MoorLIFE:
Vegetation Report
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Executive summary

Revegetation of bare peat following treatment with heather brash, lime, seed and fertiliser

The monitoring programme within MoorLIFE has shown that the revegetation of bare peat has been highly successful on all three treated sites. Average decreases in bare peat cover of between 90% and 99% were observed. Through monitoring of an untreated bare peat control, this change has been shown to be attributable to the conservation works programme, and would not have occurred without intervention, and that bare peat and erosion would still persist.

Nurse crop grasses have successfully and rapidly established on all three treated sites, with up to 77% cover on some MoorLIFE sites.

Published work on the impact of revegetation on sediment loss indicates that Moors For the Future Partnership's (MFFP) historic work has been highly successful in trapping sediment through protection of the peat surface from erosive processes and filtering organic particles from overland flow (Shuttleworth *et al,* 2015). Several years following revegetation, the sediment yields (i.e. erosion) have been reduced to rates comparable to those of intact peatland. The MoorLIFE sites have undergone the same treatments as these previously revegetated sites, and so our expectation would be for these catchments to demonstrate a highly reduced rate of erosion following revegetation.

Through the stabilisation of bare peat on MoorLIFE sites, adjacent areas of active blanket peat will be protected from erosion.

Succession of vegetation on restoration sites from nurse crop to more typical moorland species

As well as reducing erosion, the stabilisation of the fragile peat surface has enabled typical blanket bog species to colonise treatment areas just one year after seeding. Monitoring of untreated bare peat areas has demonstrated that these species would have not colonized without initial stabilisation treatments. Blanket bog indicator species such as common heather, cottongrass sedges and feather mosses have increased on all treatment sites.

The MoorLIFE project has enabled the continued collection of data from some of the first sites that were revegetated by MFFP over ten years ago. Because of this, MFFP now holds

a unique dataset which documents over ten years of vegetation development on sites that were once entirely bare peat.

Assessment of communities using NVC suggested that sites could follow similar trajectories of change, albeit with developments occurring at different rates. Black Hill had mire communities very soon after revegetation, whereas these communities developed between four and ten years after revegetation on Bleaklow sites.

The CVS classification method also shows a development of plant communities. Here it was demonstrated that it was not unusual for treated bare peat to contain several plant communities shortly after revegetation – with a range of grassland, heath and moorland habitats present. Over time, as vegetation develops, the range of habitats became narrower on both Bleaklow and Black Hill sites, with fewer grassland-type habitats present, and moorland/species poor blanket bog communities becoming more dominant.

These observations indicate how newly re-vegetated sites can be expected to develop long after the end of MoorLIFE.

Vegetation on Bleaklow, Turley Holes and Rishworth Common is expected to continue to develop greater structural complexity, with indicator species becoming more frequent across the sites and contributing to a more significant proportion of overall cover. Currently, plant communities are dominated by grassland-type communities (in particular U2 *Deschampsia flexuosa* heath), but can be expected to gradually develop more typical blanket bog communities such as M19 *Calluna vulgaris-Eriophorum vaginatum* blanket and raised mire within ten years.

Success of Sphagnum applications

Transect surveys on treated MoorLIFE sites confirmed that *Sphagnum* cover was extremely low at the start of the project – with less than 0.1% cover on Turley Holes. Surveys on Black Hill in 2012 suggested that six years after initial peat stabilisation works, *Sphagnum* cover had increased, but was still extremely low, at 3% of the surveyed area. The transect surveys have provided a baseline of *Sphagnum* cover against which changes in *Sphagnum* cover can be monitored and quantified in future.

The Black Hill surveys also indicated that *Sphagnum* recolonisation was not uniform across sites, and could potentially be linked to brash source. This is evidence that stabilisation of

bare peat will provide more favourable conditions for *Sphagnum* mosses, and that brash from *Sphagnum* rich donor sites can increase the rate of colonisation of suitable areas.

While the MoorLIFE project has used a wide variety of methods of *Sphagnum* reintroduction methods (MFFP, 2015), monitoring of *Sphagnum* reintroduction has focused on bead applications.

Baseline data collected on *Sphagnum* bead applications on Black Hill and Rishworth Common will enable the success of propagule applications to be assessed. Three years have passed between the Black Hill applications and the end of the MoorLIFE project. Results from Rosenburgh (2015) indicate that it can take 18 to 24 months before results of beads are readily observable. Therefore it is expected to be several years before the success of these applications can be quantified.

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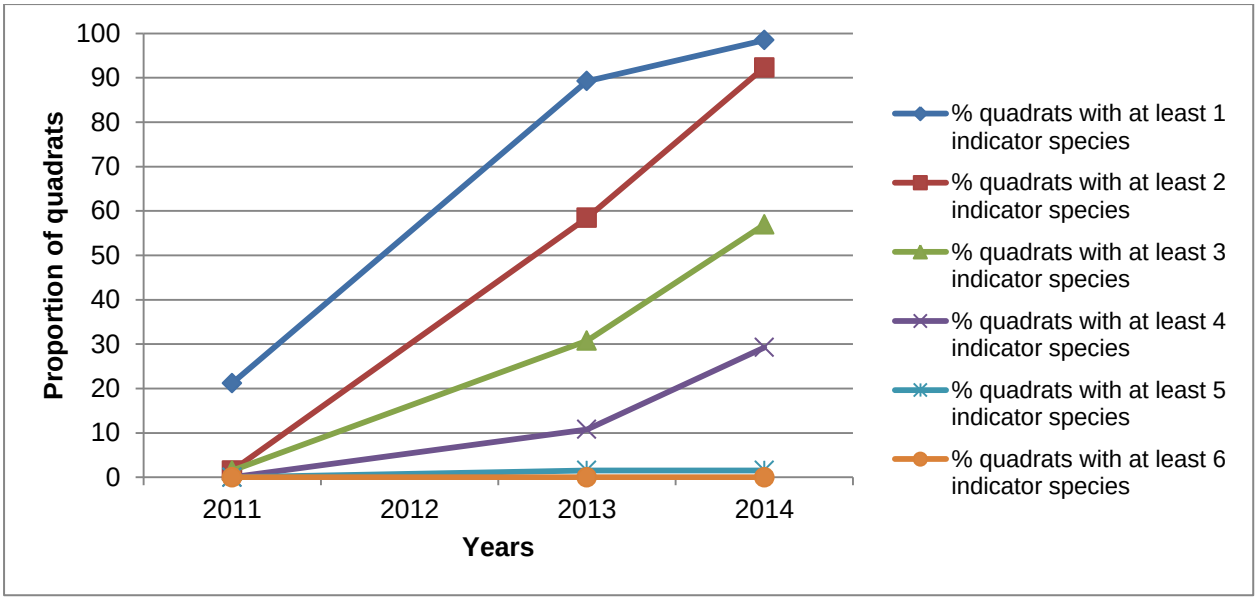


1. Introduction

Blanket bog in the South Pennines has suffered from significant and extensive vegetation loss and erosion. Wildfires and overgrazing have contributed to the loss of vegetation while high levels of acidity remain due to historic air pollution. This, combined with the high erosion rates of exposed peat generally prevent, or at best impede, the natural recovery of the vegetation.

The blanket bog areas of the South Pennine Moors Special Area of Conservation (SAC) are now a mosaic of Active Blanket Bog and various erosion features, with a low diversity of plant species. Many of the drivers of habitat degradation in the South Pennines have been addressed and ameliorated – such as issues of grazing and air quality. However, due to climatic conditions, the vegetation types present and past damage, the natural recovery of vegetation is extremely slow and erosion rates of bare peat are so high that they threaten the remaining areas of intact active blanket bog.

The plant communities, identified through the British National Vegetation Community system (NVC), (Rodwell, 1991), that remain on intact areas of South Pennines blanket bog are generally a mix of M19 *Calluna vulgaris – Eriophorum vaginatum* blanket mire and M20 *Eriophorum vaginatum* blanket mire. The species that are typically found in these habitat types are common heather (*Calluna vulgaris*), bilberry and cowberry (*Vaccinium* sp), crowberry (*Empetrum nigrum*) Ericaceous dwarf shrubs, cloudberry (*Rubus chamaemorus*) and feather (pleurocarpus) mosses. *Sphagnum* mosses are key blanket bog species as they are important peat building plants. Because of their ability to take in water from the atmosphere, and being sensitive to poor air quality, *Sphagnum* was largely lost in the South Pennines blanket bog habitats.

The MoorLIFE project was a five-year project that began in 2010 and was the biggest moorland conservation project in Europe at that time. Its aim was to protect active blanket bog within the South Pennines SAC and increase biodiversity through stabilisation and revegetation of eroding surfaces. Its objectives were:

1. Stabilisation of inactive bare peat (through establishment of nurse crop on bare peat);
2. Restore moorland vegetation on these, and previously stabilised sites, and onto active blanket bog communities (through plug planting and application of *Sphagnum* propagules); and
3. To reduce peat and water flow and restore hydrological integrity (through gully blocking).

Works were undertaken across four sites: Bleaklow, Black Hill, Rishworth Common and Turley Holes (Figure 1).

The MoorLIFE project had an extensive, landscape-scale, scientific monitoring programme. It was designed to monitor and assess the impact that the conservation works had on vegetation succession and hydrology. This report focuses on the results of the vegetation monitoring programme, the aim of which was to monitor the success of vegetation establishment and succession to more typical blanket bog plant communities.

Its objectives were:

1. To monitor the revegetation of areas of bare peat following treatment with heather brash, lime, seed and fertiliser;
2. To monitor the succession of vegetation on restoration sites from nurse crop to more typical moorland species;
3. To monitor the success of *Sphagnum* applications.

2. MoorLIFE sites

2.1. Turley Holes

Turley Holes is the most northerly of the MoorLIFE sites, situated approximately 30 km north-west of Bleaklow. The site has the similar expansive areas of bare peat on its slopes, with peat pans dominating on the flatter areas. Peat stabilisation works (geotextiles, heather brash, lime, seed and fertiliser) and diversification (plug planting and Sphagnum applications). This site has received treatments of lime, seed, fertiliser, plug plants and Sphagnum bead applications as part of the MoorLIFE project.

2.2. Rishworth Common

Rishworth Common is north of the Peak District National Park and the site is divided by the M62 motorway. In 2010 the area to the south of the motorway had large areas of bare peat which received stabilisation treatments of lime, seed, fertiliser, and diversification treatments of plug plants and Sphagnum bead applications. Areas to the north of the M62 were well vegetated, if species poor, and were treated with Sphagnum beads in 2014 and 2015.

2.3. Black Hill

Black Hill was considered here as a previously revegetated site, having undergone initial stabilisation treatments in 2006. Black Hill was the first MoorLIFE site to receive applications of Sphagnum propagules in September 2012. No other treatments were applied.

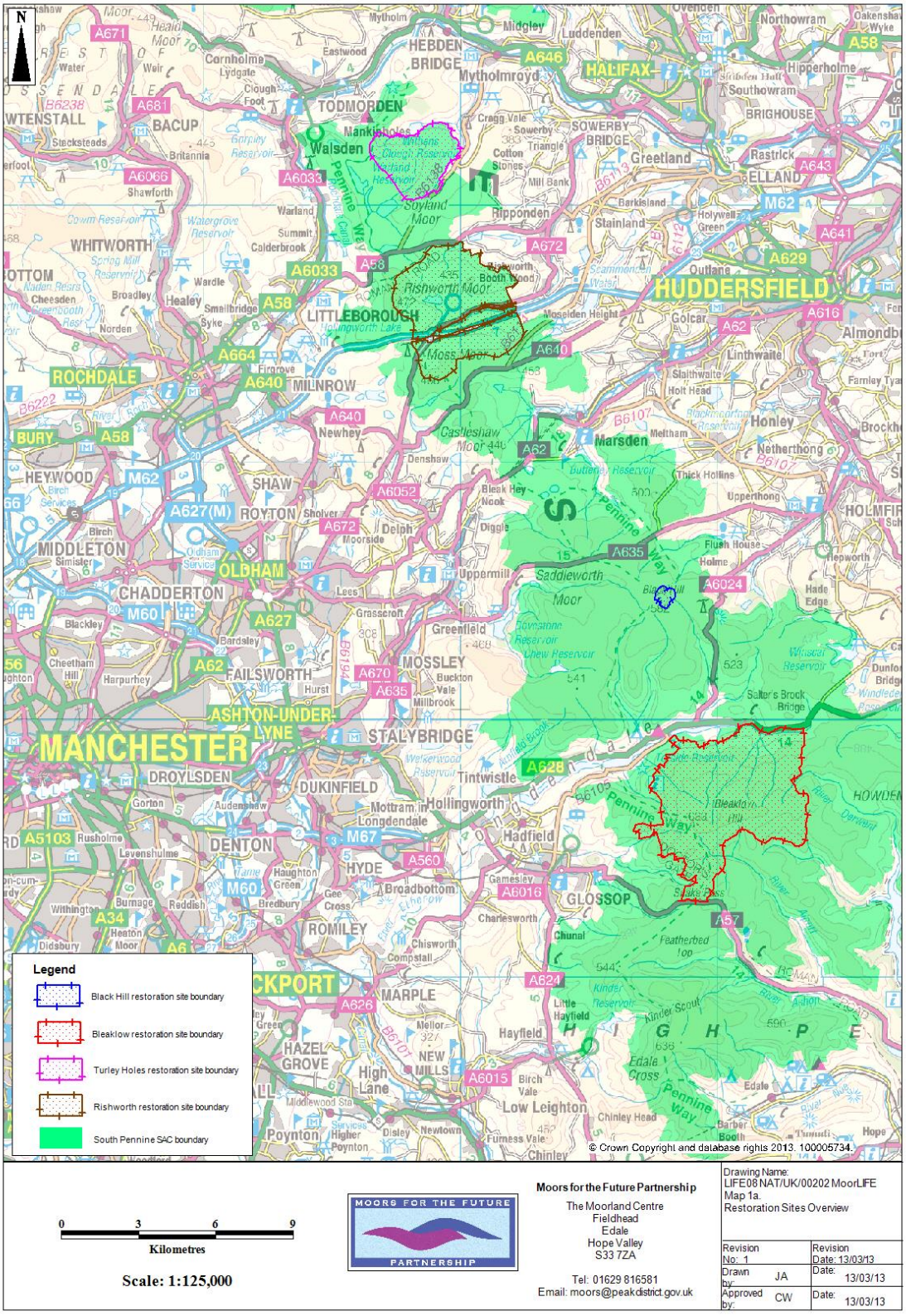


Figure 1 - overview of the locations of the four MoorLIFE sites in the north of England.

Figure 2 - Aerial views of the four MoorLIFE sites. Clockwise from top left: Bleaklow (Woodhead), Black Hill, Turley Holes and Rishworth Common.

2.4. Bleaklow

Bleaklow is the second highest hill in the Peak District National Park with a summit of 630m. Extensive areas of bare peat have been successfully revegetated over more than ten years through conservation works (Figure 2). As such some areas of Bleaklow are considered by MFFP as being in a state of 'previously' revegetated. The MoorLIFE works focused on peat stabilisation of the last large areas of bare peat on privately-owned moorland. Peat stabilisation works (geotextiles, heather brash, lime, seed and fertiliser); diversification (plug planting and *Sphagnum* applications) and gully blocking were undertaken across the plateau by the MoorLIFE project.

3. Methods

Four scenarios were represented in the vegetation monitoring:

Treatment sites

These were sites that received full peat stabilisation treatments of brash, lime, seed and fertiliser. This scenario was monitored on Bleaklow, Rishworth Common and Turley Holes.

Previously re-vegetated sites

Previously revegetated sites were present on Bleaklow (Peaknaze) and Black Hill. These were sites where initial restoration treatments took place between 2003 and 2006. At the start of the MoorLIFE project, previously re-vegetated sites were between four and seven years post initial restoration activities. Monitoring of these sites enabled an assessment of how vegetation continues to develop on sites following completion of capital works.

Bare peat reference

A number of sites were used as untreated, bare peat reference sites.

On Bleaklow, one of MFFP's long-term bare peat reference sites was used as a comparison for Bleaklow quadrats.

