Moscar Science Project

Annual Report 2015/16

Report to

Natural England

Prepared by:

Moors for the Future Partnership

2016

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Suggested citation: Crouch, T., Benson, J., Walker, J. (2016) Moscar Science Project: Annual Report for 2015/16. Moors for the Future Partnership, Edale.

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1. Executive summary

The Moscar Science Project is funded by Natural England. The aim of the project is to provide evidence of the benefits of blocking erosion gullies within private grouse moor Higher Level Stewardship agreements in the Upper Derwent and Peak District generally. This annual report provides a summary of the monitoring programme and the results so far. Table 1.1 below summarises the main objectives and the method of monitoring used to evidence these objectives.

Table 1.1: Moscar Science Project objectives and method of monitoring

OBJECTIVE		MONITORING METHOD
1.	**Biodiversity**	
a.	What effect do the restoration interventions have on the species composition, abundance, distribution and breeding status of birds?	Breeding bird survey
b.	What effect does gully blocking have on the species composition of vegetation?	Vegetation monitoring (local scale)
c.	Do the restoration interventions move the SSSI unit towards Favourable Condition Status?	Vegetation monitoring (site scale)
2.	**Cultural service**	
a.	What effect does footpath restoration have on visitor use of the site?	Footpath monitoring (video footage)
3.	**Economics**	
a.	What effect do the restoration interventions have on grouse abundance, distribution and breeding status of birds?	Breeding bird survey
b.	What effect do the restoration interventions have on shoot productivity (grouse bag numbers)?	Grouse survey
c.	Does gully blocking effect heather plant health and, as a consequence, its resilience to disease and pests, e.g. heather beetle?	Vegetation monitoring (quadrats associated with dipwell clusters and transects)
4.	**Ecosystem services (hydrology)**	
a.	What effect do the restoration interventions have on water tables on the site? i) local scale, ii) site scale	Automated and manual water table monitoring
b.	What effect do the restoration interventions have on fluvial particulate organic carbon loss from the site?	POC monitoring
c.	What effect do the restoration interventions have on the levels of fluvial dissolved organic carbon and colour from the site? i) local scale, ii) site scale	Water quality monitoring
d.	Provide background information on water flow from the site.	Rainfall and water flow monitoring

2. Introduction

The Moscar Science Project (MSP) is funded by Natural England (NE). The purpose of the project is to deliver a comprehensive monitoring programme to evidence the benefits from blocking erosion gullies within private grouse moor Higher Level Stewardship (HLS) agreements in the Upper Derwent and Peak District generally. The project will evidence the impacts of works on biodiversity, cultural services, economics and ecosystem services. This links with Natural England's Outcomes Approach; an approach based around developing multiple outcomes which will be used to progress blanket bog restoration in England (Natural England, 2015).

The MSP will deliver an improved understanding of the benefits of blanket bog restoration on private grouse moors by monitoring and analysing the data for:

- The effects of restoration interventions on the species composition, abundance, distribution and breeding status of birds;
- The effect of gully blocking on the species composition of vegetation;
- The ability of restoration interventions to move the SSSI unit towards Favourable Condition Status;
- The effect of footpath restoration on visitor use of the site;
- The effect of restoration interventions on grouse abundance, distribution and breeding status of birds;
- The effect of restoration interventions on shoot productivity (grouse bag numbers);
- The effect of gully blocking on heather plant health and, as a consequence, its resilience to disease and pests, e.g. heather beetle;
- The effect of restoration interventions on water tables on the site;
- The effect of restoration interventions on fluvial particulate organic carbon (POC) loss from the site;
- The effect of restoration interventions on the levels of fluvial dissolved organic carbon (DOC) and colour from the site;
- The effect of restoration interventions on peat erosion rates;
- Background information on water flow from the site.

3. Site description

The Moscar Estate is located in the Peak District, west of the city of Sheffield (Figure 3.1). The Estate is split by the A57 Snake Road. The land to the North (referred to as Derwent Moors) is managed moorland and supports deep peat and dry, heather dominated bog. There are a substantial number of gullies, particularly towards the North where they feed towards Rising Clough (Natural England, 2012). This area is the focus of the capital works and monitoring programme. The land to the South (referred to as Moscar Moor) is also managed moorland, and has some gully networks, but is currently not part of the capital works programme. This has been designated the control site.

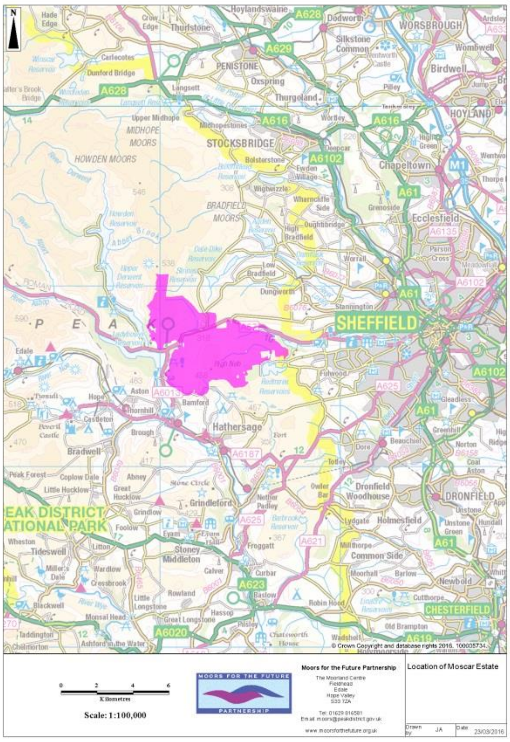

Figure 3.1: Location of Moscar Estate

4. Summary of weather for 2015

A summary of the weather conditions over the last year is provided below. This provides important contextual information for interpretation of the results.

The winter (December, January and February) of 2014/2015 was fairly typical. The mean temperature for the UK was 3.9 ˚C, which is 0.2 ˚C above average and the total rainfall was 367 mm, which is 111% of the average (Met Office, 2016).

The spring (March, April, May) of 2015 was also fairly unexceptional overall. The mean temperature for the UK was close to average; however, this consisted of a near average March (+0.1 ˚C), followed by a warm April (+0.5 ˚C) and a cooler than average May (-0.8 ˚C). The total rainfall was 252 mm, which is 106% of the average (Met Office, 2016).

The summer (June, July, and August) of 2015 was mostly characterized by a cool, westerly Atlantic flow with the UK often under the influence of low pressure systems. The mean temperature for the UK was 13.9 ˚C (-0.4 ˚C) and the mean rainfall was 272 mm, which is 113% of the average (Met Office, 2016).

September and October were generally quiet and settled with high pressure often bringing dry, sunny conditions. However, November was mostly a very mild, dull and unsettled month with several autumn storms bringing windy conditions and some very wet weather (more than 200% of average rainfall) to upland areas of the north and west. The contrasting character of the months resulted in overall seasonal statistics which are fairly unremarkable (Met Office, 2016).

The winter (December, January and February) of 2015/2016 was remarkable. It was the third-warmest and second wettest in the UK since 1910. Nine named storms from mid-November led to some impacts from strong winds, and rainfall caused extensive flooding across many northern and western parts of the UK (Met Office, 2016).

To summarise, anomaly graphs (Figure 4.1 and Figure 4.2) are presented below. These graphs show the monthly difference in temperature and rainfall from the 1981-2010 average.

