Portmoak Biodiversity Training Day
March 18th 2006
Bog Restoration: Theory and Practice

DEFINITIONS

- A mire is a general term for a wetland characterised by vegetation which ultimately forms into peat (Lindsay 1995).
- An *ombrotrophic* mire derives both water and nutrients exclusively from atmospheric precipitation (Moore 1982, Ratcliffe 1964).
- *Ombrotrophic* comes from the Greek: *ombros* = a storm of rain, *trophos* = feeder.
- In Britain the colloquial term for such rain-fed mires is bogs (Ratcliffe 1964).
- This contrasts with fens, which are *minerotrophic* mires, and receive some of their water and nutrients from the groundwater table (Lindsay 1995, Moore 1982).

General features of undamaged bog habitats (from Lindsay 1995)

- they are nutrient poor or *oligotrophic*
- conditions are acidic (pH 3.5 – 4.5)
- the climate is moist and bogs typically occur where annual rainfall is 800-1200 mm and with annual wet days of 140-180 (Rodwell 1991).
- waterlogging results in reduced decomposition so that dead plant material accumulates
- the living vegetation grows on top of the partly decomposed plant material (peat) and is cut off from any nutrient supply at ground level
- peat depth is greater than 1 m
- formation takes place over a long time-scale which in Britain is usually between 3000 and 9000 years
- biodiversity is low but specialised and dominated by *Sphagnum* mosses

Formation of Raised Bogs

Many raised bogs began life as a shallow basin formed in relatively impermeable glacial clays. In early post-glacial times (10-12,000 years ago) the basins became a lake with a fringe of fen vegetation.

Over perhaps the next 2000 years the lake became overgrown by fen plants which failed to decay completely because of waterlogging and therefore tended to accumulate filling the basin with fen peat.

The mound becomes cut off from the original mineral source at ground level resulting in a switch from minerotrophic to ombrotrophic conditions. Such conditions are intolerable to most plant species. Cushion-forming mosses known as *Sphagnum* are very resistant to microbial decay and begin to dominate the vegetation (Gore 1983).

After 5000 – 7000 years the central parts of the bog, called the *catotelm,* may rise more than 10 m above the ground (Lindsay 1995).

The thin protective surface layer, sealing the catotelm from the atmosphere, is termed the *acrotelm* and is usually 20 - 30 cm deep (Gore 1983). Bog profiles can vary from a dome to a plateau.

The steeper margins are called the *rand* and the entire raised bog is often surrounded by a moat-like *lagg* normally supporting fen vegetation (Gore 1983).

A raised bog is waterlogged to the extent that it consists of a mixture of 95-98% rainwater bound together by 2-5% peat solids. Even dead *Sphagnum* retains water with the result that downward progress of rainwater is slow and usually outweighs the evapotranspiration taking place at the surface from the living plants. The process is dynamic so that in the summer the dome will reduce in size and then rebound during the wetter winter months. **Illustrate with the Church Spire of Hatfield & Thorne Moss.** If the acrotelm is damaged or the water table is lowered then the catotelm will oxidise and shrink.

Characteristics of the Sphagnum plant

- The growing point is the capitulum.
- There is a main stem with no roots.
- Two types of cells (a) photosynthetic and (b) water-filled hyaline cells.
- A Fascicle consists of Spreading branches and Pendant branches.
- Hummocks: *Sphagnum magellanicum, Sphagnum capillifolium.* (70cm above water table.
- Lawns: *Sphagnum papillosum.*
- Pools: *Sphagnum fallax, Sphagnum cuspidatum.* (45cm above water table)
- Reproduction is by airborne spores or regeneration of windblown fragments.

Value of Raised Bogs

- 50 species of plant are characteristic but occur in other habitats. Examples are bog cottons, sphagnum, bog rosemary, cranberry, sundews and cross-leaved heath.
- Invertebrates: many are specialized and rare.
- Snipe, meadow pipit and skylark are typical species of birds (but possible migrants).
- Peat preserves a record of vegetation history, climate change and human land-use.
- Peat is a carbon sink and locks up atmospheric carbon for many thousands of years.
- Bleak, watery wasteland or valuable “wilderness” experience (education and recreation).
- It has been used for fuel and is in great demand from the horticultural industry in the northern hemisphere.

Condition of Raised Bogs

Sites with predominantly natural primary bog: None in England (where most of them used to be). In Scotland 55 out of 851.

Types of damage

- Peat extraction
- Afforestation
- Agriculture
- Overgrazing
- Procedures common to these exploitations: drainage, removal of the surface vegetation, drying of the excavated peat on the surface and provision of tracks for access.
- Land-use changes in the surrounding area resulting in lowering of the water table.