Small areas of bare peat on Turley Holes and Rishworth Common were protected from works to provide on-site reference areas. These areas were extremely small and with limited space for quadrats. Unfortunately, the bare peat reference site on Rishworth suffered a degree of damage and so monitoring here was discontinued.

Intact reference

Quadrats on intact reference sites were situated within the dipwell clusters which were established as part of the water table monitoring (Maskill, *et al* 2015). Dipwell clusters were established to monitor water table and consisted of one automated dipwell and 15 manual dipwells within a 30 x 30m^2 area. Vegetation quadrats established within clusters were to inform vegetation changes alongside changes in hydrology. They were not monitored annually, but used as a reference to indicate the plant communities present on uneroded sites.

Table 1 shows the sites monitored the status they represent, and the number of quadrats that were monitored on each site.

3.1. Objectives 1 and 2 – stabilisation of bare peat

In late 2010 / early 2011 fixed 2 x 2m vegetation quadrats were established on Woodhead, Turley Holes and Rishworth Common. Repeat visits were made to each quadrat in summer 2011, 2013 and 2014. The three treatment sites were monitored, along with bare peat control areas established on each site.

Data collected from fixed quadrats included:

- Percentage cover of bare peat.
- Percentage cover of standing water.
- Percentage cover of main vegetation types: grasses, sedges and rushes; nurse crop species; dwarf shrubs; herbaceous species; invasive species; tree and shrub species; mosses and lichens. These are broken down further into plant species wherever possible
- The average heights of dwarf shrub, moorland graminoids (grasses, sedges and rushes) and nurse crop
- Presence of grouse, hare or sheep droppings.
- Heather condition.
- Signs of grazing.

Fixed point photos were taken of each quadrat at each monitoring visit.

The surveys were designed to enable assessment of habitat condition against the Common Standards Monitoring targets used by Natural England and the Joint Council Conservation Committee (JNCC, 2009) for Sites of Special Scientific Interest (SSSI). Here it is not intended to be an assessment of habitat condition, but as a way of analysing presence/absence information collected for positive indicator species. Presence/absence data could be regarded as being less subjective than percentage cover estimates and is a useful way of combining data collected by many surveyors with a variety of experience over several years. A summary of the targets is provided in Appendix 1.

The data was also entered into a computer programme, MAVIS (Modular Analysis of Vegetation Information System; freely available from the Centre for Ecology and Hydrology), to enable a number of other classifications to be calculated. These included:

- National Vegetation Classification
- Countryside Vegetation System classification
- Ellenberg scores for light, pH, wetness and fertility

National Vegetation Classification communities were assigned to each monitoring area as a way of monitoring progress towards typical blanket bog communities. The Countryside Vegetation System classification contains 100 vegetation classes. More information about the classes can be found in Bunce *et al* (1999). These methods of classification provide a way of describing the plant communities present and monitoring changes in plant assemblages, rather than simple changes in individual species or species groups.

Table 1- Sites monitored for vegetation

Site name	Year of initial restoration activity	Restoration status during MoorLIFE	Number of 2x2m fixed quadrats monitored	*Sphagnum* monitoring
Bleaklow – Peaknaze				
Joseph Patch	2003		35	
Shining Clough	2003	Previously revegetated	11	None
Sykes Moor	2004		22	
Shelf Moss	2004		9	
Bleaklow – National Trust	2008	Previously revegetated	-	Transects
Black Hill	2006	Previously revegetated	26	Transects and quadrats
Bleaklow – Woodhead	2010	Treatment	58	Transects
Rishworth Common	2010	Treatment	24	Transects and quadrats
Turley Holes	2010	Treatment	31	Transects

3.2. Objectives 2 and 3: Sphagnum transects

Fixed width transects were one of the methods used to monitor success of *Sphagnum* mosses on restoration sites and to create a baseline against which long-term changes can be monitored. These were undertaken on sites prior to treatment with *Sphagnum* fragments or beads and were designed to be a rapid assessment of a site, rather than an extensive survey.

Transect routes were mapped on the area of interest and the start and end points uploaded onto a handheld GPS unit. Transects were spaced with a distance of 50m between them. Initially only every third transect line was surveyed to ensure an evenly distributed coverage of the area. If time permitted, surveyors would then walk the transects in between to increase the area surveyed. Transects were orientated either north-south or east-west, so as to cut across the gullies present on the sites. The width of transects depended on the abundance of *Sphagnum*, and the structure of the vegetation and how much it obstructed a surveyor's view.

The following variables were recorded for each patch of *Sphagnum*:

- Species.
- Approximate area of the *Sphagnum* patch.
- Lengths of the longest and shortest axes of the patch.
- Situation type (undulating ground, hagg top, gully side or gully floor).
- Gully width and depth (where applicable).
- Surface gradient (shallow 0-10 degrees; moderate 11-30 degrees; steep 31+ degrees).
- The presence of standing water within two metres of the *Sphagnum* patch.
- A list of other plant species present within a 2 x 2 m quadrat centred on the *Sphagnum* patch.
- A list of other plant species present within a 2 x 2 m quadrat centred on the *Sphagnum* patch, with an estimate of their relative cover using the DAFOR scale
- Coordinates of the *Sphagnum* patch.

The total area of *Sphagnum* cover was calculated by estimating the total area of *Sphagnum* patches recorded and calculating the proportion of the total area surveyed (the product of transect length and distance scanned by surveyor) in order to compare sites.

The *Sphagnum* patches were mapped using MapInfo v.10 to assess the spatial distribution.

3.2.1. *Objective 3: Sphagnum quadrats*

Quadrats were used within MoorLIFE to assess the success of *Sphagnum* propagule application. These surveys involved a much more detailed survey and involved counting individual beads within a quadrat. These surveys were better able to assess success of *Sphagnum* at a smaller scale than the transect surveys. On Black Hill, surveyors accompanied *Sphagnum* spreaders along pre-mapped application transects. These transects were orientated east to west and were spaced 14 metres apart. Surveyors installed 1 x 1m quadrats in areas observed to have been treated with *Sphagnum* beads. Quadrats were located every 150 m along the spreading transects on flat, well-vegetated areas. Quadrats were placed on particular vegetation types dominated by either dwarf shrubs, cotton grasses, other grasses or mosses, with a surveyor alternating between a different vegetation type wherever possible.

Quadrats were orientated north-south, and marked with a single wooden stake in the south-west corner. For each quadrat the surveyor noted the coordinates, percentage cover of the four plant types, percentage cover of bare peat and standing water within the quadrat, and the proximity of any standing water, ponds or pools within sight of the quadrat.

4. Results

4.1. Bare peat treatment sites

4.1.1. *Turley Holes*

4.1.1.1. Changes in bare peat and total vegetation cover

Bare peat cover decreased significantly by 99% between 2010 and 2014 on Turley Holes (Table 2), with a concurrent increase in vegetation of 148%. In contrast, bare peat cover remained high on the untreated area of Turley Holes (Figure 3) and showed no significant change over the project at 99% in both 2010 and 2014.

Table 2 - Turley Holes median percent cover and Mann-Whitney U test results. (Significance levels: * 0.05, ** 0.01, *** 0.001)

Cover type	Pre-works	2014	Significance
Bare peat	100	1	U = 13.0, p < 0.001***
Total vegetation	<1	149	U = 5.0, p < 0.001***
Dwarf shrub	0	6	U = 38.0, p < 0.001***
Moorland herb species	0	0	U = 450.0, p > 0.05
Grasses, sedges, rushes	<1	53	U = 24.5, p < 0.001***
Nurse crop	0	10	U = 45.0, p < 0.001***
Mosses, lichens and fungi	0	71	U = 0.0, p < 0.001***

Significant changes were observed in all plant groups with the exception of moorland herb species.

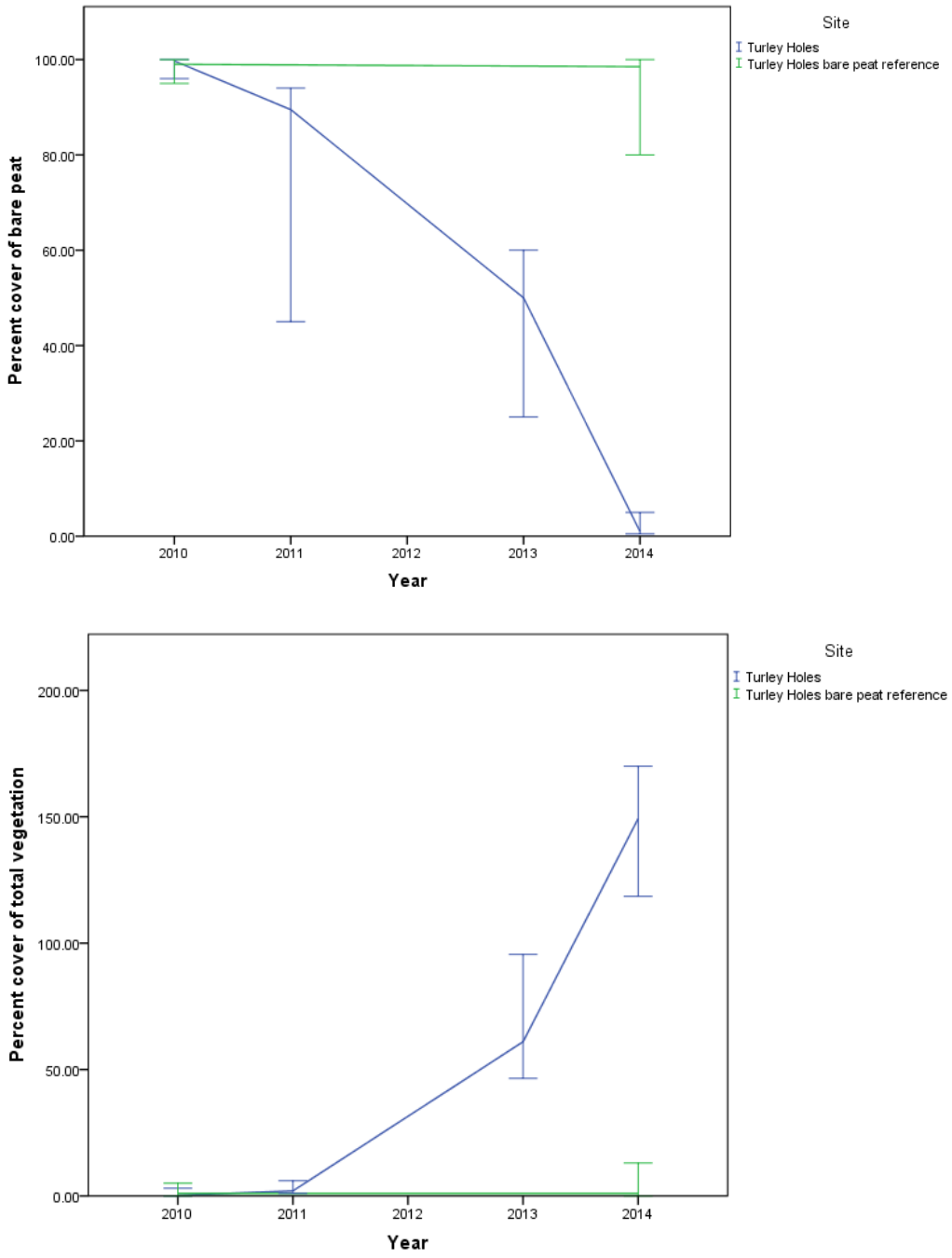


Figure 3 - Changes in percent cover bare peat and total vegetation on Turley Holes treatment and bare peat reference sites.

4.1.1.2. Nurse crop cover

Nurse crop cover made up 10% of quadrat area in 2014 and was present in 91% of quadrats.

4.1.1.3. Dwarf shrub cover

Dwarf shrub cover increased significantly over the monitoring period and was dominated by common heather. All quadrats on Turley contained common heather, and 96% of quadrats contained multiple heather plants (Figure 4). Other dwarf shrub species present were crowberry (28% of quadrats) and bilberry (3% of quadrats).

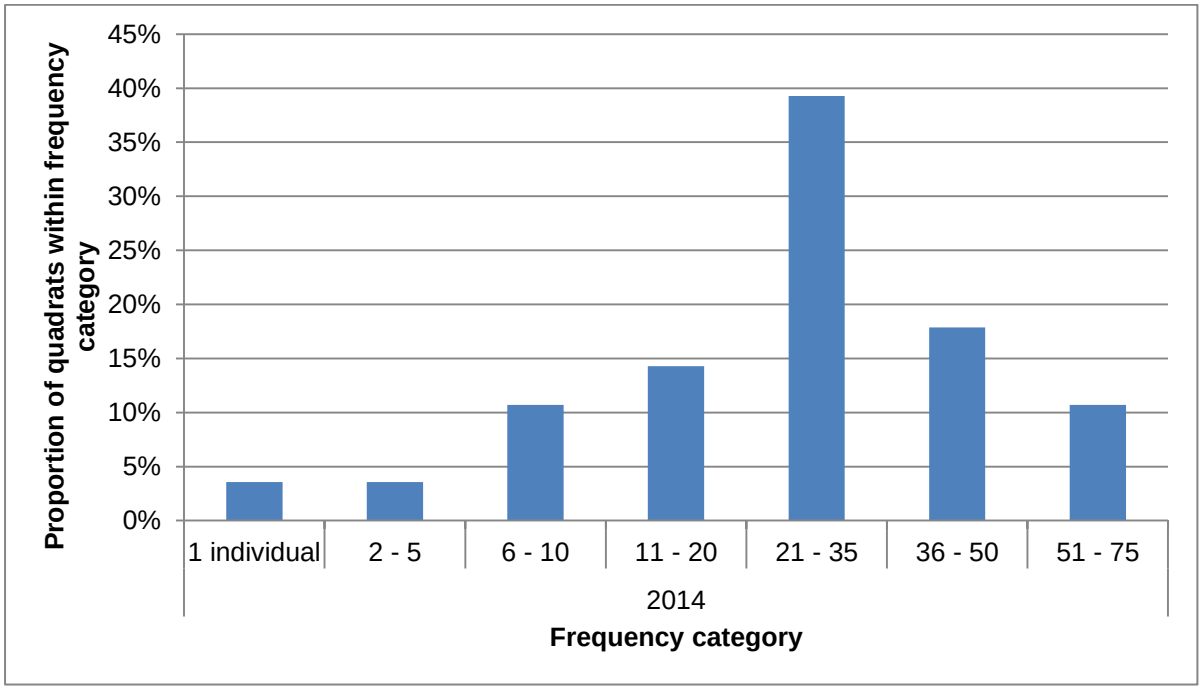


Figure 4 - frequency of common heather within treated quadrats on Turley Holes in 2014.

Crowberry was found in 28% of quadrats, and bilberry was found in 3%.

4.1.1.4. Moorland herb species

There were no significant changes in moorland herb cover on Turley during the project. In 2014 only 2% of quadrats contained a moorland herb species – this was heath bedstraw (*Galium saxatile)*.

4.1.1.5. Grass, sedge and rush species

This group of plants was mainly composed of wavy hair-grass (25% cover), common cottongrass (9% cover) and hare's-tail cottongrass (1% cover).

Wavy-hair grass was present in the majority of quadrats (84%). While common and hare's-cottongrass cover was relatively low, it was also present in most quadrats (91% and 84% respectively).

4.1.1.6. Moss, lichens and fungi cover

Median cover of moss, lichen and fungi was 71% on Turley Holes. Cushion mosses had a median cover of 25% and feather mosses 3.5%. Cushion mosses were found in 97% of quadrats, and feather mosses in 66%.

Sphagnum was found in one quadrat in 2014, where it had not been present in previous years.

4.1.1.7. Common Standards Assessment

4.1.1.7.1. Frequency of species

All quadrats on Turley Holes gained blanket bog indicator species. In 2014, all quadrats contained at least two indicator species (Figure 5). Nearly three-quarters of quadrats contained at least four indicator species. The most commonly occurring indicator species were common heather, common cottongrass, hare's-tail cottongrass, feather mosses and crowberry.