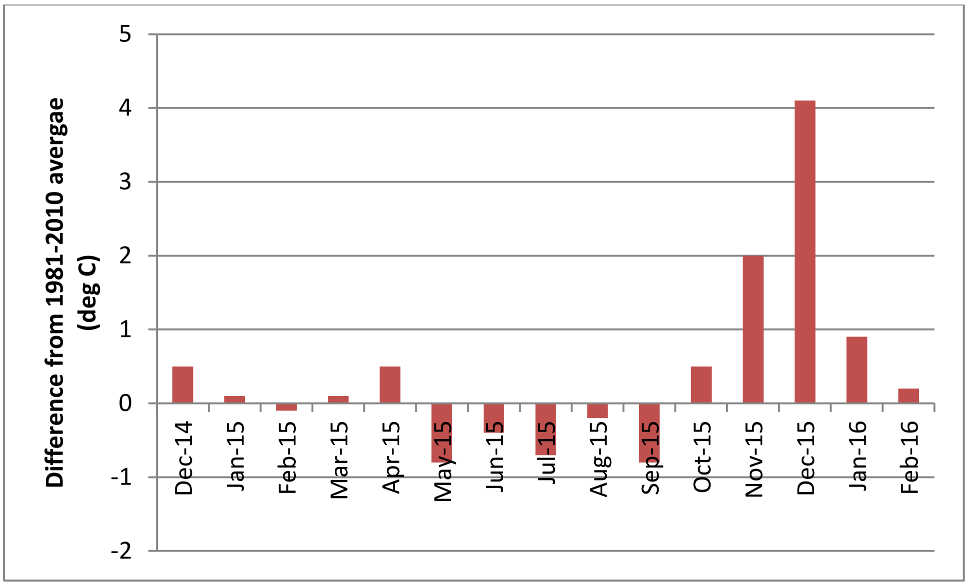

Figure 4.1: Mean UK temperature anomaly 1981-2010

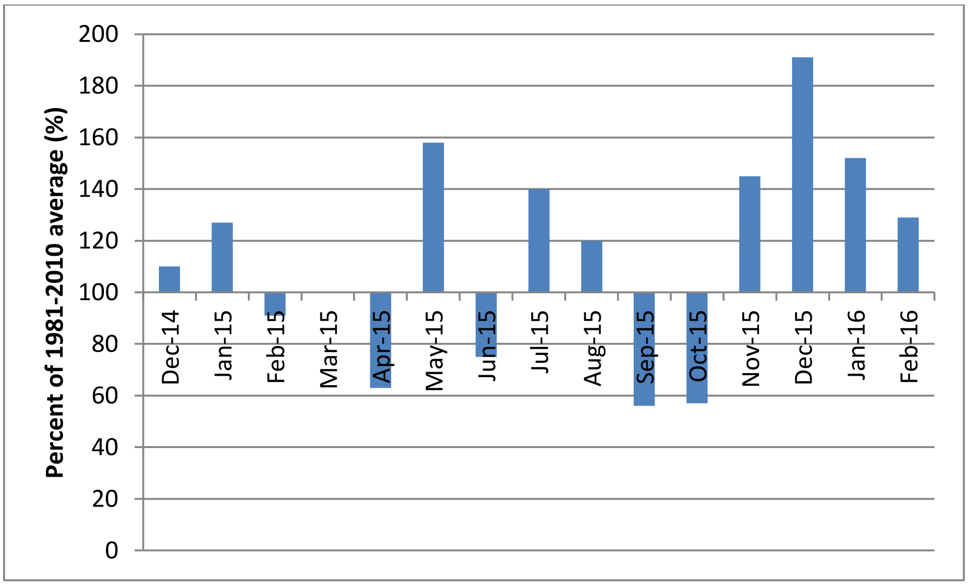

Figure 4.2: UK rainfall anomaly 1981-2010

5. Summary of capital works

The following summary gives an overview of the restoration activities delivered by MFFP on the Moscar Estate (see Table 5.1 and Figure 5.1). This work was funded through the Moscar HLS Scheme and delivered through the MFFP's Private Lands Project (PLP). The Moscar Science Project was set up in conjunction with the Moscar HLS Scheme to monitor the benefits of this capital works programme.

Table 5.1: Summary and timeline of capital works

Restoration activity	**Date started**	**Date completed**
Whinstone Lee Tor footpath restoration: • 2472 m of upland footpath created (2308 m substrata path; 164 m of pitch path; 66 stone pitch water bars; 13 aggregate water bars; 39 stone pitch fords; 90 T top dressing. • 1.6 ha of bare peat restoration (322 bags of heather brash; 1550 kg of lime; 160 kg of seed; 768 kg of fertiliser.	13 Oct 2014	Jul 2015
Sphagnum harvesting: • 15,000 clumps of *Sphagnum* harvested from gullies before gully blocking.	26 Oct 2015	28 Oct 2015
Sphagnum translocation: • 15,000 clumps of *Sphagnum* planted.	29 Oct 2015	27 Nov 2015
Gully blocking (peat dams) and re-profiling: • 324 peat dams built • 1200m gully reprofiling • 83 bags of heather brash spread	1 Dec 2015 8 Feb 2016	22 Dec 2015 1 Mar 2016
Gully blocking (stone dams): • 292 dam units installed	23 Jan 2016	25 Jan 2016

