Methods of protecting areas around permanent quadrats from the effects of the observer.
*	Ensuring vegetation in permanent quadrats, or changes noted in permanent quadrats, are reasonably representative of the vegetation as a whole - if not, then be aware of the limitations of the results.
*	Course of action if significant change is noted (i.e. chain of responsibility).
**	Training of assessors.
**	Control of observer error.
**	Production of standard forms for data collection and data management.
**	Provision of maps, statements of aims and methodology, and copies of previous data.
**	Resources required (time and equipment (see Tables 2 and 3)).

Table 2: During planning of monitoring schemes, time should be allowed on-site for the following items.

Relocation of quadrats.

Assessment.

On-site training where necessary.

Re-marking of quadrats and/or reinstatement of grid.

Assessment of error, and re-checking of quadrats where necessary.

Slower working in poor weather conditions.

Any additional monitoring e.g. site inspection, hydrology, Level 1 monitoring photographs, etc.

Table 3: Equipment required for monitoring includes the following items.

Paperwork (maps, aims/methodology, data sheets, copies of previous data), ideally on waterproof paper

Handbooks, sample bags and equipment for species identification

Standard quadrats, sub-divided if necessary

Stock of replacement canes/marker posts

Compass and ranging poles (for relocation of lost quadrats)

Camera with wide angle lens and, if taking stereo-pairs, a motor drive

Colour film for slides or prints as preferred

Means of reducing damage to side of quadrat, e.g. ladder/duck boards

Means of marking posts/canes, e.g. marker pens, paint

Checklists of equipment for the entire trip, and for use on each individual site.

Off-site training of assessors

Before any field work is undertaken, team leaders should satisfy themselves that all team members are fully conversant with the aims and methodology of all monitoring schemes requiring assessment. Each team member should be supplied with a **site pack** of details and maps. Notes should be made of any unfamiliar species so that adequate field training can be given before any assessments are made. Assessors should be made familiar with any equipment or techniques they will be expected to use, e.g. cameras, stereo-photography, before they try to use them in the field.

Measures of relative abundance

During monitoring, any convenient measures of vegetation can be made. It is essential, however, that any measures of relative abundance can be made with a good degree of precision, not only on the first but on subsequent occasions. Cover-abundance scales have already been rejected as inadequate for this type of work, and must be replaced with a method that is more precise, repeatable, and amenable to mathematical manipulation.

Cover, assessed as frequency of hits by **point quadrats**, is an attractive alternative as the data obtained are easily analysed, and number of quadrats required can be determined without reference to the vegetation. Furthermore, information is collected much more efficiently than by measures of abundance. Point quadrats have the disadvantage of difficulty of use in tall vegetation which is easily lodged or moved by a slight breeze.

Density, the number of individual plants per unit area, is an important measure particularly if populations of individual species are being monitored (see p 39). Density can, however, be discounted for routine monitoring as it is time-consuming to implement, and inappropriate for many species particularly bryophytes.

Frequency, measured simply as presence or absence of species within a quadrat, retains the advantages of point quadrats, without their major disadvantages. Moreover, frequency measures are obtained relatively rapidly, with several species being recorded for each placement of a quadrat. Frequency is not, however, a simple and obvious measure of abundance. A species that was present in 25 out of 50 quadrats examined would have a frequency of 50%, indicating that there should be a 50% chance of finding the species in any one quadrat examined, i.e. it is a measure of distribution.

When ecologists refer to frequency they mean, unless stating otherwise, **rooted frequency**, i.e. the frequency of species rooted within the quadrat. It is also possible to measure **shoot frequency**, where those species with any aerial shoots within or overhanging the quadrat are recorded. Both measures have advantages, but rooted frequency will result in far fewer difficult decisions and is therefore recommended for speed and accuracy. It is a measure that can give slightly misleading information without supplementing as, for instance, when a large plant rooted outside the quadrat covers most of the quadrat with its foliage thus excluding other species. Supplementary information (see pp 33 - 35) provides sufficient detail to interpret this type of data. Assessors must be made aware of which measure they are to use. Instances have been noted of both measures inadvertently being used within one scheme.

Frequency can be measured as presence/absence in each quadrat placed, so that frequency is given as a score out of the total number of quadrats examined (or as a proportion). Alternatively, presence/absence can be scored in sub-divisions of a quadrat to give a frequency measure for the single quadrat, so-called **local frequency**.

Frequency data can provide additional measures and information. The number of species recorded in each quadrat can be averaged across a suite of quadrats to give the mean number of species per unit area, a measure of **species richness**. The total number of different species recorded from the quadrats is another useful measure. Sub-divided quadrats can provide small-scale species maps which are a useful visual supplement to the numerical data.

Frequency has a possible disadvantage. It is conceivable that the density of a species could change and its frequency remain stable because its distribution is unchanged relative to the size of quadrat being used. Small quadrats are less likely to suffer from this problem than larger ones; the use of **nested quadrats** is a good solution. In nested quadrats, frequency is recorded in a series of frames placed one inside the other (Figure 1). Obviously, species recorded in the smaller quadrat are automatically included in all larger ones, and so on, so recording can still be rapid.

The relative ease of collecting and processing frequency data make it a highly recommended method for monitoring vegetation. Discussion of methods of data analysis below (see pp 18 - 26) assume that frequency is the measure used, though the methods are also directly applicable to cover measured by point quadrats.

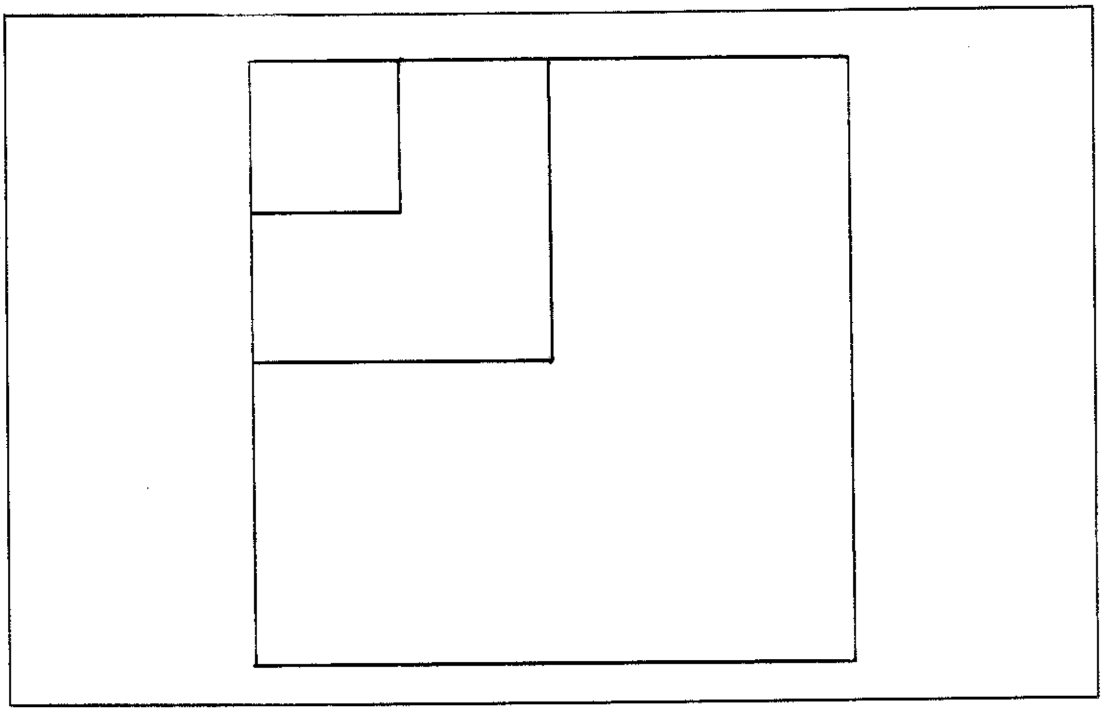

Figure 1: Nested quadrats can be used if there is uncertainty about the most appropriate size.

Methods of assessment

Three basic methods are likely to be considered for Level 3 monitoring of vegetation.

Permanent quadrats

Permanent quadrats have been favoured in most studies of change. They have the important advantage of reducing or eliminating sampling error, and provide a tangible point of reference for the demonstration of change. They can also be placed to monitor particular key species, or some other aspect of interest. However, the disadvantages are potentially great. Changes noted in permanent quadrats cannot be regarded as estimates of change in the wider vegetation, even if the quadrats are themselves regarded as providing good estimates of the vegetation itself (Goodall 1952). Moreover, any change noted over one period may be correlated with change in another period (Goodall, 1952). In other words, a quadrat or suite of quadrats may, by chance, show a large change in, say, bare ground when the wider vegetation shows no change or a decrease. As permanent quadrats are not redistributed (i.e. the vegetation is not independently sampled on each occasion), similar directional change is likely to be recorded on a further occasion, reinforcing the earlier conclusion. This problem can be overcome by redistributing the quadrats after the second assessment so that, after the very first assessment, two suites of quadrats are assessed at each visit. If significant changes are noted in permanent quadrats, then the observer needs to satisfy himself that they reflect change in the wider vegetation. This may require a program of restricted random sampling.

Random quadrats

The placement of a suite of random quadrats at each visit to a site is a means of obtaining unbiased samples. Random quadrats are, however, subject to large sampling errors because they are not necessarily well dispersed across a site. Areas of concentration and under-representation can change from assessment to assessment, so that spurious differences may be deduced. Random samples may be, but are not necessarily, representative of the vegetation as a whole. Similarly, the differences between random samples may be, but are not necessarily, representative of changes in the vegetation as a whole.

Restricted random quadrats

To obtain a more even distribution of quadrats while retaining the unbiased nature of randomised quadrats, the site can be sub-divided into blocks and random samples taken in each. Blocks can be either the squares of a regular grid, or strata based on variation in, for example, vegetation, soil or topography.

Once the site has been stratified, samples are taken on a strictly random basis from each block. For ease of analysis blocks of equal size with an equal number of quadrats in each are useful.

