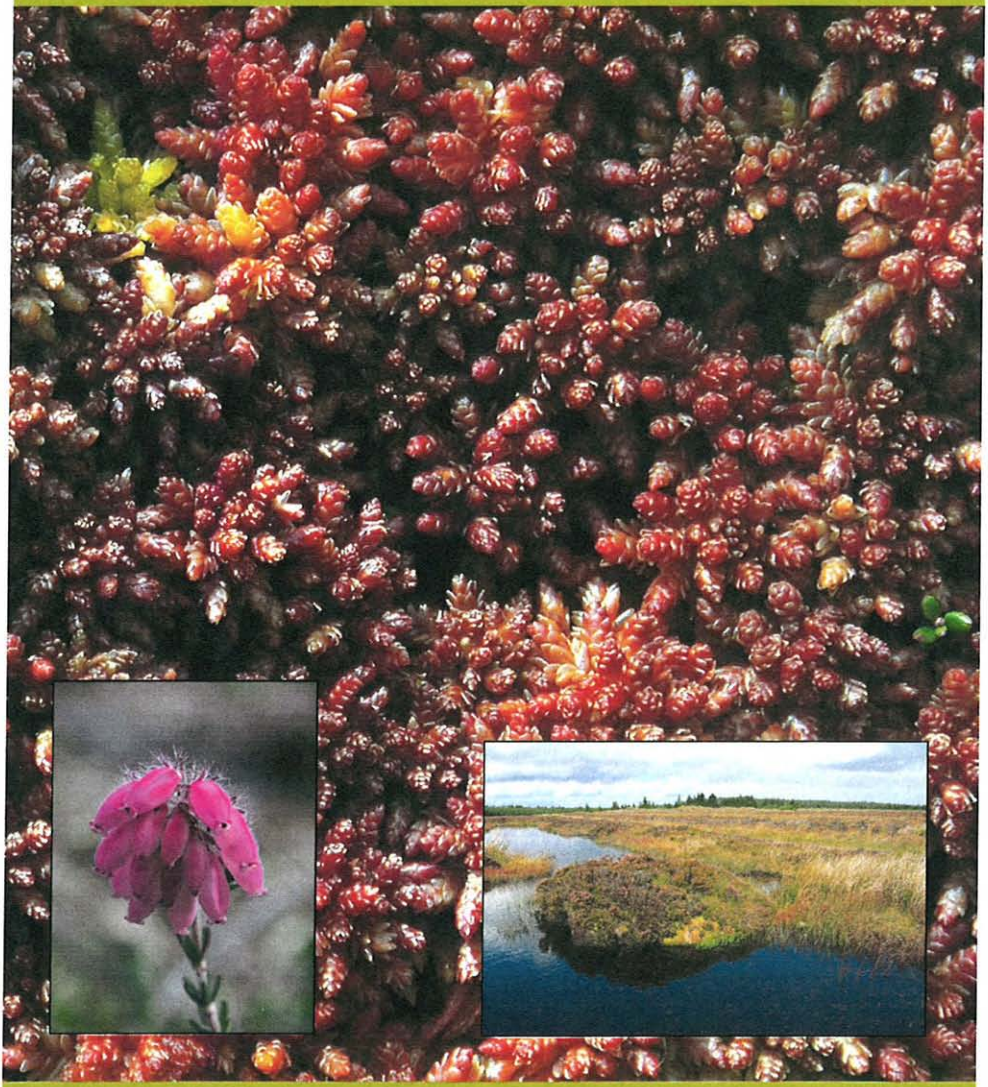
The Border Mires
a conservation history



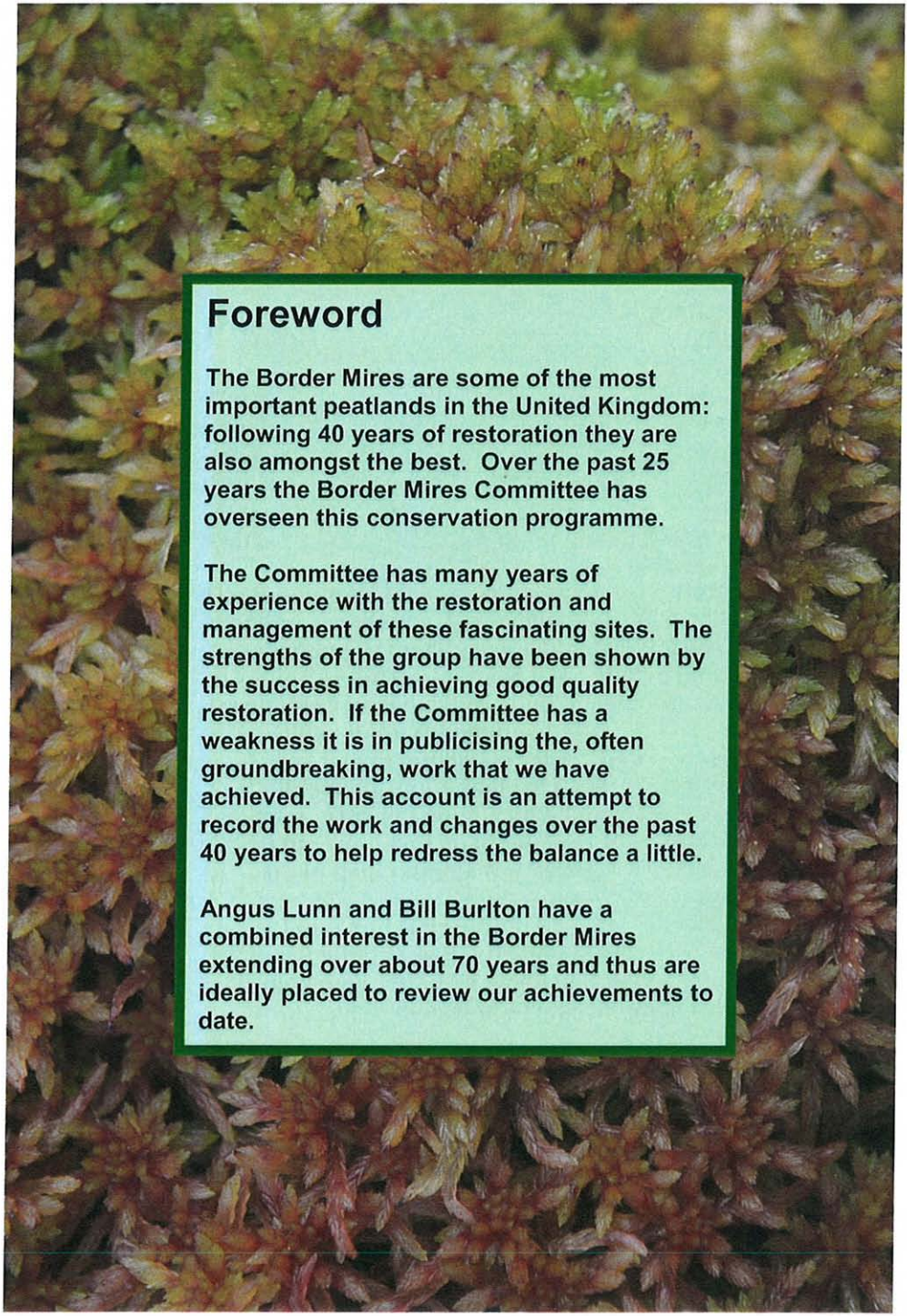
Angus Lunn and Bill Burlton

The Border Mires: a conservation history

Angus Lunn and Bill Burlton

2010

Above: Chipping trees on Grain Heads Moss as part of the LIFE project. Cover: Sphagnum moss, Inset left: Cross leaved heath, Inset right: Bell Crag Flow.



