A Practitioners Guide to Sphagnum Reintroduction

by Moors for the Future Partnership

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Aims of this Document

The purpose of this practitioners' guide is to provide land managers with information about the main techniques being used to re-introduce Sphagnum mosses, predominantly to blanket bogs, in the South Pennine Moors Special Area of Conservation (SAC).

The guide has a number of purposes:

1. To provide an introduction and justification for the need for Sphagnum reintroduction and information on how to decide when and where intervention may be required;
2. To describe how Sphagnum works have been undertaken through the EU-LIFE+ funded MoorLIFE project;
3. To provide an overview of techniques available, including:
   a) Types of material to be applied;
   b) Application methods (including planting densities, locations etc.)
4. To provide an overview and summary of ongoing research and development trials into the reintroduction of sphagnum, and recommendations for setting up and monitoring sphagnum recovery;
5. To describe a series of case studies to show how and where different techniques are being trialled; in almost every case, the techniques are still in development and the success of each technique is still to be determined.
6. To provide guidance for the selection of methods, based on experience and learning within the Moors for the Future Partnership and wider upland and peatland restoration community;
7. Provide details of organisations involved in Sphagnum reintroduction so that knowledge and results can be shared.

Sphagnum reintroduction is a rapidly growing field of research and development with current methodologies to be refined over time, and new techniques developed. This 'Best practice' guide is therefore an ongoing resource that the Moors for the Future Partnership (MFFP) aim to regularly update. This guide is not a comprehensive list of all techniques used to reintroduce *Sphagnum*, nor is it a complete list of research taking place on how Sphagnum can be reintroduced and diversified. The guide should instead be used as a reference to some of the practical work taking place in the Pennines and as a signpost to where more information and specific expertise can be found. This first version (2015) has been funded by MFFP's European Union's LIFE+ funded 'MoorLIFE' project. MoorLIFE aimed to protect Active Blanket Bog by revegetating bare and eroding peat in the South Pennine Moors Special Area of Conservation (SAC) and Special Protection Areas (SPA).

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1. Introduction and justification for the need for Sphagnum reintroduction.

1.1. Why is Sphagnum moss important?

Peat accumulates in response to the very slow rate at which plant material decomposes under conditions of waterlogging (JNCC, 2008). On blanket bogs, which form in the uplands where all of the water present comes from precipitation (e.g. rain, snow or cloud), this is a slow process and peat accumulates at about 1mm every year (see Lindsay 2010). These bogs are termed ombrotrophic, meaning that all of their nutrients are brought in in rainfall and they are generally very acidic and nutrient poor. The term Blanket Bog comes from the way the peat layer blankets the ground. These peat accumulations provide habitats for a wide array of rare peatland plants and protected bird species e.g. Dunlin, Merlin and Golden Plover (JNCC, 2011).

Active Blanket Bogs are those that contain areas within them that still support peat formation; although there may be other areas within the site which are in various stages of degradation, including areas of bare peat with no vegetation cover at all. *Sphagnum* mosses are the main constituents in active blanket peats in the UK, (although other plants such as common cottongrass *Eriophorum angustifolium* will also form peat) and as *Sphagnum* has nearly totally disappeared from the South Pennine Moors SAC (JNCC 2001), peat forms much more slowly.

Accumulations of both living and dead *Sphagnum* can hold large quantities of water inside their cells, as well as between the individual stems which form 'hummocks', which makes its presence in the uplands important as 70% of our water supplies come from the uplands. The empty cells help retain water in drier conditions.

The blanket bog of the South Pennine Moors SAC is important for Ecosystem Services (Bonn *et al* 2010) in terms of:

- Flood-risk management
- Water quality
- Carbon security

Large parts of the UK's upland blanket bog, particularly in the South Pennines Moors SAC, are degraded due to a range of historical factors resulting in large-scale carbon loss through peat erosion.

1.2. The loss of Sphagnum through the ages

Sphagnum mosses have much reduced in the South Pennine Moors over the past 200 years; it is believed that *Sphagnum* was abundant and dominant but began to decline in the 1300s (Tallis, 1964) resulting in an increase in hare's tail cottongrass *Eriophorum vaginatum*. This has been attributed to several anthropogenic reasons which have all contributed to the loss of *Sphagnum*:

- Evidence of charcoal showing that there has been regular burning, with managed burning becoming regular from 1800 (Tallis, 1964) (these were fires on much larger scales than today, predominantly for sheep management) and gutters (very long gullies) began then which led to an increase in localised erosion gullies, peat-pipes and an increased drying out of the peat. Repeated burning also led to a change in the vegetation, with an increase in the dominance of hare's tail cotton grass and heather. Some *Sphagnum* species are especially sensitive to burning e.g. *S. tenellum*;
- In addition, there have been significant numbers of wildfires –which have destroyed the vegetation and roots creating bare areas and gullying and can cause the formation of peat-pipes. Tallis (1964) indicates that the major loss of *Sphagnum* in the Pennines was associated with fire damage prior to the Industrial Revolution;
- Climate and climate changes over the centuries – variations in temperature, rainfall and mini-ice ages. These are particularly significant within the Peak District, as changes do not have to be significant to take the area outside the zone where peat formation could be initiated due to its rainfall and temperature.
- Grazing with sheep - Whilst sheep generally do not eat *Sphagnum*, they will pull-up and trample it;
- Creation of drainage grips, predominantly in the 1960s & 1970s, increasing the areas available for agriculture and grouse moor management;
- Peat extraction – for fuel;
- Air pollution – The most significant historic factor has been acid rain from the industrial areas of Lancashire and Yorkshire, particularly from sulphur based acids released by burning coal, which has caused the loss of mosses. This loss is a critical factor as it is the mosses that predominantly formed the original blanket peat. Losses across the Peak District have been so significant that there is very little remaining, leading to a shortage of source material for recolonization. This has caused acidification of peat to less than 3.5pH, with 13 times more sulphuric acid being

deposited on the South Pennines compared to NW Scotland and Ireland; there are many *Sphagnum* species that are intolerant to these low levels.

1.3. Why we need to reintroduce *Sphagnum* Moss?

The major factor inhibiting re-establishment of in the Peak District and South Pennines is absence of material for colonisation; other factors include low pH and the absence of a stable, high water table (Carroll *et al*, 2009).

There are two main elements of Sphagnum reintroduction:

1. sourcing material
2. application methods.

Development of large scale propagation and delivery methods has the potential to revolutionise peatland restoration. However, in order to take these and other areas with less significant erosion but an absence of moorland bryophytes specifically, into Favourable condition, a method of collecting, spreading and establishing was required.

A previous report by MFFP, funded by Natural England and United Utilities suggested that the dominant factor causing an absence of *Sphagnum* mosses in the Peak District is simply absence and a consequent lack of source material. As part of the bare peat restoration work MFFP were undertaking during the original HLF Funded Project (2003-2008) *Sphagnum* re-introduction was identified as the ultimate end goal. *Sphagnum* is the key component to a fully functioning blanket bog and the re-introduction of *Sphagnum* would be required to complete the restoration process, by stabilising the whole of the bog surface, re-invigorating peat formation and increasing the wetness of the bog surface, reducing the subsequent risk of wildfire. The main issue to overcome was the lack of original source material. The restoration work that MFFP had been doing was working on a landscape scale, treating 550ha of degraded moorlands. This would require significant amounts of *Sphagnum* to allow its re-introduction. MFFP had been working with Micro-Propagation Services (MPS) creating dwarf shrub plug plants to increase the diversity on the restored sites. MFFP asked MPS if it would be possible to micro-propagate *Sphagnum* in the same way they did with the dwarf shrub species. *Sphagnum* was harvested from the few available Peak District sources and then after some significant research and development, supported by the Co-operative Foundation and Natural England, it became possible to produce local *Sphagnum* on the scale that MFFP required.