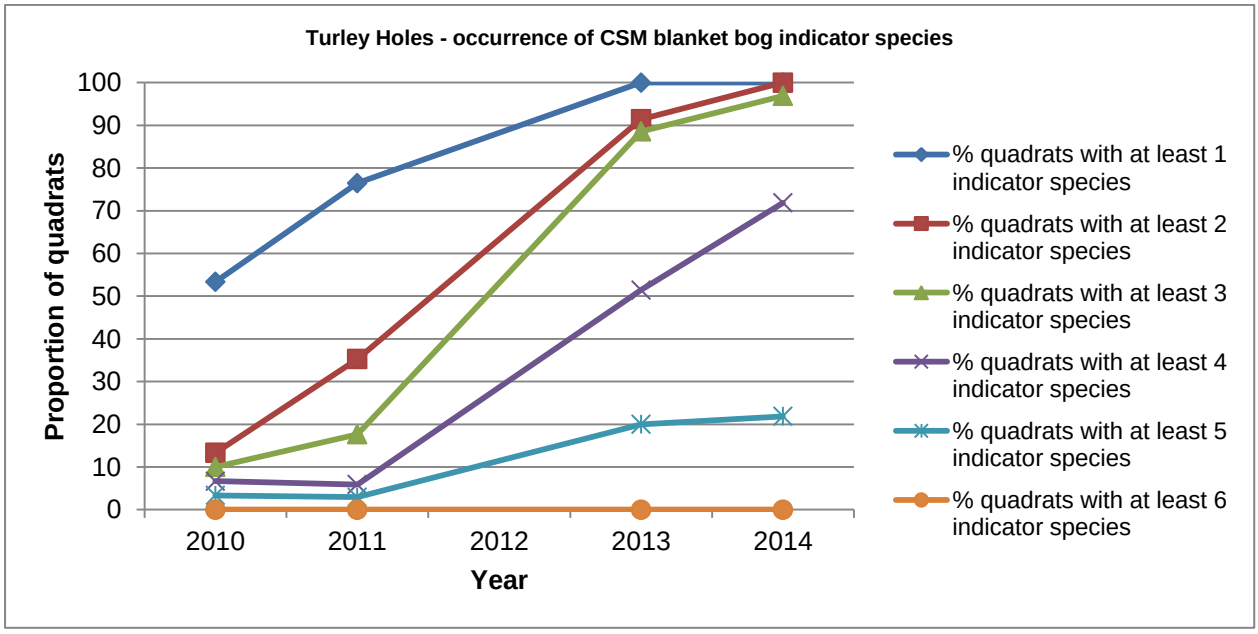


Figure 5 - Changes in the proportion of quadrats containing multiple indicator species on Turley Holes.

4.1.1.7.2. Vegetation composition – cover of indicator species

In 2014, 25% of quadrats on Turley had at least three indicator species contributing to 50% or more of vegetation cover.

The average cover of indicator species increased in each year of monitoring. By 2014, indicator species contributed, on average, 34% of vegetation cover (Figure 6). On the intact reference site, indicator species contributed an average of 83% vegetation cover.

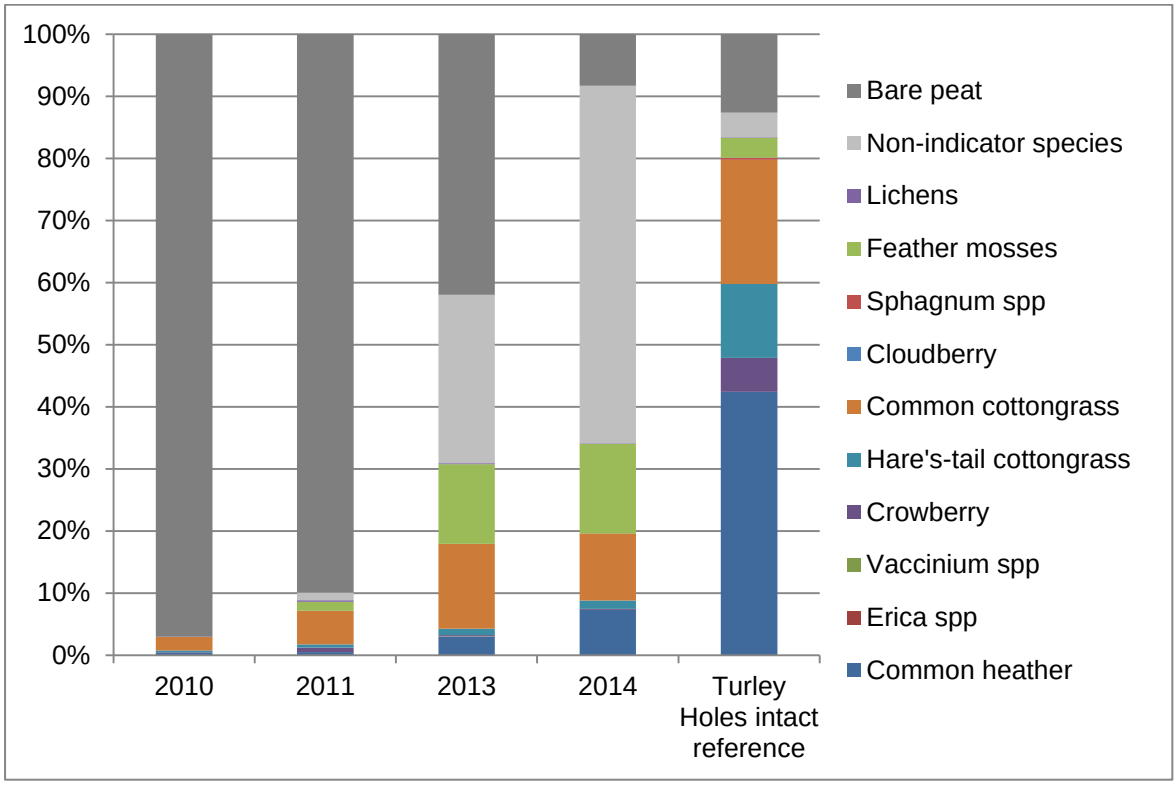


Figure 6 - changes in the proportion of blanket bog indicator species, non-indicator species and bare peat on Turley Holes.

Hare's-tail cottongrass and Ericaceous species did not collectively exceed 75% of vegetation cover in any quadrat on Turley.

4.1.1.8. Plant community development on Turley Holes

When assessed using the Countryside Vegetation System, quadrats on Turley Holes were assigned to four categories (Figure 7). 88% of quadrats were categorised as being species poor blanket bog, 6% montane heather moorland, 3% cottongrass bog, and 3% rye grass/bent grass sward.

Turley Holes treated quadrats were strongly associated with NVC communities H9 *Calluna vulgaris-Deschampsia flexuosa* heath and U2 *Deschampsia flexuosa* grassland. M20 *Eriophorum vaginatum* blanket and raised mire and M19 *Calluna vulgaris-Eriophorum vaginatum* blanket mire were also associated habitats.

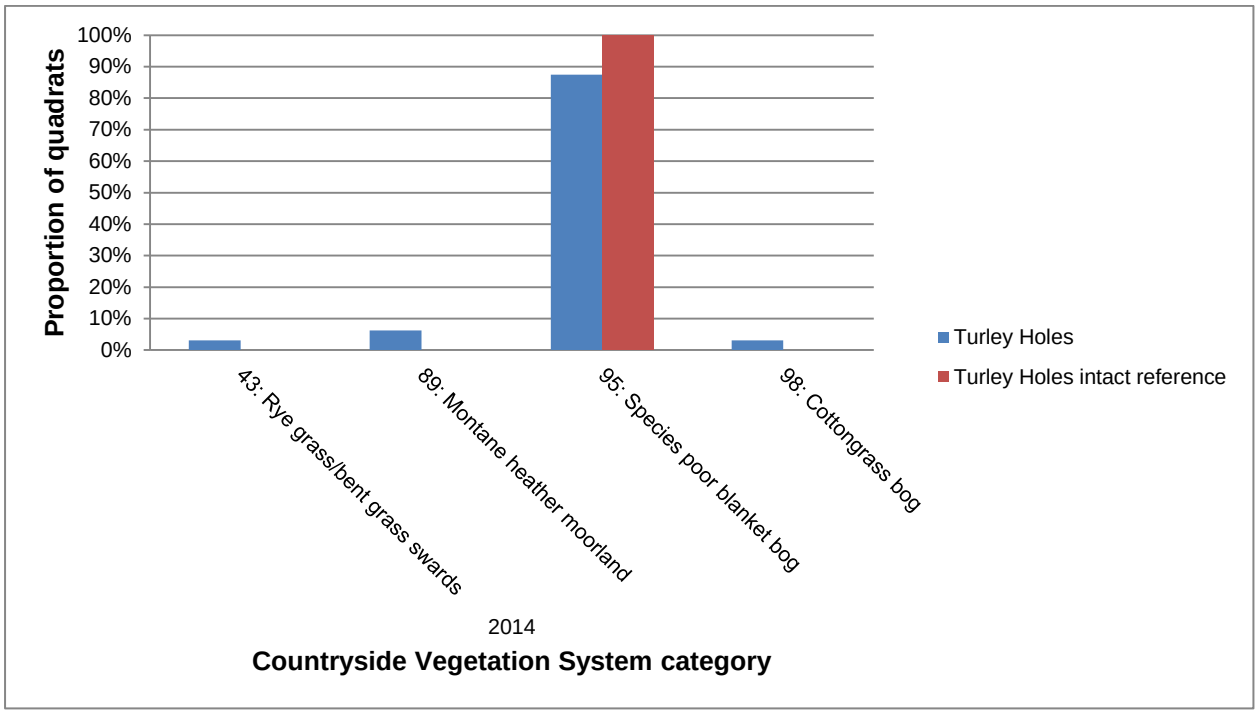


Figure 7 - Countryside Vegetation System categories for quadrats on Turley Holes treatment sites and intact reference in 2014.

4.1.2. *Rishworth Common*

4.1.2.1. Changes in bare peat and total vegetation cover

Between 2011 and 2014, bare peat cover decreased significantly by 90%, with a concurrent increase in vegetation of 108% (Table 3). Because of problems with the bare peat reference site at Rishworth, the site is compared to the Turley Holes bare peat reference site (Figure 8).

Table 3 - Rishworth Common median percent cover and Mann-Whitney U test results. (Significance levels: * 0.05, ** 0.01, *** 0.001)

Cover type	Pre-works	2014	Significance
Bare peat	99	9	U = 0.0, p < 0.001***
Total vegetation	<1	109	U = 0.0, p < 0.001***
Dwarf shrub	0	4	U = 31.0, p < 0.001***
Moorland herb species	0	0	U = 300.0, p > 0.05
Grasses, sedges, rushes	<1	33	U = 12.0, p < 0.001***
Nurse crop	0	33	U = 0.0, p < 0.001***
Mosses, lichens and fungi	0	22	U = 0.0, p < 0.001***

Significant increases were seen in all plant groups on Rishworth with the exception of moorland herb species.

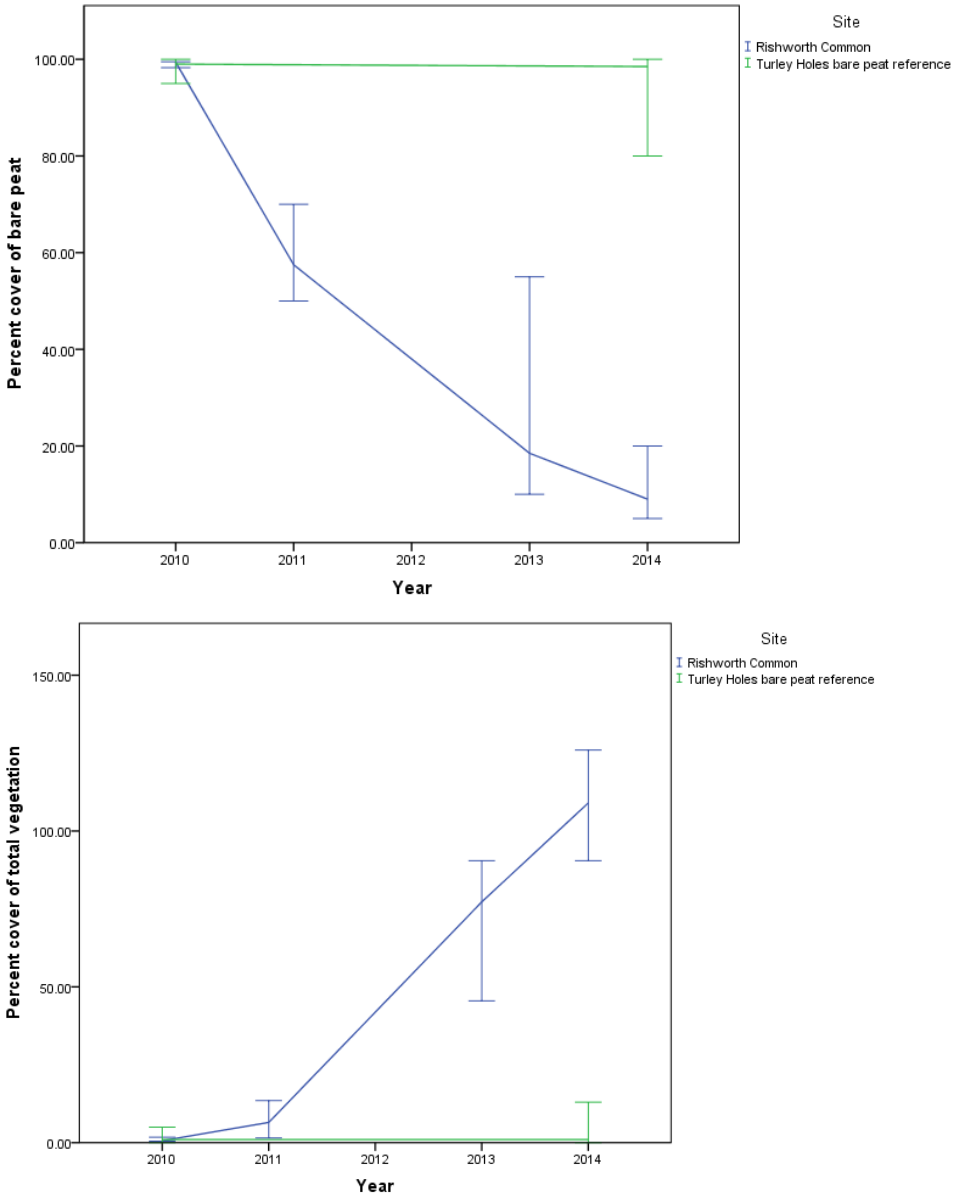


Figure 8 - Changes in bare peat and total vegetation on Rishworth Common, compared to the Turley Holes bare peat reference site.

4.1.2.2. Nurse crop cover

Nurse crop cover was a dominant vegetation type on Rishworth in 2014, contributing to a median of 33% of quadrat area. Nurse crop grasses were present in all quadrats.

4.1.2.3. Dwarf shrub cover

Dwarf shrub cover increased significantly over the monitoring period and was dominated by common heather. Common heather was present in 88% of quadrats in 2014, with 85% of quadrats having multiple plants (Figure 9). Other dwarf shrub species that were present included bilberry (8% of quadrats), cowberry (8%) and cross-leaved heath (4%).