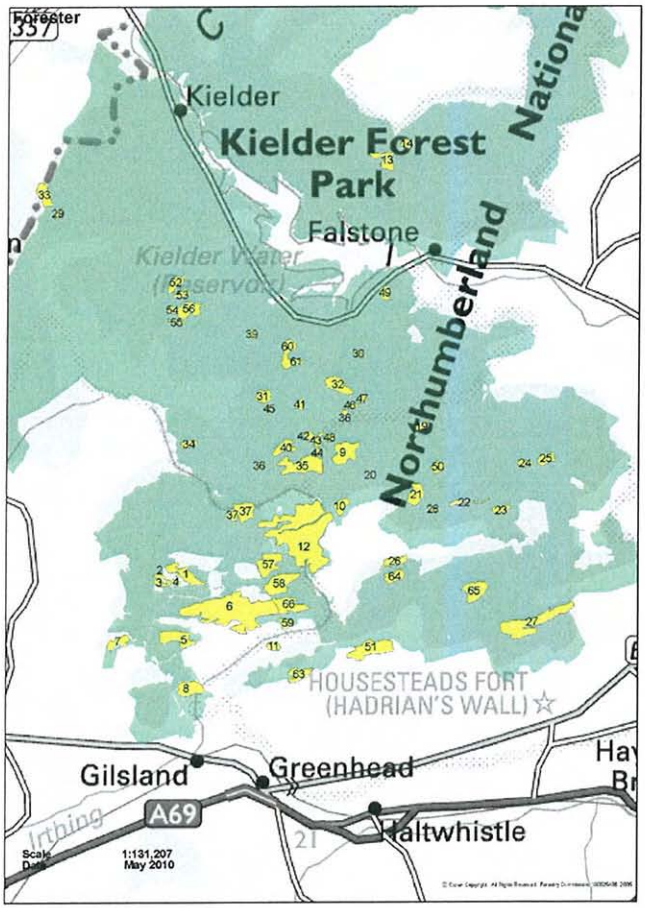
Foreword

The Border Mires are some of the most important peatlands in the United Kingdom: following 40 years of restoration they are also amongst the best. Over the past 25 years the Border Mires Committee has overseen this conservation programme.

The Committee has many years of experience with the restoration and management of these fascinating sites. The strengths of the group have been shown by the success in achieving good quality restoration. If the Committee has a weakness it is in publicising the, often groundbreaking, work that we have achieved. This account is an attempt to record the work and changes over the past 40 years to help redress the balance a little.

Angus Lunn and Bill Burlton have a combined interest in the Border Mires extending over about 70 years and thus are ideally placed to review our achievements to date.

Context



In the uplands of west Northumberland and adjacent east Cumbria, north of the Tyne Corridor and on Forestry Commission land, are discrete areas of exceptionally deep peat - the Border Mires. Before afforestation they were set within a matrix of other types of moorland, on mineral soils, and thousands of years before that, before agricultural settlement of the region, the mires (although less extensive than now owing to continuing peat accretion) were islands in a matrix of native woodland. Afforestation of the moorland landscape by the Forestry Commission (FC) in the period 1926 to 1980 (as Kielder Forest), left many of these peat lenses unplanted, and they now form islands or peninsulas within spruce forest. They have mainly bog vegetation, on ombrotrophic (rain-fed) peat, with some local poor-fen soakways (where there is some component of surface run-off).

The origin of these mires came about through two main processes:-

- *terrestrialisation* - by succession from shallow meres through fen and carr, as vegetation in-filled the water bodies;
- *paludification* - by expansion of mire vegetation over mineral soils as the bogs grew and spilled out from their original areas.

Those formed by terrestrialisation are raised mires, whilst others, the result of the expansion and coalescence of raised mire units by paludification of adjacent mineral soils, are intermediate mires (a type of blanket mire). Additionally, a few

sites at higher altitude are thick lenses of peat set within extensive upland blanket mire. There are rather similar, although fewer, sites on the Ministry of Defence's Otterburn Training area, in the Simonside hills, in Cumbria west of the Spadeadam sites and immediately south of Kielder Forest in the Hadrian's Wall area.

Most of the mires lie at altitudes of 200-300m where precipitation is 890-1145mm per year, increasing northwards as altitude increases. The underlying rocks are southwards-dipping Lower Carboniferous sediments, consisting of a rhythmic sequence of limestones, shales, sandstones and coals. Thicker resistant beds form striking west-east ridges (cuestas), with south-facing dip slopes and north-facing scarps. As the ground rises northwards, however, hills become more rounded. During glacial stages ice sheets flowed eastwards across the area, eroding enclosed depressions in the weaker rocks which became the sites for numerous meres. The ice also deposited patchy till, which is clayey and impervious, and depressions in the till held other meres. Four of these meres survive, but the others have been in-filled and succeeded by the mires described here.

The raised mires are found mainly in the south of the area, and because they lie in depressions between cuestas they are surrounded by higher ground (unlike typical raised bogs elsewhere) and are *constrained raised mires.* Like the topography, they are oriented west-east but as the general ground level rises northwards and precipitation increases, they are replaced by larger intermediate mires of various shapes. Finally, on the highest ground (above about 400m and with more than about 1145mm of precipitation), extensive upland blanket bog (not normally included with the Border Mires) occurs. There are scores of constrained raised mires and a dozen or so intermediate mires in the area. One of the latter - Butterburn Flow - appears to have developed partly on a wide terrace of the River Irthing. Depths of peat are up to 11 metres and commonly up to 7 metres.

Peatland or Mire?

When the Border Mires were named the usage of "mire" was more or less synonymous with peatland; present usage is that mires are ecosystems developed on peat soils which still support vegetation that is normally peat-forming. In this sense most of the Border Mires still pass as mires.

Locally the terms 'moss' and 'flow' are used to refer to some of the mires while 'flothers' was also used on a now lost site.

Conservation value

The conservation value of the Border Mires lies particularly in their naturalness. They are nationally and internationally important ecosystems, with intact hydrology and peat-forming vegetation, and they support uncommon and rare plants and invertebrates. The sites are fragile and many are of considerable size, and they represent a wide range of hydro-topographical and climatic conditions. Their peat stratigraphy also provides a very

complete record of Holocene change, including short-term climatic fluctuations, and has been the focus of much recent research. This has included analysis of pollen, testate amoebae, macroscopic plant remains, geochemistry and peat humification, backed by ^{14}C dating.

Most have a more or less continuous *Sphagnum* carpet (the main species are *Sphagnum magellanicum, S. papillosum, S. capillifolium, S. tenellum* and *S. cuspidatum*) and much of their vegetation belongs to NVC community M18a (*Sphagnum magellanicum-Andromeda polifolia* sub-community of the *Erica tetralix-Sphagnum papillosum* raised and blanket mire). Characteristic plants are round-leaved sundew *Drosera rotundifolia*, cranberry *Vaccinium oxycoccos*, bog asphodel *Narthecium ossifragum* and bog rosemary *Andromeda polifolia*. Great sundew *Drosera anglica* occurs on three of the bogs, and its hybrid with *D. rotundifolia* occurs on one. Rare or uncommon sedges are bog-sedge *Carex limosa*, tall bog-sedge *C. magellanica* and few-flowered sedge *C. pauciflora*; white beak-sedge *Rhychospora alba* is also present on a few bogs. In soakways are various poor-fen species including, very locally, stunted common reed *Phragmites australis*. On some bogs are hummocks of the rare *Sphagnum fuscum* and *S. imbricatum* (now *S. austinii*), and on one bog, at Spadeadam, is dwarf birch *Betula nana* at one of its three English sites. Apart from the dominant *Sphagnum*, the prominent species are typically hair's-tail and common cottongrasses *Eriophorum vaginatum and E. angustifolium*, deergrass *Tricophorum cespitosum*, cross-leaved heath *Erica tetralix* and heather *Calluna vulgaris*.

A recently identified new taxon of deergrass, the hybrid *T. cespitosum* nothosubsp. *foersteri* is the characteristic deergrass of

Above: main picture, Cranberry. Inset top, Large Heath: Inset bottom left, dwarf birch on Berry Hill Moss. Far left: bog asphodel

the raised and intermediate mires in west Northumberland. It is a sterile hybrid between the two deergrass subspecies (*T. cespitosum* subsp. *germanicum* and *T. cespitosum* subsp. *cespitosum*), and all extant British records of the hybrid are from or immediately adjacent to Northumberland, centred on the Border Mires. The more widespread form of *foersteri* is non-proliferous. The proliferous form (in which some of the flowers proliferate to give green plantlets), however, occurs on many of the mires.

In 2001 Turner found a nationally important liverwort, Veilwort *Pallavicinia lyelli,* was found in two small patches of purple moor grass at the edge of Butterburn Flow. This was the first record for the north of England.