Problems to be overcome during restoration

- water levels are too low for peat-building *Sphagnum* species
- water levels fluctuate more than in a pristine bog
- water storage capacity is lower than an undamaged bog
- rewetting dried peat may lead to release of nutrients
- bare, dry peat is an inhospitable environment for bog vegetation establishment

In Canada there are large areas of abandoned mined peatlands that have become available for restoration and where the surface is bare, dry peat. A number of research groups are attempting to address the problem using both laboratory/glasshouse expts and field trials and have published many papers in scientific journals. Main conclusions:

- Raise water table
- Stabilise the water table to allow *sphagnum* patches to establish and coalesce to reform an acrotelm:

    Create surface pools and semi-permanent shallow basins (not permanent inundation)

    Straw mulch

    Commensal species

    Sphagnum translocation

History of Vane Farm

- Valleyside mires occur on gently sloping or almost level ground lying between higher steeper terrain and a water body which forms the lower margin (Lindsay 1995).

- Portmoak Moss is situated on the east side of Loch Leven sandwiched between the loch, the River Leven and a steep escarpment forming the west side of Bishop Hill.

- Similarly, the raised bog immediately to the west of Vane Farm lies between the south of the loch and a steep escarpment forming the north side of Benarty Hill.

- The geology and history of the area suggest that both raised bogs formed part of two valleyside mire complexes which have now disappeared (Bell 1796, Tyldesley 1995).

- Records describe Scotlandwell Moss as a large area of wetland, meadow, peat bog and reed-covered marshland continuous with Portmoak Moss which was itself larger than today and closer to the shores of the loch (Bell 1796, Munro 1994).

- For Vane Farm Moss there is no record of any commonty for domestic peat cutting. The “Moss” is described in the Statistical Accounts of Scotland 1791-1799 as covered in heath and “could not be cultivated without much labour and expense” but, no record of any peat cutting.

- Unlike Portmoak Moss, it was not cut round the edges leaving the dome intact but was sliced right across the middle like two halves of a cake.

- The eastern section of the bog was cut leaving a system of bulks and hollows. It seems likely that the peat supplied the local distilleries in the late 18th and early 19th centuries; Portmoak Moss was also used for this purpose for a brief period (D. Munro personal communication).

- Therefore, by the 20th century, both raised bogs had been damaged as a result of peat cutting destroying the hydrology which maintains the classical dome shape. The hydrology of both sites was further compromised by the lowering of the water table, the isolation of the bogs from the loch shores and the loss of their associated valleyside mires due to drainage.

- Vane Farm Moss was drained and planted with conifers in the 1940s and became known as the Waterbutts Plantation. The trees were clearfelled in the 1970s and this allowed invasion by birch scrub (Ellis 1999).

- The RSPB owns 63ha of remnant raised mire of which 20ha is to be restored. The invading birch scrub was removed in 1997 and the large volume of brash removed by machinery and voluntary work parties in 1998/99.

- 69 peat dams were then installed, which made the area wetter but birch regeneration was nevertheless considerable (50-90%). The numerous birch stumps were treated chemically to inhibit growth (Money 1999).

- The site consists of uncut bog in the west and cut bog in the east. The cut edge is sliced across the central dome and is visible as a peat bank right across the bog running in an approximately north-south direction

- The peat depth on the remnant dome of the uncut area ranges from 3.1-4.6m. On the western and northern edges of the uncut area, the peat depth is much less at 0.4-2.4m. In the cut area 0.2-1.3m is the peat depth (McPherson 2000). The water table averaged 550mm in July 2000 (McPherson 2000) which is lower than the 400mm regarded as the minimum requirement for *Sphagnum* regeneration (Grosvernier et al 1997).

- In the cut area, peat has been removed virtually to the sandy ground beneath the peat (Dadds 1998). It is likely that water escapes through the sand, leading to an unstable
- water table. Vane Farm Moss is more damaged than Portmoak Moss but, being in a more remote situation, has fewer restrictions imposed on it in terms of land management. There is much scope to experiment with the hydrology of the site.

Translocation experiments at Vane Farm in 2003/2004

- In 1998 a grid system of 40 marker posts for measurements of peat depth, water table and vegetation survey established. 2003 was an exceptionally dry year. In 2004: 62% of monthly readings were 400mm or less in the uncut area near the remnant dome. In the cut area and the north and west uncut areas, only 30% of readings were less than 400mm. Most of sphagnum patches were found near the remnant dome (179) and none in the cut area except near the peat bank even 5 years after water table improvements. Therefore *sphagnum* translocation considered in the cut area of the bog.