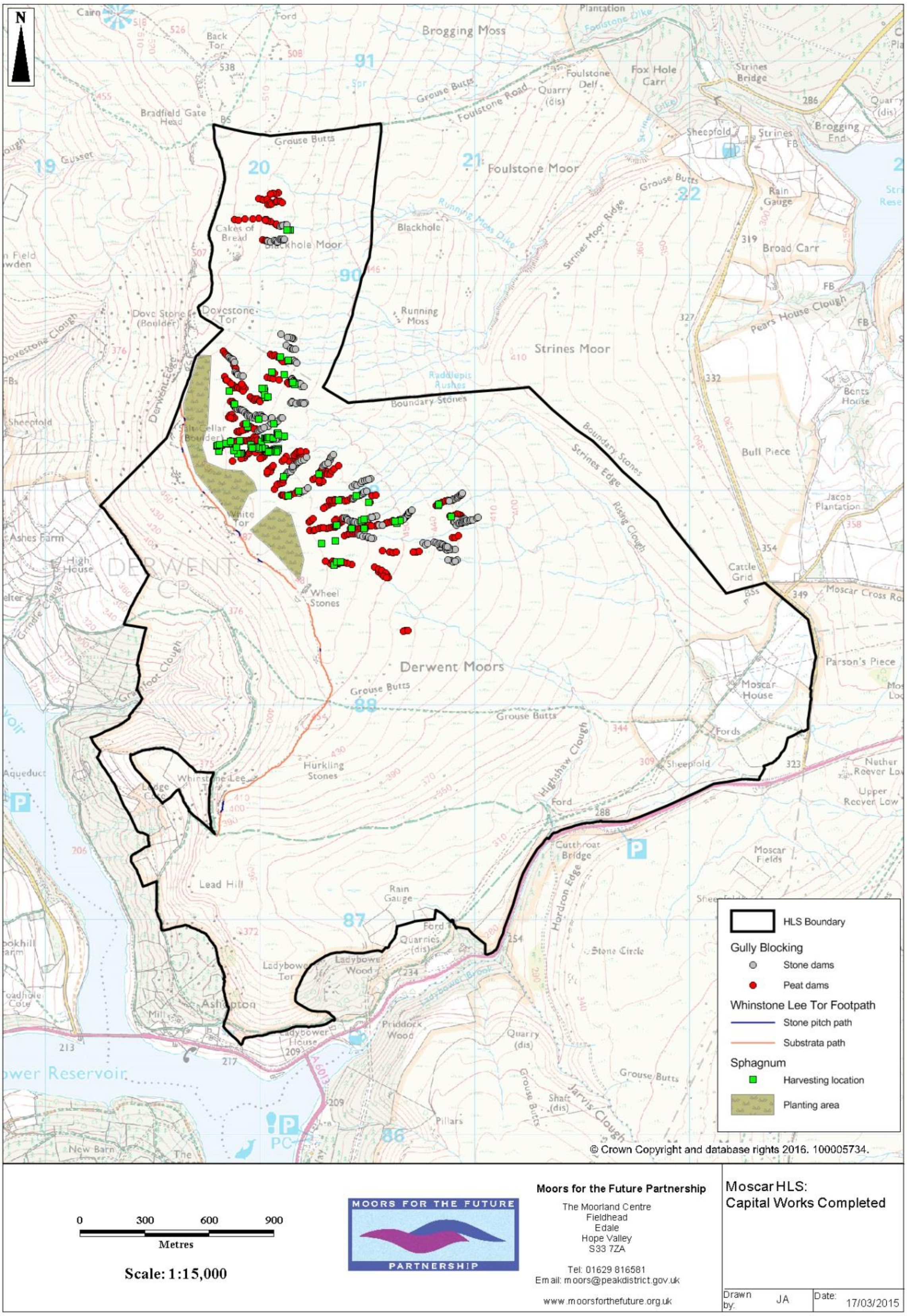

Figure 5.1: Capital works delivered under the Moscar HLS scheme

6. Methodologies

The Moscar Science Project monitoring programme has been designed to evidence the project objectives (as outlined in Table 1.1). An overview of the Moscar Science Project monitoring is presented in Figure 6.1. Where possible a Before-After-Control-Impact (BACI) monitoring design has been used. This is the most powerful monitoring design, enabling assessment of the Before (pre-restoration baseline) and After (post-restoration) condition of the site, as well as comparison of a Control (reference site) with the Impact site (restoration site). Before and After sampling will determine how the restoration changed the site through time from its baseline condition. Control and Impact sampling will allow the effects of restoration actions to be separated from natural variability, stochastic events (e.g. an extremely wet winter), and underlying trends. A Control site which has identical conditions to the Impact site is not always available; therefore, the term Reference site is used to describe areas near the restoration but not part of the area directly affected by the restoration project. The restoration and reference sites are monitored at the same intensity to allow for direct comparison of the different monitoring samples.

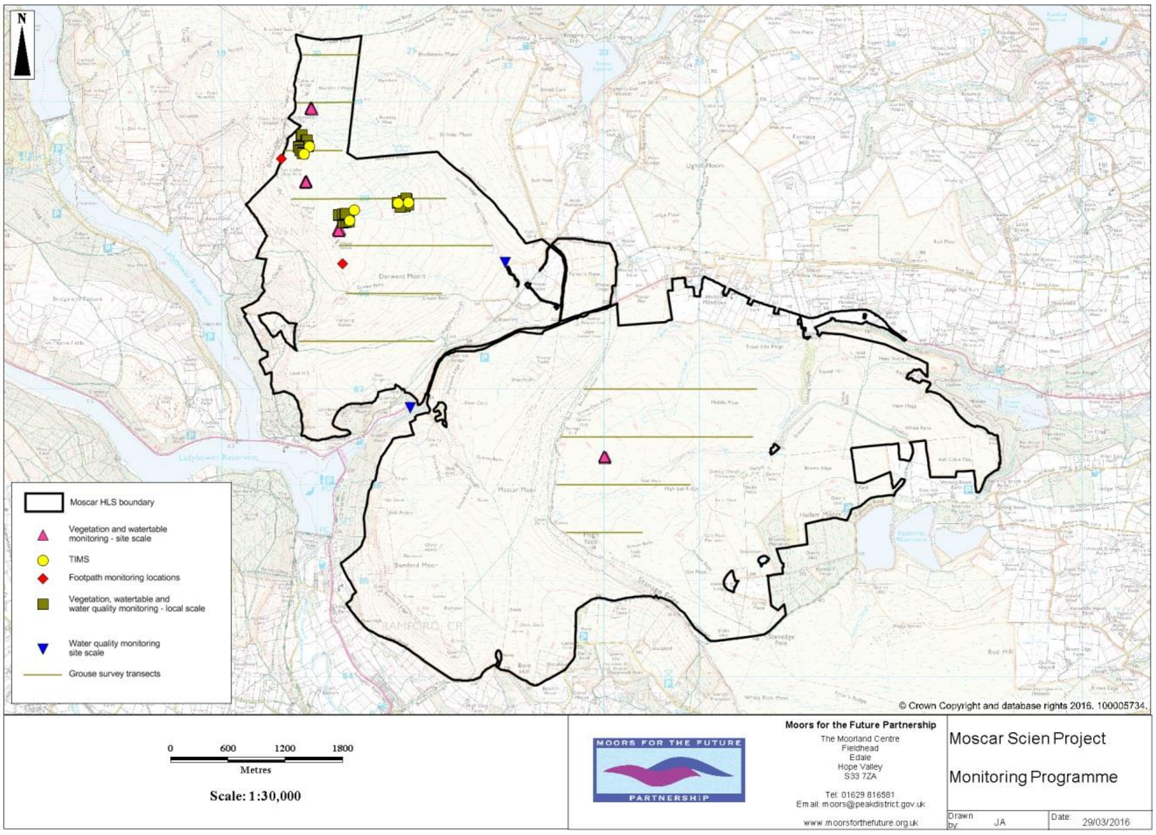

Figure 6.1: Moscar Science Project monitoring programme

6.1. Breeding bird surveys (1a; 3a)

The survey methodology employed was based on that of territory mapping (Gilbert *et al.* 1998) as used for the British Trust for Ornithology (BTO) Breeding Bird Survey (BBS). The criteria used in the assessment of breeding birds have been adapted from the standard criteria proposed by the European Ornithological Atlas (EOAC 1979) and are grouped into three categories: **possible** breeder, **probable** breeder and **confirmed** breeder. Birds that were considered not to be using the survey area for breeding were categorised as 'non-breeders', either because there was no suitable habitat for the species, they were passage migrants or the species were colonial breeders and any colonies would have been obvious during the survey. The criteria used to determine the breeding status (possible, probable or confirmed breeder) of birds during surveys are shown in Table 6.1.

Primarily focussing on waders, raptors and red grouse, this study also recorded the breeding status of other bird species encountered during the survey. The one exception to this was *Anthus pratensis* (meadow pipit). This species was ubiquitous throughout the site and so as not to divert attention away from the target species a tally of meadow pipits was taken per 1km OS grid square during each survey visit. The number of pipits recorded in the first visit (i.e. largely before their numbers were swelled by first and second brood offspring) was taken as an indication of the abundance and distribution of this species.

Table 6.1: Criteria used to determine breeding status of birds during surveys

Confirmed breeder	**Probable breeder**	**Possible breeder**	**Non-breeder**
Distraction display or injury feigning	Pair in suitable nesting habitat	Observed in suitable nesting habitat	Flying over
Used nest or eggshells found from this season	Permanent territory (defended over at least 2 survey occasions)	Singing male	Migrant
Recently fledged young or downy young	Courtship and/or display		Summering non-breeder
Adults entering or leaving nest-site in circumstances indicating occupied nest	Visiting probable nest site		Observed in unsuitable nesting habitat
Adult carrying faecal sac or food for young	Agitated behaviour		
Nest containing eggs	Brood patch of incubating bird (from bird in hand)		
Nest with young seen or heard	Nest building or excavating nest-hole		

In 2014, three visits were carried out to provide a reasonable level of accuracy for determining the population status of breeding birds within the survey area. The surveys were undertaken by a single surveyor to minimise disturbance to ground-nesting birds. They were carried out during three time periods: 30th April - 7th May 2014; 16th May - 6th June 2014 and 11th June - 27th June 2014, following the recommended methodology. Surveys were carried out between 8 am and 6 pm during suitable conditions (no precipitation, wind lower than Beaufort Force 5 and avoiding times of low visibility).