The Border Mires are a main habitat of the large heath butterfly *Coenonympha tullia*, which otherwise in Britain is found principally in Scotland. Its requirements include hare's-tail cottongrass (as larval host plant) and cross-leaved heath (as nectar source for the adult), together with a water-table at or near the ground surface. The mires are also habitat for a number of other nationally rare and scarce invertebrates, including the flies *Spilogona depressiuscula* and *Coenosia paludis*, and the ground beetles *Agonum ericeti* and *Carabus nitens*. Several species of Odonata breed in bog pools, the most abundant being large red damselfly *Pyrrhosoma nymphula* and black darter *Sympetrum danae*.

Both adder and common lizard are found and frog, toad and palmate newts are on many of the sites. Roe deer cross the mires between areas of forestry and newly born fawns have been found on Falstone Moss; badgers also forage over the sites. Bird life includes meadow pipit and skylark; occasional breeding of curlew, golden plover and dunlin have been recorded; and hen harrier and kestrel are amongst the birds of prey seen hunting over the bogs.

Curlew nest on Felecia Moss

As intact *Sphagnum* mires, the Border Mires are the best series in the British Isles outside of the Flow Country of northern Scotland. Their survival is probably due to a combination of factors. The 'inter-cuesta' setting of many of them hampers artificial drainage and, by maintaining a very high water-table, burning is made harder. Additionally, their location in the Anglo-Scottish Border region where Border wars and local predatory raiding, which was continuous until the 17th century, set back agricultural progress. In fact, Mosstroopers, otherwise known as Border Reivers, derived their name from their ability to navigate stolen stock through the complex of wet 'mosses'. Additionally, the moorland vegetation of the huge post-enclosure hill sheep farms in which the mires were located (extensive purple moor grass, *Molinia* , grassland and *Molinia-Eriophorum vaginatum* mire) was of very low stock-carrying capacity, perpetuating a low level of pressure by human activities on the environment. Also, unlike the case further south in the Pennines, industrial air pollution has not so far had a pronounced effect on peat chemistry. Since incorporation in the forest estate, there has been a virtual absence of burning or farm stock grazing for about 50 years. Butterburn Flow was grazed by sheep until the foot-and-mouth disease outbreak in 2001 but has subsequently remained ungrazed.

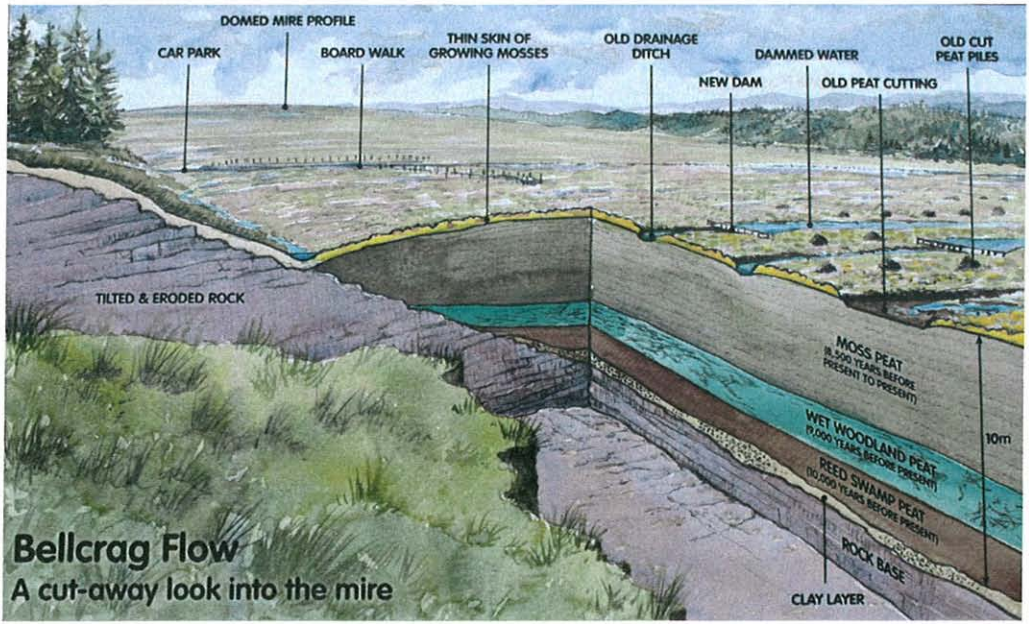
Bog Rosemary

Condition of the mires

Why, given all of this, and the survival of many mires within the forest, had conservation action become necessary?
There are several reasons:-

1. Prior to afforestation there had been attempts by hill farmers to drain some sites.
2. During the two World Wars timber shortages were a significant threat to the war effort. The Forestry Commission was therefore created with the single purpose of establishing a strategic timber resource (though now changed). This involved afforestation in the uplands and, in England, notably Kielder. As part of the process many of the mires sites were drained then planted or left for planting (once the mire had drained) often leaving only the wettest central part of the mires open.
3. FC drained and planted land adjacent to sites, sometimes running drains across the mire or around the margins.
4. On one site, Bellcrag Flow, peat was being extracted and in preparing the ground considerable drainage was undertaken on the eastern part of the site. The ill-fated venture was short lived and the planning permission has now lapsed.

The main post-World War II expansion of the forest, up to about 1960, was in the southern part of Kielder Forest, just north of Hadrian's Wall, and area where many mires are concentrated.



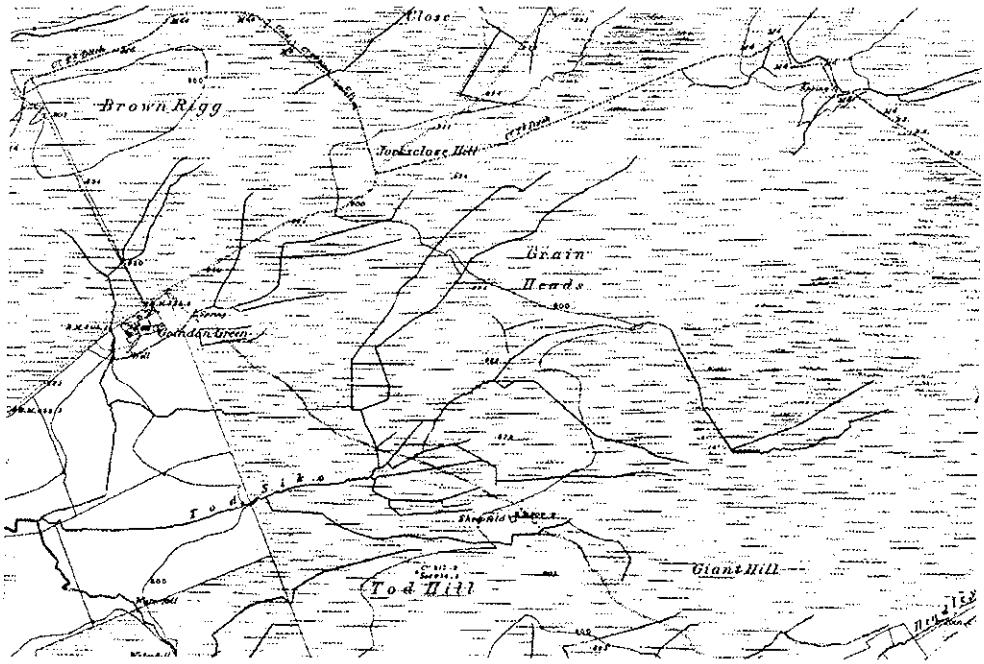
A section of the Bell Crag Flow Interpretation

In establishing new plantations, the Forestry Commission ploughed the moorland with specially adapted tractors and ploughs in order to plant on the turves upturned from the furrows while at the same time creating drains (grips) in order to lower the water-table. As a result, even when trees were not eventually planted, the *Sphagnum* carpet was adversely affected and the vigour of heather increased. These changes together eliminated or reduced the populations of most of the characteristic mire species. Additionally, the lowered water table allowed natural regeneration of Sitka spruce on the mires, with further adverse effects on water-tables (through increased evapo-transpiration) and on floristic composition. The groundwater mound theory of mire hydrology (which applies to thick lenses of peat) claims that tapping the groundwater mound at any point will lower the water-table throughout the mire, so damaging surface hydrology and altering the vegetation over the entire system (and eventually lowering the peat surface through shrinkage and oxidation). Even marginal drainage therefore has deleterious effects throughout the mire, the more so as such drainage, together with evapo-transpiration by the tree crop planted on the margin, leads to local peat shrinkage (hydrologically equivalent to digging peat at the margin).