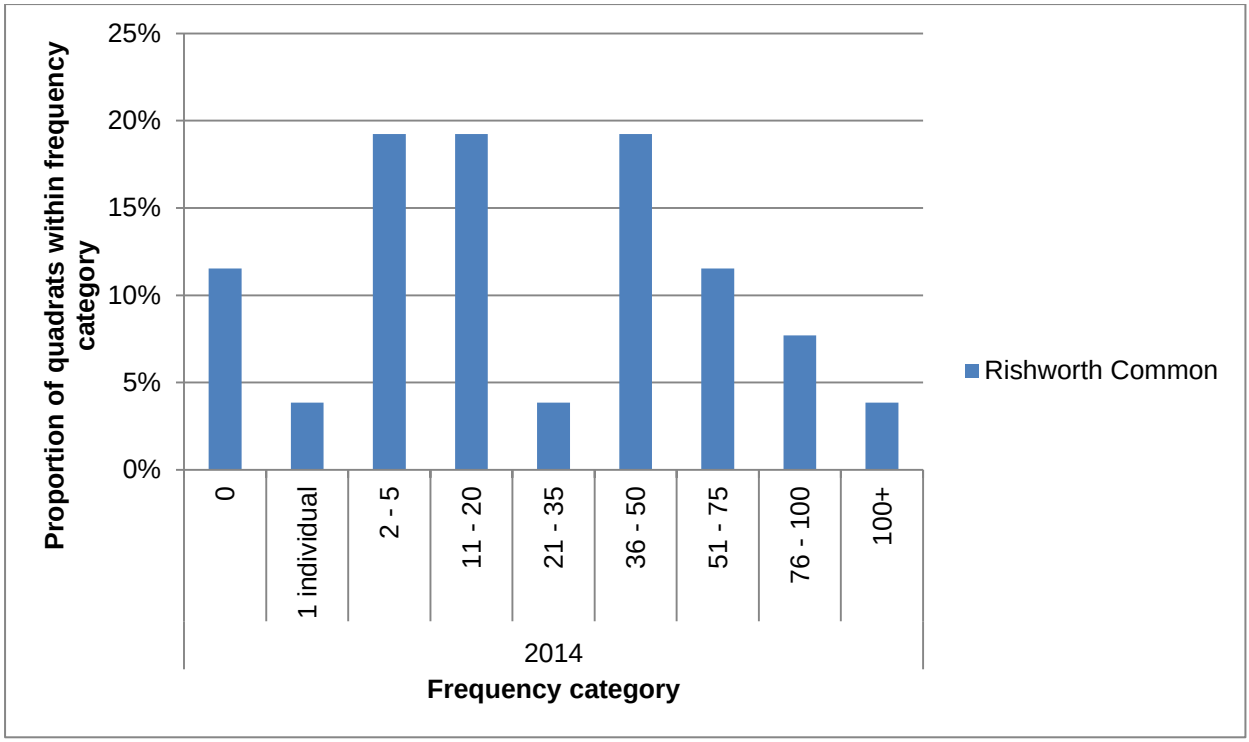


Figure 9 - Frequency of common heather on Rishworth Common in 2014.

4.1.2.4. Moorland herb species

Moorland herb species cover remained low in 2014. Cloudberry was the only moorland herb species present, and only in one quadrat.

4.1.2.5. Grass, sedge and rush species

Within this group of plants wavy hair-grass contributed most to the proportion of cover within quadrats with a median of 13% and was present in all quadrats. Median common cottongrass cover was 6.5% and was present in 96% of quadrats. Hare's-tail cottongrass had 2% cover and was present in 81% of quadrats.

Other species present, but with less than 1% cover, included Yorkshire fog (19% of quadrats), purple moor-grass (19% of quadrats), creeping soft-grass (8% of quadrats), and mat grass (4% of quadrats). Heath rush was present in one quadrat.

4.1.2.6. Moss, lichens and fungi cover

Cushion mosses had the highest quadrat cover within this group of plants and the highest occurrence, with a median of 7% cover, and present in all quadrats on Rishworth. Feather mosses had a median cover of 5% and were present in 96% of quadrats.

Other plant types present in re-vegetated areas but at less than 1% cover were *Polytrichum* mosses (58% of quadrats), lichens (27%), liverworts (19% and fungi (16%).

4.1.2.7. Common Standards Assessment

4.1.2.7.1. Frequency of species

All quadrats on Rishworth contained at least one positive indicator species by 2013, and this was maintained in 2014 (Figure 10). 85% of quadrats contained at least four indicator species. Rishworth was the only site where some quadrats contained at least 6 species, with 12% of quadrats achieving this in 2014.

The most commonly occurring indicator species on Rishworth were feather mosses and common cottongrass, followed by common heather, hare's-tail cottongrass and lichens.

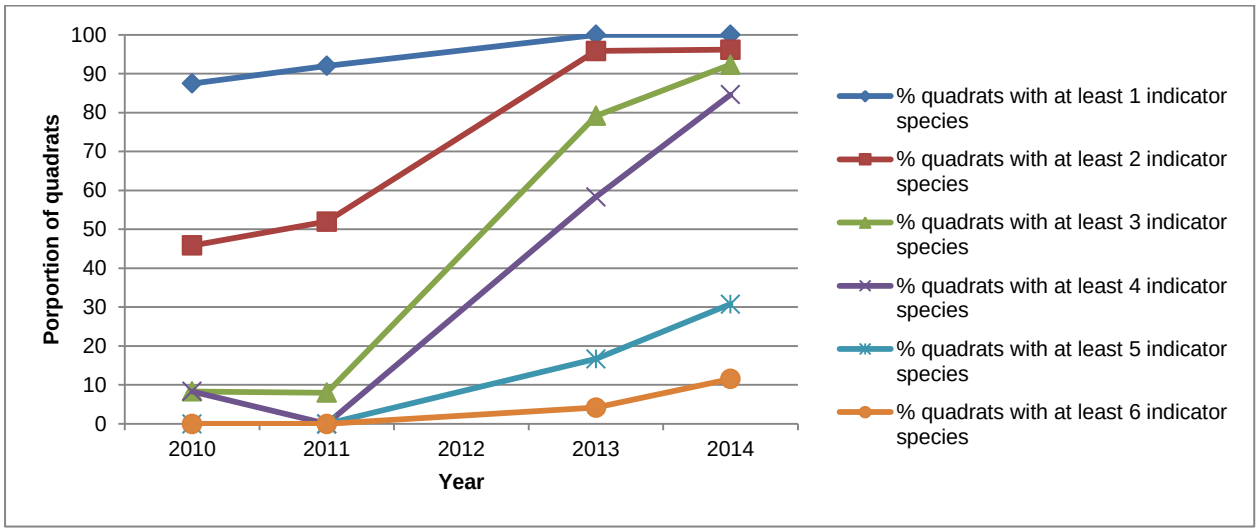


Figure 10 - changes in proportion of quadrats containing multiple blanket bog indicator species.

4.1.2.7.2. Vegetation composition – cover of indicator species

In 2014, at least three indicator species contributed to more than 50% of vegetation cover in 8% of quadrats.

Over the course of the monitoring period, the average cover of indicator species has increased (Figure 11). By 2014, indicator species contributed 31% of quadrat cover in re-vegetated areas of Rishworth with non-indicator species covering 53%.

On intact areas of Rishworth, indicator species contributed 75% of quadrat cover.

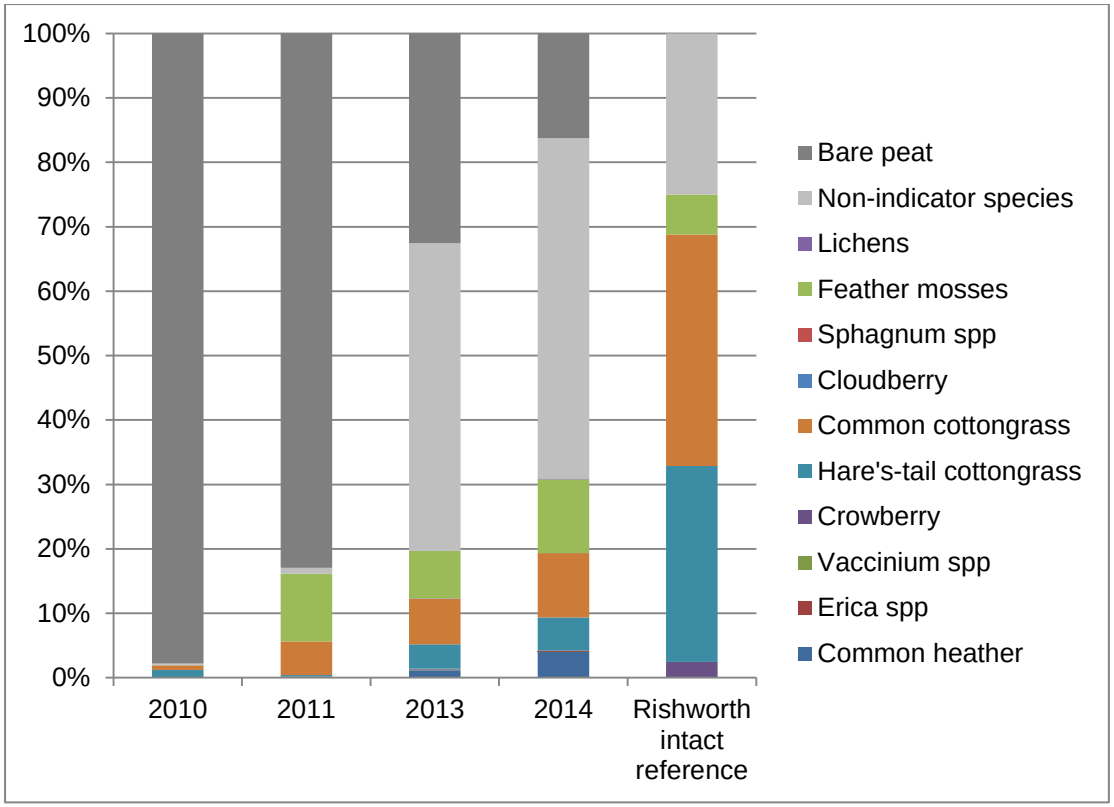


Figure 11 - changes in the relative proportion of blanket bog indicator species, non-indicator species and bare peat on Rishworth Common.

Hare's-tail cottongrass and Ericaceous species did not collectively exceed 75% of the vegetation cover on treated areas of Rishworth.

4.1.2.8. Plant communities in re-vegetated areas of Rishworth

When assessed using the Countryside Vegetation System, quadrats on Rishworth were assigned to four vegetation categories (Figure 12). 85% of quadrats were assigned to species poor blanket bog.

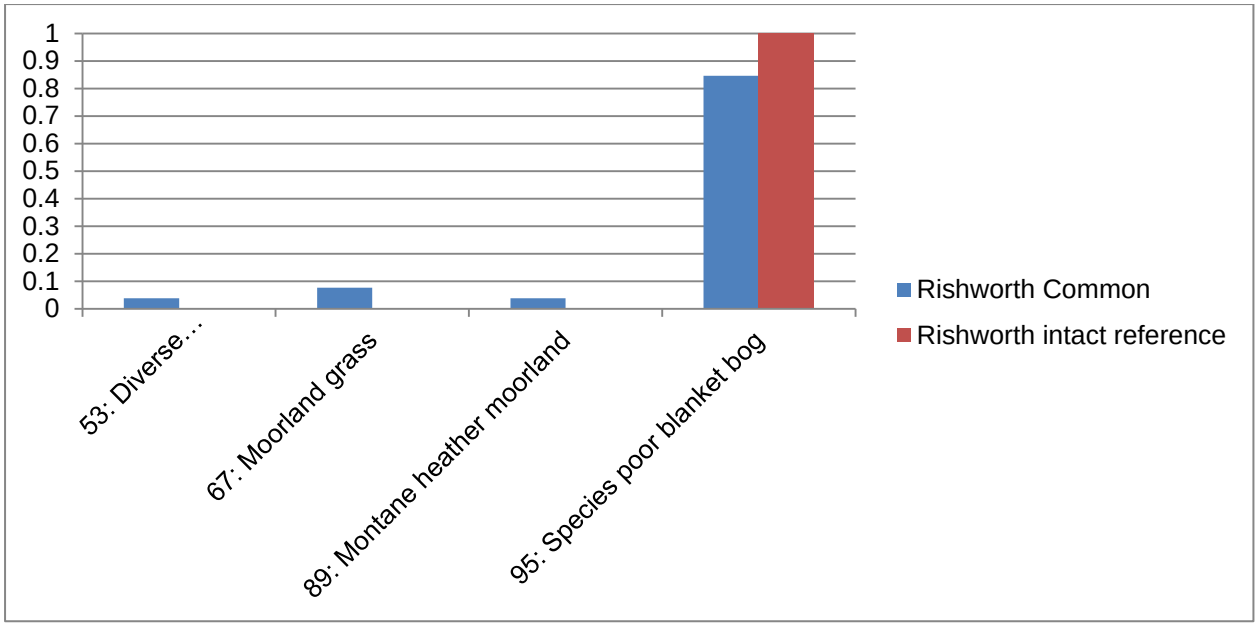


Figure 12 - Countryside Vegetation System classification of treated quadrats on Rishworth Common in 2014 and on the Rishworth intact reference site in 2012.

In 2014, re-vegetated areas of Rishworth were most strongly associated with the NVC types U2 *Deschampsia flexuosa* grassland, M19 *Calluna vulgaris-Eriophorum vaginatum* blanket mire and M20 *Eriophorum vaginatum* blanket and raised mire.

4.1.3. *Bleaklow: Woodhead*

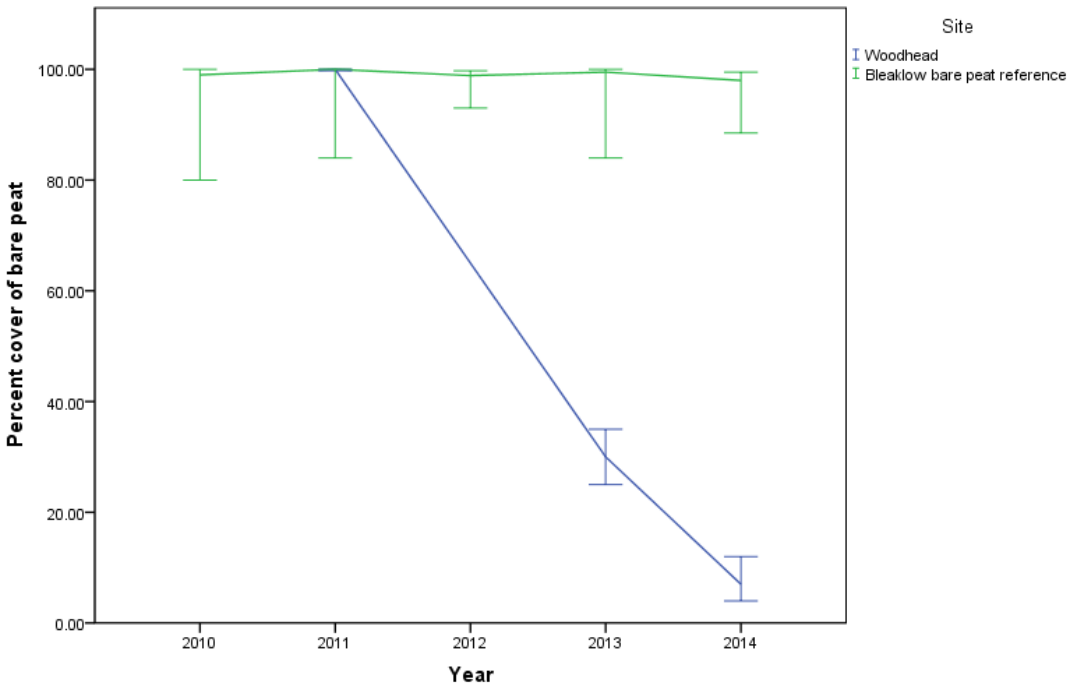
4.1.3.1. Changes in bare peat and total vegetation cover

Between 2011 and 2014, bare peat cover decreased significantly, by 93%, with an increase of vegetation of 104% (Table 4; Figure 13). In contrast, bare peat cover remained high on the Bleaklow bare peat reference site and showed no significant change over the course of the project (2011: 100%, 2014: 98%).

