Restoration of Blanket bogs; flood risk reduction and other ecosystem benefits

Annex 2. The development of plant diversity

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1. SUMMARY

The Dark Peak Site of Special Scientific Interest (SSSI), overlapping the South Pennine Special Area of Conservation (SAC), contains extensive areas of highly degraded Blanket bog. These areas are characterised by a dearth of indicator species, severe erosional gullying and the potential for irreversibly altered hydrological regimes. Consequently, there is a strong requirement for detailed monitoring to show the progress and the nature of the developing floral community in these areas which are presently undergoing such intensive management and restoration.

The aim of this investigation is to show the development of the re-vegetated plant community and to detail its trajectory towards Blanket bog favourable condition.

Permanent 2 m x 2 m quadrats were positioned in areas of formerly 100% bare peat and used for annual surveys of vegetation conducted in late summer from 2010 up to the present (2014). A control area was kept as untreated bare peat for comparison.

The results showed that by 2014, after four growing seasons, bare peat cover had declined by 88%, replaced mainly by a dominant cover of grasses (mainly *Deschampsia flexuosa*) and acrocarpous mosses, along with a strong cover of *Calluna* and some pleurocarpous mosses. Other species were present at very low cover. The cover of non-indicator species appeared to have reached an asymptotic maximum (due to a simultaneous increase and decrease in the cover of acrocarpous mosses and grasses, respectively). The cover of indicator species, although relatively low, appeared to be rising, mainly due to the cover of *Calluna* and pleurocarpous mosses. With regards to favourable condition, the percentage of quadrats achieving the targets associated with some key attributes relating to the number and cover of indicator species and the cover of bare peat is rising but still below the minimum requirement of 90%.

The implications of these results are that there is a positive return of indicator species but that the present dominance of grasses and the rising cover of *Calluna* may contribute to a future competitive exclusion of species indicative of Blanket bogs.

2. INTRODUCTION

The original notification of the Dark Peak SSSI was primarily as result of its upland breeding bird interest, with the result that much of the site includes a variety of degraded forms of Blanket bog and dry heathland. The later Special Area of Conservation (SAC) moderation of the notification recognised this area as containing rare upland habitats typical of northern England, even though these habitats were highly degraded.

In addition to the dearth of indicator species in degraded areas such as these, there have also been severe erosional processes and gullying causing changes to hydrological regimes, in particular the lowering of water tables. There is currently scant evidence available to support a return of *Sphagnum* species in particular and enough diversity of other indicator species in general under such severely eroded and gullied terrain. Similar problems of diversity (if not hydrology) may be experienced in Blanket bog-designated areas that have become dominated by *Molinia*. Thus the achievement of "Favourable Condition" status on these sites may require extreme management intervention, including a complete exclusion of grazing and burning pressure coupled with a prolonged period of intense stabilisation, re-vegetation and gully-blocking measures.

In theory for general upland areas, a site was designated as a Blanket Bog due to (i) a dominance of indicator species (including *Sphagnum* bog mosses, other bryophytes, cotton-grasses, dwarf shrubs, and occasionally lichens) and (ii) a depth of more than half a metre of peat. However, many sites that fulfil only one of these requirements may still have been designated as Blanket bog. The assumption here is that a more complete expression of this feature occurred on the site in the past and that all attributes on the site would once have satisfied the target compliance for Favourable Condition. A further assumption is that, in the expert opinion of the surveyor, the site has the potential to return to this state again in the future. Indeed, under the revised CSM guidance (JNCC 2009) there is clear instruction that degraded mire communities or those areas of deep peat currently vegetated by dry heath or acid grassland communities should only be assessed against the Blanket bog criteria if restoration back to Blanket bog communities is considered feasible. However, it is unclear how this assessment can be made in the absence of supporting evidence.

PAA (2005) commented on problems associated with choosing the appropriate habitat feature for assessing condition using the CSM methodology. This is because highly degraded habitats often bear little floristic resemblance to their former and thus potential future habitat type. For example, *Molinia* swards are commonly assessed as either Wet heath or Blanket bog, although it could also be assessed as "purple moor-grass-tormentil mire community". The precise choice that is made can

influence the CSM status that is eventually awarded to the site. JNCC guidance for designation as blanket bog habitats is the average depth of peat (generally being >0.5m), but PAA (2005) suggested that areas exist with sufficient depth for designation as Blanket bog but which also have a strong Dwarf shrub community. In such cases perhaps these areas should be treated as transitional between Blanket bog and Dwarf shrub heath. This may be particularly relevant for upland habitats in the Peak District and South Pennines, especially on their eastern side, because these areas are amongst the driest regions in Britain where Blanket bog still survives but may not have the correct conditions to become active bogs in the future. The opposite case also was found, such as Heptonstall Moor, with insufficient depth of peat but some characteristic Blanket bog vegetation. In both cases, English Nature (now Natural England) suggested that where the blanket peat had been so badly eroded that its hydrological integrity cannot be effectively restored, then restoration of bare peat to a degraded Blanket bog habitat should be the aim (PAA, 2005).

For many degraded areas with extensive bare peat and gullying, PAA (2003) suggested extensive grazing exclusion together with brashing, or cover with geojute on steeper parts, and then re-vegetation using seed, lime and fertilising. Gully blocking was also recommended. For surrounding areas there could be general specifications for stocking levels but a suspension of all burning.

There are 168 SSSIs lying within or below the Upper Derwent Catchment area. Natural England's long-term objective for many degraded upland SSSIs of the South Pennines is for their restoration specifically towards either Blanket bog or Dwarf shrub habitats that are rich in *Sphagnum* and dwarf shrubs but poor in graminoids (PAA, 2003). This objective has recently gained impetus from "Biodiversity 2020", a government strategy that aims to increase the proportion of SSSIs that are in Favourable condition to at least 50% by 2020 (Natural England, 2015).

However, current assessment for condition status is of not of a sufficient detail or temporal resolution to show the effect of management in making progress towards favourable condition.

The aim of this investigation is therefore not only to show the development of this artificially re-vegetated plant community in terms of its general cover characteristics, but also to take advantage of this unique opportunity to detail its trajectory towards Blanket bog favourable condition.

3. METHODS

3.1 Monitoring vegetation in the field

Quadrats measuring 2 m x 2 m were set up in two key locations of the MSW project area on Kinder; (i) within the unrestored control area and close to the micro-catchment known as Firmin and (ii) within the re-vegetated part of the project area and close to the micro-catchments known as Olaf and Nogson. Annual surveys of vegetation were conducted in late summer from 2010 up to the present (2014).

The cover of broad vegetation types was expressed as a percentage of total quadrat area. Percentage cover was allowed to run over 100% and this was rationalised as being due to understorey plants and overlapping vegetation layers.