Once the supply was available the means of application was investigated. MFFP have developed moorland restoration techniques to work over a landscape scale. MFFP investigated the survival of beads and also moss fragments, collected from other sites. Working with MPS the *Sphagnum* bead (Beadamoss®) was developed. The micro-propagated *Sphagnum* is chopped into fragments and placed in a special gel bead. The bead gel aided application as it reduced desiccation of the moss and provided a vital food source. Each bead contains a number of strands of *Sphagnum* of different species. Due to the logistical challenges involved in working in such remote locations, and due to scale of materials required to undertake the works, MFFP have utilised helicopters for large parts of the operations. The original intention was to apply *Sphagnum* across the restoration sites using helicopters. However technical difficulties surfaced when working with the beads (due to their high moisture content) and a re-focussing away from blanket coverage to more targeted application meant that helicopter application was abandoned as a plan and different means of application were developed.

2. Rationale for the use of BeadaMoss®

Why did the Moors for the Future Partnership seek to develop BeadaMoss® for *Sphagnum* application? The simple answer is that it was seen as an answer to large-scale of *Sphagnum* to remote sites with very little source material available that requires large-scale application to cover the whole site.

- It requires a small amount of source material to produce significant volumes of material for application;
- Beads can be applied in a relatively dry state and do not require large quantities of water, reducing the cost of flying material to site;
- It is relatively quick, cheap and easy to manufacture;
- MFFP would able to distribute a mixture of different *Sphagnum* species, in a precisely developed mix across large areas, quickly and efficiently;
- It would be safe in terms of bio-security;
- The beads offer a significant logistical advantage as the beads are manufactured to order and will allow the ability to plan and organise a delivery programme.

2.1. Research undertaken

MFFP aim to undertake evidence-based conservation and the re-introduction of *Sphagnum* was backed by various research works. There has been an on-going PhD at Manchester Metropolitan University (funded by MMU and MFFP) (Rosenburgh, 2015). This work has informed the development of the *Sphagnum* beads and other application methods. The partnership created between MFF, MMU and MPS has undertaken many small scale trials including various MSc projects focusing on *Sphagnum* application as part of the restoration process. The Moors for the Future Science programme has also undertaken a number of monitoring schemes and a number of research projects. This includes monitoring of the large-scale applications on Black Hill and Rishworth, the *Sphagnum* Propagules Trial (see Case Study 1 – MFFP: Sphagnum Propagules Trial) and work with Natural England on the *Sphagnum/* trails in the South Pennines as part of the Natural England Favourable Condition study.

Moors for the Future have also worked towards developing a shared understanding of Sphagnum application across various partnership organisations. The *Sphagnum* Technical Advisory Group (TAG) allows various moorland practitioners, experts and academics meet to discuss different techniques and share successes in order to ensure that we get the best means of Sphagnum application for each different situation (see the Practitioner's Matrix Selection of Methodologies).

2.2. MoorLIFE Project: sphagnum reintroduction on bare peat, fire-damaged areas

Revegetation of fire damaged areas began in the Peak District National Park with the Moorland Management Project and MFFP began work in the SAC in 2003 with the original Heritage Lottery Funded project. Primarily, the aim was peat stabilisation for landscape purposes, as the amount of bare and eroding peat within the Peak District was significant (over $33km^2$) (PDNPA, 2000). This was achieved using the following techniques:

1. Heather Brash: MFFP have applied more than 70,000 bags, with one bag covering approximately $64m^2$ to a depth of 1cm. This brash provided the following benefits:
    a. Forms a protective lattice layer to physically prevent peat erosion;
    b. Introduction of moorland plant propagules, including heather seeds, mosses and lichens;
    c. Introduction of endo-mycorrhizal fungi within the plant material. These fungi are essential for moorland plants to be able to remove nutrients from the peat.
2. Geotextile – a protective, degradable mesh made from jute is applied on steeper slopes (greater than 45^o) where brash would not be suitable;
3. Grass seeds with lime and fertiliser (applied shortly after the brash) – to tie the lattice together very quickly. These grasses are not resilient and are therefore not permanent, as they need repeated applications of lime and fertiliser to persist;
4. The vegetation cover is intended to gradually develop into a sward dominated by cottongrass and dwarf shrubs, either through natural re-vegetation or coming in with the brash. However, there were situations where colonisation sources were up to 200m away from the bare peat and so we instigated the use of plug plants. Native species are selected for this, including cloudberry *Rubus chamaemorus*, crowberry *Empetrum*

nigrum, bilberry *Vaccinium myrtillus*, hare's tail cottongrass *Eriophorum vaginatum* and common cottongrass *Eriophorum angustifolium*.

5. An additional piece of work involves blocking of erosion gullies, using a mixture of techniques such as stone blocks, peat, plastic piling or timber. These have a variety of different functions, including reducing the erosion of peat, raising the water tables and reducing water loss from the peat body.

These techniques, when combined together, reduce the erosion of bare peat (through particulate organic carbon (POC)) by approximately 95% within two years of the work starting (Pilkington and Crouch, 2015). They also have an impact on surface wetness, reducing the speed that water flows off of the bog surface directly and creating micro-climates that reduce evaporation from the bog surface (Allott *et al*, 2015).

However, the vegetation created through these restorative actions do not equate to the creation of active blanket bog, which requires the formation of peat. In turn, for this to happen, the peat body needs to remain saturated, to prevent oxidation of the peat, and ideally, the surface needs to stay wet to allow growth of *Sphagnum* mosses, which are a key component of the vegetation community.

3. New/Current Approaches

3.1. Alternative methodologies

An issue was raised in 2013 about the lack of success being seen in beads. Other treatments were being trialled and experimented with by other organisations and contractors and questions were being asked if beads were the best solution. The perception was that the fragments contained within the bead were too small to survive in the climate in which they were being placed. This was not a criticism of the contractors or application but the reality of a moor is that there is existing vegetation and that a large percentage of this will be either (a) unsuitable for beads to settle in a suitable place or (b) the existing vegetation will out compete with the tiny *Sphagnum* fragments. Our trials (ROSENBURG 2015) suggest that sphagnum will grow and establish from the bead application but the timescales for extensive coverage of may take longer than anticipated and so therefore alternative options were sort. Due to our working relationship with MPS, MFFP were able to develop alternative methods of *Sphagnum* application.