Table 4 – Woodhead median percent cover and Mann-Whitney U test results. (Significance levels: * 0.05, ** 0.01, *** 0.001)

Cover type	Median percent cover		Significance
	Pre-works	2014	
Bare peat	100	7	U = 146.5, p < 0.001***
Total vegetation	<1	104	U = 0.0, p < 0.001***
Dwarf shrub	0	1	U = 482.5, p < 0.001***
Moorland herb species	0	0	U = 1584.0, p < 0.001***
Grasses, sedges, rushes	0	3	U = 262.5, p < 0.001***
Nurse crop	0	77	U = 0.0, p < 0.001***
Mosses, lichens and fungi	0	14	U = 35.0, p < 0.001***

Significant increases were seen in all plant groups on Woodhead.



a)

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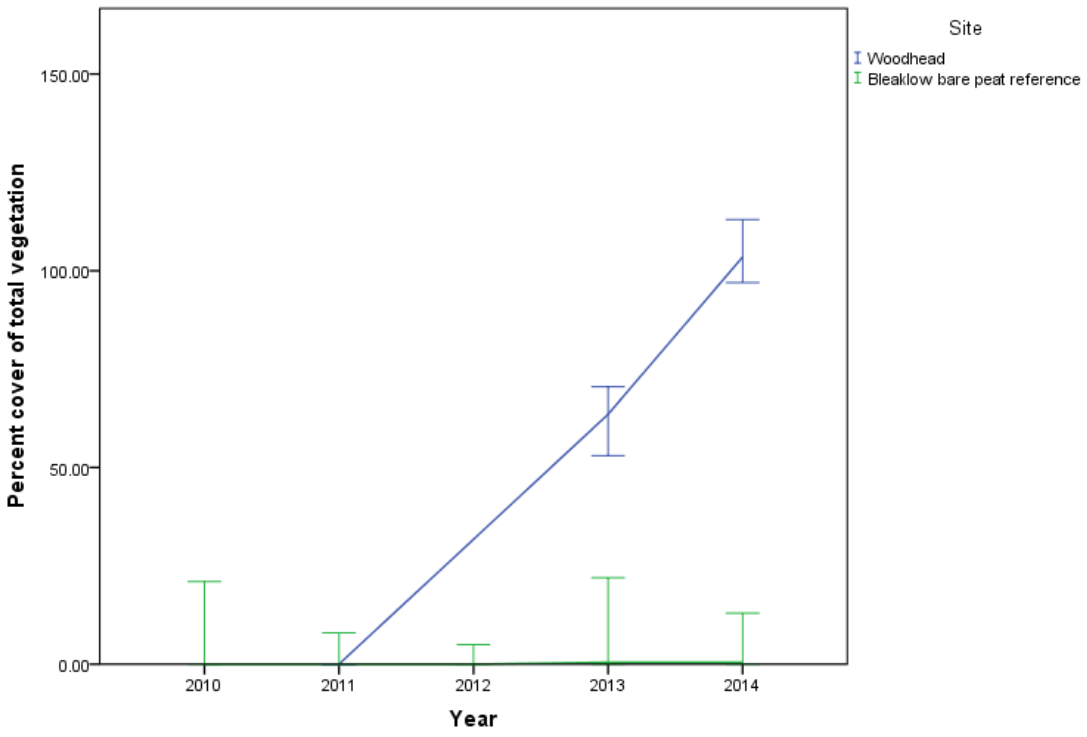


Figure 13 - change in bare peat and vegetation cover on Woodhead between 2011 and 2014

4.1.3.2. Nurse crop cover

Nurse crop grasses were the dominant vegetation within quadrats on Woodhead, making up 77% of quadrat area. Nurse crop grasses were present in all quadrats on Woodhead.

4.1.3.3. Dwarf shrub cover

Dwarf shrub cover increased significantly over the monitoring period and was predominantly common heather. In 2014, common heather was present in 77% of quadrats (Figure 14) and over two thirds of quadrats had multiple heather plants.

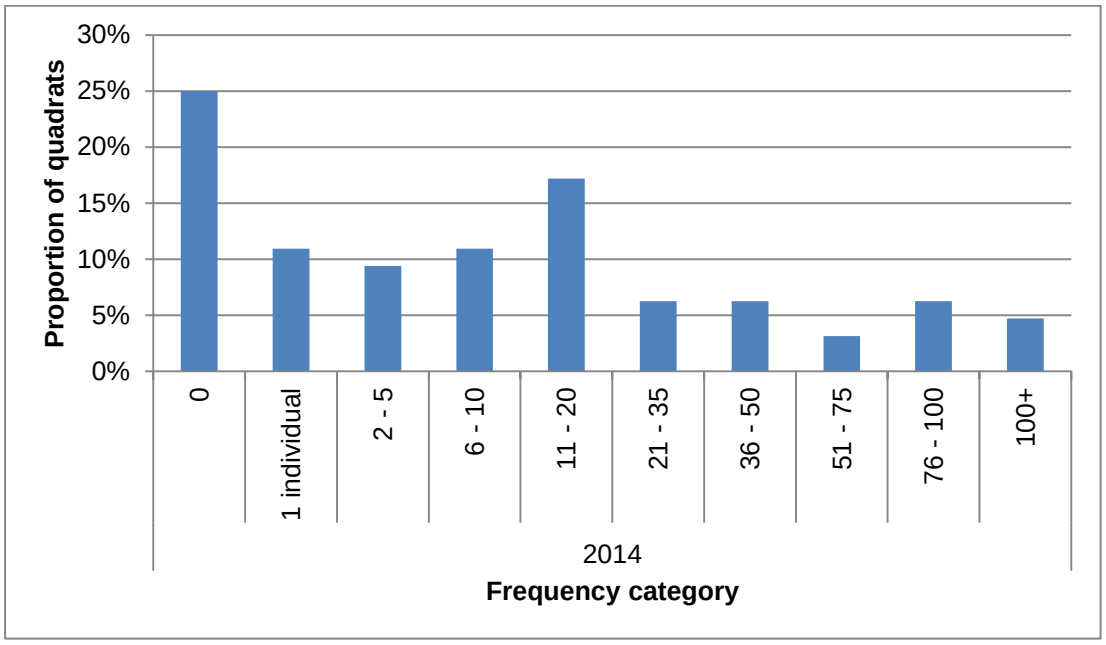


Figure 14 - Frequency of common heather in quadrats on Woodhead in 2014.

Other dwarf shrub species that were present within quadrats were bilberry (9% of quadrats) and crowberry (5% of quadrats).

4.1.3.4. Moorland herb species

Moorland herb species cover in quadrats remained low in 2014. The increase in herb species was predominantly due to heath bedstraw, which was present in 25% of quadrats. Cloudberry was not present within any quadrats on Woodhead in 2014.

4.1.3.5. Grass, sedge and rush species

Within this group of plants wavy hair-grass was the most common species with a median cover of 2% and was present in 83% of quadrats. Other species of grass were present but their contribution to quadrat cover was minimal.

Common cottongrass and hare's-tail cottongrass were present in 38% and 32% of quadrats on Woodhead, but had a low median percent cover of less than 1%.

4.1.3.6. Moss, lichens and fungi cover

This group of species was dominated by mosses, with feather mosses accounting for a median of 4% cover and cushion mosses 2%.

No *Sphagnum* moss was present within quadrats.

4.1.3.7. Common Standards Assessment

4.1.3.7.1. Frequency of species

All quadrats on Woodhead gained blanket bog indicator species, with 92% of quadrats containing at least two in 2014 (Figure 15). Nearly a third of quadrats contained at least four indicator species. The most commonly occurring indicator species were feather mosses, common heather, common cottongrass, lichens and hare's-tail cottongrass.

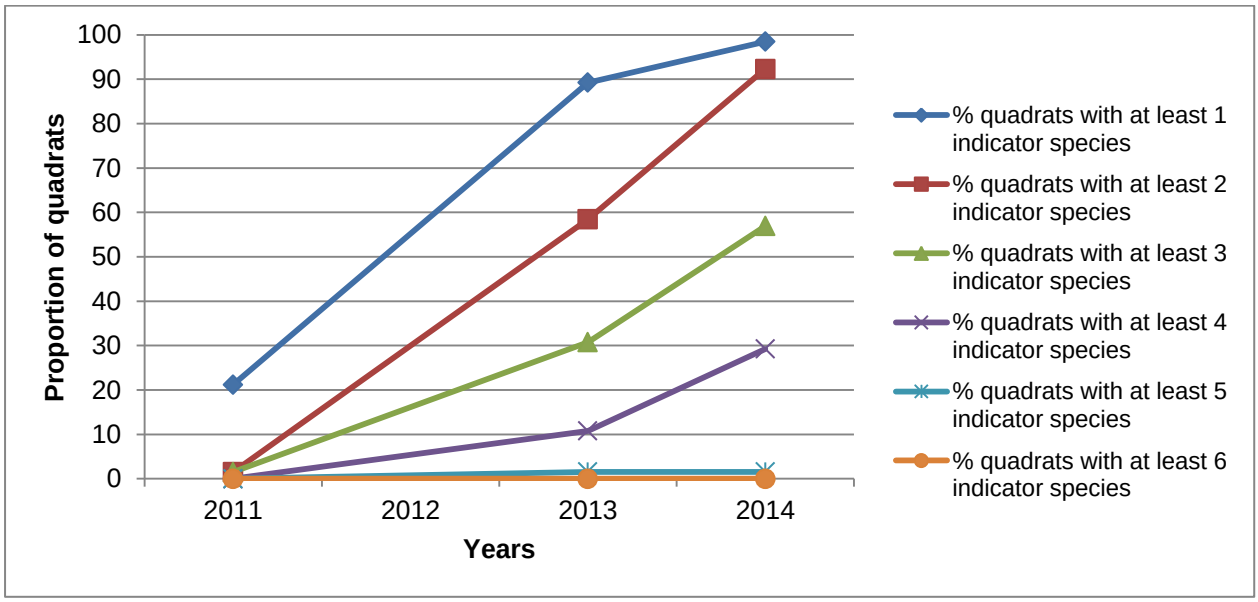


Figure 15 - changes in the proportion of quadrats containing multiple blanket bog indicator species. No quadrats were found to contain 6 or more indicator species.

4.1.3.7.2. Vegetation composition – cover of indicator species

In 2014, 8% of quadrats on Woodhead had at least three indicator species contributing to 50% or more of total vegetation cover.

Indicator species increased following initial works between 2011 and 2013. By 2014 indicator species contributed, on average, 19% of cover in re-vegetated areas of Woodhead (Figure 16), with non-indicator species covering 67%.

On one area of intact blanket bog on Bleaklow, indicator species contributed to over 70% of the vegetation cover.

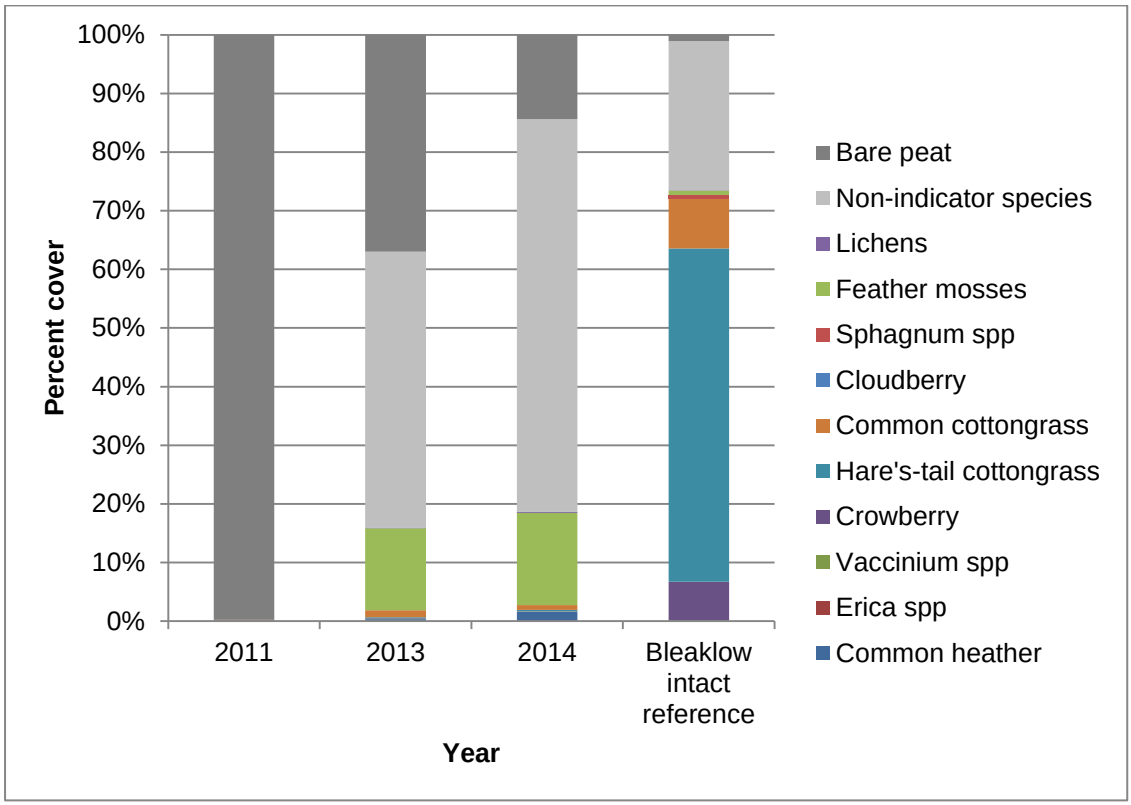


Figure 16 - relative proportions of blanket bog indicator species, non-indicator species and bare peat on Woodhead, 2011 to 2014.

Hare's-tail cottongrass and Ericaceous species did not collectively exceed 75% of vegetation cover in any treated quadrat on Woodhead (see Appendix 1).

4.1.3.8. Countryside Vegetation System

When assessed using the Countryside Vegetation system, quadrats on Woodhead were assigned to the CVS eleven categories. More than half of these were grassland type habitats, with just over a quarter being associated with moorland-type habitats (Figure 17). 14% of quadrats were categorised as species poor blanket bog.

Woodhead treatment areas were most strongly associated with U2 *Deschampsia flexuosa* grassland and H9 *Calluna vulgaris-Deschampsia flexuosa heath* habitats.

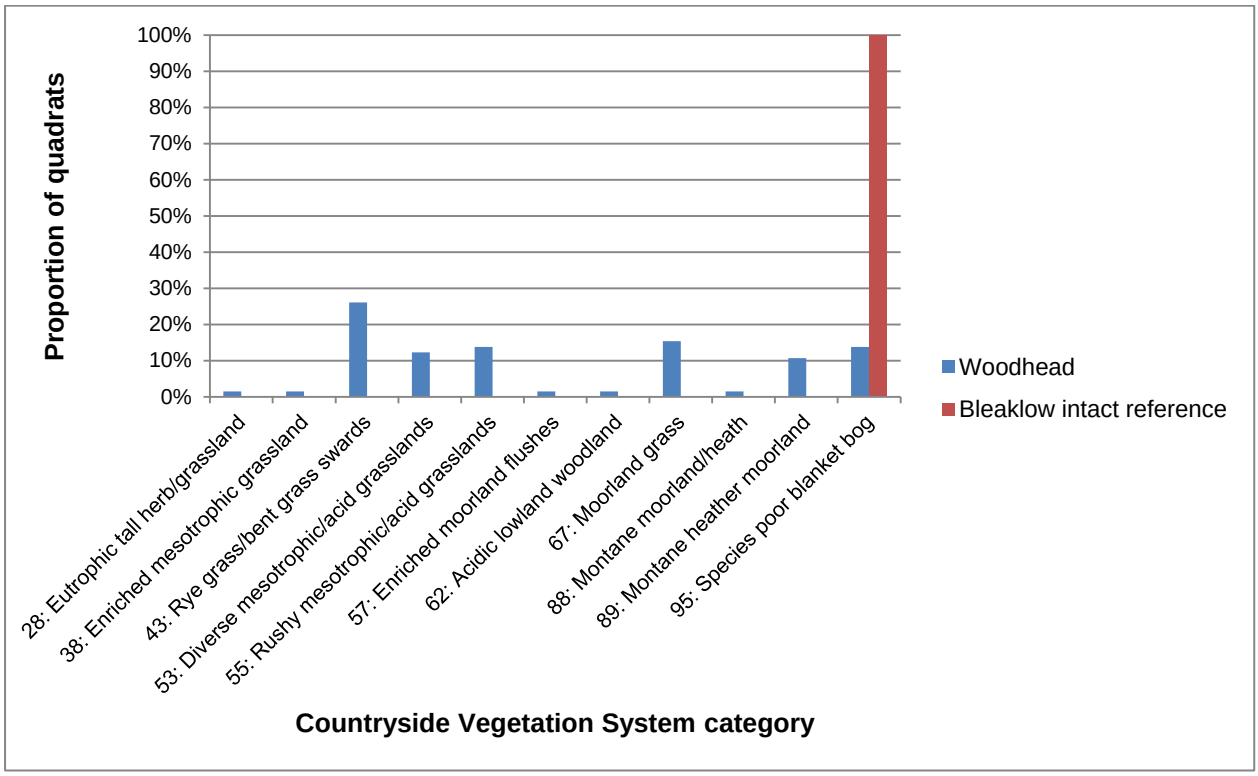


Figure 17 - Countryside Vegetation System categorisation of quadrats on Woodhead in 2014 and an intact reference site on Bleaklow in 2011.