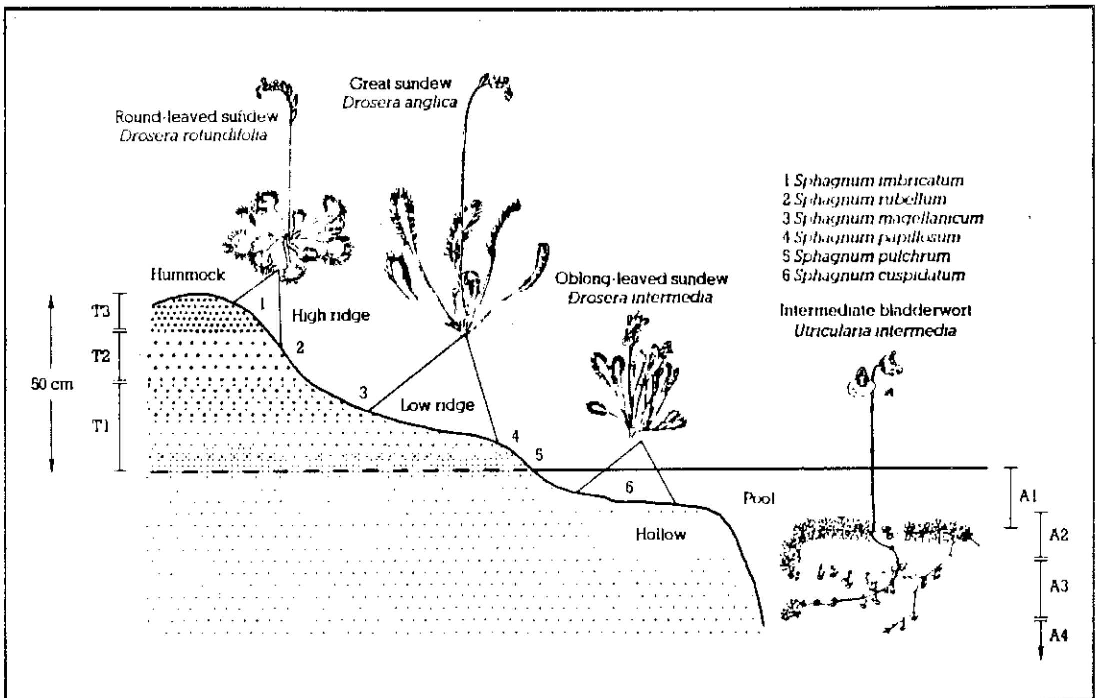

Figure 2: Microtopographical variation on bog surfaces (reproduced from Lindsay *et al.* 1988).

Special problems arise on patterned bogs with ridges and pools providing micro-topographical variation which is reflected in small-scale and predictable variation in the plant community (Figure 2). The proportion of each micro-topographical zone, and the truncation of one end of the range or the other, are important diagnostic features of the condition of a site. Most monitoring schemes on patterned sites should take them into account and endeavour to represent them adequately. The zones can be accommodated by restricted random sampling using the method outlined below (p 35).

Quadrat size, shape, and subdivision

Large permanent quadrats are difficult to assess without damaging the quadrat area. Even placing a hand on the ground to support the body weight while examining the centre of a quadrat may make a significant depression in a soft peatland site. If non-permanent quadrats are to be used within a large stand of vegetation then a large quadrat is physically difficult to handle. For these reasons, the traditional one-metre square is discounted for peatland monitoring in favour of a half-metre square. To obtain a reading of local frequency in permanent quadrats, the frame should be partitioned into 10 x 10 cm subdivisions.

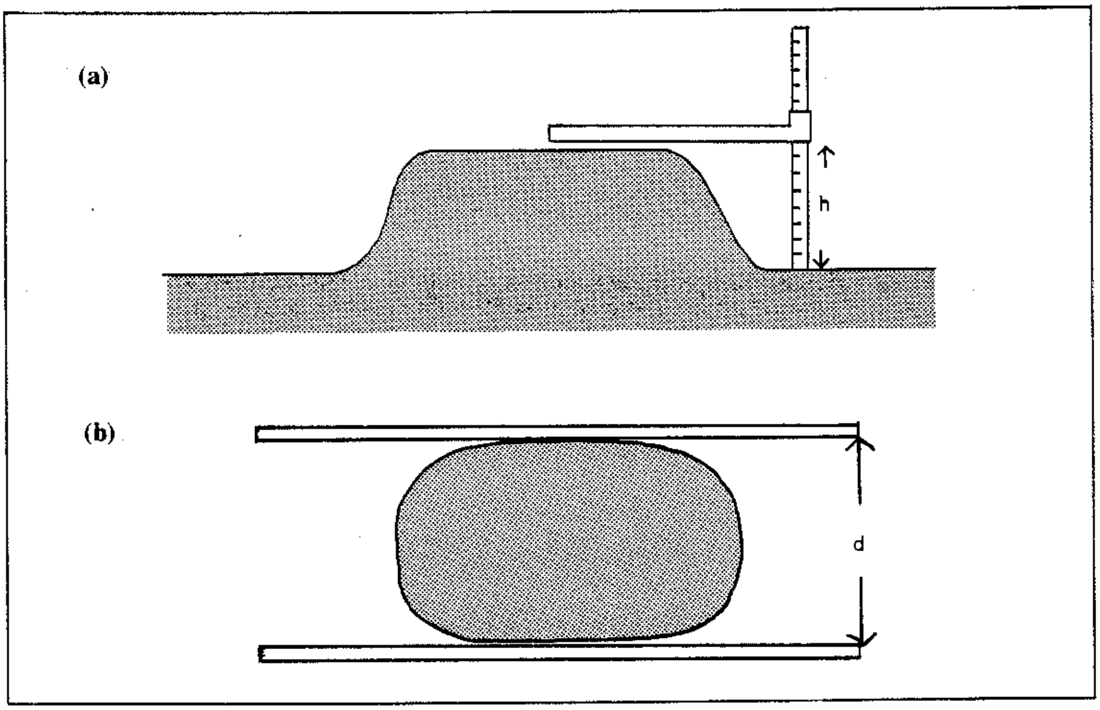

Figure 3: **Tussocks and hummocks can be measured using a sliding bar on a rule (a) for height (h), and two canes (b) to indicate maximum width and length (e.g. d) which can then be measured with a tape.**

Monitoring tall vegetation presents many difficulties. The damage caused by assessing permanent quadrats is excessive, and it is impossible to place a subdivided quadrat over the vegetation. With tall fen communities, it is frequently impossible to place any quadrat over the vegetation. In these circumstances, the permanent quadrat approach must be abandoned in favour of random or restricted random samples within a large defined stand. Damage-associated change is thus minimised, and the need for a subdivided quadrat is dispensed with. The problem of quadrat placement in tall vegetation can be solved by the use of a circular quadrat made of a length of flexible tubing which can be threaded through the base of the vegetation and joined to complete the sampling unit. To obtain the equivalent area of a half metre square requires a piece of tubing of 177 cm length. Because of the problems of handling this, it is recommended that the equivalent of a quarter metre square quadrat is used, i.e. a length of tubing of 88.5 cm. A similar method has been used successfully for monitoring fen vegetation in a management experiment (Rowell, Guarino & Harvey, 1985).

Large hummocks and tussocks are difficult to sample with standard sized quadrats. The problem can be solved by using the hummocks/tussocks as individual recording units defining their own boundaries. Aspects of growth, senescence or damage can be assessed by recording height and other dimensions using simple equipment (Figure 3).

Analysis of quadrat data

The aim of this section is to provide a range of very simple techniques which can be used for the exploration of monitoring data collected by the methods recommended here. More complex techniques exist, particularly for time series and in the field of multivariate analysis. On occasion, some of the simple non-parametric techniques may also prove useful.

<u>The whole community</u>

When data have been collected over time on a large number of species, it is difficult to visualise overall changes in the vegetation. Multivariate analytical techniques provide a means of reducing the complexity of the data so that a large proportion of its variability can be viewed in a simple diagram.

Multivariate techniques are most familiarly used to analyse spatial data, for instance in the separation of quadrats into similar groups representing, perhaps, communities. Ordination techniques allow the plotting of quadrats (or groups of quadrats, depending on how a sample is defined) onto a graph to show the relationships between quadrats/stands in terms of similarity of their botanical composition. Points on the graph which are close together are more similar than those which are far apart (Figure 4a). If successive observations are treated as in a similar way to spatial samples, then the same techniques can provide an analysis of the relationship between assessments (Figure 4b).

One possible technique for achieving this type of analysis is principal components analysis, often referred to by its initials, PCA. The analysis can indicate visually the relationship between years with the two axes of the graph representing the main components of variation that can be extracted from the data. It is possible (from the species weightings on the components) to ascertain the main contributors to the differences between assessments. The main contributors to variation between assessments can then be investigated further if the actual changes are regarded as potentially significant.

<u>Individual species</u>

Graphs (time series)

Data obtained by repeated visits to a site assessed by either permanent quadrats or random quadrats can be displayed graphically to give a visual representation of any changes that may have occurred. Two types of change are likely to be detected:

- Linear trends where relative abundance either increases or decreases more or less steadily.
- Cyclic fluctuations where an increase or decrease is matched by an opposite, subsequent trend (often referred to as 'background' changes).

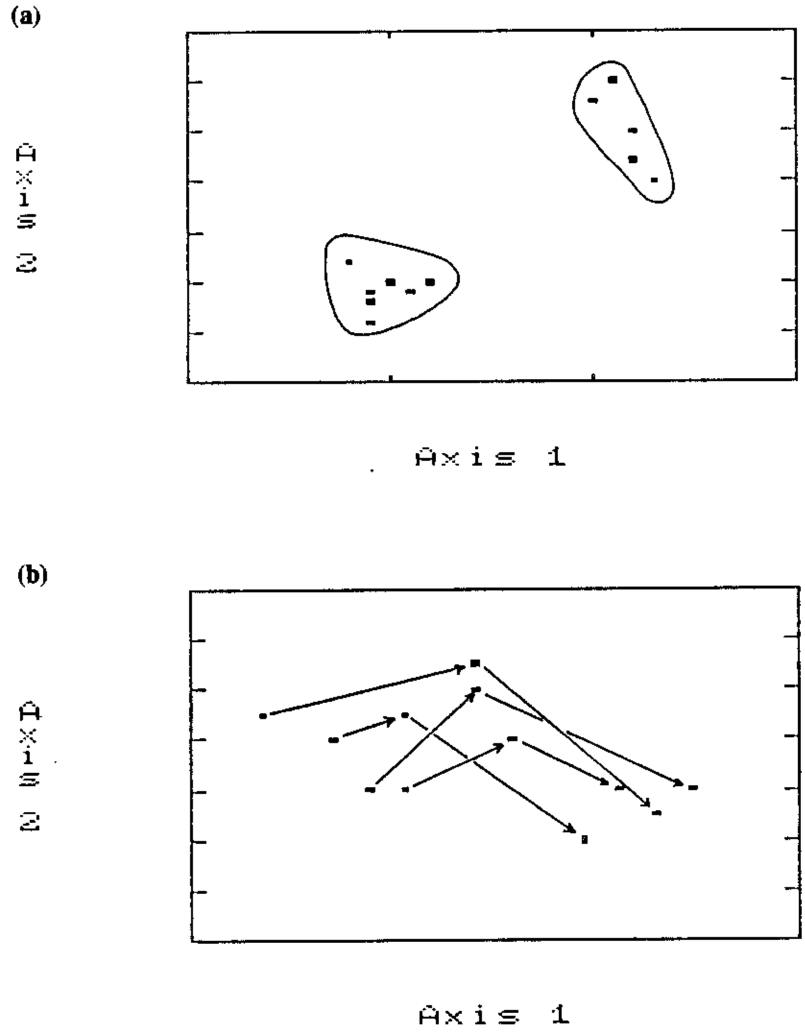

Figure 4: Ordinations are most usually used to display relationships between samples taken from different places at the same time (a); two groups of samples can be differentiated here. They can also show relationships between samples taken from the same place at different times (b); the arrows show the direction of change in composition of the samples.