3.1.1. *SoluMoss®*

The next option produced was SoluMoss®. In order to overcome the issue of small fragments SoluMoss® uses longer strands of propagate *Sphagnum* suspended in a liquid solution. The liquid solution is used as a means of application originally designed to allow a spray of *Sphagnum* to scatter the strands across the application area. The liquid solution also provides a small degree of protection to the *Sphagnum* during application, reducing desiccation of the *Sphagnum*. SoluMoss® was trialled on a small-scale application on a moor outside Buxton. The spray application was shown to cause the *Sphagnum* strands to become suspended on the intact vegetation and, despite the liquid solution providing a small level of protection, the risk is there that the *Sphagnum* will be too exposed and dry out before it could reach the bare peat areas. Following the potential risk of desiccation during a spray application MFFP enquired if spot treatment of SoluMoss® was possible. MPS adjusted the applicator and produced single 5mm blob of SoluMoss® on demand. This allowed direct treatment of SoluMoss® on to the peat surface amongst existing vegetation. This should lead to a better establishment rate of the sphagnum.

3.1.2 *Plugs & Micro-plugs*

The lack of *Sphagnum* available for translocation, bio-security issues and the lack of reliability in its supply is also a major issue at these early stages; this meant that MFFP looked at alternative methods of sourcing *Sphagnum* plants for planting. Working with MPS, MFFP developed the *Sphagnum* plug plant. This used locally sourced propagated *Sphagnum* grown on top of a peat plug wrapped in paper. The idea behind the plug was that it would provide a reliable, uniform source to allow large scale planting by teams of contractors across many sites. These plugs were trialled at Black Hill and Featherbed Moss (Bleaklow). They were seen to provide a successful method of introducing *Sphagnum* on to a restored moor. However, as the *Sphagnum* grew on top of the peat, rather than growing from within the peat plug, the peat plug itself appears to be superfluous to the application and significantly increased the cost and difficulty of planting because there was additional weight to transport on to the hill and increased the work required of the contractors undertaking the work (removing the full plug from the tray and deeper/larger holes required for planting).

As a result, experiments were then undertaken to just utilise the grown *Sphagnum* by separating the plant from the peat plug and the “micro-plug” was created. This provided a small-scale clumps, similar to the RSPB translocated clumps, but from a controllable source, with lower bio-security issues and allowed the appropriate *Sphagnum* species to be planted to suit a particular site’s needs. Logistically, there are significant advantages over the translocated material as they can be supplied to order and delivered whenever they are required (subject to a six month growing period). The micro-plugs come in a plastic bag and this, due to the lightweight nature of the material, allows contractors to carry their daily allowance required for planting on to the hill. This will remove any need for helicopters, removing the constraints of weather from the process as well as reducing the operational impacts, both financial and through carbon emissions.

Approaches undertaken by other organisations

3.1.3 Clumps

During this period, MFFP was working with our partnership organisations to develop the best way to re-introduce *Sphagnum* across the Peak District moors. The RSPB at Dove Stone Reserve (Mossley, Greater Manchester) had been working on translocating whole harvested handfuls (clumps) of *Sphagnum* from both donor sites and on-site to the areas requiring *Sphagnum* reintroduction (see Case Study 3 – RSPB: Sphagnum harvesting and translocation at Dove Stones Reserve).

Due to the success that RSPB had been demonstrating with these "planted" *Sphagnum* hummocks, MFFP began working on developing a method of large-scale application of "planted" *Sphagnum*. There are several issues surrounding translocation of *Sphagnum* from outside the area which will need to be investigated and resolved before this becomes a viable source for planting *Sphagnum*. MFFP are reviewing the issues concerning the risks involved in disease movement from donor to restoration sites; these include *Cryptosporidium baileyi* (Bulgy-eye disease) that affects birds and *Lochmaea suturalis* (heather beetle) that affect mainly *Calluna vulgaris* (ling or common heather). This is likely to restrict this technique to areas within the management of one land manager or to movement within a site.

3.1.4 – Sphagnum Rich Brash – North Pennine AONB

Other organisations are undertaking moorland works in the Yorkshire Dales and North York Moors. The situations they were dealing with were different to the conditions in the South Pennines. This resulted in the creation of different techniques for the re-vegetation of bare peat and the re-introduction of sphagnum. They were able to utilise the increased sphagnum resources in the area to create a sphagnum rich brash which allowed stabilisation and sphagnum re-introduction to occur at the same time. The team at the North Pennines AONB have been working on this technique and the work they have done is covered in the case study below (Case Study no. 4 - North Pennines AONB Partnership: Bare peat restoration). Sphagnum rich brash has been seen to be successful across other work areas and there is the opportunity to continue with this work should the donor sites and cutting equipment be available.

4. Selection of Methodologies –

Although MFFP and other moorland restoration practitioners and researchers across the UK have made huge progress in recent few years in regards to *Sphagnum* reintroduction, it is still a relatively new field of work with a lot more work to do to. Based on what has been learned so far, this section will cover which methods of reintroduction are suitable where based on the right conditions being in place prior to treatment.

			Sphagnum Coverage			Risks				
Desired Outcome	**Treatment Type**	**Costs/ Budget**	**Short-term impact (1-3yrs)**	**Medium-term impact (3-7yrs)**	**Long-term impact (7+yrs)**	**Success/Failure**	**Bio-Security**	**Logistics**	**Projects**	**Science**
		What funds are available?	Based on science/ experience	Based on science/ experience	Based on science/ experience	Potential for loss & problems	Issues surrounding translocating diseases	remote sites, availability/ turnaround	Where/which sites has this been done?	What trials/ experiments are set up?
Sphagnum Introduction	**Beadamoss**	Low cost for a large volume	None	Possible	Still to be clarified.	High potential for loss but due to large-scale coverage this can be acceptable	Low risk as manufactured	Manufactured - ordered in time	MFFP - MoorLIFE, Catchment Restoration Fund. Joint Universities Companies (Germany).	MFFP - Monitoring on Black Hill, Rishworth South. RSPB (Dovestones) - Monitoring. Manchester Met Uni (various). National Trust (Featherbed) - Monitoring
		Can cover a large area				Species mix within the beads ensures suitability for some regardless of area treated		Always available		
								Needs to be delivered to lift site and flown to treatment site if remote		
	Micro-plugs	High cost for small volume	Immediately visible	Growth expected year on year	Still to be clarified; results to date suggest that it will be good.	Potential for loss of not planted correctly in suitable areas	Low risk as manufactured	Manufactured - ordered in time	MFFP - MoorLIFE, Catchment Restoration Fund, Making Space for Water.	MFFP - MoorLIFE (Woodhead and Rishworth South). Kinder (CRF Project). Sphagnum Molinia Trials (Rishworth and others). Micro-Prop (Black Hill, Featherbead and others)
		coverage dependent on spread but potential to cover a wide area thinly				Species mix within the plug ensures suitability for some regardless of area planted		Always available		
								Needs to be delivered to lift site but can be carried on to site by the Contractors		
	Clumps (formerly Hummocks)	Varying costs depending on accessibility to source material	Immediately visible	Growth expected year on year	Still to be clarified; results to date suggest that it will be good.	Potential for loss of not planted correctly in suitable areas	High risk potential	Variations depending on donor-site location	MFFP - MoorLIFE, Catchment Restoration Fund. RSPB (Dove Stone Reserve)	MFFP - CRF Project Kinder - Monitoring. RSPB Dovestones - Monitoring.
		On-site translocation costs low					Permissions an issue depending on landowners & NE	May need Contractors for harvesting		
								Possible lack of source (or known sources)		