During the surveys, identification was focused on the most commonly encountered species: dwarf shrubs (*Calluna vulgaris*, *Empetrum nigrum*, and *Vaccinium myrtillus*); cotton grasses (*Eriophorum angustifolium* and *E. vaginatum*); grasses (*Molinia caerulea*, *Deschampsia flexuosa*, *Lolium perenne*, *Agrostis capillaris*, and *Festuca ovina and rubra*); invasive plants such as *Chamaenerion angustifolium*; trees and shrubs such as *Betula* spp and *Salix spp*; feather mosses, cushion mosses, liverworts and lichens. Other species were also noted when encountered.

3.2 Data analysis

Percentage cover data was entered on spreadsheets and frequency of occurrence of species within quadrats was calculated by converting cover data to presence/absence data.

First, percentage cover data for the different sites were analysed for general floristic characteristics; this included the change in the cover and frequency of occurrence of each individual species between the control and the treatment area. In addition, the change in cover of major categories such as indicator species and non-indicator species was shown, together with a breakdown of the main species contributing to these changes. Tests were carried out to verify the statistical significance of these changes.

Secondly, survey data were analysed systematically according to CSM attributes and targets. For each attribute, this was done by estimating the frequency of occurrence of quadrats that achieved the minimum requirement (or target) for that attribute (expressed as percentage of the total number of quadrats). For example, for the attribute concerning the requirement for at least six indicator species, a graph was drawn to show the percentage of quadrats achieving at least six

indicator species in the four years since restoration. For all attributes, the criterion used to determine whether a given site achieves Favourable condition status or not is that at least 90% of quadrats should achieve achieving the target. The shape and slope of regression lines describing the relationship between time (in years) and the percentage of quadrats achieving the target was used to give an indication of trajectory towards Favourable condition, although it is acknowledged that judgements based on extrapolation of regression lines are subjective.

Note: The choice of attributes and indicator species was made according to the lists provided in CSM guides by JNCC for upland habitats and of Blanket bogs in particular.

3.3 Statistical analysis

Due to the frequent lack of normally-distributed variables, all statistical testing to show differences between the control and treatment areas was carried out using the non-parametric Mann Whitney U test for unpaired samples. The p-values for the tests are reported in the text or the caption of Figs and Tables or in the Tables themselves.

Regression lines were fitted to show the relationship between ecological variables (such as cover and frequency) and time. A linear or quadratic regression model was used to describe the relationship and the details of the test were provided, including the F ratio, the regression coefficient and the p-value.

4. RESULTS

4.1 Bare peat area over the whole project area from aerial surveys

Aerial imagery from 2014 allowed for classification of bare peat areas with 8 cm resolution. This was aggregated up to a classification of 1 m grid size, providing a high resolution of bare peat patches on the banks of gullies and isolated bare peat patches within more homogenous vegetation cover. According to this calculation, the area of bare peat within the whole of the Making Space for Water project area amounted to 9.8 Ha in 2014. However, aerial imagery for the 2005 landscape audit used data aggregated up to 5 m grid size so the area of bare peat according to this calculation amounted to 6.9 Ha in 2014, down from 28.4 Ha in 2005 or a decrease of 75.6% in the area of bare peat over the whole of the Making Space for Water project area.

4.2 General cover characteristics from quadrat surveys

4.2.1 Change in cover of species 2010–2014

By 2014, which was three years (or four growing seasons) after restoration, vegetative cover in the former bare peat patches of the treatment area had changed from virtually zero to 39% total grasses, 27% acrocarpous moss spp, 11% *Calluna vulgaris*, 6% pleurocarpous moss spp, 3% *Rumex acetosella*, 4% *Polytrichum* spp and 2% Liverwort spp. (Fig. 1). There was also less than 1% cover of *E. vaginatum*, *Cladonia* spp., *Chamerion/Epilobium* spp., *Betula* spp. and *Salix* spp. Bare peat cover, originally at 100%, had declined by 88% and there was also 34% cover of dead plant material.

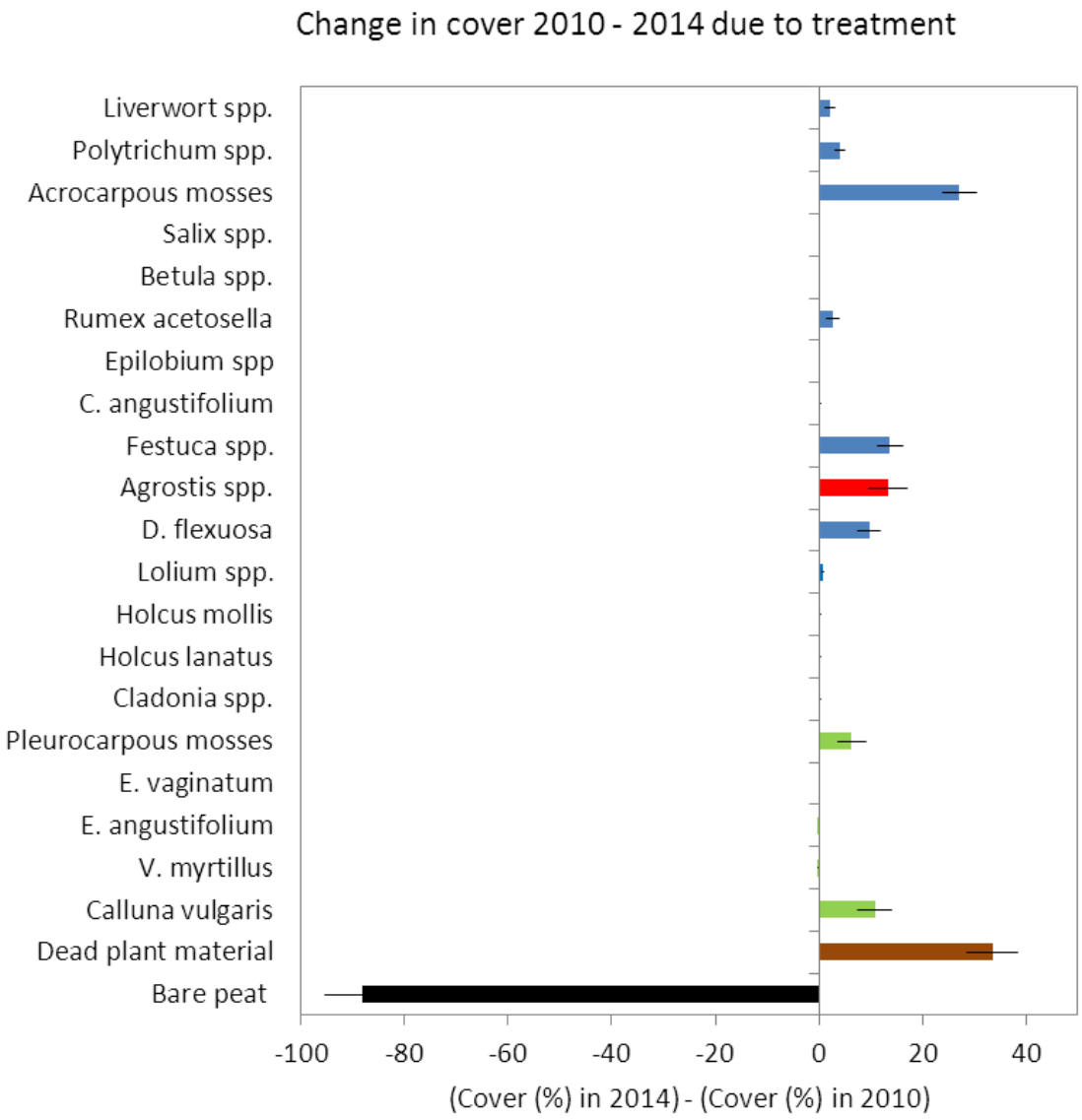

Fig. 1. Change in cover (%) of bare peat and plant species.