Graphs[1] are only a useful presentation of monitoring data if a reasonable number of visits has been made, because graph lines invite the deduction of potentially spurious trends. Eight or more years data are probably required before a useful graph can be drawn. Even then, the investigator should beware of interpreting sections of cyclic trends as linear trends. The discussion below covers the display of change relative to the first monitoring assessment, and

1 Strictly, the style of graph should be a line graph (Figure 4), histograms being reserved for data relating to periods rather than to points in time.

the identification of linear trends and cyclic fluctuations. These methods can be used to display either abundance data for single species or values for species richness.

(a) Relative change

To display change relative to the first or some other assessment, **index numbers** can be used. The first visit or agreed standard for the site should be taken as the base point, and values for all other visits calculated as a proportion thereof (Table 4). Index numbers are independent of the initial magnitude of the data, so that relative rates of increase or decrease can be easily judged; an index number of 175 indicates a growth of 75% over the initial reading. This approach can be very useful for comparing species with very different levels of abundance, or data from two sites or sub-sites, but should only be used with large frequency values (perhaps 50+) resulting from the amalgamation of data from a number of quadrats.

Table 4: Frequency data obtained over several years, worked to provide semi-averages and three-year moving averages.

Year	Frequency	Index	Semi-averages	3-yr moving average
1970	216	100		
1971	192	89		193
1972	170	79		181
1973	180	83		183
1974	199	92	224.3	210
1975	250	116		226
1976	229	106		247
1977	261	121		271
1978	322	149	.... mid-point	282
1979	264	122		269
1980	220	102		251
1981	269	125		262
1982	297	138		267
1983	236	109	268.8	255
1984	231	107		248
1985	278	129		276
1986	318	147		301
1987	306	142		

(b) Linear trends

Linear trends are displayed by plotting a line calculated to minimise deviations of the data from the trend. The simplest method is to calculate a mean value for each half of the dataset (Table 4), and to draw in the line which connects them (Figure 5a); the use of **semi-averages.** A more rigorous method for obtaining a trend line is to calculate the equation of the **least squares line.** The line is then plotted by calculating two points, and joining them by a straight line (Figure 5b). The equation of the least squares line is calculated as follows.

Straight line graphs have the general equation $y = mx + c$, where x and y are variables, m is the gradient of the line, and c is the point where the line intersects the y-axis of the graph. The two constants m and c can be calculated from the observed values of y at different times.

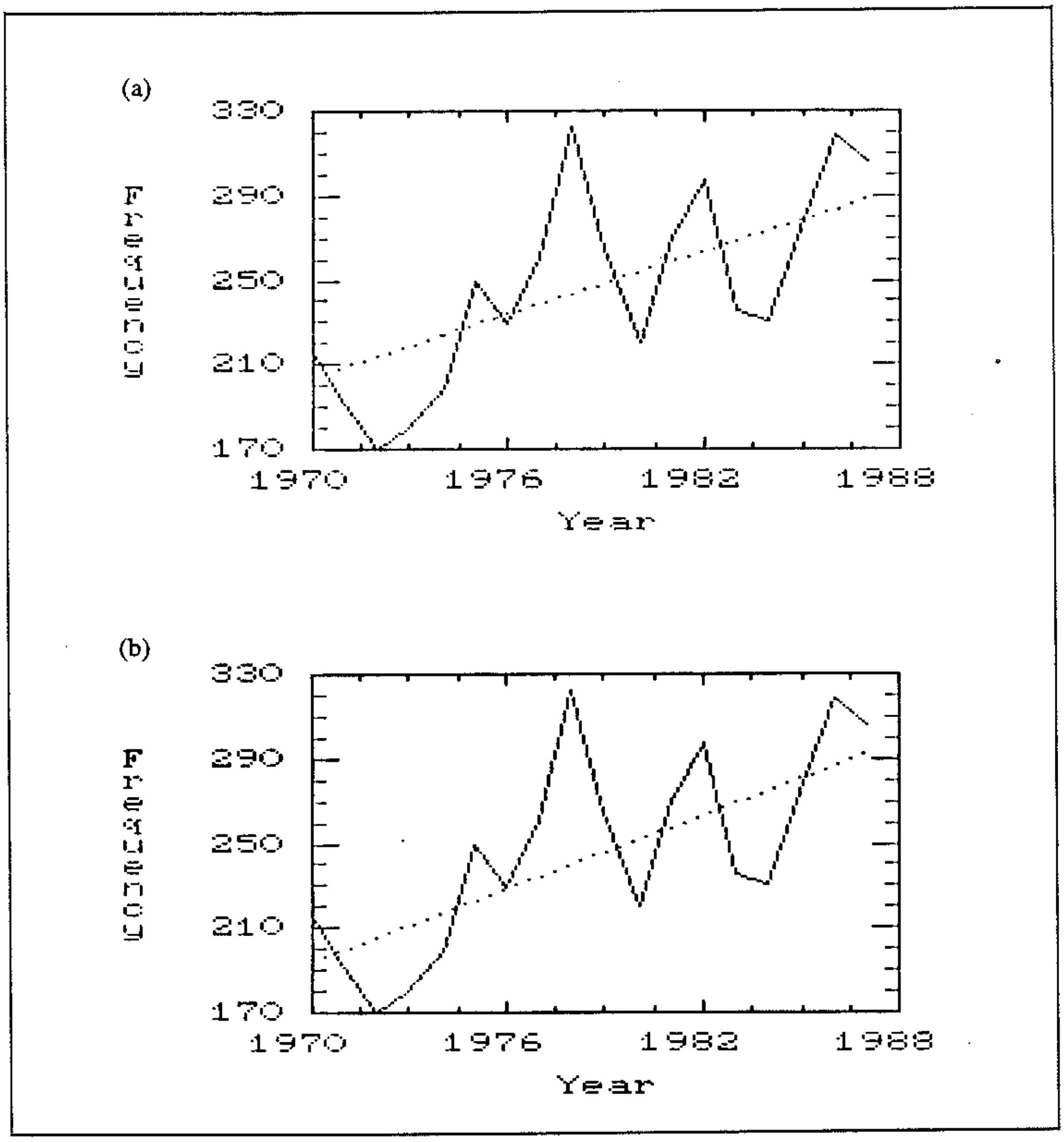

Figure 5: Trend lines can be calculated by the methods of (a) semi-averages or (b) least squares.

Referring to the data in Table 4, if the mid-point on the time scale is represented by $x = 0$, and the other equally spaced values by x = -1, -2, etc., and +1, +2, etc., as appropriate (Table 5), then m and c can be calculated as follows,

$m = \Sigma(xy)/\Sigma x^2$ = 2498/408 = 6.122

$c = \Sigma y/n$ = 4132/17 = 243.1

So that $y = 6.122x + 243.1$

To draw in the line of the equation, solve the equation for two values of x. For example when $x = 0$ (the year 1978) then y = 243.1, and when x = 5 then y = 273.7. Plot the two points, and connect with a straight line.

Table 5: Data from Table 4 worked for the calculation of the equation of least squares. Data for 1987 has been ignored to simplify the example calculation.

Year	No. of years since mid-year (x)	Frequency (y)	x^2	xy
1970	-8	216	64	-1728
1971	-7	192	49	-1344
1972	-6	170	36	-1020
1973	-5	180	25	-900
1974	-4	199	16	-796
1975	-3	250	9	-750
1976	-2	229	4	-458
1977	-1	261	1	-261
1978	0	322	0	0
1979	+1	264	1	264
1980	+2	220	4	440
1981	+3	269	9	807
1982	+4	297	16	1188
1983	+5	236	25	1180
1984	+6	231	36	1386
1985	+7	278	49	1946
1986	+8	318	64	2544
Total		4132	408	2498

If the data involves an even number of years, then the coding of the years from the mid-point takes the form of ...... -2.5, -1.5, -0.5, +0.5, +1.5, +2.5 ......, otherwise the procedure is identical.

(c) Data smoothing

In addition to a trend, a dataset may contain a cyclic element which will often be difficult to separate visually from other fluctuations. If sufficient data have been collected, then a **moving average** can be calculated (Table 4) and plotted. The moving average reduces fluctuations (smoothing the data) and, provided the period selected for calculation of the average does not coincide with periodicity, cycles should be discernible (Figure 6).

These methods of analysing time series data provide useful summaries of monitoring data collected over a long period of time, and help to decide whether changes are linear or cyclic. In most situations, however, we need to know whether apparent changes are real, or a manifestation of sampling error or random variation. **To discern real changes, statistical comparisons must be made.**

Comparisons of means

(a) Permanent quadrats

Frequency data from permanent quadrats on peatlands should be obtained from readings of presence/absence in 10 x 10 cm sub-divisions of a 50 x 50 cm frame. Each permanent quadrat provides a single value for each species which can be used with values from other quadrats to calculate a **mean** and a **variance**. This mean can then be compared with the mean for a former or later set of quadrats. **Angular transformation** (see Appendix 1) should be carried out before analysis.