			Sphagnum Coverage			Risks				
								May be large distance transportation & storage issues		
								Unless source is on-site, flying may be necessary for transporting to site		
Diversification of Sphagnum Sp.	**BeadaMoss**	Low cost for a large volume	None	Possible	Still to be clarified.	High potential for loss but due to large-scale coverage this can be acceptable	Low risk as manufactured	Manufactured - ordered in time	MFFP - MoorLIFE, Catchment Restoration Fund. RSPB (Dove Stone Reserve). Joint Universities Companies (Germany). Yorkshire Peat Partnership (Yorkshire Dales).	MFFP - Monitoring on Black Hill, Rishworth South. RSPB (Dovestones) - Monitoring. Manchester Met Uni (various). National Trust (Featherbed) - Monitoring
		Can cover a large area				Species mix within the beads ensures suitability for some regardless of area treated		Always available		
						Diverse mix of species ensures diversification is possible		Needs to be delivered to lift site and flown to treatment site if remote		
	Micro-plugs	High cost for small volume			Still to be clarified; results to date suggest that it will be good.	Potential for loss of not planted correctly in suitable areas	Low risk as manufactured	Manufactured - ordered in time	MFFP - MoorLIFE, Catchment Restoration Fund, Making Space for Water.	MFFP - MoorLIFE (Woodhead and Rishworth South). Kinder (CRF Project). Sphagnum Molinia Trials (Rishworth and others). Micro-Prop (Black Hill, Featherbead and others)
		coverage dependent on spread but potential to cover a wide area thinly				Species mix within the plugs ensure suitability for some regardless of area planted		Always available		
						Diverse mix of species ensures diversification is possible		Needs to be delivered to lift site but can be carried on to site by the Contractors		
	Clumps (formerly Hummocks)	Varying costs depending on accessibility to source material	Immediately visible	Growth expected year on year	Still to be clarified; results to date suggest that it will be good.	Potential for loss of not planted correctly in suitable areas	High risk potential	Variations depending on donor-site location	MFFP - MoorLIFE, Catchment Restoration Fund. RSPB (Dove Stone Reserve). Joint Universities Companies (Germany).	MFFP - CRF Project Kinder - Monitoring. RSPB Dovestones - Monitoring.
		On-site translocation costs low				Good potential for diversification if permission can be granted for on or off-site translocation	Permissions an issue depending on landowners & NE	May need Contractors for harvesting		

			Sphagnum Coverage			Risks				
								Possible lack of source (or known sources)		
								Excellent Sphagnum ID skills required to identify species for harvesting - a specialise harvesting job		
								May be large distance transportation & storage issues		
								Unless source is on-site, flying may be necessary for transporting to site		
Carpet Covering	**BeadaMmoss**	Low cost for a large volume	None	Possible - small coverage	Are slow to grow due to the original size of the Capitula in each bead therefore it may take over 10 years to be near any carpet coverage	Species mix within the beads ensures suitability for some regardless of area treated and will further improve coverage across the site	Low risk as manufactured	Always available	MFFP - MoorLIFE, Catchment Restoration Fund. Joint Universities Companies (Germany).	MFFP - Monitoring on Black Hill, Rishworth South. RSPB (Dovestones) - Monitoring. Manchester Met Uni (various). National Trust (Featherbed) - Monitoring
		Can cover a large area but a large quantity required for a carpet covering or long timescales				Only worked in small scale trials so far. No evidence of success 3 years after spreading		Needs to be delivered to lift site and flown to treatment site if remote		
	Micro-plugs	Coverage dependent on spread but potential to carpet a wide if planted thickly	Immediately visible	Growth expected year on year	Still to be clarified; results to date suggest that it will be good.	Potential for loss of not planted correctly in suitable areas	Low risk as manufactured	Manufactured - ordered in time	MFFP - MoorLIFE, Catchment Restoration Fund, Making Space for Water.	MFFP - MoorLIFE (Woodhead and Rishworth South). Kinder (CRF Project). Sphagnum Molinia Trials (Rishworth and others). Micro-Prop (Black Hill, Featherbead and others)
			In Molinia trials (36 plugs per m2) carpet coverage has been achieved in 3 months			Species mix within the plugs ensures suitability for some regardless of area treated and will further improve coverage across the site		Always available		

			Sphagnum Coverage			Risks				
								Needs to be delivered to lift site but can be carried on to site by the Contractors		
	Clumps (formerly Hummocks)	Varying costs depending on accessibility to source material	Immediately visible	Growth expected year on year	Still to be clarified; results to date suggest that it will be good.	High success rate would ensure a good way to achieve carpet cover	High risk potential	Variations depending on donor-site location	MFFP - Catchment Restoration Fund. RSPB (Dove Stone Reserve). Joint Universities Companies (Germany).	MFFP - CRF Project Kinder - Monitoring. RSPB Dovestones - Monitoring.
		On-site translocation costs low	Anticipated doubling in size over 2 to 3 years			Potential for loss of not planted correctly in suitable areas	Permissions an issue depending on landowners & NE	May need Contractors for harvesting		
								Possible lack of source (or known sources)		
								May be large distance transportation & storage issues		
								Unless source is on-site, flying may be necessary for transporting to site		

5. Research

5.1. Questions being answered

MFFP along with other practitioners are currently working on the following questions in order to learn more about the gaps in knowledge relating to *Sphagnum* reintroduction. If you have any answers to any of these questions, please let us know.

These are areas that are currently being investigated to further improve our methods of *Sphagnum* reintroduction:

- What are the best methods to use in different situations (with cost comparisons);
- How, where and when to plant (a guide to planting different propagules);
- What are the application and production logistics of each propagule type;
- What is the best way to cover large areas;
- What access is there to *Sphagnum* sources – Harvesting from existing sources or manufacturing?
- What permissions have been granted for collection of material and planting of collected material?
- Will lowland *sphagnum* be suitable for application on the uplands and will this be a sustainable source of *sphagnum* for harvesting?
- What are the implications of *Sphagnum* genetics, i.e. are there implications of using a homogenous gene pool (i.e. grown from micro-propagated material) or distributing material around the country (translocated material)?

5.2. Sphagnum Seminar Report

In 2014, a MoorLIFE *Sphagnum* seminar was held at Manchester Metropolitan University, the workshop summary from this seminar, including the gaps in knowledge identified by the various practitioners and the presentations made by all speakers are available here MoorLIFE seminar | Moors for the Future Partnership.

5.3. The Future

In the future we hope to be able to answer all of the above questions and continue to develop the Moors for the Future *Sphagnum* Practitioners' Guide. The hope is that this will aid the application of Sphagnum across different areas, large or small for different aims and purposes, whether a site requires reintroduction or diversification. This guide is intended to be a continually developing guide that will be updated with new studies and findings. MFFP will continue to run the *Sphagnum* Technical Advisory Group (TAG) as a discussion group to share findings and ideas.

Please feel free to contact MFFP for updates on what we have learned since this report was produced or if you wish to become involved in the *Sphagnum* TAG.

6. Case Studies

These case studies show how and where different techniques are being trialled; in almost every case, the techniques are still in development and the success of each technique is still to be determined.