A route was mapped out prior to the surveys being undertaken to ensure full coverage of the survey site with an approximate detection distance of 200 m. This route was followed as fully as possible but due to the difficult nature of some of the terrain and the health and safety concerns of a lone-working surveyor, some deviations from the planned route were necessary. Where this occurred every effort was made to observe the area in question for an additional time period from as close a distance as possible.

All of the surveys were carried out within the acceptable time period (i.e. before the end of June) and are not considered to have significantly affected the results recorded. Breeding Bird Survey guidelines state that the first survey should be carried out in April, however this was not possible at this site due to the date the surveys were commissioned. In addition poor weather hampered survey efforts during the second and third survey visits which initially were scheduled to be carried out between 8th May – 28th May and 29th May – 18th June respectively. Some of this delay was at the landowner's request, due to the fact that newly fledged grouse chicks are particularly vulnerable to injury when flushed in windy conditions. As a consequence any wind conditions above a gentle breeze (Force 3) were considered unsuitable for surveying after 10th May 2014. Surveys were carried out across ~18km^2 of land (made up of 22 whole or partial Ordnance Survey (OS) 1km grid squares), centred around grid reference SK 220 879 to the west of Sheffield. The location in a local context is shown in Figure 6.2. The red line indicates the site boundary.

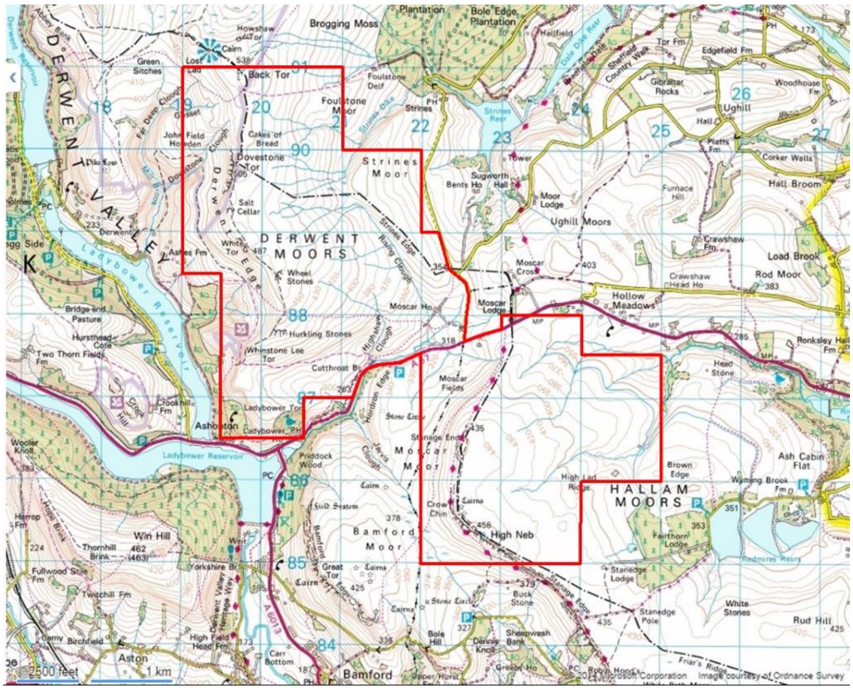

Figure 6.2: Map showing the survey area located within the red boundary

6.2. Vegetation monitoring - local scale (1b; 3c)

In order to monitor the effect of gully blocking on the species composition of vegetation, a series of 2 x 2 m quadrats was set up across three paired gully systems located on Derwent Moors. A paired gully system consists of two nearby gullies that are approximately similar. Within each paired gully system, one gully was blocked (treatment gully) and one remained unblocked (reference gully). By leaving an unblocked gully it will be possible to determine relative changes in vegetation following gully blocking, as well as absolute differences. On each gully, quadrats were set up along a transect, with quadrats located at 1, 5, 7 and 10m from the gully edge. This was repeated three times per gully, with a transect located approximately at the top, middle and bottom of each gully. In total, there are 12 quadrats per gully and 72 in total (see Figure 6.1). At each quadrat the following variables are recorded: percentage cover of bare peat, percentage cover of vegetation (by species) and vegetation height. In order to monitor whether gully blocking affects heather plant health and, as a consequence, its resilience to disease and pests, e.g. heather beetle, the growth phase of any heather present in the quadrat is recorded, as well as any signs of heather beetle or damage caused by heather beetle. Fixed point photographs are also taken. These quadrats were set up and baseline monitoring carried out on the 14th, 15th and 16th of December 2015.

6.3. Vegetation monitoring - site scale (1c; 3c)

In order to monitor whether the restoration interventions move the SSSI unit towards Favourable Condition Status a network of 2 x 2 m quadrats have been set up across the site. This consists of four clusters of ten quadrats; three 'treatment' clusters located on Derwent Moors and one 'reference' cluster located on Moscar Moor (see Figure 6.1). At each quadrat the following variables are recorded: percentage cover of bare peat, percentage cover of vegetation (by group and species) and vegetation height. In order to monitor whether gully blocking affects heather plant health and, as a consequence, its resilience to disease and pests, e.g. heather beetle, the growth phase of any heather present in the quadrat is recorded, as well as any signs of heather beetle or damage caused by heather beetle. Fixed point photographs are also taken. In 2014, vegetation monitoring was carried out on the 7th, 8th and 28th of August and in 2015 on the 21st, 22nd and 30th of July and the 4th August.

6.4. Footpath monitoring (2a)

The effect of footpath restoration on how visitors use the path was monitored before and after restoration. This involved one person standing close to the footpath and recording videos of visitors using the footpath. Visitor use of the Whinstone Lee Tor footpath was carried out on two sections of footpath (Wheel Stones and Salt Cellar – see Figure 6.1) on the 18th July 2015, prior to restoration and again on the 6th December 2015, after footpath restoration. The number of people following the correct line of the footpath was compared before and after restoration.

6.5. Summer grouse surveys (3b)

In order to monitor the effect of restoration interventions on shoot productivity (grouse bag numbers), pre-shoot season surveys of grouse were carried out. A Distance Sampling approach (Buckland et al., 2001) was taken, with grouse surveyed from line transects of known length. Transects ran East-West, parallel to one another and spaced at 0.5 km intervals. Seven transects measuring 14.8 km in length were established on Derwent Moors and four transects measuring 12 km in length on Moscar Moor (see Figure 6.1).

While walking along these transects the observer counted the number of all grouse detected. When detected, the perpendicular distance to the bird(s) was recorded as was the bearing to the bird(s), number of birds detected, type of cue (visual, aural or both), activity and vegetation. A key assumption with the method when using these data to estimate densities is that all objects located on the line are detected with certainty. This assumption is easily met when surveying grouse.

Summer grouse surveys were carried out on the 5th, 6th and 7th of August 2014, and 5th, 11th, 12th and 13th August 2015.