Bare peat (black bars) and other vegetation (coloured bars) are expressed as the difference in cover from 2010 (before restoration) up to 2014 and corrected for changes in the control. Green, blue and red bars signify indicator species, non-indicator species and negative indicator species, respectively, n= 9 (control) and 10 (treatment), error bars represent ± 1 standard error.

4.2.2 Cover and frequency of species 2014

Although the cover of *Calluna* did not rise above 11% in the three years since restoration, and that of pleurocarpous mosses did not rise above 6%, the percentage of quadrats having some presence of these species/types was between 90% and 100%, indicating their widespread distribution throughout the survey site and their potential for development. This was also the case for grasses, acrocarpous mosses, *Polytrichum* mosses and liverworts (Fig. 2).

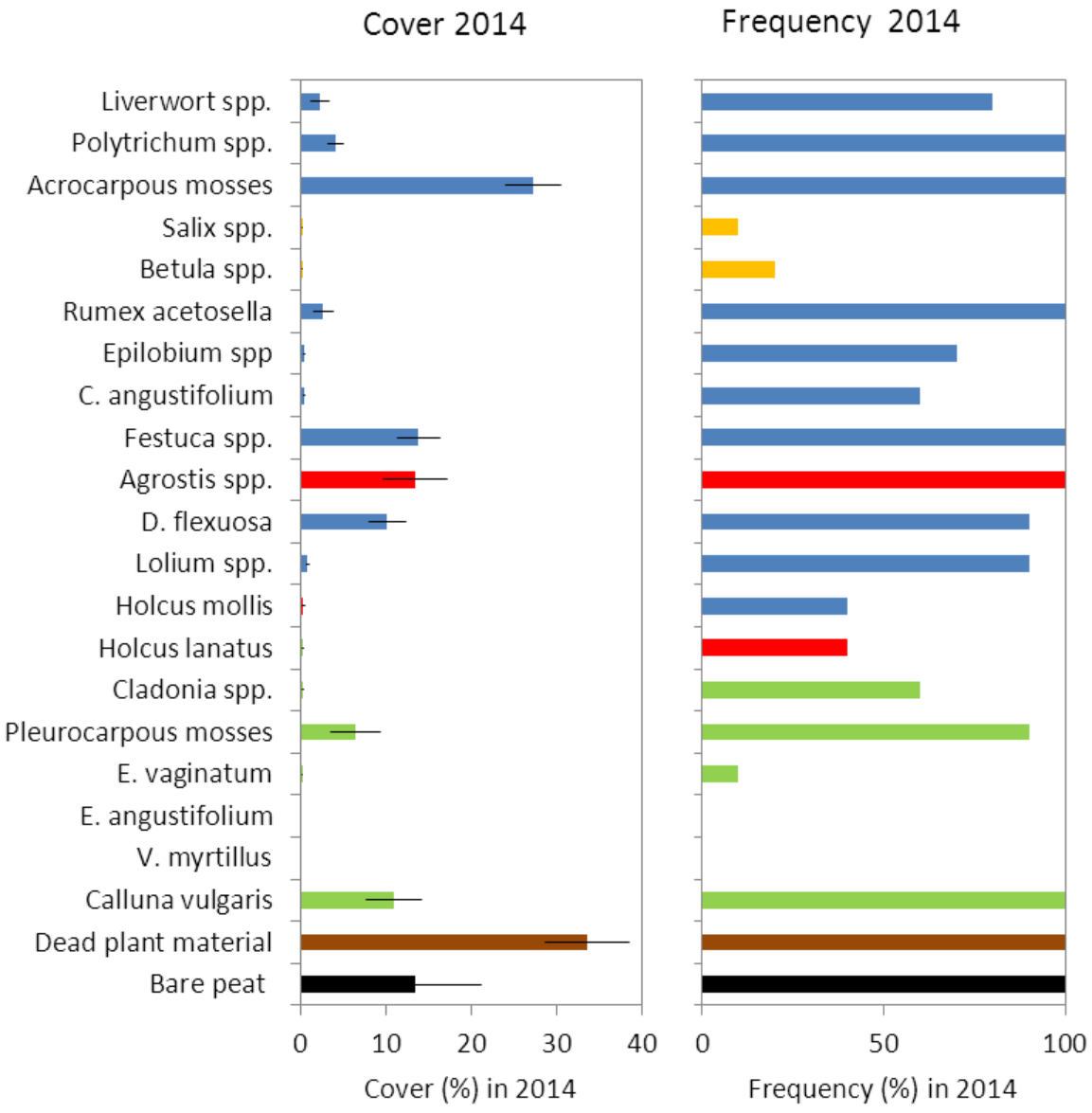

Fig. 2. Cover (%) and frequency (%) of bare peat and plant species

Bare peat (black bars) and other vegetation (coloured bars) are expressed as cover in 2014 (left) and frequency of occurrence in quadrats (%) in 2014 (right), corrected for changes in the control. Green, blue and red bars signify indicator species, non-indicator species and negative indicator species, respectively, n= 10, error bars represent ± 1 standard error.

4.2.3 Changes in bare peat and vegetative cover

The restoration treatment was applied in the beginning of the 2011 growing season; after that first growing season, the cover of bare peat and vegetation in the restored treatment areas were already significantly reduced and increased, respectively, when compared to the untreated control (Table X). These significant differences were repeated in each successive year.

Table 1. Results of statistical testing for the cover of bare peat and vegetation

Cover type	2010	2011	2012	2013	2014
Bare peat cover	n/a	< 0.001	< 0.001	< 0.001	< 0.001
Vegetative cover	n/a	< 0.001	< 0.001	< 0.001	< 0.001

Values in the table are p-values resulting from the non-parametric Mann Whitney U test for differences between the control and treatment areas. Significant differences at p < 0.05 are highlighted in grey

The cover of bare peat remained at 100% in the control and there was a significant negative and quadratic relationship between time and bare peat cover in the treatment area (Fig. 3 (left), F = 66, d.f. = 2, 2, p = 0.02, R^2 = 0.99). Bare peat cover was reduced to approximately 10%.