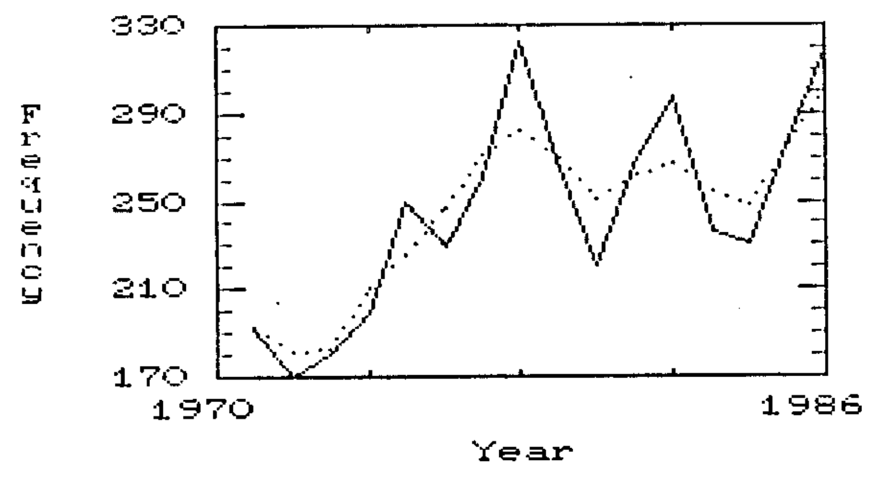

Figure 6: Plot of raw and smoothed (3 year moving average, see Table 4) frequency data.

Table 6: Sample data from a set of permanent quadrats sampled at times T_1 and T_2.

	Local frequency		
	T_1	T_2	Difference T_1-T_2
Quadrat 1	10	12	+2
Quadrat 2	16	20	+4
Quadrat 3	11	9	-2
Quadrat 4	21	25	+4
Quadrat 5	5	8	+3
Quadrat 6	18	15	-3
Quadrat 7	2	3	+1
Quadrat 8	10	10	0
Quadrat 9	17	22	+5
Quadrat 10	1	2	+1
Total	111	126	+15

Successive datasets obtained from a single subject should be treated as **self-paired samples** (Snedecor & Cochran 1967, p 91). Each successive dataset should be tested against the first dataset obtained to assess whether there has been any significant change since the monitoring scheme was established (Table 6). The **null hypothesis** to be tested is that the average difference between the two datasets (the quadrats at the first and later assessments) is not significantly different from zero. The appropriate test is a two-tailed **Student's *t*-test.**

Referring to Table 6, the mean difference between assessments at T_1 and T_2 is 15/10 = 1.5. For the test of significance,

t = Mean difference/Standard error of the mean difference

Standard error $= \sqrt{((\Sigma Di^2 - ((\Sigma Di)^2/n))/(n-1))}/\ n$

Where Di = difference T_1-T_2

n = number of differences = 10

So that $Di^2 = 85$

$\Sigma(Di)^2 = 225$

Standard error = 0.833

t = 1.800

t has $(n-1)$ = 9 degrees of freedom

From a table of the distribution of *t*, if we had set a lower limit of 95% for rejection of the null hypothesis, then t should be 2.262 or greater for the difference between years to be considered significant. With a value of 1.800 the null hypothesis should be accepted, i.e. there is no reason to believe that the apparent mean difference between years is real.

Note that when doing successive *t*-tests (or any other statistical test) at the 95% confidence level, we must accept that there is a 5% chance of accepting or rejecting the null hypothesis wrongly. The more tests that are done (i.e. the more sampling occasions) then the more likely this is to occur.

(b) Non-permanent quadrats

(i) Random samples

When a peatland site is monitored using non-permanent quadrats, plain undivided 50 x 50 cm frames should be used. These provide data on the presence of species at a single location. One set of quadrats obtained during a monitoring visit provide a score for each species. Provided the samples are located on a **strictly** random basis (in which case the data follow the binomial distribution) the **Chi-square test** can be used to analyse the data. The null hypothesis to be tested is that there is no difference between the number of quadrats containing the species at the first (or standard) and the later assessment.

To make this type of analysis, the data obtained from two visits to a site are entered into a **2 x 2 contingency table** (Table 7). Each species is treated separately, with the number of quadrats containing the species on the first, and then the second, visit being entered in the left hand column of the table. The Chi-square calculation is carried out as follows.

$$X^2 = ((|ad - bc| - \tfrac{1}{2}n)^2 n)/((a+b)(c+d)(a+c)(b+d))$$

$$= ((13920 - 5720 - 200)^2 \cdot \text{x } 400) / (200 \text{ x } 200 \text{ x } 200 \text{ x } 200)$$

$$= 16.000$$

For significance at the 95% level, the value of X^2 must be equal to or greater than 3.84, so we should conclude that the frequency of the species in question was significantly different on the two occasions it was measured.

Table 7: Frequency data from 200 randomly placed quadrats assessed on two occasions (T_1 and T_2), entered into a 2 x 2 contingency table.

	Quadrats with		Quadrats without			
T_1	*a*	96	*b*	104	200	(*a*+*b*)
T2	*c*	55	*d*	145	200	(*c*+*d*)
	(*a*+*c*)	151	(*b*+*d*)	249	400	(*n*)

The formula for the calculation of X^2 given above is suitable for a total number of observations of less than 500, i.e. up to 250 quadrats at each of the two visits. If 500 or more observations are available, then the following formula should be used.

$$X^2 = ((ab\text{-}bc)^2 n)/((a+b)(c+d)(a+c)(b+d))$$

(ii) Restricted random samples

As an example of the testing of apparent differences between datasets obtained by restricted random sampling, suppose five sets of 100 samples are taken, equal numbers of each set from the blocks as described above, on two separate occasions. A suitable null hypothesis is that the difference between the means of the two lots of five sets is not different from zero. A suitable test of significance is **Student's *t*-test** but, as the data do not conform to the normal distribution (actually approximating to the binomial distribution), the original data must be transformed as described in Appendix 1 (Table 8).

t = Deviation of difference between means from zero / Standard deviation of the difference of means

Deviation of difference between means from zero = 28.12 - 26.56 = 1.56

Pooled variance = ((3536.56 - 3527.17) + (4067.98 - 3953.67))/(4 + 4) = 15.463

df = 4 + 4 = 8

Standard deviation of the difference of means =
$\sqrt{(2 \text{ x variance} / n)} = \sqrt{(2 \text{ x } 15.463 / 5)} = 2.487$

$t = 1.56 / 2.487 = 0.627$

From a table of the distribution of t entered at 8 degrees of freedom, the calculated value of t must equal or exceed 2.31 for rejection of the null hypothesis. We must therefore conclude that there is no reason to believe that the apparent difference between means is real.

Table 8: Example data from restricted random sampling on two occasions (T_1 and T_2) as described in the text, with angular transformations to a, and elements of the calculation of t.

	T_1		T_2	
	Raw data	a	Raw data	a
	18	25.1	12	20.3
	18	25.1	19	25.8
	20	26.6	25	30.0
	21	27.3	25	30.0
	23	28.7	32	34.5
n		5		5
means		26.56		28.12
Σx^2		3536.56		4067.98
$(\Sigma x)^2/n$		3527.17		3953.67
df		4		4

Number of quadrats

The view is frequently expressed that the number of quadrats to be set up in a Level 3 type of monitoring scheme is a function of time and manpower available. Unfortunately, inadequate monitoring and over-sampling can result, and are both a waste of those valuable resources. Inadequate monitoring produces data which are difficult to analyse, with a risk of the deduction of spurious trends. Number of samples should be based on criteria designed to allow confident detection of changes in the vegetation.

Statistical methods exist for the calculation of the number of samples required to obtain an estimate of a mean within desired limits of precision. In some cases (strictly random sampling), it is possible to use this approach to calculate how many samples would be necessary to detect a certain level of change. In most cases, however, the calculation depends on a knowledge of the variance of the population, and provides only the number of samples required to sample that same population to the required level of precision. This is not particularly useful because, in monitoring, it is the change in the population that we are interested in. There is no way of estimating the likely variance of any change before it has occurred, or of knowing what the variance of the population will be once a change has occurred.

As there is little else that can be done, it seems reasonable to take the approach of making sure that the sampling regime employed does give a good estimate of the population itself, and that the level of precision is at least sufficient to distinguish change if it is assumed that the population variance will not increase. For the particular sampling methods discussed above, the problems are

* How many permanent quadrats should be set up?
* How many random quadrats should be recorded?

* How many sets of quadrats should be taken from the blocks of a restricted random arrangement?

In all cases, an important *a priori* decision must be taken. What level of change is it necessary to detect? The answer to this is likely to be different for each species within the monitoring scheme, so the importance of focusing on key species becomes even clearer.

Strictly random quadrats

For random quadrats, the number of samples required to detect particular levels of change can be determined without reference to the vegetation itself once the approximate frequencies of the key species are known. **Number of samples is, in this case, independent of the variability of the vegetation.** By reference to Table 9, it is immediately obvious that, if 100 samples are taken and provide a frequency of 50, that we can be 95% certain that the frequency actually lies between 40 and 60. The smallest level of change that could be detected with this number of quadrats is ±20% as a subsequent value of 30 would be within the range 21 to 40, and a value of 70 within the range 60 to 79.

Permanent quadrats

When setting up a system of permanent quadrats, it may be felt necessary that they should reflect the broader vegetation. If so, then they can be placed in a restricted random fashion across the site.

Rather than attempting to represent the whole community, an indicator species approach may be taken. In this case, quadrats should clearly concentrate on the indicator species and should attempt to cover their full environmental range on the site as a series of classes, e.g. relatively wet, dry, and intermediate.

Guidance can be given on the number of samples necessary to obtain a mean that lies within certain confidence limits (usually 95%). Some sampling is required first to gain an estimate of the variance of the key species. This initial assessment sampling should continue until the mean values for the species of interest, which will usually vary wildly when calculated over the first few samples, have stabilised (calculation of a running mean, see Figure 7).

Table 9: 95% confidence limits for binomial distribution (Grieg-Smith 1983).