The following case studies cover:

1. Trials of different propagated propagules on stabilised bare peat by MFFP in Peak District
2. Landscape – large scale reintroduction methods for propagated sphagnum on stabilised bare peat by MFFP in the Peak District
3. Harvesting and translocation of collected sphagnum into existing vegetation by the RSPB in the Peak District
4. Use of sphagnum rich heather brash by the North Pennines AONB Partnership in North York Moors.
5. Use of Sphagnum enriched heather brash on bare peat by MFFP in Peak District

6.1. Case Study 1 – MFFP: Sphagnum Propagules Trial

6.1.1. *Introduction*

For the past 7 years MFFP have been working with Micro-Propagation Services (MPS) in the development and application of BeadaMoss®. There have not been conclusive results produced in this time. Through work with the *Sphagnum* Technical Advisory Group (TAG), and the work undertaken by other organisation like the RSPB and Yorkshire Peat Partnership, alternative methods of *Sphagnum* application have been developed and tested. Whilst some of the results being demonstrated by these other techniques appear to show success there has been no real like for like comparison between the different micro-propagated materials. MFFP wanted to set up a landscape scale trial to compare the 5 different techniques in order to try and demonstrate the strengths and weaknesses of each of the application methods. This should provide evidence to allow practitioners to make informed decisions about what techniques would be best suited to their situation.

The Micro-catchment (MC) trial aimed to compare the different forms in which propagated *Sphagnum* can be applied in order to restore *Sphagnum* on degraded blanket bog. This trial will 'make use' of the latest developments and maximise our learning potential from these works for future applications.

Four headwater micro-catchments (1 ha) were treated with one of four different *Sphagnum* propagule types; BeadaMoss®, SoluMoss®, plugs, and clumps. A fifth micro-catchment will act as a control as non-intervention maybe a method of establishment once the area is stabilised and re-vegetated. These applications were replicated three times.

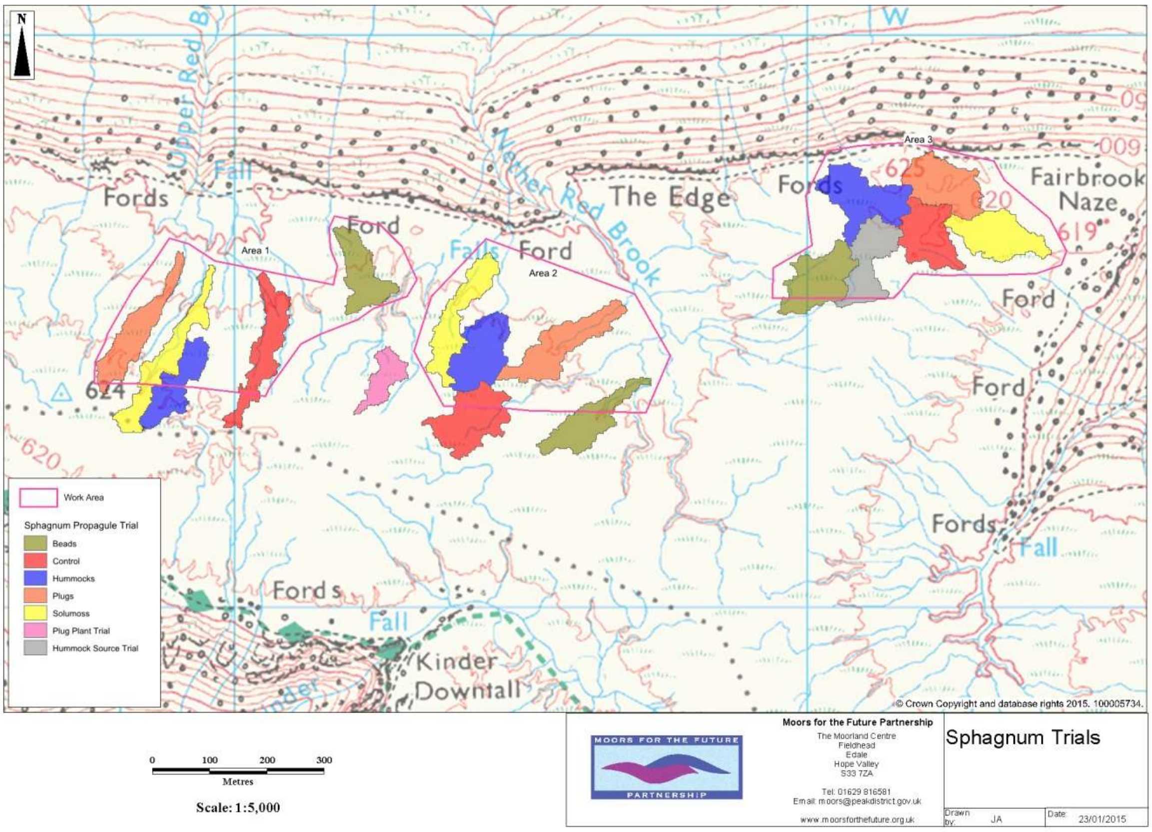

Figure 1 - the trial sites on Kinder Edge

6.1.2. *Methods*

6.1.2.1. Quadrats

Each individual micro-catchment was allocated 10 quadrats and the treatment within the quadrats was planted by a Researcher during the initial monitoring (the wider MCs were treated by Contractors)

6.1.2.2. Quantities

Table 1 shows what treatment each micro-catchment and quadrat within the trial received.

Table 1 - treatments applied

Propagule type	No of Quadrats	No of propagules per quadrat	Vol. of propagules per quadrat	Total (all MCs)
BeadaMoss®	30	420	0.07 (L)	105 L
SoluMoss®	30	72ml (18 x 4ml)	0.072 (L)	100 L
Microplugs	30	9		6250

Clumps	30	4		N/A

A standard amount of BeadaMoss® and SoluMoss® was placed each quadrat; however, as plugs and clumps were not be identical in size the length, width, depth and circumference of each plug and clump was recorded. Each plug / clump within a quadrat was numbered and its position within the quadrat recorded in a sketch. Plugs and clumps will be identified to species where possible. A visual estimate of percentage cover was be made for all *Sphagnum* propagule types along with the percentage cover of dwarf shrub, cotton grass, other grasses, mosses (inc. any existing *Sphagnum*), bare peat and standing water, as well as the proximity to nearest standing water / pool outside of the quadrat will be recorded.

6.1.3. *Summary*

These quadrats will be regularly surveyed during the year to monitor the success of each propagule, however it is not envisaged that any clear indication of the success of the BeadaMoss® and SoluMoss® for a few years due to the initial size of each individual plant within the propagules.

6.1.4. *Biosecurity*

For the purpose of this trial, the clumps planted were harvested from a nearby source to limit the issues surrounding disease translocation. MFFP are reviewing the issues concerning the risks involved in disease movement from donor to restoration sites; these include *Cryptosporidium baileyi* (Bulgy-eye disease) that affects birds and *Lochmaea suturalis* (heather beetle) that affect mainly *Calluna vulgaris* (ling or common heather).