The corollary of all of this is that blocking drains anywhere on the system, including at the margin, should have an opposite and whole-bog beneficial effect, and this is the rationale of much remedial work. However, it is still unclear whether the luxuriant growth of heather which characterises many bogs set within the forest is caused entirely by water-table lowering, or is rather a consequence of the cessation of sheep-grazing. Perhaps both are implicated - water-table lowering on the bog crown and absence of grazing on sloping margins.

Conservation history

The sites were largely unknown to naturalists until after the Second World War. Many (in Northumberland) came to notice as a result of vegetation mapping by Lunn in the mid-1950s (published in a generalised form in 1976), although independently of this Butterburn Flow had become an SSSI in 1959 and Coom Rigg Moss had been declared a National Nature Reserve in 1960. At this time FC was rapidly expanding its plantations, which eventually involved drainage of even the wettest mire sites and afforestation with Sitka spruce and/or lodgepole pine. After the Northumberland and Durham Naturalists' Trust (now Northumberland Wildlife Trust) was set up in 1962 it turned its attention to negotiating to save the best of the mires which had not yet been planted. The Trust considered an initial report, listing the main sites and classifying them by conservation importance, in 1965. This was followed by a further assessment report in 1967, confirming the most important sites. As a result, in 1970, eight of these mires were leased by the Trust from the Forestry Commission as nature reserves (the original Border Mires): most of these would otherwise have been afforested and destroyed. It was then that the collective name "Border Mires"



The area around Grain Heads Moss as it appears on an 1860s Ordnance Survey map

was coined, to describe all the mire systems in the area. The sites were Falstone Moss, Felecia Moss, Gowany Knowe Moss, Haining Head Moss, Hobbs Flow, Hummel Knowe Moss, The Lakes and The Wou (part of which had been leased by the Trust from the previous owner in 1968). Haining Head Moss, Hummel Knowe Moss and the Wou are only partly on Commission land, but the non-FC sections are adequately protected as SSSI units (and the non-FC part of The Wou is now owned by Northumberland Wildlife Trust). After the lease expired on the eight reserves, they were absorbed into the collective of Border Mires, although NWT retains an agreement to regard 21 Northumberland sites as its reserves along with Butterburn Flow in Cumbria which it does so in collaboration with Cumbria Wildlife Trust.

Early conservation action by the Trust's conservation volunteers, from 1971 at Haining Head Moss, was to block drains with peat dams (cut by hand from turfs upturned from the drains), which proved to be very effective. During the next decade UK forestry policy changed and from 1986 the FC has led a partnership, the *Border Mires Management Committee* (see box on page 11), which accepted responsibility for commissioning applied research and for conservation actions on (eventually) a list of 55 mire sites in Kielder Forest, including Spadeadam in Cumbria. Many of the additional Northumberland sites were identified in a survey by Smith and Charman (1988), based on up-to-date maps and aerial photography, and the Spadeadam mires were incorporated in the early 1990s.

The Border Mires Committee

Since 1986 the conservation of the Border Mires has been overseen by the Border Mires Committee. Forestry Commission lead this group which comprises:

- Forestry Commission
- Northumberland Wildlife Trust
- Northumberland National Park Authority
- Natural England
- University of Newcastle upon Tyne
- Royal Air Force (Ministry of Defence)

The RAF joined at the start of the LIFE project and have remained a member since this time. The responsibilities of Natural England were formerly held by English Nature and before that the Nature Conservancy Council.

Northumberland Wildlife Trust accepts responsibility for the Cumbria sites on behalf of Cumbria Wildlife Trust.

The area of the 55 mires, including their immediate input slopes (draining to the mires), totals 2,850ha, and of the mire surfaces themselves approximately 2,000ha.

Over time 29 of these sites acquired SSSI status, as Butterburn Flow SSSI (Cumbria), and as units within the Spadeadam Mires SSSI (7 sites in Cumbria) and Kielder Mires SSSI (21 'Border Mire' sites in Northumberland). Of the 55 sites, 13 are in Cumbria and the remainder in Northumberland. 18 Border Mires lie inside the Northumberland National Park (12 of these being SSSI units). Ramsar designation was given to 8 sites in 1985, these were described by Ratcliffe in *A nature conservation review* (1977), and were referred to there as the "Irthinghead Mires", a name not now in use other than in the Ramsar designation. Grain Heads Moss became a second National Nature Reserve, also in 1985. It was not in the list of sites originally identified by the Trust because at the time of survey a much larger area of mire (of which the present site is part) was being drained and afforested and it was assumed that the site was lost. In fact part had proved too wet, had survived, and was still of very high quality. Three of the non-SSSI sites have been notified to the planning authorities by Northumberland Wildlife Trust as Local Wildlife Sites.

The Border Mires Committee has adopted and implemented two management plans, the first running from 1996-2001 (extended until 2003 to cover the LIFE project: see below), and the second from 2004-2009. A third, from 2010-2020 has just been adopted.

In 1996 the three SSSIs (with multiple sites), together with other mire SSSIs in the area, were recommended to the European Commission as a candidate Special Area of Conservation (cSAC: now confirmed as a SAC) under the EU *Habitats Directive*: "Border Mires: Kielder-Butterburn" (thus extending the term Border Mires both off FC land and into high-altitude blanket bog). The habitats for which the SAC was proposed included blanket bog (which where active, as here, is a priority habitat), and all of the Border Mire sites are, for SAC purposes,

Above: The Lakes: wet mire where self-seeded Sitka spruce rarely grow
Below: Harelaw: Self-seeded Sitka spruce growth after about 10 years

Above: Long Moss: Recovery on area cleared using a cable crane
Below: Gowany Knowe: Growth over area dammed 8 years previously

interpreted as "blanket bog". Thus the 29 Border Mire SSSI sites are also designated as units within a SAC. The Border Mires are within the Border Uplands Natural Area.

Although not part of the Border Mires in the original sense of deep peat systems (nor counted in the total of 55 sites), the Kielder Western Moors (the unplanted blanket bog above the forest on the Northumberland-Cumbria boundary) are managed by the Border Mires Committee and have their own management plan. The area is within the Kielder Mires SSSI (as the "Glendhu Hill, Sighty Crag and Humble Hill" part) and is within the SAC. Many other mires in west Northumberland/east Cumbria are not on FC managed land but, with one or two exceptions, have similar ecological characteristics. Muckle Moss and Greenlee Lough are National Nature Reserves.

The details, including conservation status, of the 55 Border Mires are listed on page 16.

Surveys and reports

Following the initial Northumberland and Durham Naturalists' Trust reports, a series of other surveys and reports have informed the activities of the Border Mires Committee:

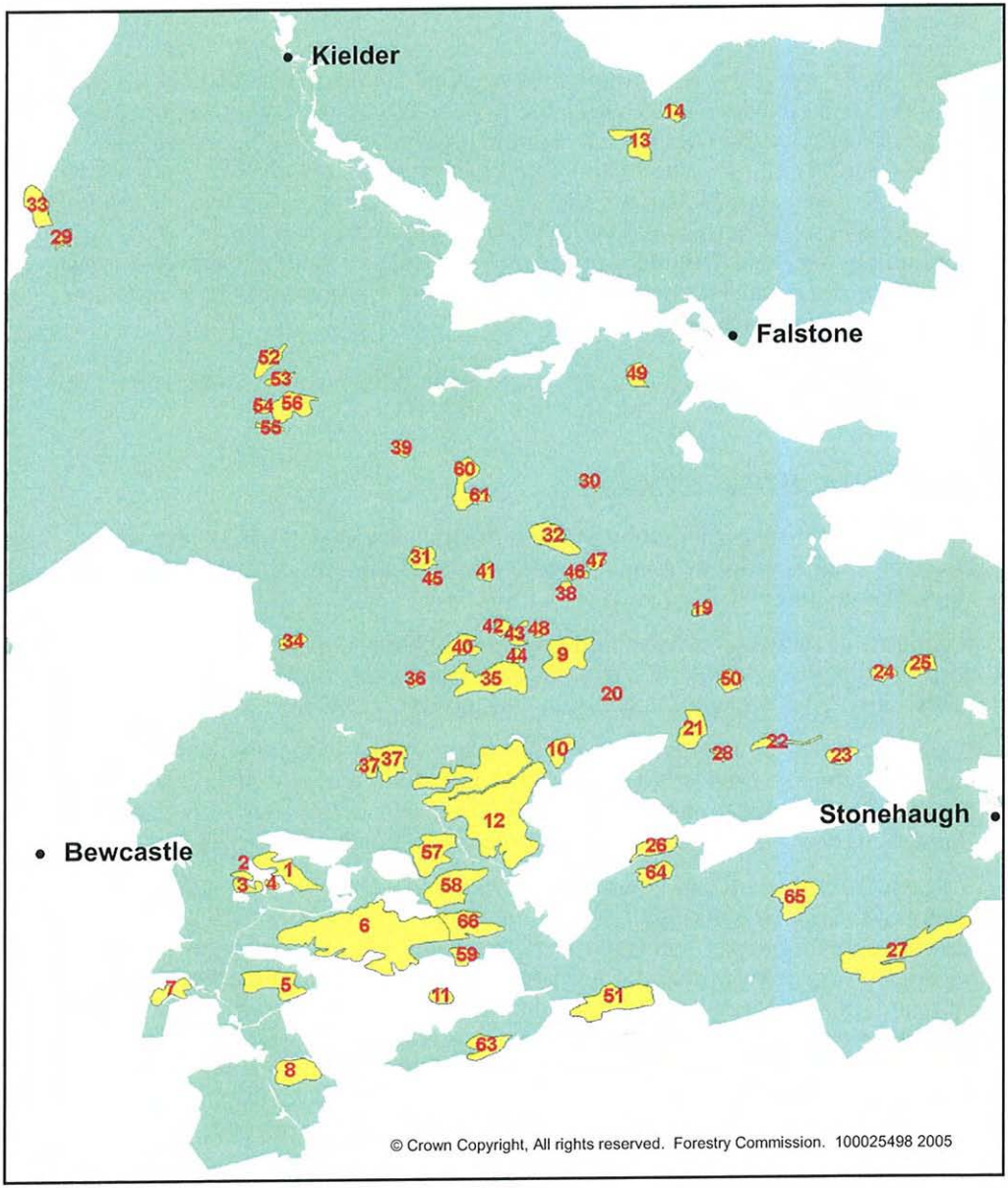
1. Smith and Charman (1988), and Charman and Smith (1992), described in detail the vegetation of 34 of the Northumberland sites, and Smith subsequently related this to the National Vegetation Classification (1993).

2. Holmes (1992) reassessed the conservation value of the mires, largely confirming the initial classification by the Trust and the appropriateness of their subsequent designation as NNRs and/or SSSIs. His criteria were area, extent of *Sphagnum*-dominated vegetation and amount of drainage attempted.

3. Lowe (1993) surveyed the natural hydrological boundaries (effectively the extent of the peat lenses) of 48 Northumberland sites by reference both to former vegetation types and the occurrence of peat depths greater than one metre. He was able to measure the areas of planted and non-planted (open) mire surfaces, respectively, and found that 63% of the total area was open mire. This information, together with similar data gathered by White (1994a,b,c) on the Cumbrian sites, was the basis of subsequent management actions in clearing afforested sections to the site boundaries, and planning restocking limits so as to leave adjacent input slopes draining to the mire surface unplanted.

4. There have been several invertebrate surveys, including of large heath and small pearl-bordered fritillary butterflies, Odonata, spiders and carabid beetles. Wainwright (unpublished) demonstrated an association between the large heath butterfly and the drier margins of the mires dominated by hare's-tail cottongrass and heather, and Dennis & Eales (1999) noted that it was the larger mires which contained the large heath populations.

The Border Mires - location and designations



Notes on the Table (right)
County: N - Northumberland: C - Cumbria
NNP: Site within Northumberland National Park
NNR: National Nature Reserve

Site Name	Map No.	Area (ha)	County	NNP	MOD	SSSI unit	SAC unit	NNR	Non SSSI	Ram-sar
Andrews Knowe	29	7.9	N			Y	Y			
Archies Rigg	30	6.9	N						Y	
Bell Crag Flow	27	150.2	N	Y		Y	Y			
Berry Hill East	6	51.7	C		Part	Y	Y			
Berry Hill West			C		Part	Y	Y			
Blind Moss & Hurtle Winter	35,36	104.2	N	Y		Y	Y			
Birky Grains 1 and:	45	4.8	N						Y	
Birky Grains 2	31	28.9	N						Y	
Butterburn Flow	12	446.7	C			Y	Y			Y
Byreshields Hill and:	61	9.8	N						Y	
Stott Craggs 1	60	43.8	N						Y	
Stott Craggs 2			N						Y	
Chirdonhead Moss	46	9.2	N			Y	Y			
Chirdon Burn Moss	42-44	28.6	N			Y	Y			
Chirdonhead 2	47	11.0	N						Y	
Chirdonhope Moss	48	9	N						Y	
Christys Moss and:	32	49.6	N			Y	Y			
Robins Knowe			N			Y	Y			
Cocklaw Moss	11	16.8	C						Y	
Coom Rigg Moss	9	73.6	N	Y		Y	Y	Y		Y
Deer Hill	66	62.0	C						Y	
Earls Seat	14	14.3	N						Y	
Falstone Moss	49	20.6	N			Y	Y			
Felicia Moss	21	42.7	N	Y		Y	Y			Y
Foalstand Rigg	5	65.5	C			Y	Y			
Gair Sike Hill	58	79.3	C						Y	
Gowany Knowe	50	20.5	N	Y		Y	Y			Y
Grains Heads Moss	65	61.2	N	Y		Y	Y	Y		Y
Grey Mares Hill E	1	54.9	C			Y	Y			
Grey Mares Hill W	2-4	28.2	C			Y	Y			
Haining Head Moss pt	26	30.9	N	Y		Y	Y			Y
Harelaw Moss	23	20.9	N	Y					Y	
Hawthorne Moss	28	5.3	N	Y					Y	
Hobbs Flow	33	40.8*	N			Y	Y			
Horse Hill Moss	24	16.1	N	Y					Y	
Hummel Knowe Moss pt	51	94.5	N	Y		Y	Y			Y
Jamies Lodge	34	15.9	N						Y	
Long Moss	8	52.4	C		Y	Y	Y			
Mary's Rigg	19	9.9	N	Y					Y	
Muckle Gowany Knowe	20	1.8	N	Y					Y	
Muckle Knowe Complex	52-56	105.6	N						Y	
Paddaburn Moss	37	64.9	N			Y	Y			
Prior Lancey Moss	7	28.8	C		Y	Y	Y			
Pundershaw Moss	25	28.1	N	Y		Y	Y			
Rabbit Crag	13	40.8	N						Y	
Shilling Pot	38	5.4	N						Y	
Stour Cleugh	57	68.6	C						Y	
The Lakes	22	14.7	N	Y		Y	Y			
The Rigg	39	9.6	N						Y	
The Shanks	40	35.2	N			Y	Y			
The Wou pt	63	39.2	N	Y		Y	Y			Y
Wedges Rigg	64	31.0	N	Y		Y	Y			
Whickhope Nick	41	12.5	N						Y	
Whiteside	59	19.8	C						Y	
Yellow Mire	10	27.5	N	Y					Y	

Numbers 15-18 and 62 are other FC mires outside the Border Mires

5. Newson & Rumsby (1991) and Newson & White (1993) investigated mire hydrology, and made site-specific recommendations on the management of the input slopes. It was at first decided that it was unnecessary to clear plantation from these slopes but later the decision was reversed - restocking would not take place within 30 metres back from the mire margin.

6. Clothier (1995) surveyed the grips, in preparation for damming.

7. In 1998 Smith began an assessment, using exclosures, of the effect of grazing on Butterburn Flow, leading to two reports (Smith et al. 1990, 2002).

8. Simpson carried out a DAFOR botanical survey of the Northumberland sites in 1996-97 and of the Spadeadam sites in 2000, also noting some other organisms.

9. Jerram, for English Nature, surveyed the hydrological boundaries of five Cumbrian sites in 2000, using the criteria developed for the Northumberland sites.

10. Northumberland National Park volunteers surveyed the distribution of great sundew on the mires in 2003.

Arising from (3), (5) and (9) above, the pre-afforestation natural mire boundaries were agreed between English Nature and the FC and formally incorporated in the Forest Design Plan. Separately, it was agreed by the FC that, where possible, Norway spruce, which does not regenerate from seed as prolifically as Sitka, would be used when restocking adjacent to the mires.