6.6. Manual and automated water table monitoring (4ai; 4aii)

Manual and automated dipwells are being used to monitor the effect of restoration interventions on water tables across the site. Manual dipwells are made using 1 m lengths of 40 mm plastic waste pipe, with perforation holes drilled into the sides, and the bottom covered with duct tape to prevent peat getting in. The pipe is sunk into the peat and water moving through the peat gradually fills the pipe to the level of the water table. The small open well allows for easy measurement of the water level inside using a length of flexible tubing. The tubing is inserted into the dipwell as a surveyor blows down and listens for bubbling (Figure 6.3). The point at which bubbling is heard is the depth of the water table from the surface. The length of pipe between the water and the top of the pipe is noted, and the length of the dipwell that is above the peat is then subtracted from this measurement to give the depth of the water table below the peat surface.

Automated dipwells are made from WT HR 1000 capacitance probes from TruTrack. These are placed into plastic pipes, which are made in the same way as the manual dipwells. The capacitance probes are programmed to log water level every hour. The intensive hourly logging of water table allows the temporal behaviour of the water table to be assessed.

Figure 6.3: Surveyor measuring water level within a manual dipwell

6.6.1. Manual water table monitoring – local scale (4ai)

In order to evaluate the relative impact of gully blocking on local water tables, a number of dipwell transects were set up across three paired gully systems located on Derwent Moors (see Figure 6.1). Within each paired gully system, one gully was blocked (treatment gully) and one remained unblocked (reference gully). By leaving an unblocked gully it will be possible to determine relative changes in the water table following gully blocking, as well as absolute differences. Transects of eight dipwells were installed perpendicular to each gully, with dipwells located 0m, 0.5m, 1m, 1.5m, 2m, 5m, 7m and 10m from the gully edge. This was repeated three times per gully, with transects located approximately at the top, middle and bottom of each gully. In total, there are 24 dipwells per gully and 144 in total.

Dipwells were installed on the 10th and 11th December 2015 and left to equilibrate for a couple of weeks. Dipwells were then monitored weekly for nine weeks. These data will be used to assess the relative local drawdown effect of gullying on water tables (Allott et al., 2009), as well as the impact of gully blocking on any post-intervention water table recovery. It is worth noting that the hydrological impacts of gully blocking are still relatively unknown and that further research into this area was recommended by a recent Natural England evidence review (Shepherd et al., 2013).

The dipwells located at 1m, 5m, 7m and 10m from the gully edge also mark the south-west corner of the vegetation quadrats (see section 6.2).

6.6.2. Manual and automated water table monitoring – site scale (4aii)

In order to evaluate the relative impact of gully blocking on water tables at the site scale, a series of dipwells were installed across the site. This consists of four clusters of one automated and fifteen manual dipwells. Each cluster is set up within a 30 x 30 m area. This methodology was developed by Allott *et al.* (2009) and is used across all MFFP's monitoring projects. The automated dipwell allows the temporal behaviour to be assessed, and the surrounding fifteen manual dipwells allow the variability of water table within a small area to be assessed. Three 'treatment' clusters are located on Derwent Moors and one 'reference' cluster is located on Moscar Moor (see Figure 6.1). These dipwells also have vegetation quadrats associated with them (see section 6.3).

These dipwells have been monitored during two 'autumn campaigns' from the 19th September to the 27th November 2014 and the 29th September to the 22nd December 2015. These data will provide a baseline.

6.7. Particulate organic carbon monitoring (4b)

The loss of particulate organic carbon (POC) was monitored using Time Integrated Mass Flux Samplers (TIMS). This methodology was developed at the University of Manchester (Shuttleworth *et al*. 2011) and was based on a design first used by Owens *et al*. (2006). The methodology has been successfully used to investigate the impacts of erosion and restoration on sediment flux and pollutant mobilisation in the peatlands of the Bleaklow plateau, Peak District National Park (Shuttleworth *et al*. 2011). The sampler consists of a PVC pipe (approximately 50 mm x 0.5 m) filled with polystyrene chips and enclosed at each end by plastic 8 mm mesh (Figure 6.4). The trap is left to operate in situ for a fixed time period. Flow entering the trap is slowed by the large surface area of the polystyrene and suspended sediment is deposited within the pipe. This style of sampler is more appropriate to the site conditions than the more widely used Phillips *et al*. (2000) designed TIMS which has to be fully submerged for the entire sampling period and has a small inlet tube which could easily become blocked by larger particles of peat.

In order to monitor the effect of gully blocking on fluvial POC loss from the site, six TIMS units were deployed between the 4th February 2016 and the 1st March 2016. Three of the TIMS units were located in blocked gullies and three in unblocked gullies (see Figure 6.1).

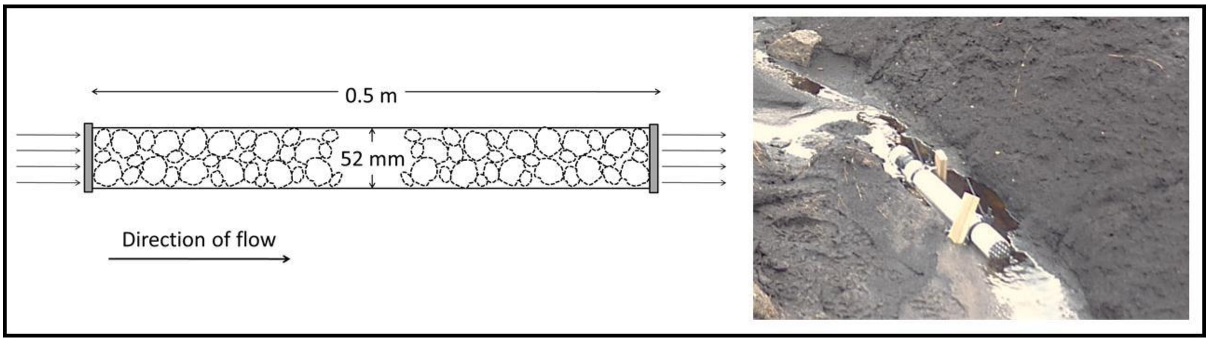

Figure 6.4. Time integrated mass flux sampler designed by Owens *et al*. (2006)

6.8. Water quality monitoring (4ci; 4cii)

The effect of gully blocking on levels of fluvial dissolved organic carbon (DOC) and colour from the site is being monitored at a local and site scale.

6.8.1. Water quality monitoring – local scale (4ci)

At the local scale this involves the collection of a number of water samples from three paired gully systems located on Derwent Moors (see Figure 6.1). Within each paired gully system, one gully was blocked (treatment gully) and one remained unblocked (reference gully). By leaving an unblocked gully it will be possible to determine relative changes in the water quality following gully blocking, as well as absolute differences. Six samples were collected from each of the blocked gullies, upstream and downstream of gully blocks, located at approximately the top, middle and bottom of the gully. Three samples were collected from each unblocked gully, from approximately the top, middle and bottom of the gully. Water samples were collected weekly during an eight week campaign starting on the 12th January 2016 and finishing on the 1st March 2016. This campaign will be repeated during autumn 2016. Water samples were analysed for Absorbance in-house using a Spectrophotometer.

6.8.2. Water quality monitoring – site scale (4cii)

At the site scale this involves monthly spot sampling from two streams; Rising Clough and Ladybower Brook (see Figure 6.1).

A year long programme of fortnightly spot sampling began near the bottom of the Ladybower Brook catchment on 9th January 2012 in an Environment Agency and Severn Trent Water funded Project, assessing the spatial variation in water quality within the water bodies of a Peak District catchment and the contribution of moorland condition (Crouch and Walker, 2013). This project was completed on 4th January 2013; however, sampling within the Ladybower Brook catchment was continued four-weekly, and is ongoing, within the Moscar Science Project. Four-weekly spot sampling began at Rising Clough in October 2014.