6.2. Case Study 2 – MFFP: Sphagnum planting on a large scale

6.2.1. *Introduction*

As part of several different *Sphagnum* trials carried out by Moors for the Future Partnership in 2015, the Woodhead trial aimed to investigate the difficulties involved in treating large areas of restored moorland with two different treatments:

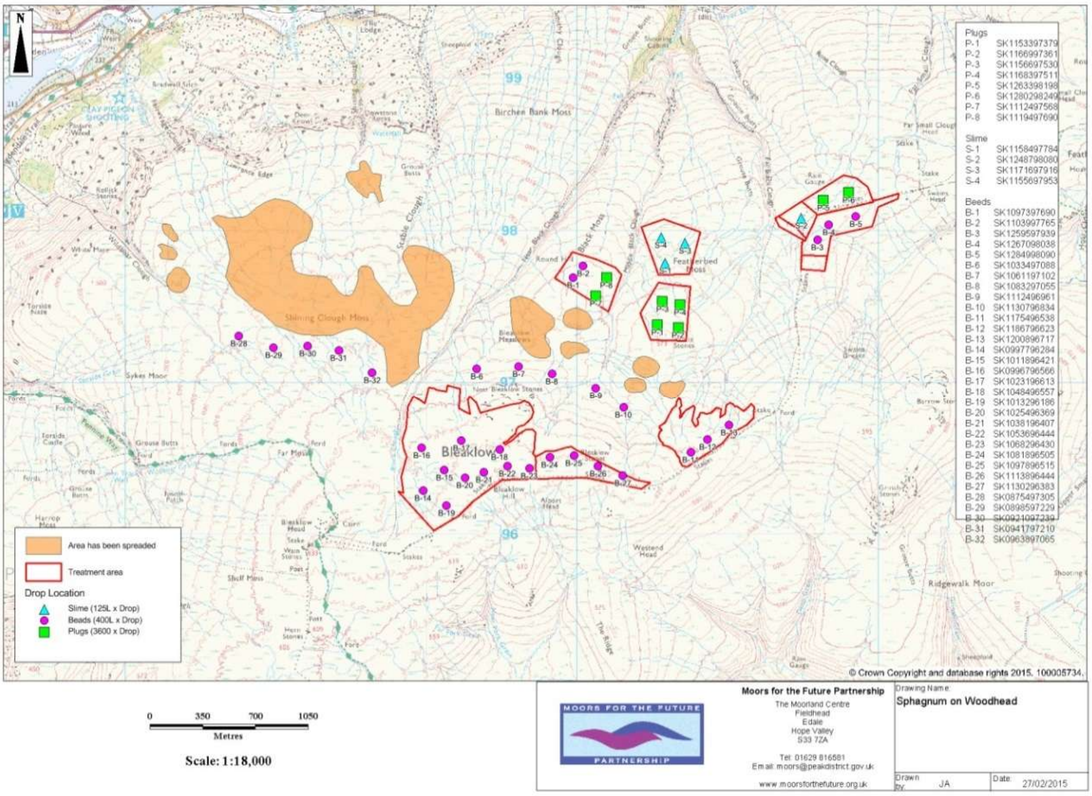

Figure 2 - The treatment areas for Woodhead

1. Micro-plugs – areas shown with green squared (Figure 2) 14,000 plugs in 1 area and 7,200 in another area (mixed with beads)

2. BeadaMoss® – a large coverage of beads across a wide area of Woodhead and are shown with pink circles (Figure 2).

6.2.2. *Methods*

All of the treatments were manufactured by Micro Propagation Ltd. and flown on to site by helicopter and the beads and micro-plugs were spread by contractors under the close supervision of MFFP staff.

The aim of this work was to identify some of the difficulties that may arise from spreading large quantities of material across large areas in bulk. In doing so, we discussed all elements of the work with the manufacturer and contractors with a feedback questionnaire.

6.2.3. *Conclusion*

1. BeadaMoss® - Application on a large scale is logistically possible and the simplest method to achieve a wide-scale spread of Sphagnum propagules. The produced product of BeadaMoss® can be ordered in advance to allow an exact delivery date (subject to conditions). This allows good co-ordination with helicopter companies and spreaders enabling an efficient delivery. The product is of standard size and weight which allows drops to be planned and priced up in advance ensuring the budget of the work is predictable. The spreaders can spread a significant amount each day by decanting the materials into back-packs. This means that the per hectare rate of application is good value.
2. SoluMoss® - The same principles of production and delivery that apply to BeadaMoss® also apply to SoluMoss® as it is a manufactured material. The application, however, proved to be a real challenge. The liquid nature of SoluMoss® was designed to be sprayed over wide areas on flat bare peat. This scenario is not found on the work sites where we attempted application. A sprayed application on the trial site saw the sphagnum fragments being suspended on the vegetation and the new application technique of blobbing the sphagnum in between the vegetation proved a significant challenge to the contractors due to the labour intensive nature of carrying the material and applicator and the distances they had to cover to achieve the required application rate.
3. Plugs – As with the BeadaMoss® and SoluMoss® the manufactured nature of the plugs allowed easy delivery on to the hill. The plugs used on this trial came in tubs and therefore had to be flown out to site. However the plugs which were used on Rishworth were delivered in plastic bags and due to their light weight they were able to be carried on to site. The light weight of the plugs in the tub actually proved a challenge for the helicopter as the bags were too light to fly safely and they had to be paired with a heavier bag to provide ballast. The plugs proved simple to plant using dibbers and the amount the contractors could achieve in a day demonstrated that this is a viable application method. Subsequent visits to the planting site suggest that the location of the plug is not as critical as we expected and that where the plug had been planted in a slightly drier location the species we saw developing was different to the species that were growing in the flushes. This needs closer monitoring as the species develop further but the suggestion is that as there are 11 species used in the mix to create the plugs a dominate species would establish best suited to the conditions where the plug was planted. The other observation from the site visit was that in the few instances where we saw a plug had failed we saw smaller

sphagnum plants growing next to it. Our thoughts were that these were fragments/capitula from the original plug that had broken off when it was disturbed and these were now establishing.

Note: these conclusions relate to the application method and the logistics involved. The success/failure of the methods are dealt with elsewhere.

6.3. Case Study 3 – RSPB: Sphagnum harvesting and translocation at Dove Stones Reserve

6.3.1. *Introduction*

The RSPB and United Utilities aim to restore blanket bog with hydrological integrity and rich in *Sphagnum* mosses. Lime, seed and fertiliser, gully blocking using stone and heather bales, and reintroduction of S*phagnum* mosses are achieving this aim. One of the techniques being used by the RSPB at Dove Stone for *sphagnum* reintroduction is transplanting whole, live plants.

RSPB currently harvests live whole *Sphagnum* plants from a non-SSSI area of Bowland, owned by United Utilities, a non-SSSI RSPB site at Denton Fell in Geltsdale and on site at Dove Stone. The priority with all harvesting is that it is sustainable and non-damaging to the donor site.

Dove Stone is a SSSI, and the RSPB currently have Natural England consent to harvest flush species only (*S. fallax* & *S. fimbriatum*).

6.3.2. *Methods*

6.3.2.1. Harvesting

Harvesting *Sphagnum* must be done carefully and with great care to avoid damaging the donor site. A total of 10 clumps (10 x 1 handfuls) are taken from any 1 m^2; Figure 3 and Figure 4 show a before and after image of *S. fimbriatum* taken from a rich area at Dove Stone.

The handfuls are then carefully placed into permeable polypropylene bags (30 handfuls per bag). If they can be planted as the same

Figure 3 – before harvesting

Figure 4 – after harvesting

Figure 5 – immediately after harvesting

Figure 6 – one year after harvesting

clump as they were harvested, it is believed that the plants will establish much more quickly.