4.2. Previously re-vegetated sites

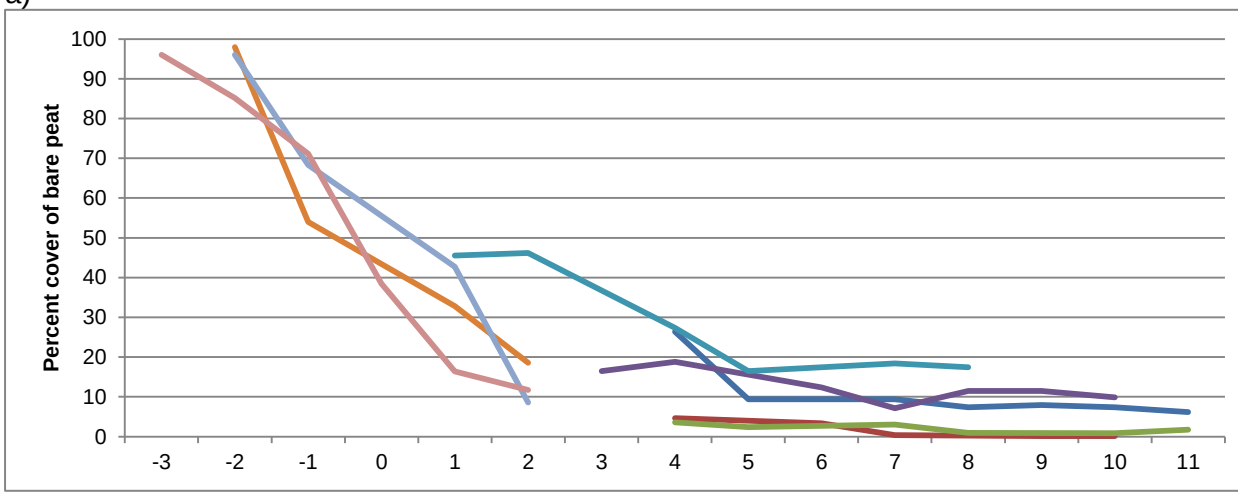
4.2.1. *Changes in bare peat and vegetation cover*

Plotting of data collected from previously re-vegetated sites alongside Woodhead, Turley and Rishworth data gives some indication of how the sites could develop after the end of the MoorLIFE project.

Treatments generally ceased on sites by two to three years post-seed application. At monitored previously re-vegetated sites, bare peat continued to decrease for a number of years following treatments, and could stabilise by approximately year five (Figure 18).

Total vegetation data is more variable but a general trend that appeared was a continued increase in vegetation cover over ten years.

a)



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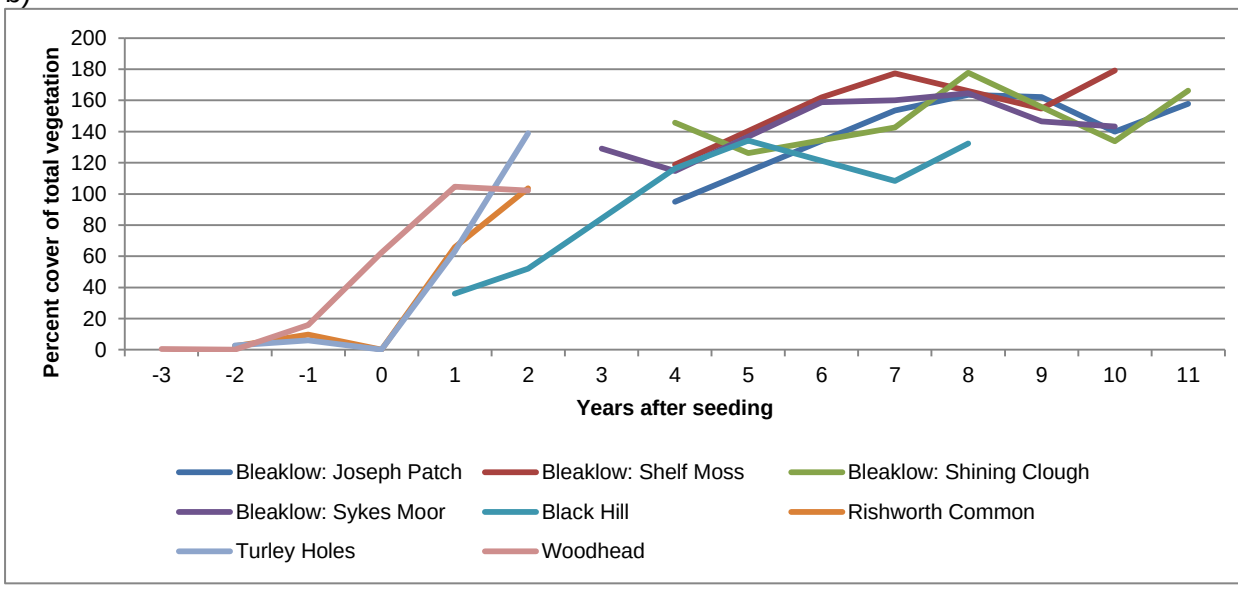
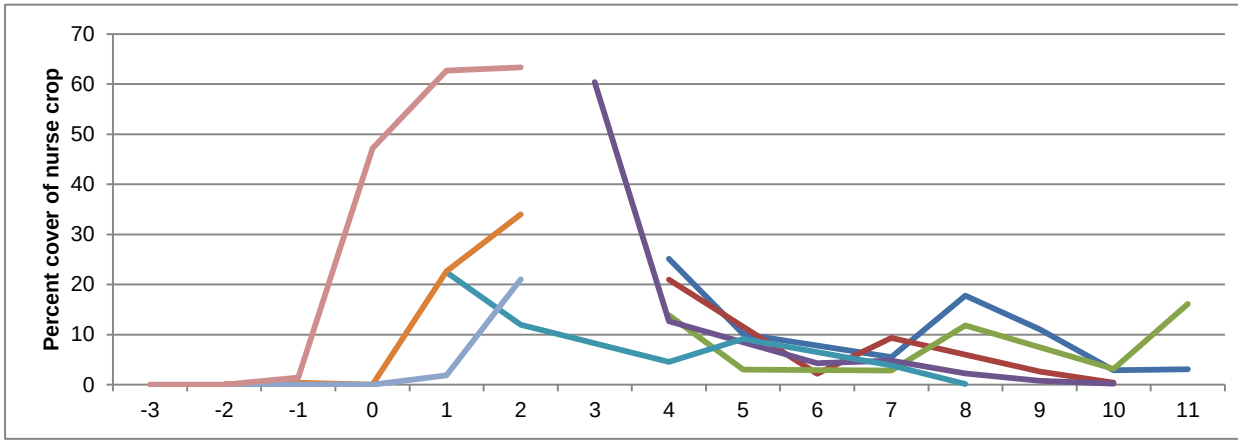


Figure 18 - change in percent cover of a) bare peat and b) total vegetation on revegetated sites of different ages

a)



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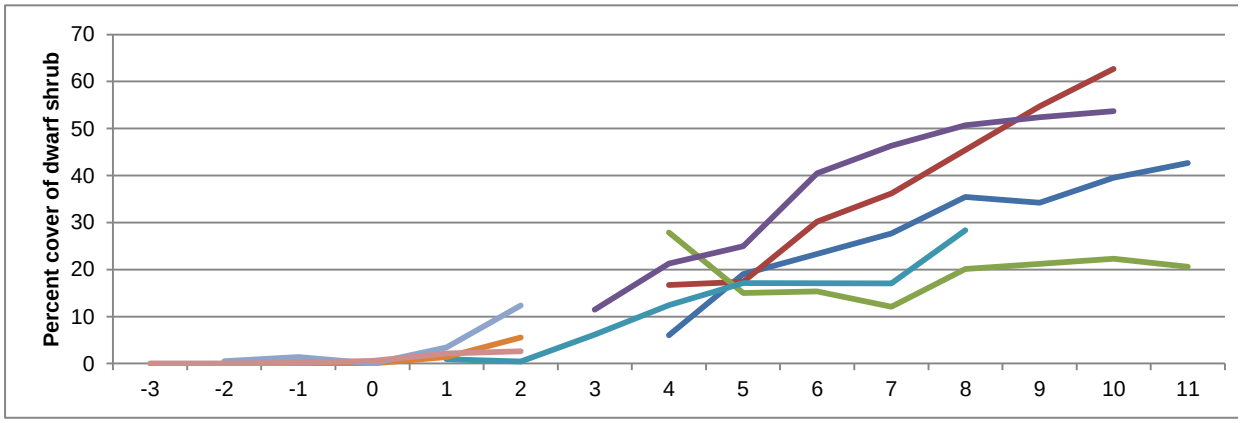

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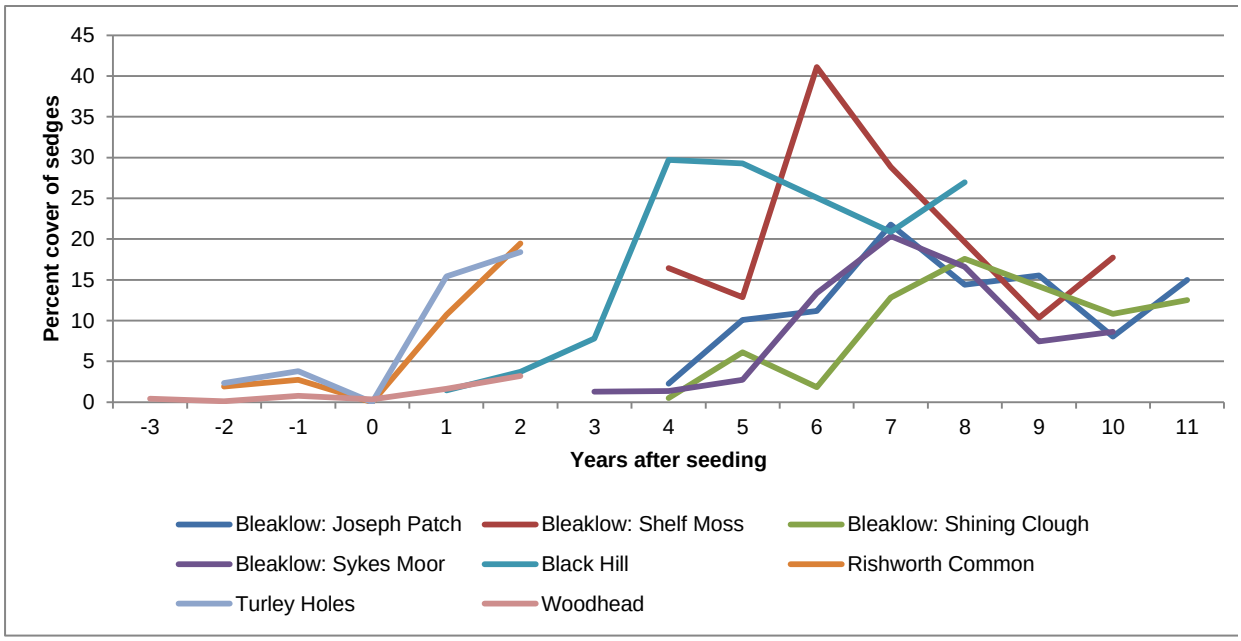


Figure 19 - changes in percent cover of a) nurse crop, b) dwarf shrub and c) sedges on revegetated sites of different ages.

Observations of nurse crop grasses on previously revegetated sites show that approximately five years after seed applications, average percent cover has typically stabilised at below 20 percent (Figure 19a). Dwarf shrub cover tended to increase steadily over eleven years on most sites (Figure 19b). While sedges did show increased percent cover across all sites in the early stages, there were signs that a decrease began to take place on many sites (Figure 19c).

4.2.2. *Common Standards Assessment for long-term monitored sites*

4.2.2.1. Frequency of species

Quadrats on previously re-vegetated sites continued to gain indicator species over an eleven year period. The proportion of quadrats containing an increased number of indicator species steadily increased. Ten years after seeding, an average of 23% of quadrats on previously re-vegetated sites contain at least six indicator species. The proportion of quadrats containing five indicator species is even higher across sites (between 44% and 67%; Figure 20).

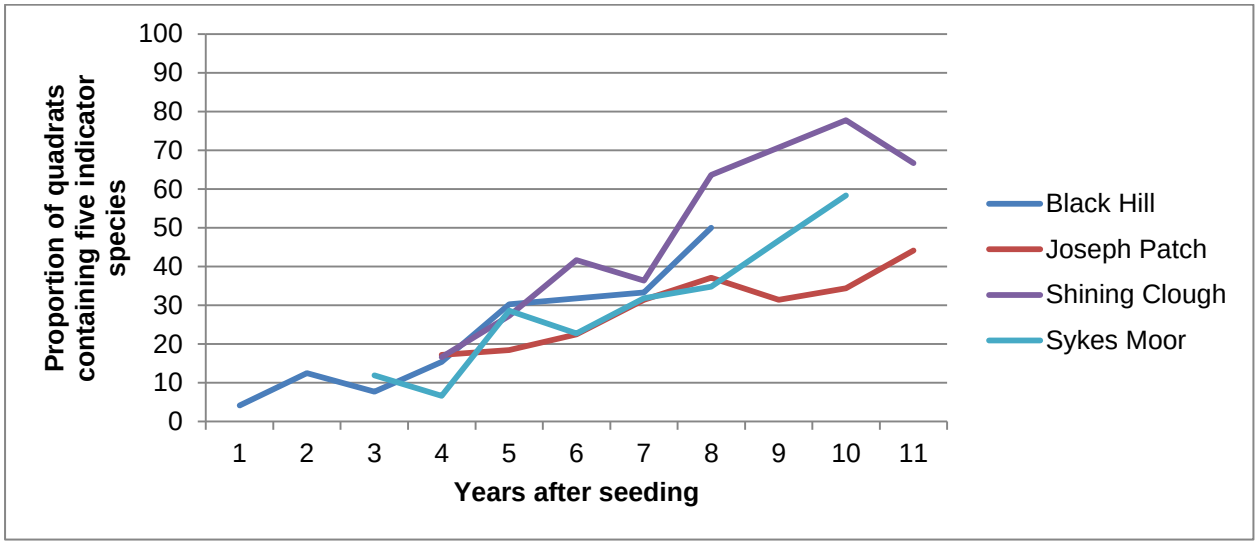


Figure 20 - changes in the proportion of quadrats containing five blanket bog indicator species over eleven years of monitoring of previously revegetated sites.

4.2.2.2. Vegetation composition – cover of indicator species

Overall, the cover of indicator species increased steadily on re-vegetated sites for the first five years after seeding. After six years, percent covers appear to stabilise, or at least exhibit very subtle changes. The average cover of bare peat and non-indicator species also remain relatively unchanged after six years (Figure 21).