At both sites stream water samples are collected using sterile 1000 ml storage bottles that are pre-rinsed with stream water three times. Samples are refrigerated within seven hours of collection and collected by Scientific Analysis Laboratories (SAL) Ltd. within 5 days of sampling. SAL has a maximum turnaround time of 10 days; therefore, samples are analysed within 16 days (as recommended by SAL) for Dissolved Organic Carbon (DOC), Particulate Organic Carbon (POC) and Total Organic Carbon (TOC). In addition to carbon, samples are analysed for colour, electrical conductivity, pH and iron. From 2016 samples will also be analysed in-house for absorbance using a Spectrophotometer.

6.9. Rainfall and water flow monitoring (4d)

In order to calculate a water budget for the site a flow station and rain gauge have / will be installed. The flow station was installed on the 24th February 2016. This consists of a water level data logger (HOBO U20-001-04) suspended inside a stilling well, constructed of plastic pipe. The stilling well is attached to a dexion structure, with a ruler for measuring stage height. Loggers are programmed to record data every 10 minutes. Data downloads will be performed every 4 weeks. The water pressure data will be converted to stage height data using a compatible air pressure file from a barometric logger. Flow gauging will be carried out under a range of flow conditions. This allows water height measurements to be converted to discharge.

A rain gauge (HOBO RG3) has been purchased. This will be installed after the bird nesting season, at the request of the landowner.

7. Results

7.1. Breeding bird surveys (1a; 3a)

Three breeding bird survey visits were carried out within the survey boundary between April and June 2014. Six species of wader and five species of raptor alongside red grouse were observed within the survey boundary during the three breeding bird survey visits. Four waders were confirmed as breeding on site, with one species regarded as a possible breeder and one as a non-breeder. Of the four confirmed breeding waders, curlew were recorded in 20 of the 22 whole or partial 1km OS grid squares that made up the site, making it the most widely distributed wader across the site. Golden plover were found in 16 squares, lapwing in 13 and snipe in 10. Oystercatcher (possible breeder) and woodcock (non-breeder) were recorded in two squares each. No raptors were confirmed as breeding within the site, one was thought to be a probable breeder, three were possible breeders and one was a non-breeder. Buzzard (possible breeder) was the most widespread raptor across the site, and was recorded in 12 of 22 whole or partial 1km OS grid squares. Kestrel (possible breeder) was recorded in seven squares, merlin (possible breeder) in four, short-eared owl (probable breeder) in two and peregrine (non-breeder) in one. Red grouse were almost ubiquitous in suitable habitat and were the most successful breeding species. An additional 19 notable species of predominantly passerine birds were recorded as holding territories on site. In this context notable is defined as being listed as a NERC 2006 Species of Principal Importance, a Bird of Conservation Concern (Red or Amber) or a species listed on the Peak District Biodiversity Action Plan.

No breeding bird survey was carried out in 2015 at the request of the landowner and landowner permission has been refused for a 2016 breeding bird survey.

7.2. Vegetation monitoring - local scale (1b; 3c)

A series of 2 x 2 m quadrats have been set up across three paired gully systems (B, H and L) located on Derwent Moors. A paired gully system consists of two nearby gullies that are approximately similar. Within each paired gully system, one gully was blocked (treatment gully) and one remained unblocked (reference gully). On each gully, quadrats were set up along a transect, with quadrats located at 1m, 5m, 7m and 10m from the gully edge. This was repeated three times per gully, with transects located approximately at the top, middle and bottom of each gully. There are 12 quadrats per gully and 72 in total. All quadrats were set up and baseline monitoring carried out on the 14th, 15th and 16th of December 2015.

Overall, the dominant species at these sites are *Calluna vulgaris* (ling heather) (62%); acrocarp (cushion) mosses (33%); and pleurocarp (feather) mosses (18%). Other ground / vegetation cover types present include dead plant material, followed by bare ground; *Eriophorum vaginatum* (hare's-tail cottongrass); *Eriophorum angustifolium* (common cottongrass); cladonia lichen; *Empetrum nigrum* (crowberry); *Vaccinium myrtillus* (bilberry), as well as standing water and heather brash (see Figure 7.1 and H and L

Table 7.1). These quadrats will be monitored again in 2016 (and subsequent years) to investigate the effect of gully blocking on the species composition of vegetation.

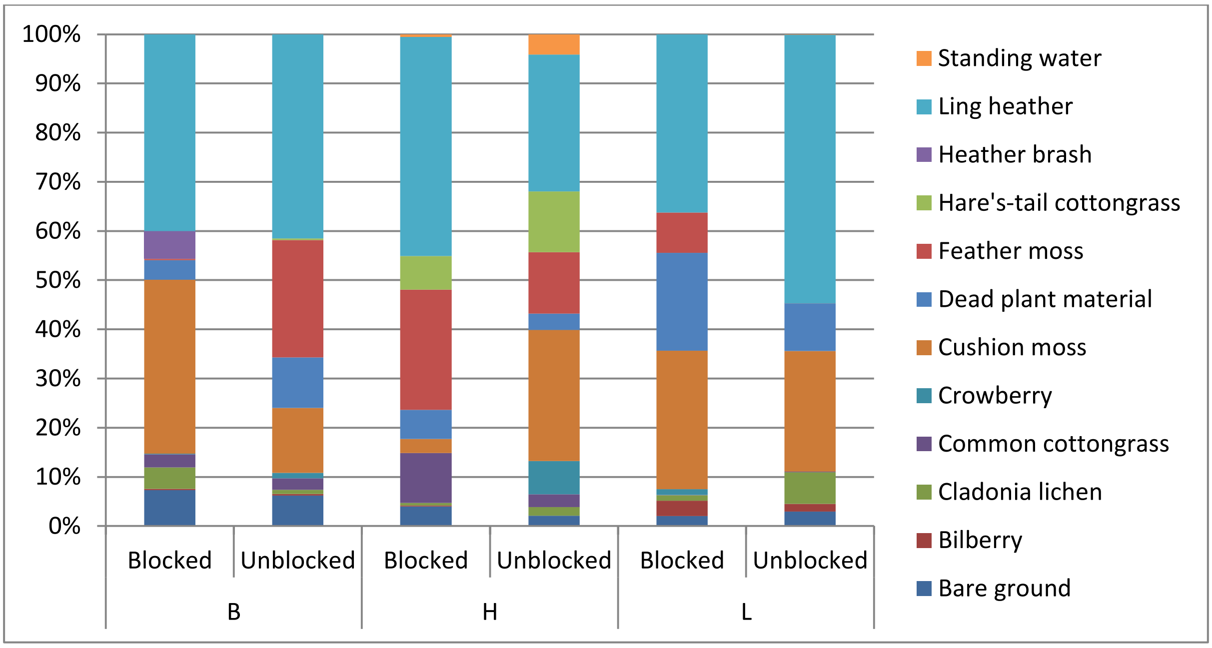

Figure 7.1: The mean composition of ground / vegetation cover at B, H and L

Table 7.1: Mean percentage cover of ground / vegetation cover at B, H and L

Species / variable	Mean percentage cover						
	Bell		Heath		Ling		Total
	Blocked	Unblocked	Blocked	Unblocked	Blocked	Unblocked	
Bare ground	11	10	6	4	3	4	6
Bilberry	0	1	0	0	5	2	1
Cladonia lichen	6	1	1	3	2	9	4
Common cottongrass	4	4	16	5	0	0	5
Crowberry	0	2	0	12	2	0	3
Cushion moss	52	21	4	47	42	33	33
Dead plant material	6	16	9	6	30	13	13
Feather moss	0	37	38	22	12	0	18
Hare's-tail cottongrass	0	1	11	22	0	0	5
Heather brash	8	0	0	0	0	0	1
Ling heather	59	65	68	49	54	75	62
Standing water	0	0	1	7	0	0	1

7.3. Vegetation monitoring - site scale (1c; 3c)

A network of 2 x 2 m quadrats have been set up across the site. This consists of four clusters of ten quadrats; three 'treatment' clusters located on Derwent Moors (Treatment 1 - 3) and one 'reference' cluster located on Moscar Moor (Reference). In 2014, vegetation monitoring was carried out on the 7th, 8th and 28th of August and in 2015 on the 21st, 22nd and 30th of July and the 4th of August. This was prior to the start of gully blocking works and as such these data provide two years of baseline data.