- Some *Sphagnum* plants were taken from an uncut area to a cut area of the bog where no *Sphagnum* was currently growing. Each experiment used a series of numbered, randomised, 0.5m x 0.5m quadrats consisting of green netting secured with garden staples at the corners. The plants were fragmented in a liquidiser and placed under the netting to prevent them from blowing away. No fragments were added to the untreated, control quadrats.

- *S. capillifolium* was chosen as it was the only species present in significant amounts known to be associated with natural raised bogs and shown to be one of the species suitable for translocation (Rochefort 2000).

- There were five experimental areas in total.

2003: Area A	Bare peat
2003: Area B	Grass growing on peat, adjacent to Area A
2003: Area C	Below peat bank
2004: Area D	New ditches
2004: Area E	No new ditches, adjacent to Area D

- Water table monitored and *Sphagnum* growth measured by counting capitula, the head formed of crowded branches around the stem apex.

- In 2004, the hydrology of the dry interior of the cut bog was modified. This was achieved by diverting water from a large wet area fringing the south of the site into newly created ditches

Area A: No *sphagnum* growth
Area B: New capitula growth in 11 of 20 quadrats: 3(3-8)after 6mths: 25(17-52) after 18mths
Area D: New capitula growth in 18 of 20 quadrats: 24(7-52) after 6mths
Area E: New capitula growth in 4 of 20 quadrats: 3(3-9) after 6mths

Growth of capitula occurred in Area B in spite of the low water table. It was thought that the grass was creating a moist microclimate and regeneration from the diaspores was found to be occurring in small pockets. Nevertheless, the slow growing *Sphagnum* was at risk of being out-competed by the grass. The diaspores in the bare peat of Area A were thought to be too exposed to desiccation and therefore did not survive.

Following the creation of new ditches, the dipwells in Area D showed a marked, if variable improvement in water table from 86cm (April) to 48cm (October).

The excavation of the new ditches caused a substantial loss of surface vegetation. It did not, however, leave a totally bare surface as in Area A. It is possible that there was less competition from the grassy vegetation but still enough present to provide shelter and a microclimate of moisture. By contrast, there was very little growth of capitula in Area E amongst vegetation that appeared from casual observation to be growing vigorously in the wetter summer of 2004.

Recommendations for larger-scale experiments in Area D

The disadvantage of carrying out *Sphagnum* translocation on a large scale is the amount of live *Sphagnum* required from a donor site (in this case from a different part of the same site). Vane Farm raised bog has substantial amounts of the less threatened *S. cuspidatum* in many of the ditches on the uncut bog and in the pools close to the peat bank. It may be more acceptable to experiment with this species by spreading it in the newly created ditches. Once the *S. cuspidatum* is established, it may provide a habitat for more typical bog species such as *S. capillifolium and S. magellanicum* (Money 1994). The new ditches may also continue to improve the hydrology and eventually create a more stable water table and wetter surface conditions.

Additional notes

- *Terrestrialisation* occurs when lakes and pools are completely replaced by peat either *rooting* or *rafting.*
- Plants take root in lakes which have become shallower as a result of silting.
- Rafting in contrast, involves the formation of a floating mat of vegetation termed “schwingmoor” or “floating mire” which gradually becomes solid peat.
- Rafting successions are particularly characteristic of small, sheltered and often deep water bodies such as kettle-holes (Tallis 1973).
- Many peatlands however, have developed by the *paludification* or swamping of dry land as a result of a rise in the groundwater table (Wheeler and Shaw 1995). Unlike terrestrialisation it can occur without any preceding fen stage.

Physical and Chemical Characteristics of Raised Bogs

- Bogs are nutrient poor or oligotrophic with the surface layer characterised by low potassium, calcium, magnesium, phosphate and nitrate (Karlin and Bliss 1984, Malmer 1986, Waughman 1980).

- *Sphagnum* mosses are able to survive in these poor nutrient conditions by exchanging the few cations available for hydrogen ions (Clymo 1963, Gagnon and Glime 1992, Gorham 1956). Clymo (1963) found that polyuronic acids in the cell walls of *Sphagnum* were the sites for cationic exchange.

- The result is the creation of an acidic environment, the degree of acidity varying between hummock and hollow *Sphagnum* species (Andrus 1986). Sphagnum, Acutifolia, Cuspidata, Subsecunda, Squarrosa, Rigida.

- Creates an acidic environment by exchanging cations for hydrogen ions and polyuronic acids in the cell walls are sites for cationic exchange.