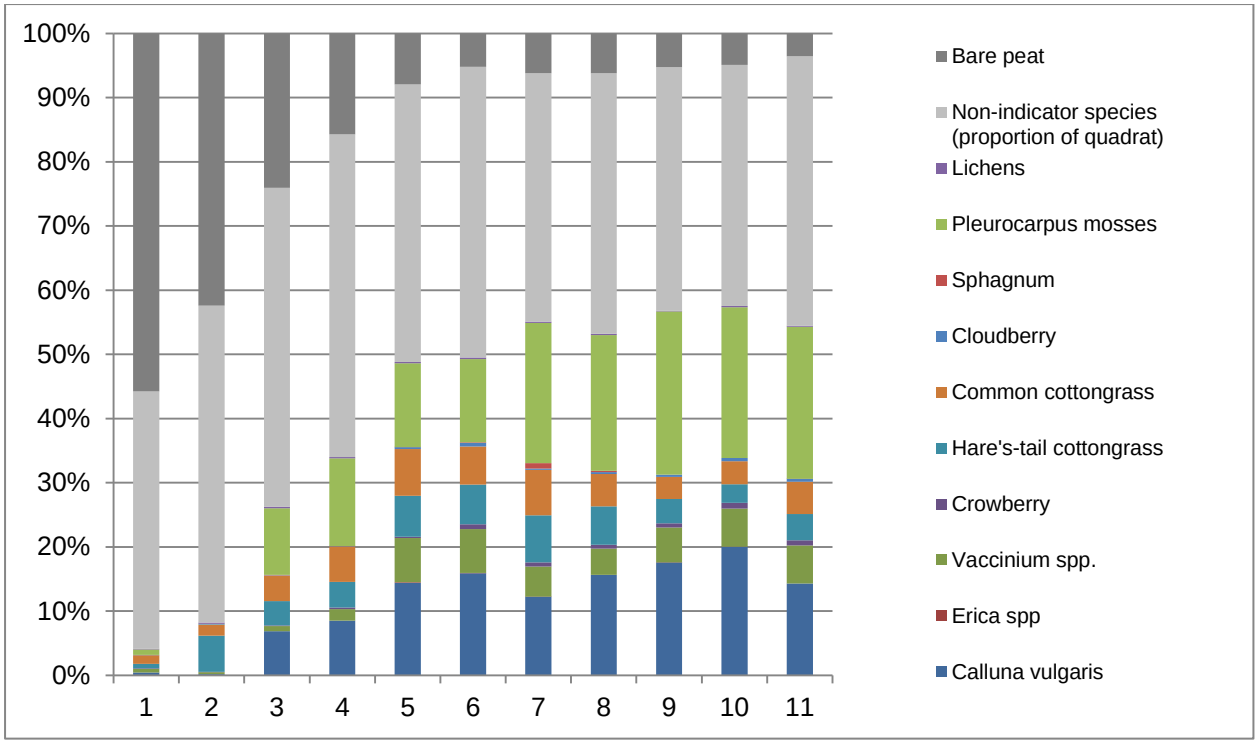


Figure 21 - changes in the proportion of blanket bog indicator species across sites of different restoration ages.

4.2.3. *Plant communities in previously re-vegetated areas of Black Hill and Bleaklow*

Classification of vegetation communities using NVC are presented in Table 5, with descriptions of the NVC communities in Table 6. Joseph Patch, Shining Clough and Sykes Moor were strongly associated with grassland and heath habitats four to six years after re-vegetation, and were still present 10 to 11 years after. However mire habitats are shown to be developing in later years.

Mire habitats appear early on Black Hill and remain relatively stable with M20 *Eriophorum vaginatum* raised and blanket mire as the top community each time.

Table 5- NVC communities present on previously revegetated sites. Data from 2007 (pre-MoorLIFE), 2010 (start of MoorLIFE) and 2014 (final MoorLIFE monitoring year) were analysed for Joseph Patch, Shining Clough and Black Hill. Sykes Moor NVC communities were categorised from 2010 and 2014 data.

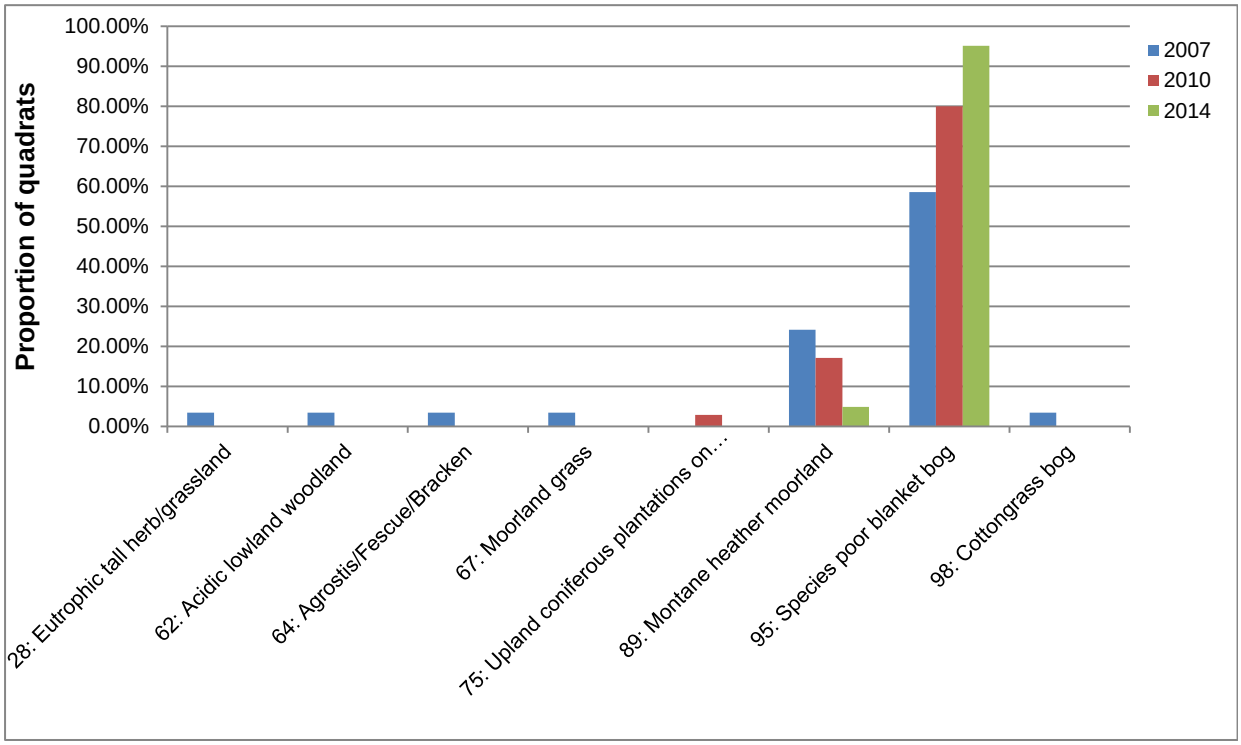
Site	Years after seeding						
	1 year	**4 years**	**6 years**	**7 years**	**8 years**	**10 years**	**11 years**
Joseph Patch		U2b 38.71 H9a 34.19 H9e 33.85		U2b 34.69 M20 33.44 M19a 32.79			U2b 37.38 H9e 35.34 M19a 33.59
Shining Clough		H9a 34.52 H9 31.93 H9e 31.62		U2 33.65 U2b 32.65 H9a 32.22			U2b 34.81 U2 30.60 M19a 28.99
Sykes Moor			H9a 41.18 H9c 39.74 H9e 38.00			M19a 37.67 M20 37.23 U2b 36.04	
Black Hill	M20 33.04 U2b 29.63 H9a 28.99	M20 38.46 M20a 35.01 M19a 33.61			M20 38.83 U2b 35.45 M20a 35.36		

Table 6 - Descriptions of NVC communities present on previously revegetated sites on Black Hill and Bleaklow.

NVC community	**Description**
U2	*Deschampsia flexuosa* grassland
U2b	*Deschampsia flexuosa* grassland (*Vaccinium myrtillus* subcommunity)
H9	*Calluna vulgaris-Deschampsia flexuosa* heath
H9a	*Calluna vulgaris-Deschampsia flexuosa* heath (*Hypnum cupressiforme* subcommunity)
H9c	*Calluna vulgaris-Deschampsia flexuosa* heath (species poor subcommunity)
H9e	*Calluna vulgaris-Deschampsia flexuosa* heath (*Molinia caerulea* subcommunity)
M19a	*Calluna vulgaris-Eriophorum vaginatum* blanket mire (*Erica tetralix* subcommunity)
M20	*Eriophorum vaginatum* blanket and raised mire
M20a	*Eriophorum vaginatum* blanket and raised mire (species poor subcommunity)

CVS categories show that in 2007, quadrats were placed in several different categories, covering a diverse range of habitats – with seven recorded on Joseph Patch and eight on Black Hill (Figure 22). The number of breadth of habitat types was reduced in 2010, and by 2014 only two CVS categories were present – species poor blanket bog and montane heather moorland.

a)



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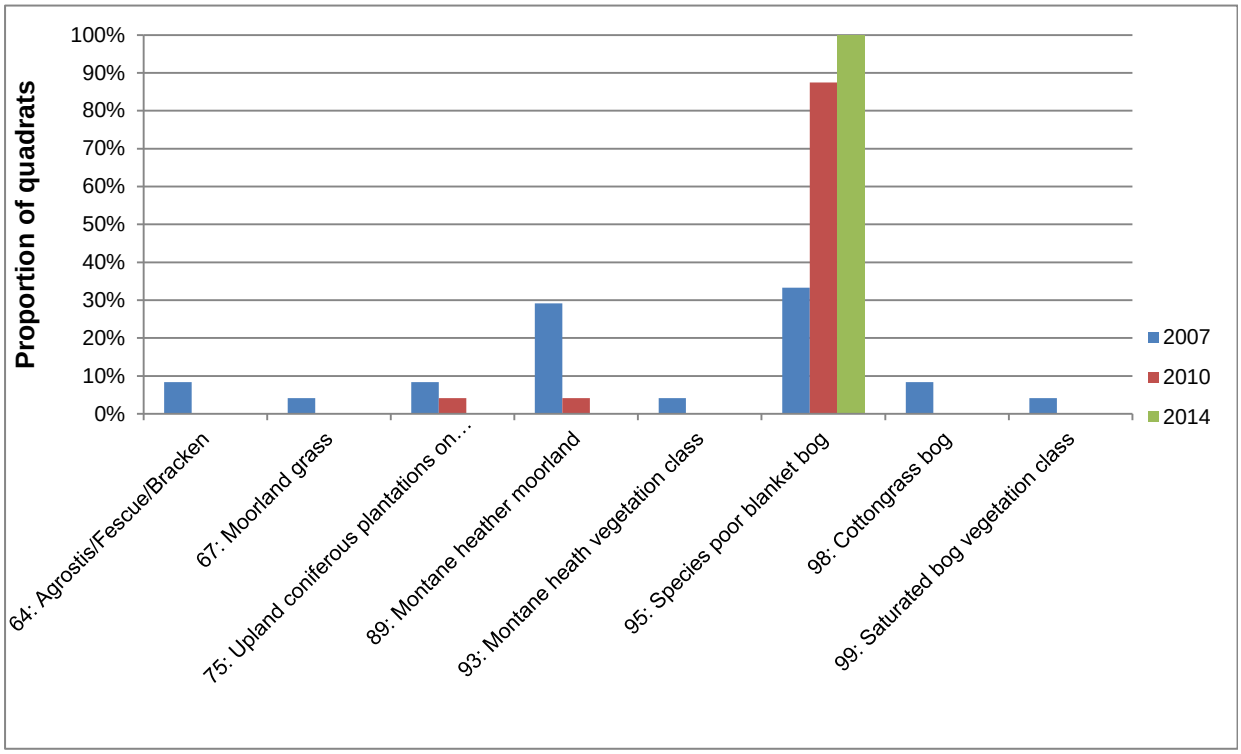


Figure 22 - CVS categories of quadrats on a) Joseph Patch and b) Black Hill

4.3. Sphagnum

4.3.1. *Sphagnum Transects*

In 2012, three MoorLIFE sites were surveyed for *Sphagnum* to create a baseline against which long-term changes can be monitored. These were Black Hill, Turley Holes, and some areas of Bleaklow. Results from Black Hill and Turley Holes are presented in Table 7.

Table 7 - results from Sphagnum transects on Black Hill and Turley Holes in 2012

	Black Hill	**Turley Holes**
Survey		
km walked in transects	3.2	3.4
% area surveyed	3.21	2.97
Total area surveyed (sq m)	14567	13685
***Sphagnum* stats**		
Number of patches found	353	31
Total area of all patches (sq m)	446.45	7.48
Mean patch size (sq m)	1.27	0.24
Median patch size (sq m)	0.06	0.18
Maximum *Sphagnum* patch size (sq m)	176	1.26
% cover of *Sphagnum* on surveyed ground	3.000	0.002
Occurrence		
Undulating ground	93%	100%
Hagg top	0	0
Gully side	1%	0
Gully floor	6%	0

On Black Hill at least five species of *Sphagnum* were identified with confidence by the surveyors. Some uncertainty about *S. papillosum* and *S. palustre* remained as these species are often difficult to tell apart in some situations. Therefore these two species were grouped together. *S. fallax* occurred most regularly, with 135 definite identifications. This was followed by *S. fimbriatum* (39 records), *S. palustre/papillosum* (6), *S. subnitens* (2) and finally *S. cuspidatum* (1).

Sphagnum patches occurred on undulating ground in 93% of cases. *Sphagnum* was also recorded occurring on gully floors (6%) and on gully sides (1%). No *Sphagnum* was recorded on hagg tops.

The majority of the individual *Sphagnum* patches were under two square metres in size. Figure 23 shows the map of *Sphagnum* transects and locations of recorded patches. Locations of areas to receive heather brash are also mapped, revealing an overlap between records of *Sphagnum* and the heather brash spread in 2005.

Turley Holes had fewer patches of *Sphagnum* within the survey area. A total of 31 *Sphagnum* patches were found and measured.

Four (possibly five) species were idenitified on the site: *S. subnitens* (8 records), *S. fallax* (6), *S. fimbriatum* (6) and *S. palustre/papillosum* (6).

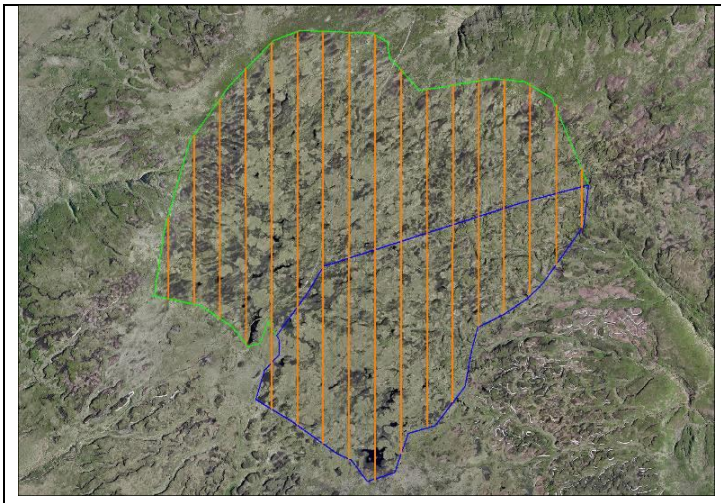
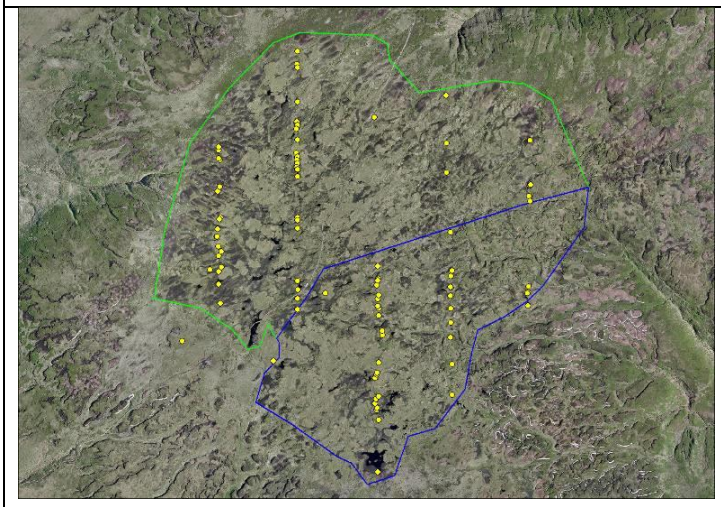
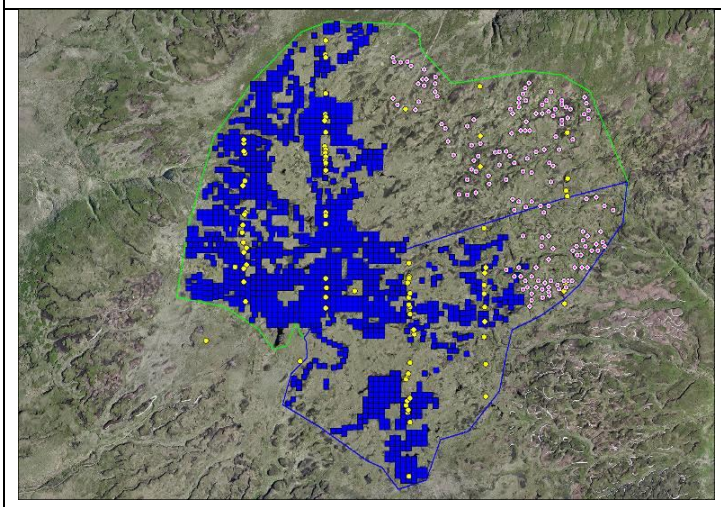
	**(a) GIS mapping of the intended survey transects across the MoorLIFE restoration area on Black Hill.**
	**(b) Every third transect was walked to ensure an even coverage of the site in the time available. Yellow circles represent the locations where *Sphagnum* patches were recorded.**
	**(c) The *Sphagnum* records were laid over GIS layers representing the spread of heather brash in 2005 (blue squares) and 2007 (white circles with red centres). The resulting map inferred that most *Sphagnum* records occurred in the areas where brash was spread in 2005.**

Figure 23 – mapping of Sphagnum recorded during transect surveys on Black Hill.