The cover of vegetation remained at 0% in the control: temporary and negligible rises in vegetative cover above 0% were due to vegetation from overhanging hag tops collapsing or being blown into the quadrat area. There was a significant positive and linear relationship between time and vegetative cover in the treatment area (Fig. 3 (right), F = 526, d.f. = 1, 3, p < 0.001, R^2 = 0.99).

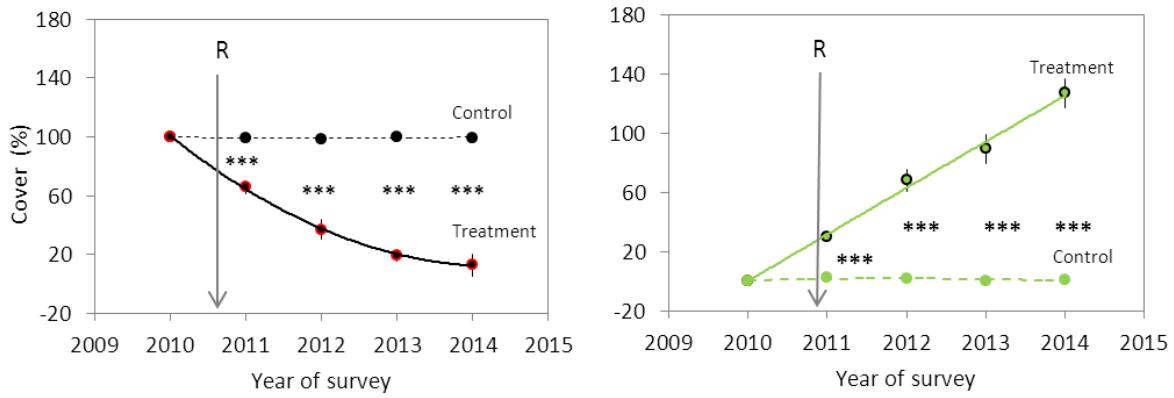

Fig. 3. Relationship between time and cover (%) of bare peat and vegetation

Bare peat (left, black lines) and vegetation (right, green lines) in the untreated control area (dotted lines) and treatment areas (solid lines) are expressed as mean cover in 2010 (before restoration) and in 2011, 2012, 2013 and 2014 (1, 2, 3, and 4 years post-restoration, respectively; data points represent the mean of n = 9 (control in 2010, 2011, 2012, 2014), 5 (control in 2013), 10 (treatment). Lines were fitted by polynomial regression (order = 2), error bars represent ± 1 standard error, asterisks represent a significant difference (P < 0.001) between bare peat cover (left) and vegetation cover (right) in the untreated control area and the treatment area for the corresponding years, R = time of restoration treatments

These trends resulted in a significant negative relationship between the developing vegetation vegetative cover and the cover of bare peat (Fig. 4, F = 48, d.f. = 2, 2, p = 0.02), the latter of which did not decline to zero, in spite of relatively high vegetative cover approaching a mean value of 120%. Values above 100% were due to the three-dimensional sub-layering of vegetation which nevertheless failed to cover all the bare peat patches.

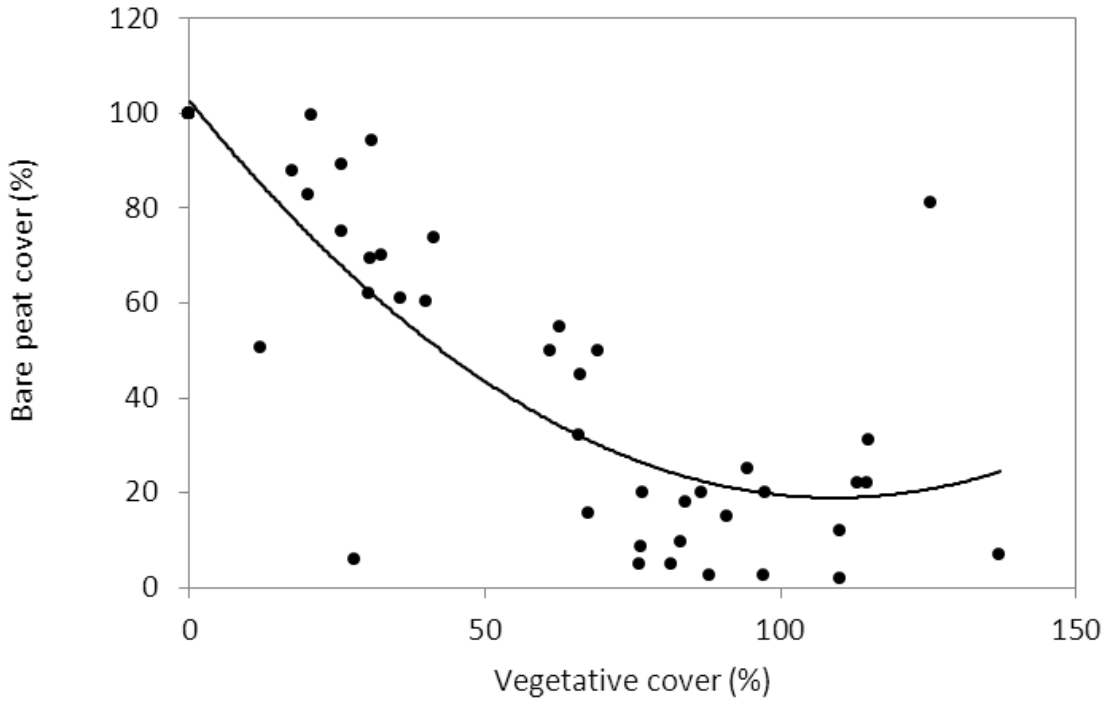

Fig. 4. Relationship between cover (%) of vegetation and bare peat

The data are for the treatment area in the year preceding restoration and the four years post restoration. Bare peat cover does not reach 0%, regardless of relatively high vegetative cover approaching 120%; the latter possible due to sub-layering of vegetation, n = 41, line was fitted by polynomial regression (order = 2)

4.2.4 Changes in blanket bog indicator/non-indicator cover

After one growing season the cover of non-indicator species in the restored treatment area was already significantly increased when compared to the untreated control (Table 2). These significant differences were repeated in each successive year. The cover of indicator species in the restored treatment area was significantly increased after two growing seasons when compared to the untreated control (Table 2). These significant differences were also then repeated in each successive year.

Table 2. Statistical testing for non-indicator and indicator groups

Cover type	2010	2011	2012	2013	2014
Non-Indicator	n/a	0.003	< 0.001	0.002	< 0.001
Indicator	n/a	0.601	0.006	0.008	< 0.001

Values in the table are p-values resulting from the non-parametric Mann Whitney U test for differences between the control and treatment areas. Significant differences at p < 0.05 are highlighted in grey.