Percentage frequency observed	Number of observations (quadrats) 10	20	50	100	1000
0	0 31	0 17	0 7	0 4	0 0
10	0 45	1 31	3 22	5 18	8 12
20	3 56	6 44	10 34	13 29	18 23
30	7 65	12 54	18 44	21 40	27 33
40	12 74	19 64	27 55	30 50	37 43
50	19 81	27 73	36 64	40 60	47 53
60	26 88	36 81	45 73	50 70	57 63
70	35 93	46 88	56 82	60 79	67 73
80	44 97	56 94	66 90	71 87	77 82
90	55 100	69 99	78 97	82 95	88 92
100	69 100	83 100	93 100	96 100	100 100

The limits set for the mean must be, at most, half of the difference that it has been decided to detect, assuming that any mean obtained by sampling at a later date will have roughly the same variance. Number of samples can then be calculated using the following formula after **angular transformation** of the data (Appendix 1).

$$n = (4 \times \text{variance}) / L^2$$ (Snedecor & Cochran 1967, p 58)

where n = number of samples required

L = the limits of the mean = ½ detection level

$$\text{variance} = (\Sigma x^2 - ((\Sigma x)^2 / n)) / (n - 1)$$

This method will work if quadrat positions are selected rather than randomised, but variance should, in this case, be calculated as the quadrats are placed.

Restricted random samples

When a site has been stratified in some way, we are dealing with sets of quadrats rather than individual samples. The **number of sets** necessary to detect a particular level of change can be calculated using the same formula as for permanent quadrats, but calculating variance as follows.

$$\text{variance} = (\Sigma x^2 - ((\Sigma x)^2 / n)) / (n - 1)n$$

where n = number of sets

To determine the variance of sets, successive sets (i.e. one quadrat from each block) of samples will have to be taken, and the variance calculated after each set.

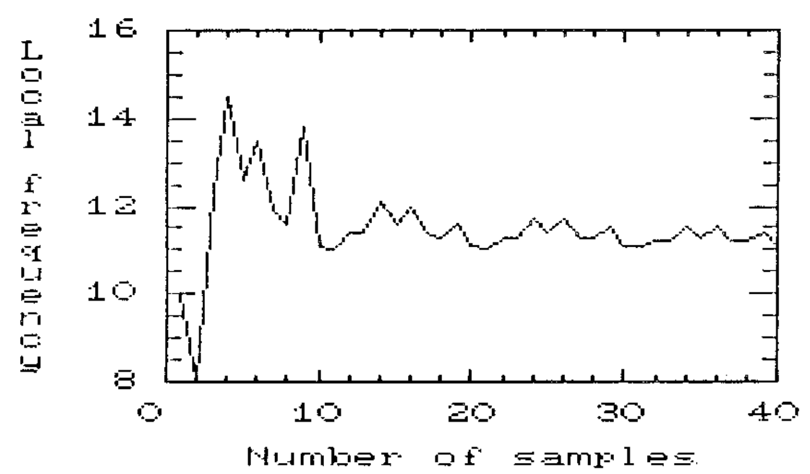

Figure 7: As more samples are taken the mean gradually stabilises.

Placement of permanent quadrats

Communities should have been mapped by previous survey as part of the Level 2 monitoring scheme or Phase 2 survey. Areas suitable for quadrat placement can be selected from the vegetation map, taking into account the aims of the monitoring scheme, the use of key species, and any other special requirements. As change may be either in extent of communities, or in their general character, both possibilities should be allowed for. Quadrats should therefore cover both the central parts of communities, and vegetation boundaries.

Frequency of recording

Desirable frequency of sampling is obviously linked to the speed of change. Smith, Wells & Welsh (1985) indicate that frequency can be linked to the observed rate of change, but this assumes that change is more or less constant. Experience following the 1976 fire at Glasson Moss suggests that this is not necessarily the case. Slow recovery for the first seven or eight years was followed by rapid recolonisation by *Sphagnum* spp. This unpredicted rapid change may have been precipitated by management changes, and emphasises the need for close additional monitoring of aspects other than the vegetation itself, e.g. water level and weather.

In the absence of better guidelines (which should become available as monitoring experience accumulates), it is necessary to hazard a prediction of the likely pattern of change, and to set recording frequencies accordingly. Annual monitoring is probably necessary for the monitoring of management changes and known threats. Bi- or triennial monitoring is probably adequate for more general monitoring purposes. In all cases, sites should be inspected annually, and casual observations made. This type of record can prove very valuable in interpreting or supplementing the more rigorous data recorded from quadrats.

Timing of recording

As the composition of vegetation changes throughout the year, it is possible that seasonal changes may be confused with other more significant changes, making interpretation of the monitoring records difficult or impossible. Avoiding this is problematical, as the same calendar time does not necessarily match biological time from year to year, depending on whether the season is late or early. Monitoring at a fixed calendar time is probably the best that can be hoped for but, ideally, biological time should be given some consideration.

Clearly, this problem argues for local/regional monitoring teams who can adapt the season's work to local conditions. At each assessment, notes on the biological condition of the vegetation, and the actual date of assessment, should be recorded on each record sheet.

FIELD PROCEDURE FOR LEVEL 3 MONITORING

Marking quadrats

Permanent quadrats, or stands in which random quadrats are assessed, need to be marked on the ground so that they can be relocated for future assessments. Ideally, the entire site should be gridded, and the sample locations related to the grid by compass bearings and measured or paced distances. Alternatively, sample points should be related to landmarks or other permanent features such as fencing.

The corners of stands, and the approximate locations of permanent quadrats, need to be indicated by an easily relocated system of markers. Posts driven deep into the peat are the usual solution, but these can be removed by the determined vandal. Driving posts in so that only a few centimetres protrude makes removal difficult, but the post can be easily lost if pushed in to ground level; this is easily done on soft peat. The post design shown in Figure 8 prevents sinking and resists extraction (because insufficient post protrudes to provide leverage against the suction of the peat). The short collar takes any length of plastic pipe for temporary marking. Unfortunately the plastic components of this design will be susceptible to fire.

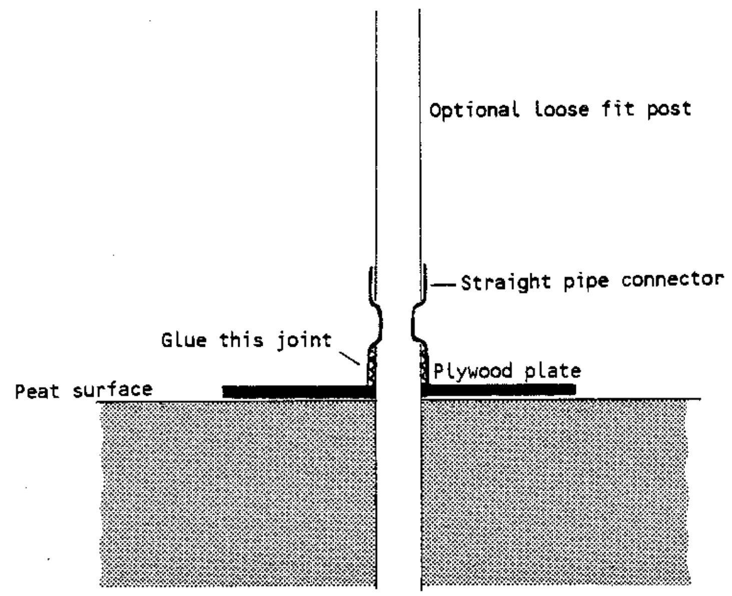

Figure 8: Design (by M. Bailey) for a marker post for peatlands. The plate prevents the post being pushed into the ground, while the protruding part is too short to allow a good enough grip to pull the post out. The extension piece is not fixed.

Metallic or treated-timber stakes should not be used on peatland sites because of the possibility of contamination. Plastic, as already noted, is susceptible to fire. The only viable alternative is untreated timber, preferably hardwood if the scheme is intended to last for a long time.

Permanent quadrats should be located a known distance and direction away from the main marker post. The distance should be considerable, probably as much as five to ten metres. The advantages of distant placement are two-fold. Firstly, the quadrats are less easily found and disturbed by anyone other than the monitoring team. Secondly, birds perch on marker posts and cause eutrophication and vegetation change around them. Here is a further reason for keeping marker posts as short as possible.

Grid, quadrat and stand marker posts need to be identified by a system of code numbers/letters. Any marking method is likely to fail in the long run (paint flakes off; alloy tags corrode where they are nailed on, and eventually fall off; the most permanent marking method would involve carving or burning the code into wood). Any failed marking should be reinstated at the time of visit.

Permanent quadrats should be marked by four canes or dowels over which the locating holes of the assessment quadrat fit. These marker canes should be pushed into the peat so that they protrude no more than 5 cm above the surface. If necessary, extension tubes can be fitted at the time of assessment so that the quadrat can be properly relocated. The tips of canes can be painted to make relocation easier; dipping in 'Japlac' enamel paint seems to work well. Each of the canes in a quadrat group should be numbered with indelible ink so that orientation of the assessment quadrat is known even if some are removed.

The need for accurate re-registration of the assessment quadrat cannot be sufficiently stressed. The variation in data likely to be produced by assessing a slightly different patch of vegetation each year will become confused with any significant change and make interpretation difficult or impossible.

While this type of comprehensive marking is possible on reserves, it can only be done on other sites by negotiation with landowners. Frequently, repeated visits to monitor are acceptable, but permanent marking is not. In such cases, non-permanent sampling should be used.

Temporary marking can be a useful technique for monitoring the limits of communities or species if used in conjunction with fixed-point photography. Conspicuous poles are erected along the boundary line to highlight it. Comparison of photographs should demonstrate any major changes. It is necessary, however, to standardise the method by which the boundary is identified.

Careful records of the location of all marker posts, quadrats, etc should be made, written up, and stored on the site monitoring file.

Relocating fixed points and quadrats

Each time the site is visited for re-assessment, all fixed points and quadrat positions must be relocated. It is necessary to have available, therefore, details of quadrat position as indicated above. If any posts or canes have disappeared, then they should be replaced and re-marked immediately.

If all canes have disappeared for a particular permanent quadrat, then a replacement should be set up and recorded. A note should be made on the record sheets and, subsequently, on the monitoring file that this is a new quadrat, and that the old one has been terminated. This will circumvent any possibility of confusion and spurious analysis in the future.

Training and monitoring of assessors

Where a team of assessors monitors a site, field training should include the following, which should be undertaken as necessary.

* Familiarisation with any new species.
* Familiarisation with assessment method.

In addition, the team leader must make periodic re-assessment of each team member. This is most simply achieved by independent assessment of a quadrat or series of quadrats, then comparison of the results. Any discrepancies should be re-checked by both parties. Provided the team leader does not refer to the original assessment until after the re-assessment, then this method monitors the team leader's performance as well as the team members'.