All four locations are well vegetated with very little bare peat. The Derwent Moors sites are dominated by ling heather and feather moss. In contrast, the Moscar Moor site is dominated by hare's tail cottongrass. See Figure 7.2 and Table 7.2 for information on the other ground / vegetation cover types present. These quadrats will be monitored again in 2016 (and subsequent years) to investigate whether the restoration interventions are helping to move the SSSI unit towards Favourable Condition Status.

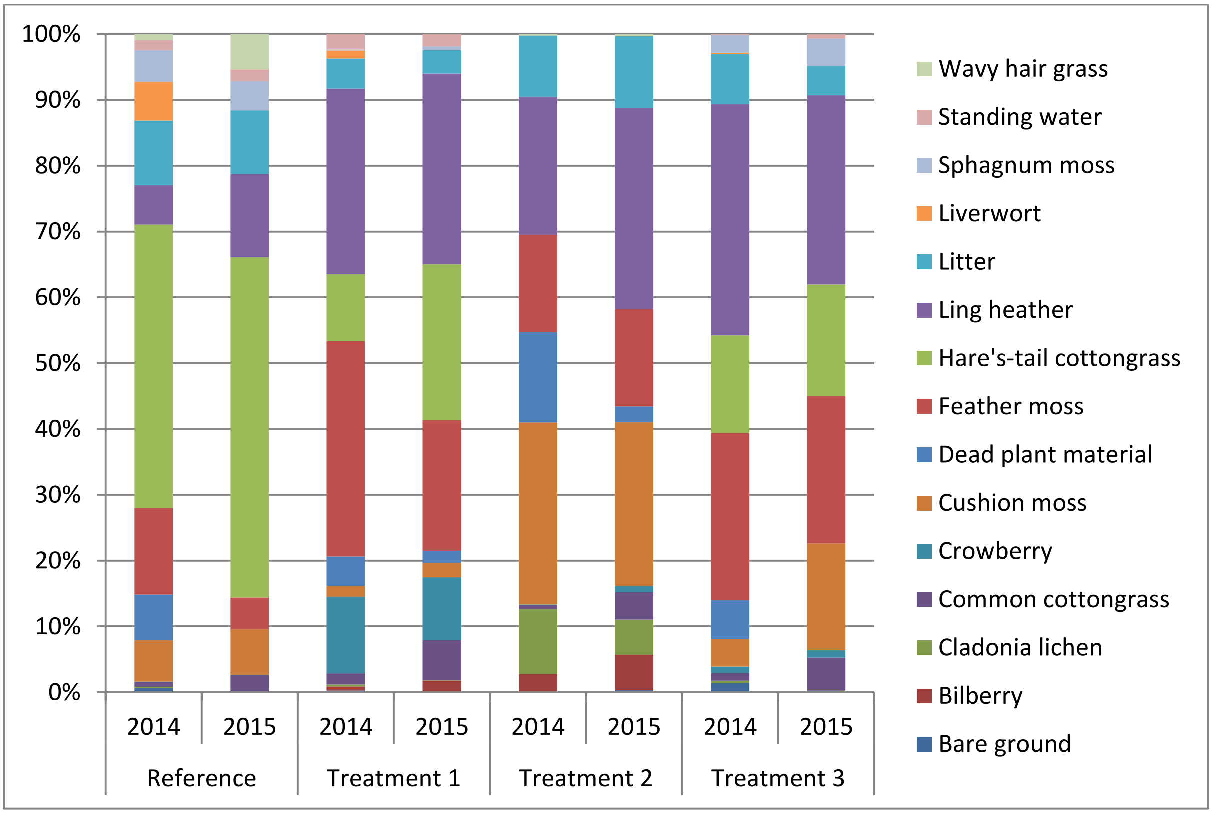

Figure 7.2. The mean composition of ground / vegetation cover at the four study sites in 2014 and 2015

Table 7.2. Percentage cover of ground / vegetation cover at the four study sites in 2014 and 2015

Ground / vegetation cover	Mean percentage cover 2014				Mean percentage cover 2015			
	Ref	T1	T2	T3	Ref	T1	T2	T3
Bare ground	1	0	0	2	0	0	1	0
Bilberry	0	1	4	0	0	2	9	0
Cladonia lichen	0	0	14	0	0	0	9	1
Common cottongrass	1	2	1	2	3	8	7	9
Crowberry	0	16	0	1	0	13	2	2
Cushion moss	8	2	38	6	9	3	42	30
Dead plant material	9	6	19	8	0	3	4	0
Feather moss	17	44	20	34	6	27	25	41
Hare's-tail cottongrass	56	14	0	20	69	32	0	31
Ling heather	8	38	29	47	17	39	51	53
Litter	13	6	13	10	13	5	18	8
Liverwort	8	2	0	0	0	0	0	0
Sphagnum moss	6	0	0	4	6	1	0	8
Standing water	2	3	0	0	2	3	0	1
Wavy hair grass	1	0	0	0	7	0	1	0

7.4. Footpath monitoring (2a)

Visitor use of the Whinstone Lee Tor footpath was carried out at two locations (Wheel Stones and Salt Cellar) on the 18th of July 2015, prior to footpath restoration and again on the 6th of December 2015, after footpath restoration.

7.4.1. Wheel Stones section

Before restoration, on the 18th July 2015, thirty-five walkers were recorded on the Wheel Stones section of path. Of these thirty-five, only four individuals (11%) followed the correct line of the footpath. The remaining thirty-one individuals (89%) walked on an eroded area to the side of the path.

After restoration, on the 6th December 2015, twenty-three visitors (twenty walkers, one runner and two cyclists) were recorded on the Wheel Stones section of path. Of these twenty-three, twenty-one individuals (91%) followed the correct line of the footpath. The remaining two individuals (9%) used the footpath most of the time, moving off the path only to avoid a particularly muddy short section.

This represents an 80% increase in visitors following the correct line of the footpath at the Wheel Stones section following restoration.

7.4.2. Salt Cellar section

Before restoration, on the 18th of July 2015, thirty-five visitors (thirty-four walkers and one runner) were recorded on the Salt Cellar section of path. Of these thirty-five, fifteen individuals (43%) followed the correct line of the footpath; nineteen individuals (54%) used the footpath most of the time, in all cases avoiding the same section of path; and one individual (3%) used the footpath only some of the time, walking mostly over an eroded area.

After restoration, on the 6th of December 2015, twenty-four visitors (fifteen walkers, eight runners and one cyclist) were recorded on the Salt Cellar section of path. Of these twenty-four, twenty-three individuals (96%) followed the correct line of the footpath. The remaining one individual (4%), a runner, used the footpath only some of the time, instead running slightly off the path over rough ground and vegetation.