There were significant positive relationships between time and the mean cover of (i) indicator species (F= 77, d.f. = 2, 2, p = 0.01), (ii) non-indicator species (F = 81, d.f. = 2, 2, p = 0.01) in the former bare peat patches of the treatment area (Fig. 5).By 2014 (three years after restoration, or four growing seasons), mean cover of indicator species was at 18% and appeared to be rising, while that of non-indicator species was at 76% and appeared to have reached an asymptotic maximum The constituent species of these categories are given in the next section.

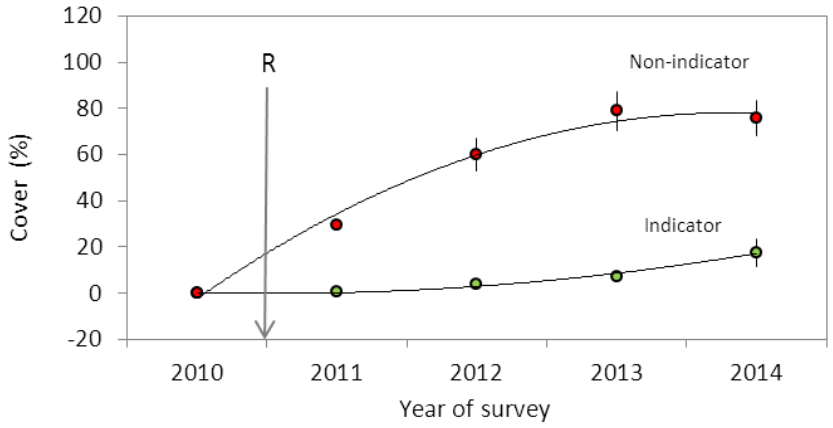

Fig. 5. Relationship between time and cover (%) of indicator/non-indicator categories
Indicator and non-indicator cover are expressed as mean cover of originally bare peat patches in the treatment area before restoration in 2010 and in 2011, 2012, 2013 and 2014 (1, 2, 3, and 4 years post-restoration, respectively, data points represent the mean of n= 10 in each case. Error bars represent ± 1 standard error, R = time of restoration treatments

4.2.5 Changes in constituent species of blanket bog indicator cover

After two growing seasons the cover of *Calluna vulgaris* in the restored treatment area was significantly increased when compared to the untreated control (Table 3). These significant differences were then repeated in each successive year. The cover of pleurocarpous moss in the restored treatment area was marginally significantly increased after two growing seasons and then significantly increased in each successive year, when compared to the untreated control (Table X). The cover of *Cladonia* spp was significantly greater in the treated area only after four growing seasons, reflecting its relatively slow growth rate. Although there was a presence of E. vaginatum and V. myrtillus in the treatment area, the cover of these two species was not significantly greater when compared to the untreated control over the duration of the monitoring period.

Table 3. Statistical testing for constituent indicator species and groups

Cover type	2010	2011	2012	2013	2014
Calluna vulgaris	n/a	0.072	< 0.001	0.007	< 0.001
Pleurocaprous moss	n/a	0.651	0.054	0.045	< 0.001
Cladonia spp	n/a	0.458	0.519	0.930	0.018
Eriophorum	n/a	none	0.479	0.605	0.607
Vaccinium myrtillus	n/a	0.939	0.748	0.636	0.939

Values in the table are p-values resulting from the non-parametric Mann Whitney U test for differences between the control and treatment areas. Significant differences at p < 0.05 are highlighted in grey.

There was a significant positive relationship between time and the mean cover of *Calluna vulgaris* (Fig. 6 (top), F = 669, d.f. = 2, 2, p = 0.001). The relationship for pleurocarpous mosses was less strong and only marginally significant (F = 16, d.f. = 2, 2, p = 0.06). Out of the minor constituents of indicator cover, only the relationship of time with the cover of *Cladonia* spp was significant (F = 59, d.f. = 2, 2, p = 0.02).

By 2014, indicator cover consisted mainly of 11% *Calluna vulgaris* and 6% pleurocarpous moss spp. There was also less than 1% cover of *E. vaginatum*, *E. angustifolium*, *Cladonia* spp. and *Vaccinium myrtillus* (Fig. 6 bottom).

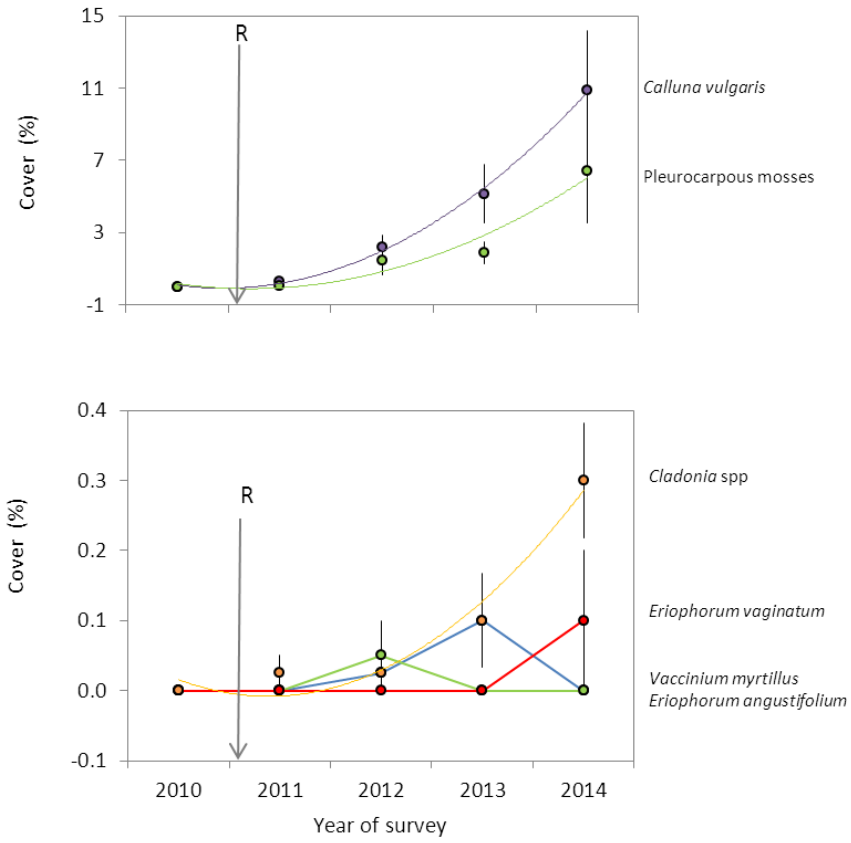

Fig. 6. Relationship between time and cover (%) of indicator species in the treatment area.

The mean cover of major (top) and other (bottom) constituent indicator cover of originally bare peat patches in the treatment area in 2010 (before restoration) and in 2011, 2012, 2013 and 2014 (1, 2, 3, and 4 years post-restoration, respectively), data points represent the mean of n= 10 in each case. Lines were fitted by polynomial regression (Calluna, pleurocarpous mosses and Cladonia spp), order = 2) or simply by joining the data points where no significant relationship with time was found (see text); Note; y-axis scale differs from top to bottom and error bars represent ± 1 standard error, R = time of restoration treatments.