The team leader should also maintain a check on level of damage caused to quadrats and their surroundings by assessors.

Protection of the vegetation and ground around permanent quadrats

On peatland sites, protection of the surroundings of permanent quadrats from damage by the recorder is essential. Trampling can cause localised ponding of water and destruction of, or damage to, the vegetation either allowing invasion by atypical species, or increasing exposure of the quadrat vegetation to the elements.

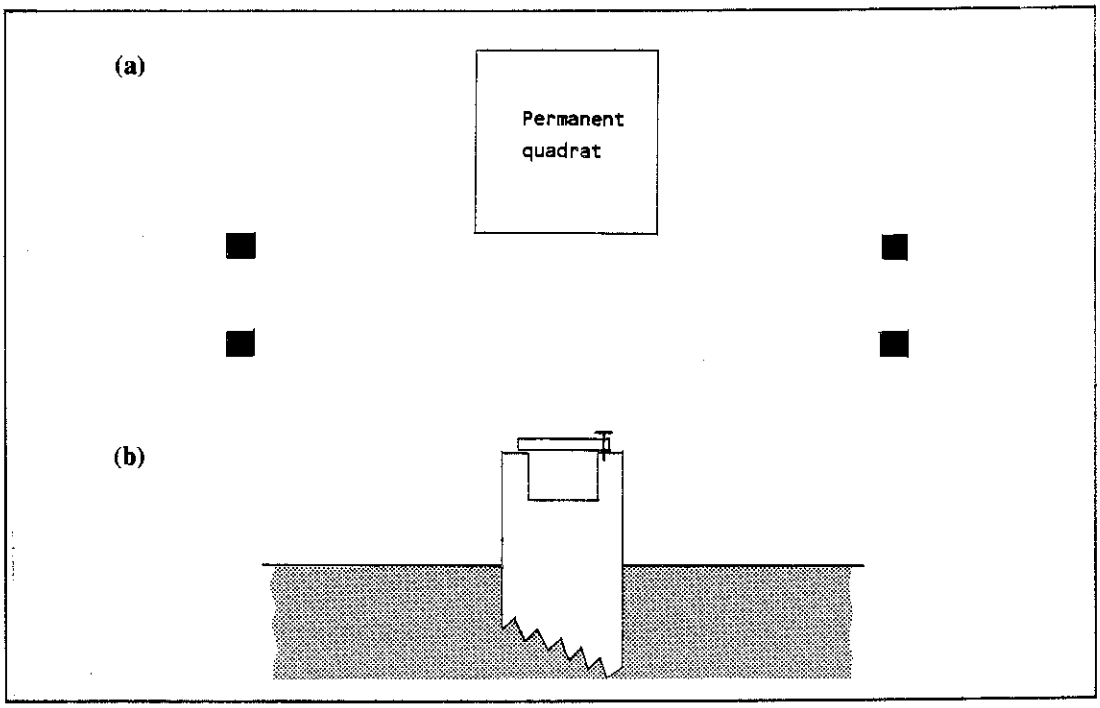

Figure 9: The placement (a) and design (b) of posts for supporting ladders at permanent quadrats. Note in particular the locking bar to prevent the ladder jumping out of the slots in the posts. Posts must be kept well away from the quadrats. (Design by R.A. Lindsay)

Attempts have been made in the past to monitor peatland vegetation from permanent boardwalks set up alongside quadrats or transects. These have inevitably led to worries about the effects of the boardwalks on the vegetation, either because of chemical leachates, perching birds, or shading/shelter effects.

Anything which spreads the weight of the observer can be used to avoid undue damage, though it must be portable. Lightweight alloy ladders have been used successfully, and are particularly useful where pool vegetation is included in the monitoring scheme. Ideally, the installation of permanent quadrats will include support legs for a standard ladder that will ensure that the ground around the quadrats remain completely unaffected. The design suggested in Figure 9 ensures that legs are situated well away from the quadrat itself, that chemical preservatives are not introduced onto the site, that the posts are difficult both to remove and to push into the peat, and that a ladder can be fixed safely onto the legs at each visit.

If any potentially polluting materials are used (despite warnings) on monitoring sites, then they should be placed downslope of quadrats so that pollutants flow away from rather than towards them.

Where random quadrats are used, such protection is not necessary, although the effect of the observer should not be discounted in more sensitive types of vegetation. Effects of the observer can be controlled to a limited extent by leaving parts of a homogeneous stand untouched after the first assessment, and only re-assessing it if the rest of the stand shows a significant change.

Assessment of vegetation

Deployment of assessors

While assessor training, supervision, and error control are all aimed at reducing observer bias, some level of bias is likely to remain. This can be exacerbated if the quadrats are divided between a team in an identical manner at each assessment, or if the team is split between, for example, management treatments.

In the first case, care should be taken to ensure that the team is rotated between quadrats from assessment to assessment. In the second, each treatment should be split between the entire team, with rotation of assessors between quadrats from assessment to assessment.

Permanent quadrats

Permanent quadrats are assessed by placing a standard 50 x 50 cm quadrat partitioned by strings into twenty-five 10 x 10 cm subdivisions. The use of a consistent design of quadrat is important, as it must fit exactly over the marker canes and define the identical piece of ground at each assessment.

Having made a list of the species rooted in the quadrat, examine each subdivision in turn and score presence or absence. Encircle the presence mark for the most abundant species in terms of cover within the subdivision (more than one species may be encircled if they are co-dominant).[2] When scoring of the entire quadrat is complete, view the quadrat as a whole. Using the list of species on the recording sheet, encircle the most abundant species as for the subdivisions (refer again to footnote 2). Asterisk any other species with cover of 25% or over.

Note on the record sheet the biological condition of the main species, i.e. in bud, in flower, fruits/seeds developing, fruits/seeds ripe, fruits/seeds shed, proportion of senescent material. This information will aid interpretation in relation to the biological timing of assessment.

Note on the record sheet any apparent damage to the quadrat or its immediate surroundings, including trampling, deposition of dung, dead animals. The location of the damage should be noted as precisely as possible, preferably on a sketch.

Some points to watch during recording:

* Photograph permanent quadrats **before** assessment, so that disturbance by the assessor is not included. (It can be instructive to take 'before and after' photographs to assess the impact of assessors).

* Cause as little damage as possible to the vegetation in or around the quadrat. If necessary, place a clipboard on the opposite side of the quadrat for leaning on. Do not 'root' in the vegetation, and do not remove pieces of plant to aid

2 As rooted frequency is scored, there may be cover of species which are rooted outside the subdivision, or even outside the quadrat. If so, add these to the species list and encircle without a presence mark.

identification or as samples. If this appears necessary, try to find samples outside the quadrat, or enlist the aid of colleagues to identify the plant *in situ*.

* Do not remove any material, such as dung, from quadrats, but do record its presence, type and extent. If a quadrat has been totally swamped and is considered, in the context of the whole suite of quadrats, to introduce an atypical element into the monitoring, then consider replacing it as detailed above.

* Adopt a standard approach to defining non-plant elements of the quadrat contents, such as bare peat and open water. For example, open water might be differentiated from standing water by the density of emergent shoots. Bare peat is that which has no bryophyte cover, but might be usefully differentiated from exposed peat, i.e. that which has no cover and can be seen from immediately above the quadrat. These definitions should be written into the methodology, and should be included in assessor training.

* Adopt a standard approach to deciding whether a plant is rooted in a subdivision, so that an individual plant is not recorded for two subdivisions. For those individuals that lie half in and half out, count them in if they are under the left or bottom edge, and out if they are under the right or top edge (Figure 10). The same decisions apply to the edges of quadrats. Again, this should be written into the methodology, and should be an element of assessor training.

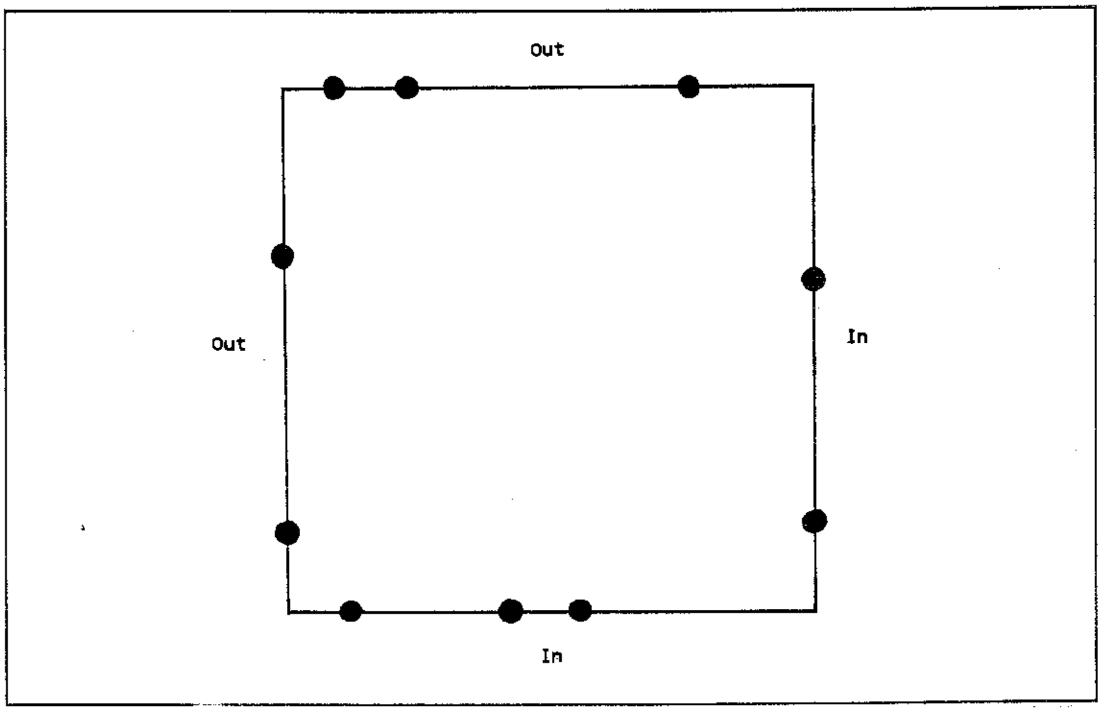

Figure 10: A standard method, such as the one shown here, must be adopted for deciding whether plants on the edges of quadrats are in or out.