6.3.2.2. Planting

Planting *Sphagnum* is done by using the following steps:

Step 1 - Take a single clump from the bag

Step 2 - Hold it tightly and make it into a mini "proto-hummock"

ALL the brown, dead material underneath the living capitula will be planted into the peat, as if it were roots, the living capitula will be above the peat. Planting in this way will allow moisture to be wick from below the peat surface allowing the sphagnum to retain moisture. The depth at which the sphagnum is planted will also protect the hummocks from the risk of frost heave, mobile peat and dry weather. Planting only occurs within areas where there is sufficient vegetation that will offer protection to the hummock during its establishment

Sphagnum should be planted into a habitat that closely resembles the original habitat:

1. Flush species harvested from flush areas should be replanted into very wet places, ideally behind gully blocks (e.g. bales or stone where the gully is shallow), in *Sphagnum* free vegetated gullies, and into seepage lines, where there is a constant flow of water (though not enough to wash it away!).

2. Aquatic species (e.g. *S. cuspidatum*) should be placed into permanent pools. *S. cuspidatum* is a species that thrives in pools and should be placed there, preferably around the edges to protect against wave action in permanent water, especially if the pool is very large.

3. Hummock and other "drier" *Sphagnum* species should be planted into wet vegetated peat pans, the wet vegetated edges of bare peat pans and wet intact but species

poor blanket bog. Seepage lines, very shallow gullies and other wet features should be targeted preferentially.

4. *Sphagnum* established best when planted into very wet, vegetated peat.

5. Once *Sphagnum* is established into wet areas, it will grow out into drier areas by itself.

Step 3 - Using a heel, make a divot in the existing vegetation making sure that the divot goes through the vegetation and into the peat.

Figure 8 - make a hole with the heel

Figure 7 – the hole

Step 4 – Place the hummock capitula-up into the ground. Push the surrounding peat back around the clump to secure in place.

Figure 9 – hummock capitula (green side) up

Figure 10 -- secure tightly

6.3.3. *Conclusion*

In the future, the RSPB hope to get consent to harvest hummock forming species as well as flush, as they have shown from their donor sites at Bowland and Geltsdale that harvesting hummock forming species is also sustainable.

6.4. Case Study 4 – North Pennines AONB Partnership: Bare peat restoration

6.4.1. *Introduction*

The North Pennines has 90,000 ha of peat with 61,000 ha of it being designated as SSSI. This is 30% of England's blanket bog or 7% of England's peat. The area is less damaged than the Peak District and South Pennines. In total, there is 2900 ha of bare peat spread over 4000 sites, with the majority of sites less than 1 ha in size. They have so far treated a total of 117ha on six sites with (including Broadmea and Moor House which are covered in more detail below).

6.4.2. *Methods*

There are five basic steps followed at all sites:

1. Grazing control – Fencing off areas to exclude stock
2. Hydrology - Gully blocking using coir rolls
3. Slopes – Re-profiling of gullies
4. Heather brash – rich on *Sphagnum* and other moorland dwarf-shrubs, herbs and sedges
5. Re-vegetation techniques – Prilled lime is added at a rate of 1 tonne per hectare to increase the pH levels, phosphate based fertiliser is then applied at a rate of 19.5kg per hectare. These are only added in the first year to boost growth. Moorland seed mix is added which includes a *Deschampsia flexuosa*, *Calluna vulgaris*, *Eriophorum angustifolium* and *E. vaginatum* and *Festuca ovina*. Clumps of *Sphagnum* moss, including *S. fallax, S. cuspidatum, S. capillifolium, S. papillosum* and *S. palustre*, can also be added in to help retain water and prevent the bare peat from drying out.

The following steps are not fixed and different combinations are used depending on the restoration site and landowner requests.

6.4.2.1. Broadmea

1. Fencing
2. Gully blocking using coir rolls
3. Stabilised and revegetated using heather brash which included *Sphagnum* species, grasses, common and hare's-tail cottongrass and other dwarf shrubs including *Erica tetralix* and *Empetrum nigrum*.
4. Lime, fertiliser and moorland seed were added.

5. *Sphagnum* hummocks were transplanted from nearby areas of intact bog and planted into the brashed areas. Approximately one clump was taken per 10m².

6.4.2.2. Moor House

1. Stabilised and re-vegetated using heather brash which included *Sphagnum* species, grasses, common and hare's-tail cottongrass and other dwarf shurbs.
2. Re-profiling of hagg edges.
3. Gully blocking using peat dams installed by specialised diggers.
4. Lime, fertiliser and moorland seed were added.
5. *Sphagnum cuspidatum* was transplanted from onsite bog pools and placed into pools created by the gully blocking. Approximately a fifth of *Sphagnum* was taken from each pool.

6.4.3. *Conclusion*

The techniques used by the North Pennines AONB Partnership have proved effective using a single application of mixed vegetation brash combined with the other techniques. Brash is spread at a thicker density compared to Moors for the Future which keeps the surface of the peat wet and provides a growing medium for *Sphagnum* and other mosses. Brash cut from good condition blanket bog has proved to give the most successful results with *Sphagnum* mosses, heather and other dwarf shrubs all being present after 18 months. Care needs to be taken when cutting from blanket bog as the ground is much softer than dry heath and cannot take more than a couple of passes. Specialised machinery should be used rather than duel wheeled tractors. Spreading of whole *Sphagnum* plants will continue to be trialled, including when best to transplant the *Sphagnum* in relation to the restoration work, impacts on donor sites and which areas are best to target with *Sphagnum* inoculation.

Figure 11 – October 2013

Figure 12 – June 2015

6.5. Case Study 5 – Moors for the Future Partnership: *Sphagnum* rich brash

6.5.1. *Introduction*

As part of the MoorLIFE Project, Black Hill was scheduled for *Sphagnum* application treatment. The site was originally restored by the Moors for the Future Partnership in 2005-2008. As this was an early restoration site, which is now well re-vegetated, the final piece in the restoration jigsaw is the reintroduction of *Sphagnum*. The site was scheduled for a blanket application of *Sphagnum* beads in the MoorLIFE project. As part of the monitoring work undertaken by MFFP, transects were surveyed to search for any existing *Sphagnum* colonies. This was to allow us to demonstrate how successful the *Sphagnum* treatment would be. The results of the *Sphagnum* transects provided some interesting results and offered the opportunity to undertake a landscape scale experiment.

6.5.1.1. Transect Results

Transects results showed approximately 3% *Sphagnum* cover with some significant and well established *Sphagnum* patches. There appeared to be a distinct east/west split in the establishment areas. The differences were so pronounced that we started an investigation into a possible explanation for this.

6.5.1.2. Brash Donor Sites

The western half of the site was treated with brash in the spring of 2006 with brash from Warslow moor (South West Peak District) and the brash from the eastern half was treated in autumn 2006 with brash cut from Burbage moor (Eastern edge of the Peak District) (see Figure 13). The Warslow site has seen an abundance of *Sphagnum* appear in the cut areas. This *Sphagnum* was present but hidden beneath heather prior to cutting but the rapid growth post cutting would suggest that it was present in significant amounts before cutting. The brash applied to the eastern edge of Black Hill came from Big Moor which is a dry site, heather and grass dominated, with very few *Sphagnum* patches. Both areas were treated with seed, lime and fertiliser in June 2006.

6.5.2. *Conclusions*

Due to MFFP observations it is hypothesised that the increased amount of *Sphagnum* re-colonising on the western half of the site was due to *Sphagnum* being re-introduced as a result of the brash being cut on a site rich in *Sphagnum*. There is a second theory that the difference between the two halves of the site could also be related to the time when the brash treatment was completed, either before or after seed establishment.