4.2.6 Changes in constituent species of non-indicator cover

After one growing season the cover of both grasses and acrcoparous moss in the restored treatment area were significantly increased when compared to the untreated control (Table 4). These significant differences were then repeated in almost each successive year. The cover of *Polytrichum* spp. and that of liverworts in the restored treatment area were significantly increased after two growing seasons, while that of *Rumex acetosella* was significantly increased after three growing seasons and then all three were significantly increased in each successive year, when compared to the untreated control (Table 4). There were more scattered differences for the cover of *Chamerion* spp. Although there was a presence of *Betula* and *Salix* spp and *V. myrtillus* in the treatment area, the cover of these two species was not significantly greater when compared to the untreated control over the duration of the monitoring period.

Table 4. Statistical testing for constituent indicator species and groups

Cover type	2010	2011	2012	2013	2014
Grasses	n/a	< 0.001	< 0.001	0.002	< 0.001
Acrocarpous	n/a	0.012	0.051	0.002	< 0.001
Polytrichum spp	n/a	n/a	0.007	0.019	< 0.001
Rumex acetosella	n/a	n/a	n/a	0.002	< 0.001
Liverwort spp	n/a	0.275	0.020	0.043	0.002
Chamerion spp	n/a	n/a	0.053	0.090	< 0.001
Betula spp	n/a	n/a	1.000	0.179	0.563
Salix spp	n/a	n/a	1.000	0.580	1.000

Values in the table are p-values resulting from the non-parametric Mann Whitney U test for differences between the control and treatment areas. Significant differences at p < 0.05 are highlighted in grey; marginally significant values are lighter grey

As major constituent species of blanket bog non-indicator cover, there were significant positive relationships between time and mean cover of (i) grasses (Fig. 7 (top), F = 33, d.f. = 2, 2, p = 0.03), (ii) acrocarpous mosses (Fig. 7 (top), F = 180, d.f. = 2, 2, p = 0.006). Out of the minor constituents of non-indicator cover (Fig. 7 (bottom), there were significant positive relationships between time and the mean cover of *Polytrichum* spp (F = 59, d.f. = 2, 2, p = 0.02), Liverwort spp (F = 19, d.f. = 2, 2, p = 0.05) and *Chamerion*/*Epilobium* spp (F = 153, d.f. = 2, 2, p = 0.006).

By 2014, non-indicator cover consisted mainly of 39% total grasses and 27% acrocarpous moss spp. There was also 4% cover of *Polytrichum* spp., 3% *Rumex acetosella*, 2% Liverwort spp. There was also less than 1% cover of *Chamerion*/*Epilobium* spp., *Betula* spp. and *Salix* spp.

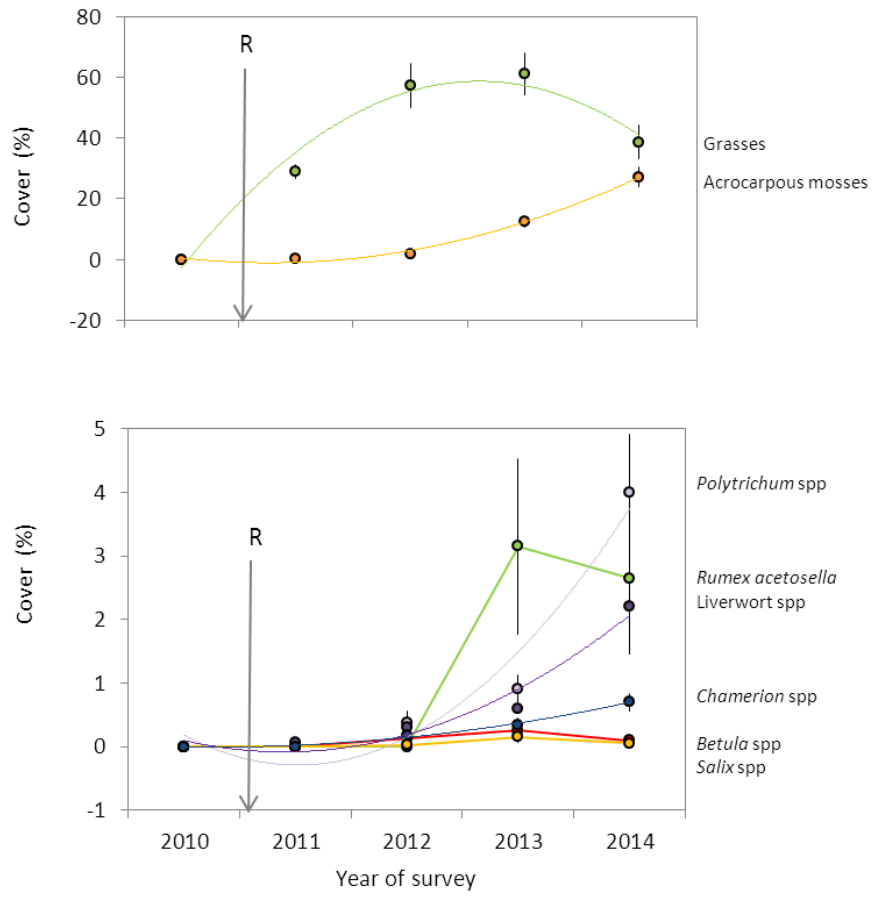

Fig. 7. Relationship between time and cover (%) of non-indicator species

The mean cover of major non-indicator cover (top) and other constituent non-indicator cover (bottom) of originally bare peat patches in the treatment area in 2010 (before restoration) and in 2011, 2012, 2013 and 2014 (1, 2, 3, and 4 years post-restoration, respectively), data points represent the mean of n= 10 in each case. Lines were fitted by polynomial regression (Grasses, acrocarpous mosses, Polytrichum spp., Liverwort spp. and Chamerion/Epilobium spp), order = 2) or simply by joining the data points where no significant relationship with time was found (Rumex acetosella, Betula spp. and Salix spp.); Note; y-axis scale differs from top to bottom and error bars represent ± 1 standard error, R = time of restoration treatments

4.2.7 Species and group dominance

The dominant cover of grasses, mainly *Deschampsia flexuosa*, and also the emerging dominance of *Calluna vulgaris*(Fig. 8) have the potential to provide competitive barriers for the establishment of a more diverse set of species indicative of Blanket bog, including other dwarf shrub species, *Sphagnum* species, *Rubus chamaemorus*, other *Vaccinium* species and others. The high cover of both acrocarpous and pleurocarpous moss cover is also a concern (see Fig. 8); while its presence may provide useful stabilisation of the peat surface, not enough is known about its potential competitive exclusion of other species and its effect on the ongoing trajectory of the habitat as a whole towards Favourable condition.