Random quadrats

Having relocated the marker posts for the corners of the stand to be assessed, the fresh set of quadrats must be located by the use of random coordinates. The exact positions should be determined on paper at base, so there is no need to wrestle with calculators or random number tables in the field. This is particularly advantageous when pool systems are involved as the locations can be plotted on a map and located on the ground without baselines or undue pacing and consequent trampling (see below).

Thrown quadrats are not an acceptable means of achieving randomisation as bias is naturally introduced, even when using an 'eyes closed and turn round three times' approach.

The procedure for determining random positions on paper is as follows.

* Establish a base grid with spacing equivalent to the size of the quadrat. Larger spacing, e.g. the convenient 1 m or one pace, is not acceptable as it obviates an important aspect of random sampling, that every point in the stand has an equal chance of being sampled.

* Select pairs of coordinates using a suitable scientific calculator, or from a table of random numbers.[3] These will determine the position of each quadrat within the subdivision. Repeat this for a total of at least 100 quadrat positions, or more for greater precision (see above). Convert the distances along each baseline/axis to paces.

In the field, find the random positions by pacing, and place the bottom left hand corner of the quadrat on the random point. Assess the quadrat (see below). To find the next quadrat position, it is not necessary to return to the base line; simply pace out from the previous quadrat.

Assessing the random quadrat involves first making a species list (this is much reduced if only key species are being assessed), and place a presence mark against each species. This is the main data record, as it represents one frequency record for each species present. Determine the species with the greatest cover and encircle the presence record for that species (more than one species may be encircled if there is co-dominance). For all other species with cover of 25% or over, asterisk the presence mark.

At the next quadrat, add any new species to the list, and mark presence and abundance as before.

The points to watch listed under the permanent quadrat approach above largely apply to random quadrats as well, particularly those relating to a standard approach for assessment. However, while care should be taken not to cause undue damage to the vegetation, the effect of the observer is not so important (so long as fairly large stands of vegetation are being assessed).

Restricted random quadrats

These are treated in essentially the same way as random quadrats, but the site must first be gridded, or stratified in some other way, and the pre-determined number of random quadrats taken in each stratum.

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3 Notes on random number tables and their use are given in Appendix 2.

In the case of patterned sites, where it is desired to accommodate the micro-topographical zones in the sampling regime, the same gridding method can be used (direct stratification using the zones would be extremely difficult owing to their small size). The grid should be large enough to include examples of all zones present in each grid square. The method is simplified if the number of samples taken in each grid square is a multiple of the number of zones to be sampled. When all the random positions within an individual grid square have been located and marked with canes, the second or third markers in any duplicated zones should be relocated to the nearest zone of a so-far unmarked type (Figure 11).

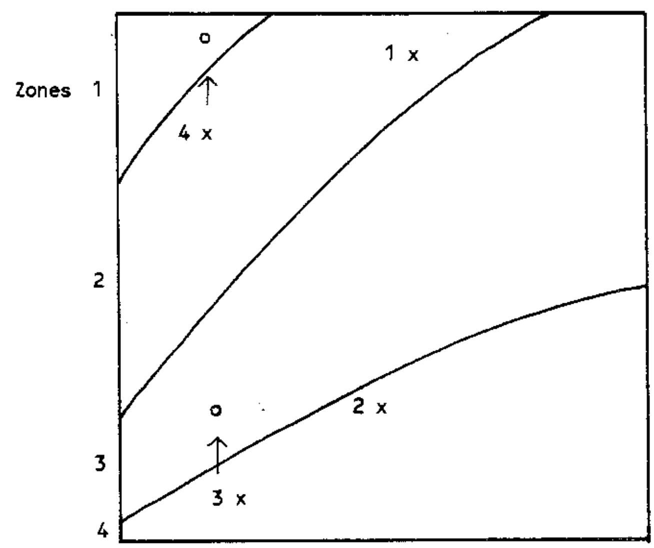

Figure 11: The original placement of random samples within a grid square on a patterned bog surface are shown here as x. Duplicates (or over-representation) are then moved to a new position (o) in the nearest vacant (or under-represented) zone. This redistribution is done once the original randomisation is complete.

A similar method could be used to locate a random sample of hummocks or tussocks.

The difficulties of working on this type of terrain, with its complex pool systems, can be alleviated if a careful plan of the pool system is made from recent aerial photographs (a scale of at least 1:10000 will be needed, although 1:25000 may suffice for strongly patterned sites). The location of quadrats can then be fixed on paper prior to the site visit (with random points falling in water being rejected as necessary), so that the amount of on-site measurement and trampling is minimised.

Primary working of data

The first working of the data should take place in the field, so that comparisons can be made with previous data for error control purposes. This simple working consists of summing the presence of species either in individual permanent quadrats, or in stands assessed by random quadrats.

Error control following assessment

Time should be allowed after assessment for primary data working, and for comparisons to be made between the new data and that collected during the previous assessment or standard, as appropriate. Note any species showing large changes in either frequency, dominance, or cover class. This examination of the data should immediately highlight any major potential changes, and it is imperative that these are re-examined on-site by the team leader to ensure that the new data are correct. The process also adds an element of interest that is often lacking from this type of routine monitoring work

Carry over of errors from one year to the next is less likely to occur if fresh species lists are made on-site without prior reference to the existing data.

The team leader should note any large changes that are confirmed on-site for checking against acceptable levels of change immediately on return to base.

Site housekeeping

Unused timber stakes, canes, etc, are often left on-site. They are not only unsightly or hazardous, but may cause a certain amount of damage to vegetation, and attract people into the monitoring area. Any excess materials should therefore be removed from the site at the end of each visit.

Storage of data

Monitoring data are irreplaceable, so their storage should be treated seriously. Once recording sheets have been checked to ensure that all additional information has been fully and unambiguously entered, and all records are fully legible, copies should be made and stored in a safe place remote from the monitoring file. Comprehensive details on record storage are given by Smith, Wells & Welsh (1985), but some advances can be made over paper storage by utilising computer storage facilities once the raw data have been given a primary working. Copies of all photographs should be stored with the data.

The ideal method of data entry to a computer is probably by means of a spreadsheet. By this method, a data table can be easily constructed with a species list and fields for ancillary information. Data can be added year by year, and the full table or selected parts of it printed out for ease of viewing. The whole dataset, or particular portions of it, can be exported to other programs for more detailed analysis.

Over long periods of time, the existence of monitoring schemes can be forgotten, and potentially useful data ignored. A register exists of permanent plots set up by the Institute of Terrestrial Ecology (Radford & Hill 1984). All monitoring schemes should be similarly registered with notes on aims, methods, personnel, location, etc.

Action following data analysis

If the level of change in any species exceeds the predetermined acceptable limit, then action depends on the method of data collection. Permanent quadrats will require a further and immediate visit to the site to assess the condition of the wider vegetation. This should not be necessary with the random quadrat method unless the stands examined were very small, or there is a suspicion that the stands are not representative.

ASSOCIATED MONITORING

Situations will arise where a general method for monitoring the abundance of species in vegetation is felt to be inappropriate. Some other methods are outlined here.

Structure of vegetation

Associated with changes in botanical composition, particularly where there have been modifications to a mowing or grazing regime, may be changes in vegetation structure (i.e. different height, layering, or species with different morphology). These structural changes may be of particular importance to animals. They may also be precursors of changes in botanical composition.

Some structural information will always be useful, and a certain amount will be inferable from the botanical data collected. Additional useful information that should be collected is:

* Estimated percentage bryophyte cover in 20% increments.
* Estimated percentage herbaceous cover in 20% increments.
* Estimated percentage shrub cover in 20% increments.
* Estimated percentage bare peat cover (total) in 20% increments.
* Estimated percentage bare peat cover (open) in 20% increments.
* Estimated percentage open water in 20% increments.
* Average height of the vegetation.

Vegetation height can be measured adequately within a quadrat by calculating the mean of twenty-five heights taken in each of the sub-units or their equivalent. The maximum and minimum heights should be highlighted, and should be measured separately if not represented in the twenty-five samples.

An alternative rapid method for measuring height is given by the Butterflies Under Threat Team (1986). If used, then one reading should be taken in the exact centre of each quadrat assessed. This method requires testing on peatland vegetation.

> The recommended standard is as follows. A disc of 30 cm diameter is made of standard hardboard, with a central slit-like hole through which a metre rule will pass: the weight of the one-eighth inch thick disc is 200 g. The metre rule is held vertical, with one end touching the ground; avoid placing it in a depression. The disc is then dropped from the top of the rule, sliding down with the rule in the slit. It is easy to read off the height at rest, if necessary easing aside any major obstruction which interferes with obtaining a fair reading. This method gives the 'average vegetation height' as far as the method is concerned.

Plate meters of this type are considered to be influenced by herbage mass and/or population density, and are perhaps more suitable if some integrated measure is considered useful. Where height *per se* is the desired measure, the HFRO sward stick provides an accurate (to ±0.25 cm) estimate. This is basically a square-section rod with a transparent 2 x 1 cm window which is lowered until it touches the vegetation.

More complex aspects of the structure of vegetation can be recorded using a vertical quadrat. Pins can be employed in much the same way as in a point quadrat, or the vegetation may be sighted through holes in the quadrat. Methods for this type of recording are detailed by Curtis & Bignal (1985).

Visual assessment of structure and structural change can also be made from stereo photographs of samples of vegetation. For short vegetation, photographs should be taken from vertically above the quadrat. Problems of height and depth of field will be encountered with tall vegetation, and side views will often be more informative.

Stereo-photography

Stereo-pair photographs of quadrats, side views of vegetation, or more general Level 1 monitoring photographs are simple to take. Take the first photograph as normal but with the body weight on the left leg. Shift the weight onto the right leg and, maintaining the same frame, take the second shot. A motor drive helps maintenance of the frame.

Stereo pairs of slides can be adequately viewed with a cheap, hand-held viewer detailed in the equipment section below. Pairs of prints can be viewed under stereo viewing equipment of the type used for aerial photographs (also detailed below).

Note that it is just possible, depending on the height of the photographer, to frame an entire 50 x 50 cm quadrat using a 50mm lens. A 35mm lens probably provides greater flexibility. Whichever focal length is chosen, interpretation of the photographs is probably made simpler if the same lens is used at each visit.

All photographs should include within the frame a label with a unique code for site and sample. A scale (e.g. a ranging pole) is extremely useful for height comparisons on fixed-point photographs. A scale is not essential in quadrat photographs if the frame is still in position. If a horizontal scale is thought advantageous, then a rigid ruler or a steel tape is easier to handle than a fabric tape which requires stretching and fixing at both ends.