4.3.2. *Sphagnum bead monitoring*

Figure 24 shows the transects walked by *Sphagnum* bead spreaders, and the locations of the quadrats established on the day to monitor the application.

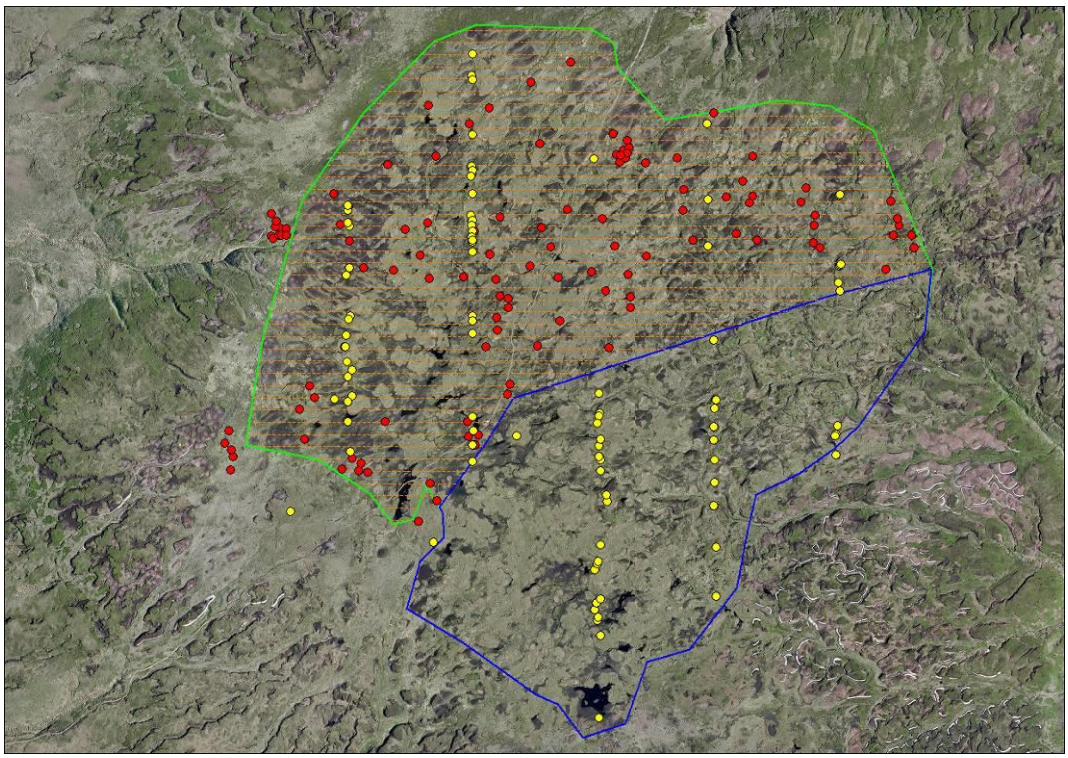


Figure 24 – transects walked by Sphagnum bead spreaders (orange) with locations of 1 x 1m quadrats established to monitor the success of Sphagnum bead applications (red dots). Yellow dots show locations of Sphagnum recorded in the transects undertaken pre-application.

In total, 97 treatment quadrats were established, with 22 untreated, control quadrats. Application ranged from 2 – 200 beads, with a mean of 30 beads per quadrat. 50% of quadrats had 20 beads or fewer.

5. Key messages

5.1. MoorLIFE treatment sites

In 2010, Woodhead, Turley Holes and Rishworth Common were covered in extensive areas of bare and eroding peat. By 2014, a significant decrease in the cover of bare peat has been observed at all three treated MoorLIFE sites. The monitoring of bare peat reference sites has shown that had works not been undertaken there would have been little or no natural re-vegetation of these sites within the same time period.

In 2014, the vegetation present on MoorLIFE treatment sites were nurse crop species and wavy hair-grass, showing that the grass seed mix has successfully germinated and rapidly established. The nurse crop has done particularly well on Woodhead, accounting for 77% of cover on previously bare peat areas.

Common heather, one of the moorland indicator species, which also formed part of the nurse seed mix, and would have been brought in with heather brash, is showing positive signs of establishment. While the percent cover is low across all three sites, multiple heather plants were recorded in the majority of quadrats in 2014. The absence of vegetation on bare peat reference sites again demonstrates that heather plants would not have established had the MoorLIFE works not take place.

The JNCC Common Standards Monitoring targets use positive indicator species as a way of assessing the status of SSSIs. Here the guidelines have been used to assess the presence of blanket bog indicator species and their contribution to the species composition in the early stages of re-vegetation. Between 1 and 2 years following seeding works, indicator species were present in all quadrats, with nearly 100% of all quadrats containing at least two. This shows that species characteristic of moorland vegetation begin to colonise treated areas rapidly following the stabilisation of the peat surface.

The most commonly occurring indicator species on both Turley and Rishworth were common heather, common cottongrass and hare's-tail cottongrass. On Woodhead feather mosses were the most frequently occurring indicators, followed by common heather and common cottongrass.

Analysis of the early plant communities developing on the three MoorLIFE sites suggest that the nurse crop is, understandably, a strong influence. Re-vegetated areas on all three sites had strong associations with *Deschampsia flexuosa* grassland and H9 *Calluna vulgaris-Deschampsia flexuosa* heath.

5.2. Previously re-vegetated sites – patterns of vegetation change

Monitoring of sites treated under the MoorLIFE project has shown the short-term impacts of the works just one year after seed applications. Data up to 2014 has been analysed for the final report, and works continued up to early 2015. The results presented here show the early development of vegetation on treated sites and continued monitoring will be required to determine the longer-term impacts of the works.

Surveys of previously re-vegetated sites on Bleaklow and Black Hill, first treated by MFFP between 8 and 11 years ago, give an indication of how MoorLIFE treatment sites could continue to develop over a longer-term period.

Continued decreases in bare peat cover were observed across all sites for a number of years after final treatments, and for most sites settled down at levels of ten percent or lower.

Total vegetation continued to increase across all previously re-vegetated sites over several years, reflecting the tendency for vegetation to become more structurally complex long after conservation works were completed. Therefore it is reasonable to expect that vegetation will continue to increase on Woodhead, Turley and Rishworth, and bare peat will decrease further from the observed 2014 levels.

While large increases in nurse crop are observed on the treatment sites two years after seeding, on most of the previously revegetated sites nurse crop grasses are shown to undergo sharp decreases in percentage cover by around four years after seeding (with Black Hill as an exception and showing slower declines from year 1). This reflects the intended purpose and behaviour of the nurse crop seed mix which is, in essence, ‘designed-to-fail’. (The nurse grasses stabilise any areas of bare peat for a period of a few years, but are allowed to decline to allow typical moorland species to colonise). The observed decline in nurse crop species follows the cessation of maintenance applications of lime and fertiliser.

Nurse crop data (on species and distribution) is particularly variable between years and this is likely to be due to surveyor confidence in grass identification. This was addressed through the MoorLIFE monitoring programme by providing specialist grass identification training following seeding of treated sites to ensure a high degree of confidence in newly seeded site data. The comparison of nurse crop cover present on sites in 2014 highlights the difference between newly and previously re-vegetated sites.

In contrast to the nurse crop grasses, dwarf shrubs continued to increase on all previously re-vegetated sites for several years after seeding took place. In 2014 dwarf shrub cover was four times higher than that of the MoorLIFE treated site.

Both bryophyte cover and sedge cover continued to increase on previously re-vegetated sites following the end of capital works. Both also appear to show signs of slight decreases from around 2010/2011. These patterns of change could be attributed to a number of causes.

Firstly, surveyors' plant identification skills could have varied between years, introducing noise into the dataset. In addition, surveyors' judgements of percentage cover would have varied. Secondly, wider environmental factors could have influenced changes in vegetation cover. Changes in annual precipitation, temperature etc could all have influenced vegetation patterns. Without data from annual monitoring of intact sites it is not possible to account for natural variation in vegetation. Another important factor to consider is that these are site-wide analyses of data that give broad patterns. Consideration is not given here to spatial variation of vegetation changes within individual sites.

Overall the long-term data shows that the positive changes observed on MoorLIFE sites are likely to be sustained.

This is an initial look at the data and more analysis is planned beyond the end of the MoorLIFE project.

5.2.1. *Previously re-vegetated sites and indicator species*

Examination of the presence/absence of indicator species, and the proportion of quadrats where indicator species occur provides a more objective method of assessing vegetation change as it is less reliant on estimated percent cover. These analyses go further than broad assessments of vegetation change by looking at individual quadrats and the proportion meeting certain conditions.

Quadrats on re-vegetated sites continue to steadily 'acquire' blanket bog indicator species over an 11 year period. Between 44% and 67% of quadrats contained at least five indicator species. The most common indicator species present on previously revegetated sites were the same as those found on the treatment sites. The main difference was the occasional occurrence of Sphagnum mosses on previously re-vegetated sites. However, these records

were not sustained between years. In 2014, no Sphagnum mosses were recorded in any previously re-vegetated quadrat.

The proportion of quadrats where at least three indicator species made up at least 50% of vegetation cover also steadily increased for the first five years after seeding. After approximately five years, the response of sites varies, with three of four sites stabilising, and one showing signs of decreasing. Continued monitoring will be important for these sites to confirm the longer-term changes in indicator species occurrence.

At a landscape level, re-vegetated sites achieved over 50% cover of indicator species seven years after seeding. These sites have remained at between 50% and 60% indicator species cover with little observable change.

5.2.2. *Previously re-vegetated sites – plant communities*

While the cover and relative proportions of blanket bog species appears to have plateaued on the oldest re-vegetated sites, the plant communities present do appear to have continued to change. Analysis of habitats using NVC and CVS classification systems suggest that plant communities are gradually moving from grassland communities to more typical blanket bog communities.

As MAVIS produced results for a range of habitats, there could be a spatial component to this. Therefore a next step is to look at the spatial distribution of plant communities to establish if quadrats within a site can be grouped into different habitat categories.

5.2.3. *Sphagnum*

Very few fixed quadrats were recorded with *Sphagnum* mosses. However, field observations showed that *Sphagnum* was present on these sites. The location of fixed quadrats on the drier, dome tops means that a number of micro-habitats are missed in this sampling method – for example gully bottoms, which are often wetter. Therefore, while the quadrats give an indication of vegetation development on drier, ‘hard-to-win’ areas, they do not provide the full picture.

Transect surveys on Black Hill provide evidence that *Sphagnum* mosses are slowly re-colonising areas of stabilised peat. However the total area covered remained very low at just 3% in 2012. On the MoorLIFE treatment sites, *Sphagnum* was more or less absent. Continued monitoring of these sites will be necessary to determine how quickly *Sphagnum* mosses are recolonising.

MoorLIFE was the first project to apply *Sphagnum* propagules at a landscape scale, in 2012. As discussed previously, during this application, a baseline survey was conducted. A repeat of this survey was not possible within the timescales of the MoorLIFE project. Surveys have recently been undertaken, three years post-application, and results of this will be reported separately at a later date. Evidence from other studies indicate that growth from *Sphagnum* beads is not observable for a number of years post-application, and so continued surveys of the Black Hill quadrats are likely to be necessary over several more years to be able to quantify the success of this method of *Sphagnum* re-introduction. The AfterLIFE report includes further details of how further monitoring and analysis will be undertaken after MoorLIFE (MFFPb, 2015).

6. References

Bunce, R.G.H., Barr, C.J., Gillespie, M.K., Howard, D.C., Scott, W.A., Smart, S.M., van de Poll, H.M. & Watkins, J.W. 1999. *Vegetation of the British countryside the Countryside Vegetation System.* ECOFACT Volume 1. London: Department of the Environment, Transport and the Regions.

JNCC, (2009). Common Standards Monitoring Guidance for Upland Habitats, Version July 2009

Maskill, R., Walker, J.S, Allott, T., Evans, M. and Shuttleworth, E. (2015). MoorLIFE: Changes to the water table and carbon budget. Moors for the Future Report, Edale, Derbyshire

MFFP a, (2015) A Practitioners' Guide for Sphagnum Re-introduction. Edale, Derbyshire.

MFFP b (2015) AfterLIFE report. Edale, Derbyshire.

Rodwell, J.S. (Ed) (1991) *British Plant Communities. Volume 2. Mires and heaths.* Cambridge University Press

Rosenburgh, A.E. (2015). Restoration and recovery of *Sphagnum* on degraded blanket bog. Ph.D thesis, Metropolitan University of Manchester.

Shuttleworth, E.L., Evans, M.G., Hutchinson, S.M. & Rothwell, J.J. (2015). Peatland restoration: controls on sediment production and reductions in carbon and pollutant export. Earth Surface Processes and Landforms, 40, 4, 459-472.

7. Appendix 1

Mandatory attributes	**Targets**
Vegetation composition - frequency of indicator species	1) at least 6 indicator species should be present. **Qualifiers:** In blanket bog, *Sphagnum fallax* scores one if other species of *Sphagnum* are present, but scores zero if it is the only species of *Sphagnum* present.
Vegetation composition - cover of indicator species	1) At least 50% of vegetation cover should consist of at least 3 species
	2) Sphagnum cover should consist not only of *Sphagnum fallax*
	3) Any one of *Eriophorum vaginatum*, Ericaceous species collectively, or Trichophorum should not individually exceed 75% of the vegetation cover.
Vegetation composition - cover of other species	1) Less than 1% of vegetation cover should be made up of non-native species
	2) Less than 10% of vegetation cover should be made up of scattered native trees and shrubs **Qualifiers:** For target (2) exclude *Betula nana* and *Myrica gale.* Refer to Woodland guidance for Bog Woodland.
	3) Less than 1% of vegetation cover should consist of, collectively, *Agrostis capillaris, Holcus lanatus, Phragmites australis, Pteridium aquilinum, Ranunculus repens.*
Vegetation structure - indicators of browsing	1) Less than 33% of the last complete growing season's shoots of dwarf-shrub species (collectively but excluding *Betula nana* and *Myrica gale) should show any signs of browsing.*
Cover of other species	2) In pioneer stage regrowth, or where there is *Betula nana* or *Myrica gale* (at any stage of regrowth), less than 66% of the last complete growing season's shoots of the dwarf-shrubs, (collectively) should show signs of browsing.