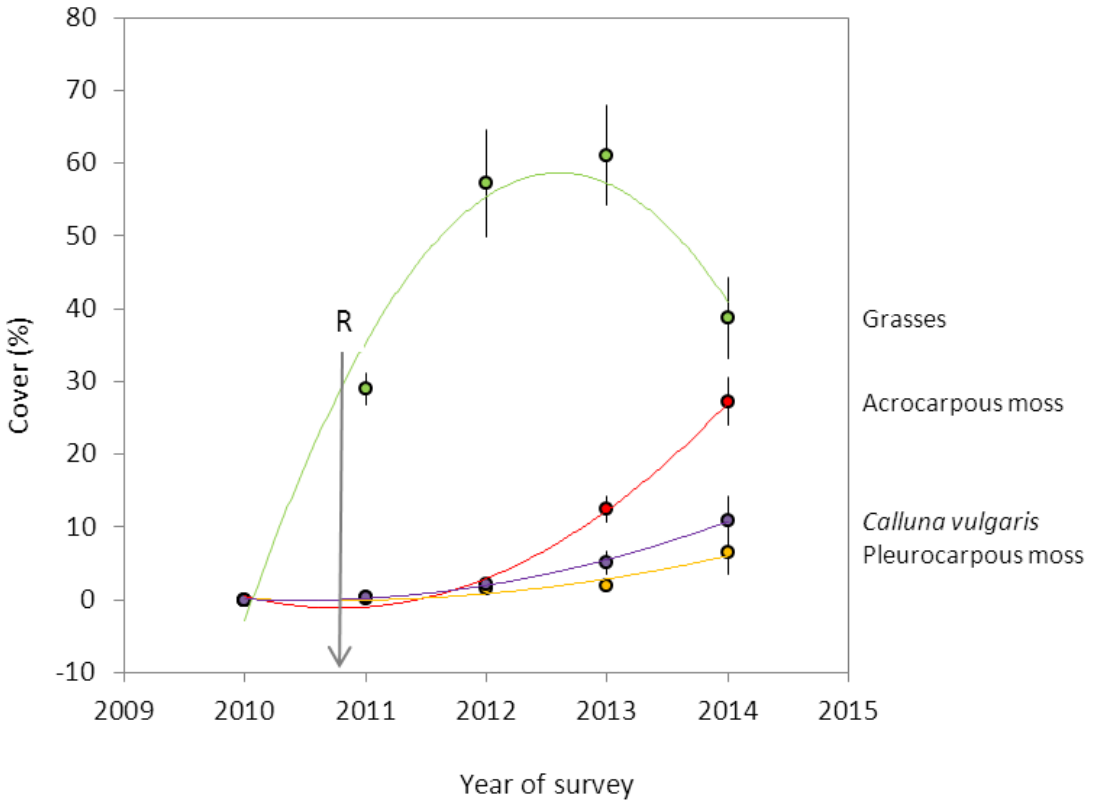

Fig. 8. Relationship between time and cover (%) of major species/groups in the treatment area.
The mean cover of major species and groups on originally bare peat patches in the treatment area in 2010 before restoration and for four years after restoration, data points represent the mean of n= 10 in each case. All relationships were significant and lines were fitted by polynomial regression (order = 2), error bars represent ± 1 standard error, R = time of restoration treatments

4.3 Trajectories toward Favourable Condition - attributes and targets

The status of Favourable condition can only be awarded to a site if at least 90% of quadrats achieve the minimum target for all attributes. Only a selection of the entire list of attributes is presented below.

4.3.1 Frequency of indicator species

The CSM Target for this attribute states that at least six indicator species should be present (see separate Appendix for details). There were no quadrats registering six indicator species; however, there was a significant and positive quadratic relationship between time and the percentage of quadrats with at least *three* indicator species (Fig. 9a, F = 45, d.f. = 2, 2, p = 0.02, R^2 = 0.98, y = 1.714 + 2.571 x + 2.857 x^2)

4.3.2 Cover of at least three indicator species

The CSM Target for this attribute states that at least 50% of vegetation cover should consist of at least 3 indicator species (see separate Appendix for details). There was a significant and positive quadratic relationship between time and the percentage of quadrats fulfilling the target for this attribute (Fig. 9b, F = 47, d.f. = 2, 2, p = 0.02, R^2 = 0.98, y = - 0.857 + 0.714 C1 + 3.571 x^2).

4.3.3 Cover of dwarf shrubs

The CSM Target for this attribute states that *Ericaceous* species collectively should not exceed 75% of the vegetation cover (see separate Appendix for details). The percentage of quadrats complying with this target remained at 100% throughout (Fig. 9c).

4.3.4 Cover of Eriophorum vaginatum

The CSM Target for this attribute states that *Eriophorum vaginatum* should not individually exceed 75% of the vegetation cover (see separate Appendix for details). The percentage of quadrats complying with this target remained at 100% throughout (Fig. 9d).

4.3.5 Cover of other species

The CSM target for this attribute states that less than 1% of vegetation cover should consist of, collectively, *Agrostis capillaris*, *Holcus lanatus*, *Phragmites australis*, *Pteridium aquilinum*, *Ranunculus repens* (see separate Appendix for details). The main species involved at this site was *Agrostis capillaris* and *Holcus lanatus* and the percentage of quadrats complying with this target declined from 100% to 0% within a few years after re-vegetation (Fig. 9e). However, there may have been problems with the identification of *A. capillaris* in the early part of its phenology. The seed mix used for re-vegetation contained *Agrostis castellana* – a species that shares some of the

distinguishing features of *A. capillaris*. Thus it is difficult to come to firm conclusions about these results.

4.3.6 Cover of native trees and scrub

The CSM Target for this attribute states that less than 10% of vegetation cover should be made up of scattered native trees and scrub. Qualifiers: Exclude *Betula nana* and *Myrica gale* (see separate Appendix for details). From data collected over the years (not shown), the frequency of occurrence of quadrats complying with this target remained at 100% throughout.

4.3.7 Cover of bare peat

The full title of this attribute is in fact "Indicators of active drainage and/or ground disturbance due to herbivore and human activity". The CSM target for this attribute states that less than 10% of the total feature area, should be disturbed bare ground (where a substrate of bare humus, bare peat, bare mineral soil, bare gravel, or soil covered only by an algal mat, has its surface broken and imprinted by hoof marks, wallows, human foot prints, or vehicle and machinery tracks (see separate Appendix for details). While the interpretation of this is open to some doubt (it is stated that the emphasis should be on "disturbed" rather than simply "bare"), nevertheless it is of interest to note the significant and positive quadratic relationship between time and the percentage of quadrats with less than 10% cover of bare peat (Fig. 9f, $F = 29$, d.f. = 2, 2, $p = 0.03$, $R^2 = 0.97$, $y = 4 - 22 x + 10 x^2$).