Monitoring of individual species

On occasion, it may be desirable to follow the performance of an individual species at a site. Many species that grow in dense clumps, such as *Sphagnum* spp, are best monitored by the quadrat techniques already discussed. Where dense or scattered populations of discrete individuals are of interest, other methods must be employed.

For dense populations set out permanent quadrats, and record the position of individuals within the quadrat. This can be achieved by recording the coordinates of each individual in relation to two adjoining sides of the quadrat (Figure 12a). Care must be taken to note the orientation of the quadrat.

For scattered populations, the positions of individuals are recorded in relation to the ends of a baseline. A simple method is to mark a baseline with hardwood posts driven in to near ground level and no more than 5 m apart (Figure 12b). These are topped with brass cup hooks. Working with adjacent pairs of posts, attach two 30m tapes to the cup hooks and record the distance on both tapes to each individual plant. Mark the plants as they are recorded.

An alternative to the tape method is to use a longer baseline, and to triangulate the individual plants with a theodolite placed first at one end and then at the other (Figure 12c).

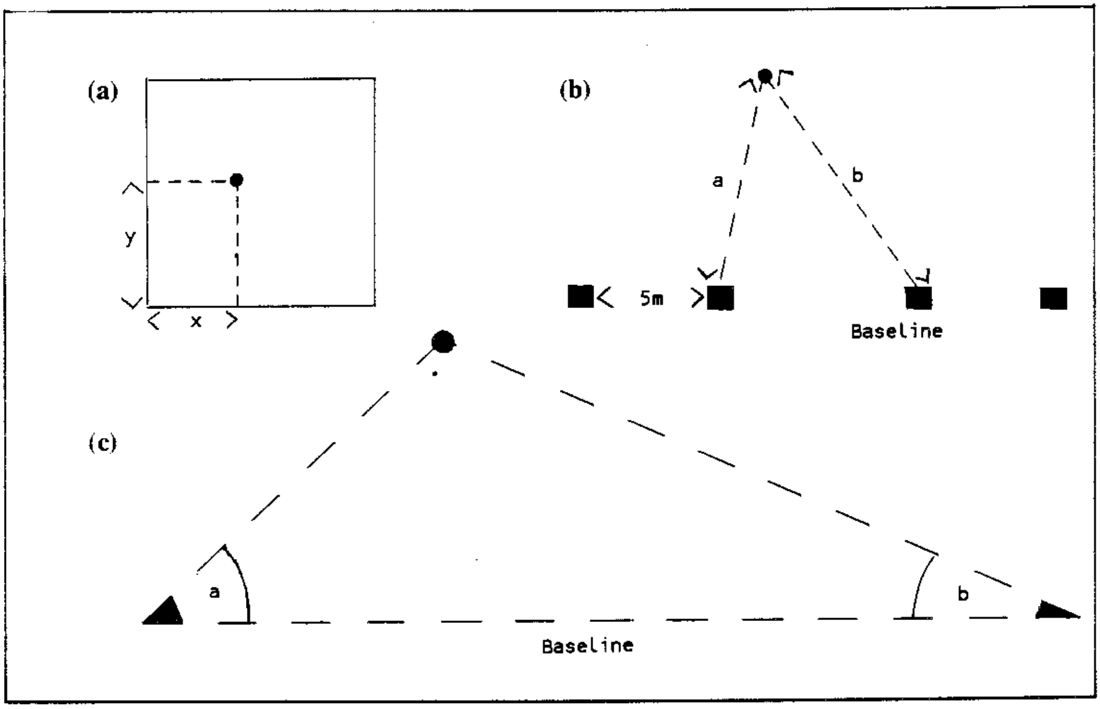

Figure 12: **The monitoring of individuals in a population of plants.**
(a) Within a quadrat record the distances x and y
(b) On a larger scale use two tapes from a pegged baseline to measure the distances a and b.
(c) Alternatively triangulate the plant from the ends of a baseline measuring angles a and b.

At the time of location of each plant, record other details of interest to the study in hand, such as number of flowers/flowering buds, height, number of leaves, presence of grazing damage, etc.

Monitoring of other site parameters (non-vegetation)

* Hydrology: advice on hydrological monitoring on peatlands will be available in a Handbook section to be produced at a later date.

* Softness: methods and equipment (i.e. penetrometers) for measuring softness of peat need investigation.

* Stocking rates: some means should be found of monitoring grazing pressure, e.g. arrange for counts during Level 1 monitoring, as well as counts being made by assessors at the time of monitoring.

* Mowing/burning dates: if these are regular or occasional events, then dates must be determined and noted.

REVIEW OF LEVEL 3 MONITORING SCHEMES

All Level 3 monitoring schemes should be reviewed every five years to examine their results and general effectiveness. Modifications, and decisions to continue or discontinue schemes, should be made at this time. Beware, however, of expecting to distinguish trends over too short a period. The review should cover Level 1 and 2 schemes as discussed above with the aim of re-assessing the status of the site.

A report on each scheme should be produced as a result of the review, and copies lodged with the general monitoring record. A chain of responsibility must be established to ensure that the results of the review are acted upon.

GENERAL METHOD FOR LEVEL 3 MONITORING

The following points cover the main aspects of the recommended approach to Level 3 monitoring.

* Level 3 monitoring should not be started unless a full account of the resources required has been made, and the availability of those resources over a long period is assured.

* Define closely the aims of the monitoring scheme.

* Consider the consequences of the various methods available, and select a method accordingly. The choice is limited to permanent quadrats or restricted random sampling on a grid basis.

* Survey the site to determine the range of communities with their distribution, and species with their approximate relative abundance.

* Select communities and species of interest.

* Determine the variability of the selected species (i.e. their mean frequency and variance).

* Decide the level of change to be detected for each species calculate the number of samples required.

* Mark up the locations of quadrats on paper.

* Locate field positions of quadrats, mark up permanent quadrats (50 x 50 cm) and fix marker posts as necessary, take samples recording rooted frequency (note that for permanent quadrats, position should be changed after each second recording).

* Compare data with previous visit, query any obvious changes, and confirm in the field;

* Work data as soon as possible after collection using graphs and statistical tests.

* Report any changes found that may have ecological significance to the site manager or other designated persons.

* Make copies of data, photographs, reports, etc, and store at two separate locations.

* Inspect all sites annually (during Level 1 monitoring), making notes as appropriate and lodging them with the general monitoring records.

* Review and report on each Level 3 monitoring scheme every five years.

EQUIPMENT

HFRO sward stick

Price about £18 - 50 (+ VAT and P & P) from:

Scottish Centre for Agricultural Engineering,
Bush Estate,
Penicuik,
Midlothian
EH26 0PY

Waterproof paper

Aquacopy waterproof photocopy paper, suitable for maps, data sheets, methodology sheets, etc.

Price (July 1987) for 250 sheet pack A4 .... £41.24 + VAT

2-4 packs .... £32.99 + VAT

5-8 packs .... £28.87 + VAT

10 + packs .... £24.74 + VAT

Also available in A3 size.

Suppliers: Hawkins & Mainwaring,
Westborough,
Newark,
Nottinghamshire
NG23 5HJ Tel 0400 81492

Stereo-photograph viewer

Simple pocket-sized instruments for viewing pairs of stereo-photographs are available at low cost. Many optical manufacturers supply these. For example:

Casella London Ltd,
Regent House,
Britannia Walk,
London
N1 7ND Tel. 01 253 8581

A plastic framed model is available at £4 (+ VAT and P&P) and a metal framed model at £16.

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APPENDIX 1 - Angular transformation of frequency data

Data is transformed for statistical purposes when it does not conform to the particular mathematical distribution on which a convenient test of significance is based, usually the normal distribution. Transformation might involve using the square root or the logarithm of the data instead of the raw values. In the case of data approximating to the binomial distribution, i.e. data of the yes/no or presence/absence sort, the transformation is more complicated. It is to a where $\sin a = \sqrt{\text{frequency}}$ expressed as a proportion. A table for conversion to a is given by Snedecor & Cochran (1967), but conversion is easily achieved using a scientific calculator with an arcsine ($\sin^{-1}$) facility.

For example, where a species occurs in 87 out of 150 quadrats,

$$\text{frequency} = 0.58$$

$$\sqrt{\text{frequency}} = 0.762$$

$$\sin^{-1}\sqrt{\text{frequency}} = 49.603 = a$$

APPENDIX 2 - Random number tables and their use

Tables of random numbers are used for selecting the coordinates of the corners of random quadrats. Large sets of random numbers are available in volumes of statistical tables such as Fisher & Yates (1963). Alternatively, they can be generated by a pocket calculator

Use of random number tables is not as straight forward as first appears. The most obvious method is to use the numbers directly, rejecting all numbers in excess of our upper limit, and all duplicate numbers. This usually involves a high level of rejection and is therefore inefficient. The following more efficient method is given by Campbell (1967); the example involves selecting at random from a group of 20.

Divide each pair of digits by 20 and take the remainder (remainder zero is, for this purpose, treated as remainder 20); these remainders are then the required random numbers.

Any duplicate remainders are ignored.

This procedure has to be modified if the size of the group is not an exact submultiple of a power of 10. Thus if the group size is 19, the pairs of digits 01 - 19; 20 - 38; 39 - 57; 58 - 76; 77 - 95 all give complete sets of remainders 1 -10, but the pairs 96 - 00 give the incomplete set of remainders 1 - 5 and must therefore be excluded because their use would unbalance the frequencies of the remainders.

For selection sets of up to 10, use only one column of digits, for sets up to 100 use two columns, and for sets up to 1000 use three columns, etc.

Cross off numbers in the table as they are used, and start each new job where the last one ended. When the set of tables is exhausted, go back to the beginning and start again.

Feedback Report Form

Peatland Management Handbook
Feedback Report Form

Please use this form to report any management innovations or additions/corrections to the Handbook that you would like to see incorporated into future revisions or supplements. Please remember that management failures are as important as successes.

Report briefly and succinctly. Remember to include information as necessary on location of sites, type of peatland and vegetation, level of success or failure, and addresses of product manufacturers.

Name ....

Organisation ....

Address ....

....

....

Postcode .... Telephone ....

I should like to (please tick):

Report a management innovation

Report an error in the Handbook

Suggest an addition to the Handbook

Please make your report below and overleaf.