A plastic piling dam on Grain Heads Moss

Management activity

Up to and including the LIFE project

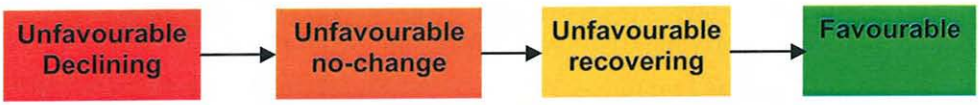
Apart from the early grip-damming work by the Trust, virtually all conservation work has been initiated by the Border Mires Management Committee, convened, led and (particularly since the LIFE project) substantially funded by the Forestry Commission. As explained above, grip-damming had priority and by 1995 there had been comprehensive work on Horse Hill and Felecia Mosses, with more than 2,000 dams installed overall. WALRAGS (water-level rain gauges) were also put in place to monitor the effects of damming and different techniques were

developed and tested. After the early manually emplaced peat dams, marine-quality plywood began to be used, together with large elm-board dams for larger drains and gullies (there was an adequate supply of elm timber owing to Dutch elm disease). In recent years plastic piling has been used on a large scale, including large, double faced, peat filled versions on the largest ditches. Latterly, where practical, plugging of grips by machine with peat bunds - blocks of peat excavated from alongside the grip - have been used, and this is indeed now the generally recommended technique in Britain (Armstrong *et al.*, 2009, and see later). The objective is to slow precipitation run-off, and drains both on the sites and at their margins have been blocked. On FC land dams have always been used, but on the part of The Wou owned by Northumberland Wildlife Trust the entire upturned furrow was mechanically replaced in the furrow after unpermitted agricultural drainage. At one site at Spadeadam, Prior Lancey Moss, grips have been completely filled with heather bales, reinforced by plastic piling. Besides grip-blocking, the first major landscape-scale project was in 1998, with partial clearance of plantation from the southern part of Butterburn Flow, substantially funded by English Nature.

Although there was some removal of regeneration, resources were not at this time available, other than at Butterburn, to remove tree crops from the mires and only a few wader pools (to provide food for wader chicks) were created.

In order to publicise the conservation work, and to facilitate public access and interpretation, a boardwalk was installed at Falstone Moss in 1996, (and another at Bellcrag Flow in 2006). However, there is public access to all of the sites except, owing to security risks, those within the boundary of RAF Spadeadam.

The adoption of UK common standards for SSSIs by English Nature in 1998 (condition assessment for all SSSIs designed to reflect whether each site meets or falls short of agreed management standards), was an opportunity to re-evaluate the success of work carried out to date and to focus on where work was required in the future. Condition categories were:



It was evident that, in order to return the mires to favourable ecological condition, now a Government target for all SSSIs, substantial additional funding was necessary. The EU LIFE fund was available for work on cSACs with priority habitats of which active blanket bog was one, and the Committee in 1998 successfully applied for funding for the *Border Mires Active Blanket Bog Rehabilitation Project*, which ran from 1998 to 2003. Northumberland Wildlife Trust was the proponent (receiving and administering the funds: most of the administration was done by Duncan Hutt) and the Forestry Commission managed the project and undertook much of the work on the ground. Total

funding, including matching in-kind contributions, was £300,000. A huge number of volunteers worked for Northumberland Wildlife Trust on damming and conifer regeneration removal. The Border Mires Management Committee steered the project.

The very considerable achievements of the project, which took place on 14 of the major SAC Border Mire sites in both Northumberland and Cumbria, despite access problems during the foot-and-mouth disease outbreak in 2001 which led to the project being extended, were:
(i) the installation of 3455 dams in ditches (including in cleared plantation areas), together with the further development of damming techniques;
(ii) the removal of 239 ha of conifer crops from and adjacent to mires, with assessments of the effectiveness and costs of the various techniques;
(iii) the clearance of 90 ha of Sitka spruce regeneration;
(iv) the creation of 130 wader pools, using explosives.

The lessons learned also set the direction of subsequent restoration work.

As a result of the project it was considered that over 500 ha of open (never planted) mire would achieve favourable ecological condition, and that 246.5 ha of cleared (formerly planted) mire was steadily improving in quality. Additionally, technical papers on grip-blocking, tree clearance (where much was learned), wader pool creation and monitoring were prepared and distributed. Two well-attended seminars cascaded the results of the project, which was also publicised in the local and national media, and the project partners visited, and learned from, cognate LIFE projects in the UK and Ireland. A report, edited by Burlton & Hutt (2003), summarised the results.

After the LIFE project the Ministry of Defence resumed management of three Spadeadam SSSI sites, but requested that they continue to be considered along with the other Border Mires.

Because the SAC includes high-altitude blanket bog (as well as the Border Mires in the original sense) one of the sites included in the LIFE project was at Kielderhead Moor (a National Nature Reserve since 1998).

When the project ended there was still much outstanding remedial work on some SSSI units and many of the non-SSSI sites. The LIFE project accomplished about a quarter of the task. It was also clear that further clearance of spruce regeneration was likely to be necessary for some years until forest restructuring reduced Sitka spruce seed influx and/or water tables became consistently high enough to retard seedling establishment. There is, in fact, doubt as to whether higher water tables alone can be effective. However, the project demonstrated that landscape-scale restoration of bog to favourable condition is possible, and once the hydrology is appropriate recovery is surprisingly quick.
This work on active mire restoration has taken on a new importance and urgency with the need to store as much carbon in peat as possible to mitigate climate change.

After LIFE

As noted, the achievements of the LIFE project accounted for only about 25% of the work necessary to rehabilitate the 55 sites. Much of the work so far had involved removing small, poor-quality conifer crops that were relatively easy and inexpensive to work. The work remaining would be a much sterner test, as the timber to be removed was larger, some of it approaching normal harvestable size. Any premature felling would impair income by reducing expected timber volume production, and many of the sites were very wet, creating difficult and costly operational conditions.

Felling plans for the forest are agreed up to 25 years in advance in Forest Design Plans. The criteria for the timing of felling are:

1. productivity of the individual timber stands;
2. existing road infrastructure and the need to build new roads;
3. the landscape and biological need to create diversity in the overall forest structure by felling individual coupes as a size appropriate to the landscape and wind-firm boundaries;
4. the need to smooth out timber supply so that regular contractual commitments are met and a range of products *i.e.* pulp, sawlogs, palletwood are supplied at a level consistent with the demands of the trade.

To minimise any additional costs to the FC business, it was planned, as far as possible, to remove mature timber from the mires only as and when areas came on stream *via* felling plans. This process was likely to take up to 25 years.

Sphagnum and heather growth on previously planted mire, Hawthorn Moss

Apart from felling, which is a constantly evolving and improving operation within the Forestry Commission, other work techniques for mire rehabilitation continued to develop after the LIFE project. As noted, much of the ditch-blocking had been carried out by manually inserting plastic piling (mostly using volunteer labour), but in 2003 a 40 ha programme of blocking up an intensively drained area on Paddaburn Moss using a mechanical excavator and peat plugs was successfully completed, with funding from English Nature. Hand ditch-blocking still had a valuable place, especially in small and sensitive areas, but the success of the excavator technique gave the Border Mires Committee confidence that large programmes of ditch-blocking were achievable quickly and at reasonable cost.

Much of the tree removal during the LIFE project had been achieved by felling, then chipping the timber. This was effective (and continued, with funding from English Nature) but was labour intensive and costly. In 2004 Northumberland National Park funded a trial with an American-sourced tree mulcher capable of reducing 10m high trees to small slivers in a matter of seconds. The mulcher consisted of a rapidly rotating circular toothed drum mounted on an excavator arm. The technique was very effective but the flotation of the machine proved less so and an excavator body is now lying under the peat surface awaiting rediscovery by the archaeologists of the future. A second trial was carried out (with wider tracks for improved flotation) by the FC at Pundershaw Moss and the suitability of mulching as a restoration technique was ratified by English Nature. Meanwhile conifer regeneration removal by volunteers continued.

English Nature surveyed the Border Mire SSSI sites and found that of the 29 sites only 1 was in favourable condition (Butterburn Flow), 3 units were in unfavourable recovering condition (Felecia Moss, Berry Hill East and Berry Hill West),15 were classed as unfavourable no change and 10 classed as unfavourable

Mulcher in use at Grain Heads Moss

declining. The issues impairing the standard were open ditches, conifer regeneration and, most importantly, timber growing on parts of the mires. The work of the LIFE project had restored parts of many of the sites, but not their entirety.