6.5.3. *The Trial*

In order to understand what caused the *Sphagnum* re-colonisation MFTF decided to split the site in to four sections.

1. North-West corner – Warslow brash area (identified by blue squares) plus Sphagnum bead treatment
2. South-West corner – Warslow brash area (identified by blue squares); no further Sphagnum treatment
3. North-East corner – Burbage brash area (identified by red & white dots) plus Sphagnum bead treatment
4. South-East corner – Burbage brash area (identified by red & white dots); no further treatment

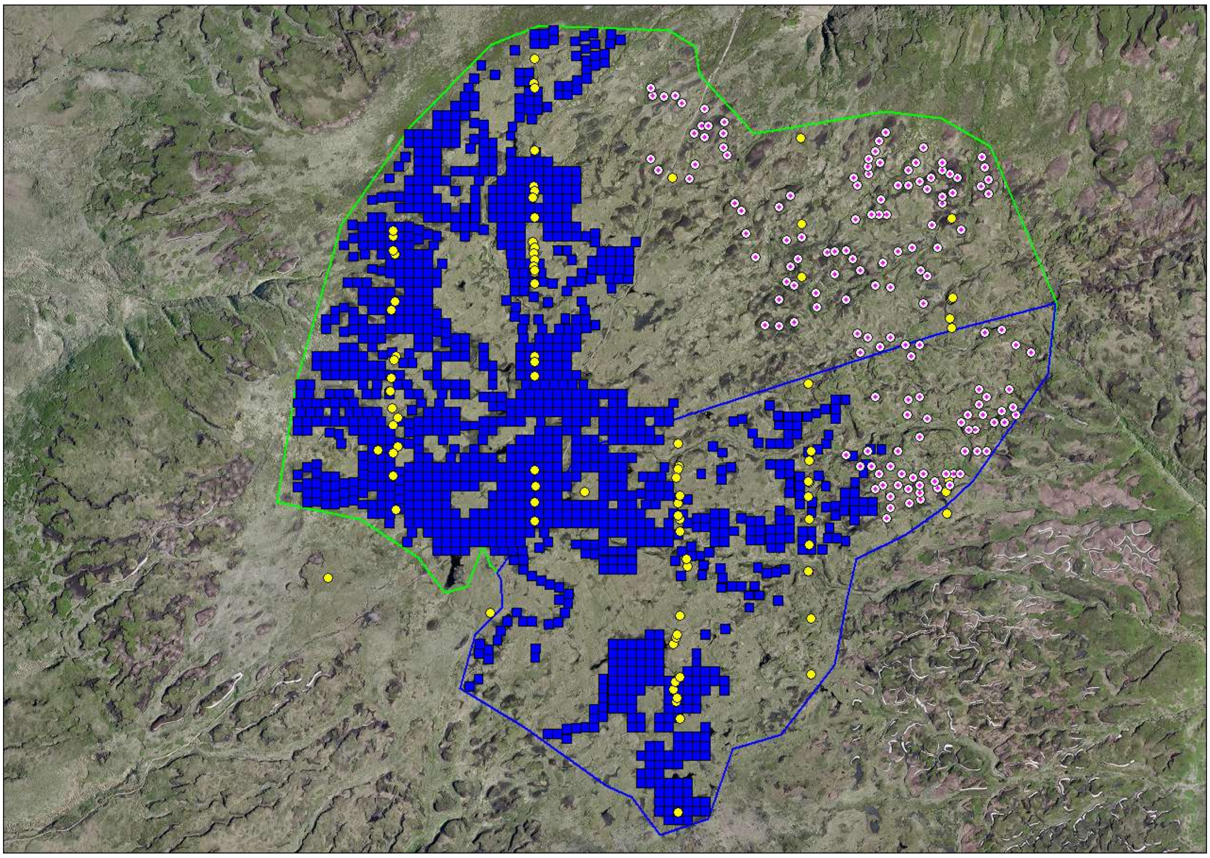

Figure 13 – Black Hill* Sphagnum*/Brash

6.5.3.1. Sphagnum treatment

The proposed *Sphagnum* treatment was to apply a blanket spread of BeadaMoss® at the rate of 35 litres per ha. The spreading contractors were instructed to target cotton grass areas and gully bottoms and to avoid application of slope sides and any dense heather stands. Quadrats were set up after the beads were applied to count the beads per quadrat plus a basis vegetation survey using the DAFOR scale. This will allow MFFP to re-visit the site to quantify the establishment and growth rate of the BeadaMoss® *Sphagnum*.

6.5.3.2. Anticipated Results

If the *Sphagnum* was mainly transported in with the brash then the South-West section should see an increase in *Sphagnum* establishment across the area compared to the South-East section, where no additional *Sphagnum* had been applied. If the reason for the *Sphagnum* establishment on a restoration site was not related to the *Sphagnum* in the brash, but was purely a result of providing an appropriate habitat to allow natural re-colonisation, then we would expect to see *Sphagnum* establishing in the South-East corner at a similar rate to the results seen in the original *Sphagnum* transects. The added treatment of *Sphagnum* beads in the northern half of the site would allow us to see (a) how successful the beads are over a large scale and (b) is it worth treating an area of establishing *Sphagnum* with additional treatment to increase the rate at which we can achieve wide *Sphagnum* coverage on a late-stage restoration site.

6.5.3.3. Initial Results

Once a repeat transect survey of the area has occurred, and the data from the follow up survey on a random selection of the installed quadrats, has occurred these results will be published here.

7. Organisations involved in Sphagnum reintroduction research and development

Project Title	Organisation Name	Site / Location	SPHAGNUM							INTRO TECHNIQUES	HABITATS/CONDITIONS					
			Form						Species		bare peat	reed beds	vegetated	upland blanket bog	standing water	lowland raised bogs
			whole plants	*spores*	*beads*	*fragments /mulch*	*slime*	*brash*								
Sphagnum farming	Joint-Universities companies	Germany	Y	Y	Y	N	N	N	Palustre	Hand spreading & mecahnical	Y	Y	N	N	Y	Y
Upland restoration project	Cumbria WT	Shap fells SSSI	N	N	N	Y	N	N	not stated	Mechanical-modified feed spreader	Y	N	Y	Y		
Yorkshire Peat Partnership	YPP	Yorks. Dales	N	N	Y	Y	N	Y	not stated	turf relocation/ reprofiling				Y		
Dovestones RSPB	RSPB	Dovestones	Y	N	Y	Y	N	Y	not stated	Hand spreading, brash			Y	Y		
Sphagnum propagation project	MFTF	Peak District & South Pennines	N	N	Y	Y	Y	Y	not stated	hand spreading	Y	N		Y		
Easdale fells	Forest of Bowland	South Pennines	Y	N	N	N	N	N	fallax, cuspidatum	hand spreading/ harvesting				Y	Y	
Lancashire Mosslands Project	Lancashire WT	Lancashire	Y	N	Y	Y	Y	N	not stated	hand application under straw				N	N	Y
North Pennines AONB	North Pennines AONB Partnership	North Pennines	Y	N	N	N	N	N	fallax, cuspidatum, fimbriatum, capifollium, papillosum	onto coil roll dams	Y	N	N	Y	Y	N

8. Suggested reading

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