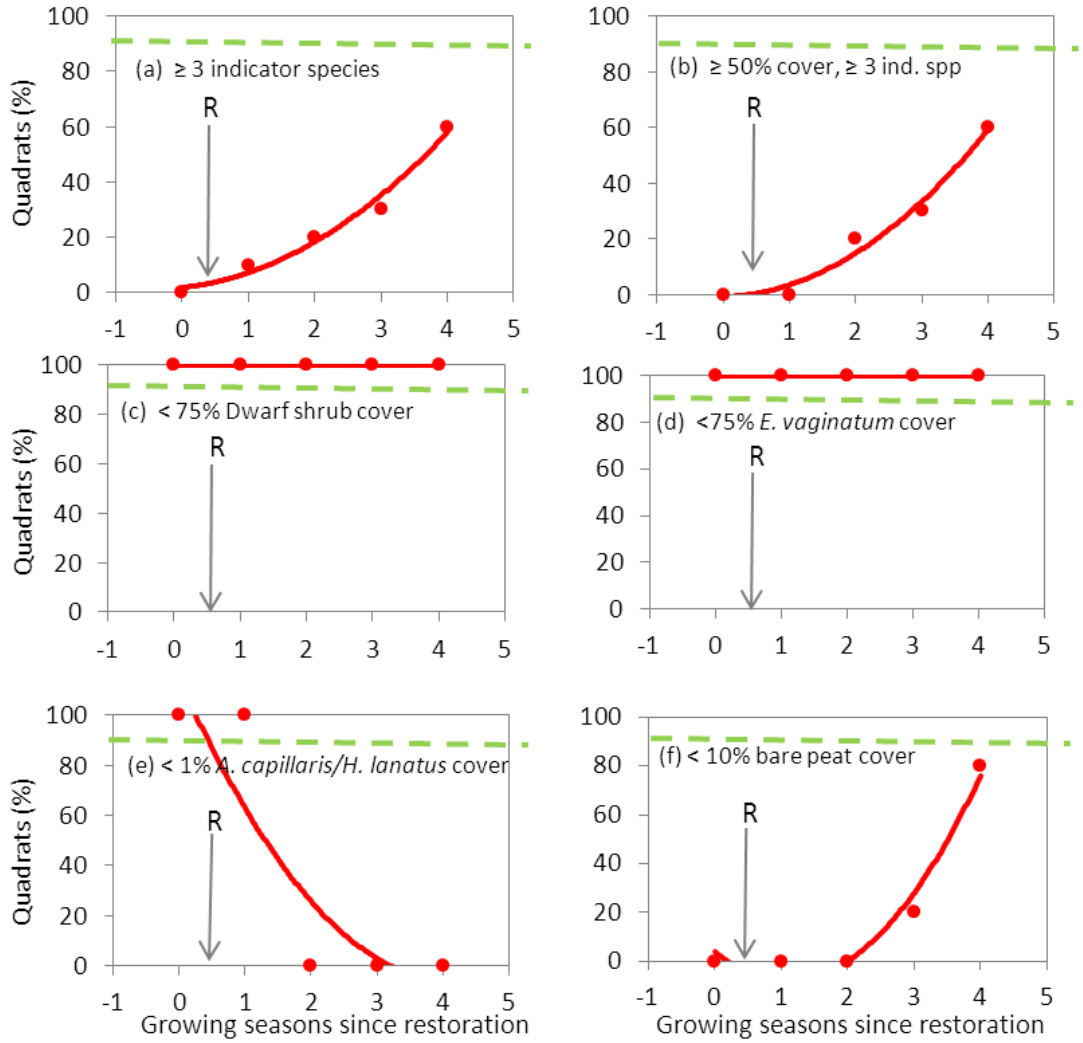

Fig. 9. Trajectories towards favourable condition

The graphs show the relationship between the number of growing seasons since restoration and the proportion of quadrats fulfilling the targets for a selection of attributes determining Favourable Condition status. The attribute targets are the presence of, from top left: (a) at least 3 indicator species; (b) at least 50% cover occupied by at least 3 indicator species; (c) less than 75% cover of dwarf shrubs; (d) less than 75% cover of Eriophorum vaginatum; (e) less than 1% cover of Agrostis capillaris/Holcus lanatus; (f) less than 10% cover of bare peat. The dotted green line indicates the minimum percentage of quadrats (90%) required to achieve favourable condition. Trend lines were fitted by polynomial regression (order = 2). R = time of restoration treatments.

5. CONCLUSIONS

The main species colonising the bare peat in the three years or four growing seasons since restoration, were, in descending cover values; grasses (of which the main component was *Deschampsia flexuosa*), acrocarpous moss, *Calluna vulgaris* (indicator species) and pleurocarpous moss (indicator group). All of the above-named species were widely distributed amongst the quadrats. Vegetative cover increased from 0 to values in excess of 100% due to sub-layering of vegetation and in a strong negative co-relation, bare peat cover declined from 100% to 12%, failing to reach zero as a result of widely scattered and relatively small bare peat patches.

Indicator cover reached 18%, mainly composed of *Calluna* and pleurocarpous mosses but also with traces of *Cladonia* spp., *Vaccinium myrtillus*, *Eriophorum angustifolium* and *Eriophorum vaginatum*. Non-indicator cover reached 76%, mainly composed of grasses and acrocarpous mosses but also traces of *Polytrichum* spp., *Rumex acetosella*, liverworts, *Chamerion/Epilobium* spp., and some scattered B*etula*/*Salix* spp.

Overall there is a strong cover of stabilising vegetation, a growing component of which are indicator species. With regards to achieving Favourable Condition, the percentage of quadrats achieving target values is still too low for a number of key attributes, especially those relating to the minimum number and cover of indicator species, the maximum cover of *Agrostis capillaris*/*Holcus lanatus* and the maximum cover of bare peat, although these percentages are currently increasing.

Although at present there is no specific attribute concerning the cover or frequency of occurrence of grasses in general, cover values for this category greatly exceeded that of all other groups/species. Grass cover, together with that of *Calluna* has the potential to cause negative competitive interaction with species more indicative of Blanket bog and this may be an issue in the future.

6. REFERENCES

JNCC, 2009. *Common Standards Monitoring Guidance for Upland Habitats* Version July 2009 http://jncc.defra.gov.uk/page-2237 accessed May 2015

Natural England, 2015. *Summary of evidence: Biodiversity*. Natural England Access to Evidence Information Note EIN004. http://publications.naturalengland.org.uk/category/5856835374415872 accessed May 2015.

PAA, 2003. *United Utilities Water PLC - Assessment of SSSIs in Unfavourable Condition* Volume 4: South Pennine Moors - Worsthorne Moor. Ref. No. 030629, July 2003. Penny Anderson Associates Limited, 'Park Lea', 60 Park Road, Buxton, Derbyshire, SK17 6SN

PAA, 2005. *Yorkshire Water Moorland SSSI recovery project*, Penny Anderson Associates Limited, 'Park Lea', 60 Park Road, Buxton, Derbyshire, SK17 6SN