The next key development was that, in 2001, a Public Service Agreement (PSA) between the Government and all statutory authorities required that 95% of all SSSIs by area should be in favourable or unfavourable recovering condition by 2010. For FC England, although the number of SSSIs in the Border Mires constituted only a small proportion of their total suite, it was a very significant part of the area which FC England needed to bring into favourable or unfavourable recovering condition in a matter of 9 years.

Heath spotted orchid at The Lakes

This clearly did not fit in with the 25-year time-scale of the Kielder District Forest felling plans and if it was to be achieved in a shorter time scale there would need to be some extensive re-planning of felling programmes and there were also likely to be substantial additional costs involved. Additional funding would be needed over and above FC local operational budgets, and a case needed to be made to Government that unless funding became available the PSA target for the FC was unlikely to be met.

In 2004 an estimate for the work, based on local knowledge, was compiled for each mire by breaking the task down into separate work elements, *i.e.* routine harvesting, subsidised harvesting, mulching, ditch-blocking and regeneration clearance. Costs were compiled using information gained during the LIFE project, standard harvesting costs (including a substantial amount of collateral felling to enable timber on mires to be accessed from the road system), a mechanical ditch blocking project as *per* the Paddaburn project and mulching as *per* the two tree mulching trials. The initial estimate was £4.7m.

After negotiation with DEFRA, FC England was granted £4m for carrying out works on the whole of their SSSI suite. This comprised £2m for grant aided works on SSSIs in woodlands in the private sector, and £2m for SSSIs on the FC estate of which a substantial proportion was to come to Kielder for mire clearance. The money was to be available in the two financial years 2006/07 and 2007/08.

In 2005 a more detailed survey was carried out of all the mire sites to be cleared, and information on tree species, size and total volume was collected along with

data on vegetation cover in the plantation and, for comparison, vegetation on the open mires. Quantitative data on ditches to be blocked and regeneration to be cleared was also collected. The information on tree size and volume gave a clear indication of the areas with larger trees which could be harvested at no net cost and areas with smaller trees which would need to be removed by subsidised harvesting or mulching. Much of the field survey work was carried out by Bill Burlton. All the work required was entered onto the FC geographical information system to enable the work to be quantified for tender.

The vegetation information (although not required for the estimate of costing) gave some indication of the quality of mire remnants in plantations and therefore a clue as to which areas might recover quicker. As a general rule areas under pine and areas with smaller trees had more remnant mire vegetation. The data would also form the basis for ongoing monitoring to record change and improvement.

Planning the harvesting work was a complex task. Felling areas are normally spread evenly over the whole 50,000 ha forest area. The mires are concentrated in the southern part of the forest in an area roughly 12,000 ha in extent. This

Bell Crag Flow: pool formed by damming former peat workings

meant re-organising felling coupes, which created a need for additional roading (which at £40,000 *per* km was a substantial part of the project cost). Also the timber product mix needed to be similar to the original felling plans because of contractual and timber industry requirements. Concentrating extra felling in one area of the forest raised landscape issues but the conservation benefits of the project took precedence. One of the SSSI mires with near-harvestable-sized timber, The Wou, was so isolated that the road cost was likely to be £150k - £200k and the decision was made to leave this area to be cleared as part of the normal felling plans.

Fortunately, work carried out in 2006-8 coincided with a period when small round-wood prices were buoyant and so more small timber could be harvested profitably than was originally estimated. This reduced the need for subsidy and lowered the overall project cost. By the same token had timber prices gone the other way it may not have been possible to do all the work. However, the savings were offset, to some degree, by the sharp rise in fuel costs in 2008 which had a marked effect on mulching costs (the machine runs with two engines - the second to power the mulcher blade - and therefore uses substantial amounts of fuel).

Some additional cash was available in 2008-09 from savings on other FC England SSSI work. With some of this extra cash, because machines were still

Construction of the Bell Crag Flow boardwalk by FC staff and NWT volunteers

on site and with the accumulated operator expertise, the opportunity was taken to extend the project to include the non-harvesting work on the non-SSSI sites. The total cost of the project was £1 042 000 which was very substantially less than the original estimate. Northumberland Wildlife Trust, National Park and other volunteers carried out damming and regeneration removal work. The following had been achieved in just 2.5 years:

Area harvested	361ha
Number of trees harvested (estimate)	800 000
Regeneration cleared	124ha
Drains blocked	15km
SSSI brought into 'unfavourable recovering' condition	1158ha

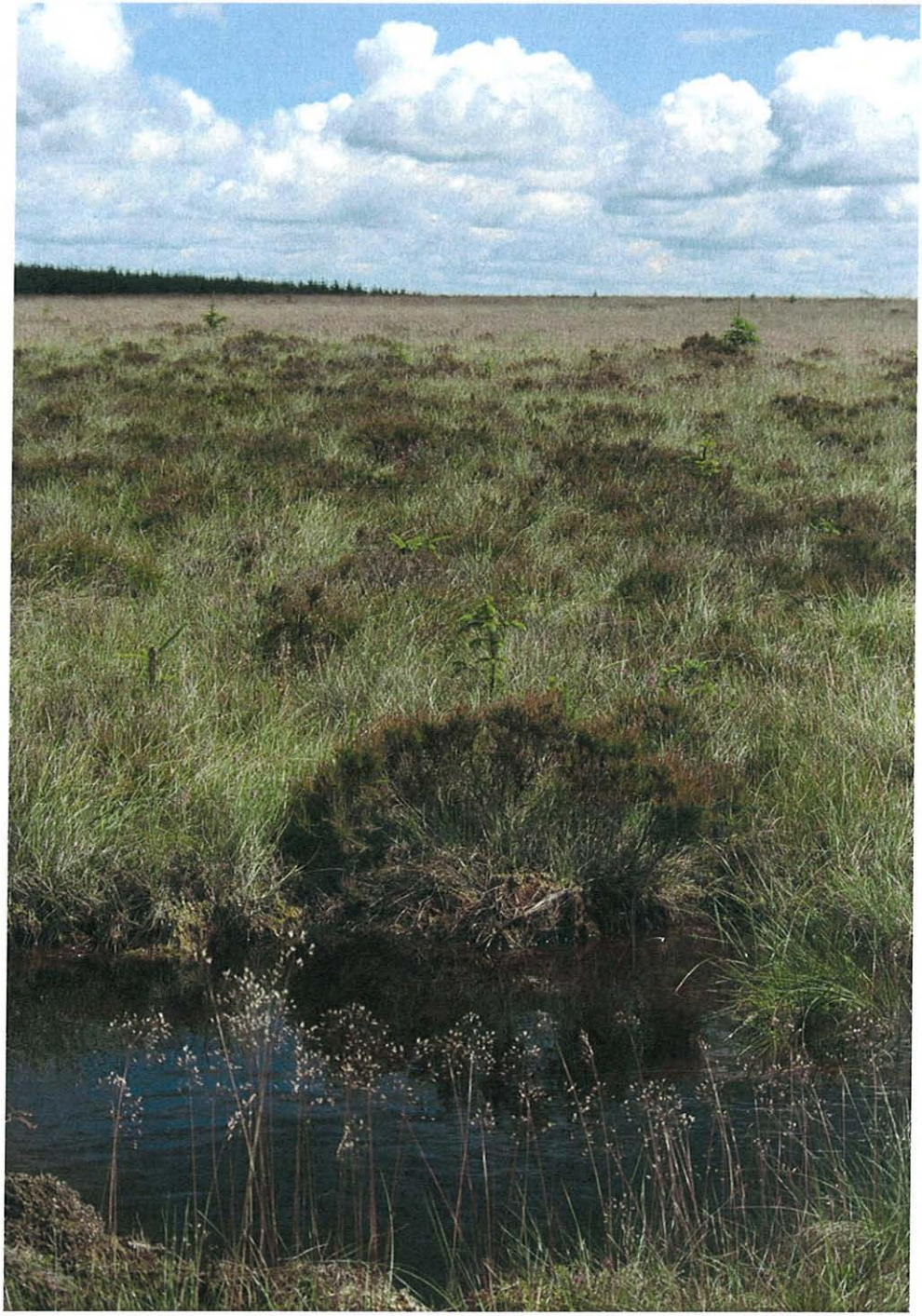
The breakdown of operational costs was:

	Cost (£)
Additional road construction	390 000
Subsidised harvesting	45 000
Mulching	424 000
Regeneration clearance	49 000
Ditch-blocking	49 000
Staff costs	85 000
TOTAL	***1 042 000***

The original long-term plan to secure favourable or recovering condition over about 25 years was therefore telescoped into 2.5 years. Apart from a small part of The Wou, all SSSI sites are clear of timber, ditches blocked and regeneration removed, and are classed as favourable (Butterburn Flow) or unfavourable recovering. The only work remaining on non-SSSI sites is removal of harvestable timber (and drains in plantations blocked as necessary), which will be done in accord with felling plans.

Over the lifetime of the work on the Border Mires and including volunteer time it is estimated that over £2 million has been spent in achieving our goals.

To celebrate the near-completion of Border Mires rehabilitation (two years ahead of the PSA target) a barbecue was held at Bellcrag Flow in August 2009.



Wedges Rigg in 2007 after damming was completed

Conclusion

To summarise, conservation work on the Border Mires falls into six phases:

1. Early grip-blocking by Northumberland Wildlife Trust volunteers on the eight original Border Mires (1970s-early 1980s)
2. Larger-scale grip blocking and the beginning of plantation clearance under the Border Mires Committee (late 1980s-1990s)
3. The LIFE project (1998-2003)
4. Reduced-scale activity with various funding sources after the end of the LIFE project.
5. The greatly accelerated planning and work under the Public Service Agreement (2001-08)
6. Ongoing maintenance, and the longer-term completion of plantation clearance on the non-SSSI sites.

In fact it seems likely that there will be a need for ongoing regeneration maintenance on all of the mires, but apart from this the final element in the rehabilitation process is time and natural processes. Monitoring the changes in cleared sites was set in train during the LIFE project and is also in place for the sites cleared to meet the PSA target. Fixed-point photography has now been set up. In time, therefore, an objective assessment can be made of the improvements to the mires. Anecdotally, a recent visual assessment of an area cleared at Berry Hill Moss (Spadeadam) at the beginning of the LIFE project in 1999 showed an actively growing *Sphagnum* layer along with the full range of mire plants and virtually no evidence of previous forest cover. This would seem to provide a positive outlook for the other cleared sites.

Grain Heads Moss, cleared of trees

References and Bibliography

Armstrong, A, Holden, J & Walker, A (2009) *Grip-blocking in upland catchments: some insights from a national survey.* Conservation Land Management **7**(4), 5-9.

Burlton F W E (1996) *Border Mires Management Plan 1996 –2001.* Forest Enterprise.

Burlton F W E (2004) *Border Mires Management Plan 2004-2009.* Forestry Commission.

Burlton FWE & Hutt D (eds) (2003) *The Border-Mires Active Blanket Bog Rehabilitation Project: final report for the EU-funded LIFE project.*

Burlton FWE and Famelton I (2002) *Creating wader pools in peatlands using explosives -report to the EU on work for the LIFE-funded Border Mires Active Blanket Bog Rehabilitation Project.*

Charman, D.J. & Smith, RS (1992) *Forestry and blanket mires of Kielder Forest, North England: long-term effects on vegetation.* In: Bragg, O.M. Hulme, P.D., & Robertson R.A. (eds.) (1992). Peatland ecosystems and man: An impact assessment. University of Dundee.

Clothier, A. (1995) *Ditch survey and mapping of the Northumbrian Border Mires and the Cumbrian Spadeadam Mires.*

Dennis. R.H. & Eals, H.T. (1999) Probability of site occupancy in the large heath butterfly *Coenonympha tullia determined from geographical and ecological data. Biological conservation*, **87** 295-301.

Eals, H.T. (1995) *A revision of the status of the large heath butterfly (Coennonympha tullia) in Northumberland, part 3.* Supported by Butterfly Conservation, Northumberland National Park, FE.

Eals, H.T. (2004) *The large heath butterfly (Coenonympha tullia). Muller 1764. A review of all the known colonies on Forest Enterprise land in Northumberland.* Report to Forest Enterprise

Holmes, P. (1992) "*Border Mires reassessment project*". EN Report.

Hutt, D. (2002) *Damming ditches in peat bogs.* Report to the EU for the LIFE funded Border-Mires Active Blanket Bog Rehabilitation Project. (and subsequent revisions)

Lowe, S. (1993) *Border Mires redefinition of hydrological boundaries.* Unpublished report by English Nature North East Region.

Lowe, S. (1995) *Border Mires. A preliminary assessment of the peatland resource in the Border Mires Natural Area, for* FE.

Lunn, A.G. (1976) *The vegetation of Northumberland. 1:200 000 map.* University of Newcastle upon Tyne, Department of Geography.

Lunn, A.G. (2004) *Northumberland.* HarperCollins (New Naturalist series).

McIntosh, R. (1995) *The history and multi-purpose management of Kielder Forest.* Forest ecology and management, **79**, 1-11

Newson, M. and Rumsby, B. (1991) *Border Mires hydrological boundaries – a reconnaissance study.* University of Newcastle upon Tyne for NCC.

Newson, M. and White, A (1993) *Hydrology and management options for a selection of Border Mires conservation units.* University of Newcastle upon Tyne

Ratcliffe, D. (1997) *A nature conservation review.* Cambridge University Press.
Simpson, G. (1996/97). *Botanical Survey of the Border Mires* (Unpublished)
Smith, R.S. (1993) *NVC mapping of 34 Border Mire sites, Northumberland.* University of Newcastle upon Tyne, for English Nature.
Smith, R.S. & Charman, DJ (1987) *Plant species-area relationships on upland mires within conifer plantations in Northumbria, northern England.* Report to the Forestry Commission, Department of Soil Science, University of Newcastle upon Tyne.
Smith, RS & Charman, DJ (1988) *The vegetation of upland mires within conifer plantations in Northumberland, northern England. J. appl. Ecol.* **25,** 579-594.
Smith, RS, Charman, DJ, Rushton, S & Buckingham (1990) *Early results from grazing exclosures on raised mire vegetation in Cumbria.* Report to the Forestry Commission.
Smith, R.S. , Lunn, A.G. & Newson, MD (1995) *The Border Mires in Kielder Forest: a review of their ecology and conservaton management.* Forest ecology and management, **79**, 47-61
Smith, RS. Charman, DJ, Rushton, S, Simpkin, J & Shiel, RS (2002) *The vegetation effects of 14-years of excluding sheep grazing at Butterburn Flow, an ombrotrophic mire in northern England.* Report to English Nature, Forest Enterprise and the British Ecological Society.
Swan, G. (1993) *Flora of Northumberland.* Natural History Society of Northumbria, Newcastle upon Tyne.
Thompson, G., Smith R., Lunn, A., Hutt, D., Burlton, W., & Charman, D. (2004) *Bogged down with conservation work: Restoration of internationally important mire sites in northern England.* Biologist 51 (1).
Turner, J. (2001) *Veilwort* Pallavicinia lyelli *in 2001.* Plantlife and English Nature Report number 189.
Webb, S. & Burlton, FWE. (2002) *Options for the removal of conifer crops on peatland sites.* Report to the EU for the LIFE funded Border-Mires Active Blanket Bog Rehabilitation Project
White, A. (1994a) *Border Mires Part 1. The Spadeadam mires: redefinition of hydrological boundaries.* Northumberland Ecological Services report for English Nature.
White, A. (1994b) *Border Mires Part 2. Assessment of the full extent/former extent of ombrotropic mire within the Border Mires area.* Northumberland Ecological Services report for English Nature.
White, A. (1994c) *Border Mires Part 3. Quality assessment, NVC mapping definition of conservation unit boundaries for non-SSSI mires.* Northumberland Ecological Services report for English Nature.

Adder

Hare's-tail cottongrass

Acknowledgements

The authors are grateful to the members of the Border Mires Committee and, in particular, to the following staff of the Forestry Commission North East England for their ready assistance in compiling this history: Graham Gill (Forest District Manager), Neville Geddes (Planning and Environment Manager) and Tom Dearnley (Ecologist).

Design and all photographs: Duncan Hutt, Northumberland Wildlife Trust.

Bell Crag Flow Interpretation (page 8): John Steele

Published by the Border Mires Committee 2010.