This represents a 53% increase in visitors following the correct line of the footpath at the Salt Cellars section following restoration.

7.5. Summer grouse surveys (3b)

In 2014, a baseline (pre-works) survey of grouse was carried out between 5th and 7th of August. In total there were 81 registrations with grouse, 40 (108 birds detected – as more than one bird was commonly observed) on Derwent Moors and 31 (109 birds detected) on Stanage Moor. In 2015, surveys of grouse were carried out on 5th of August and between 11th and 13th of August. In total there were 51 registrations with grouse, 22 (49 birds detected) on Derwent Moors and 29 (61 birds detected) on Stanage Moor (Figure 7.3). A paired t-test showed that this was a significant difference ($t = 5.989$, 10 d.f., $P = 0.000$). In 2014, the mean number of grouse per covey was 3 on Derwent Moors and 4 on Stanage Moor; in 2015 this had reduced to two on both Derwent and Stanage Moors (Figure 7.4).

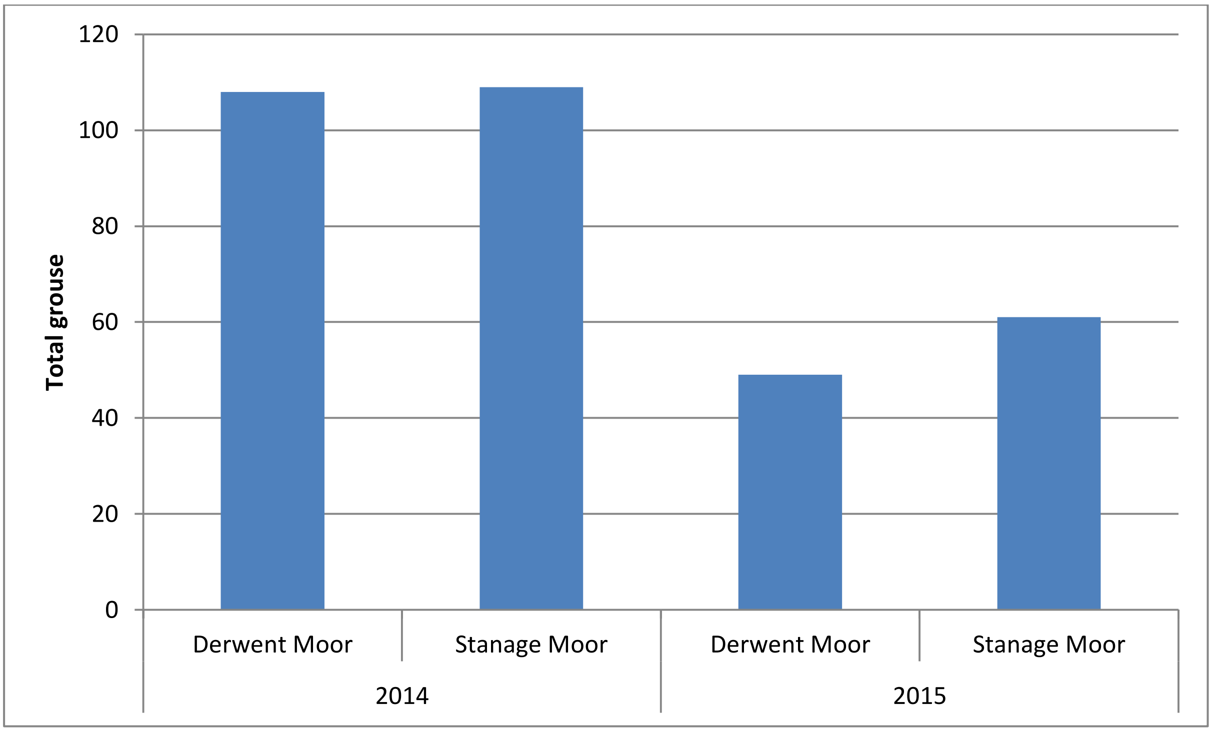

Figure 7.3: Total number of grouse detected on Derwent and Stanage Moors during surveys in 2014 and 2015

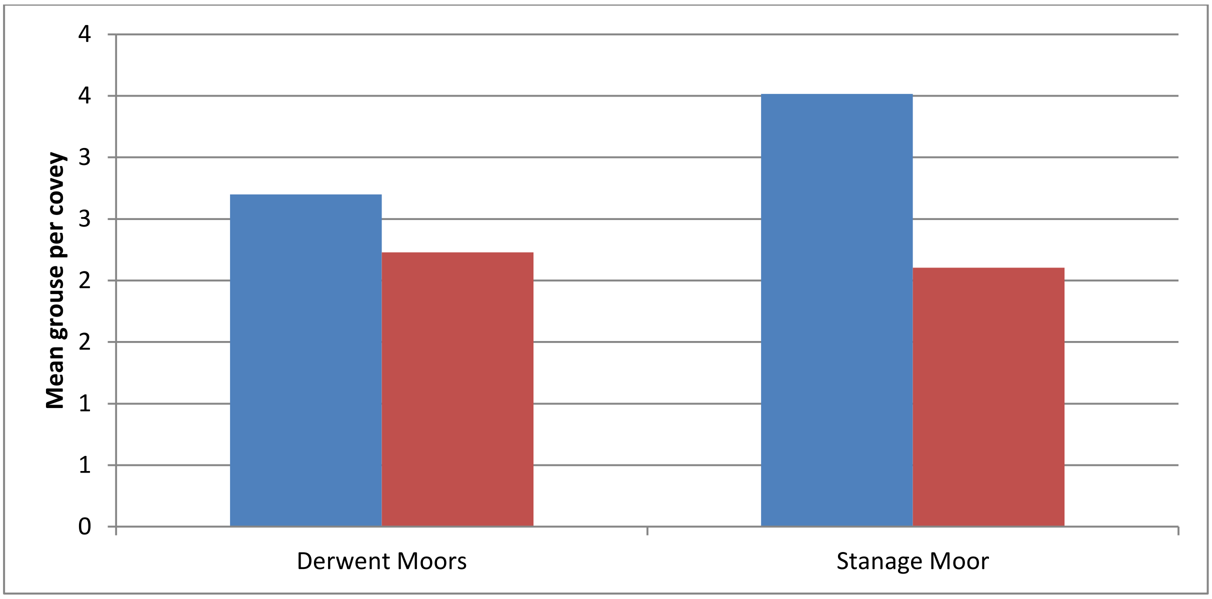

Figure 7.4: Mean grouse per covey detected on Derwent and Stanage Moors during surveys in 2014 and 2015

7.6. Monitoring water tables (4ai; 4aii)

Water tables were monitored using a combination of automated and manual dipwells. Automated dipwells are programmed to log water table height every hour, while manual dipwells are measured weekly during autumn campaigns.

7.6.1. Local scale (4ai)

Dipwell transects were set up across three paired gully systems located on Derwent Moors. Within each paired gully system, one gully was blocked (treatment gully) and one remained unblocked (reference gully). Transects of eight dipwells were installed perpendicular to each gully, with dipwells located 0m, 0.5m, 1m, 1.5m, 2m, 5m, 7m and 10m from the gully edge. This was repeated three times per gully, with transects located approximately at the top, middle and bottom of each gully.

Water tables near to gullies exhibit localised water table drawdown in close proximity to the gully edge. Typically this drawdown extends a few metres from the gully edge (Allott et al., 2009). In **Figure 7.5**, we can see there are deeper median water tables closer to the gully edge (positions 0 and 0.5m) than at 10m distance.

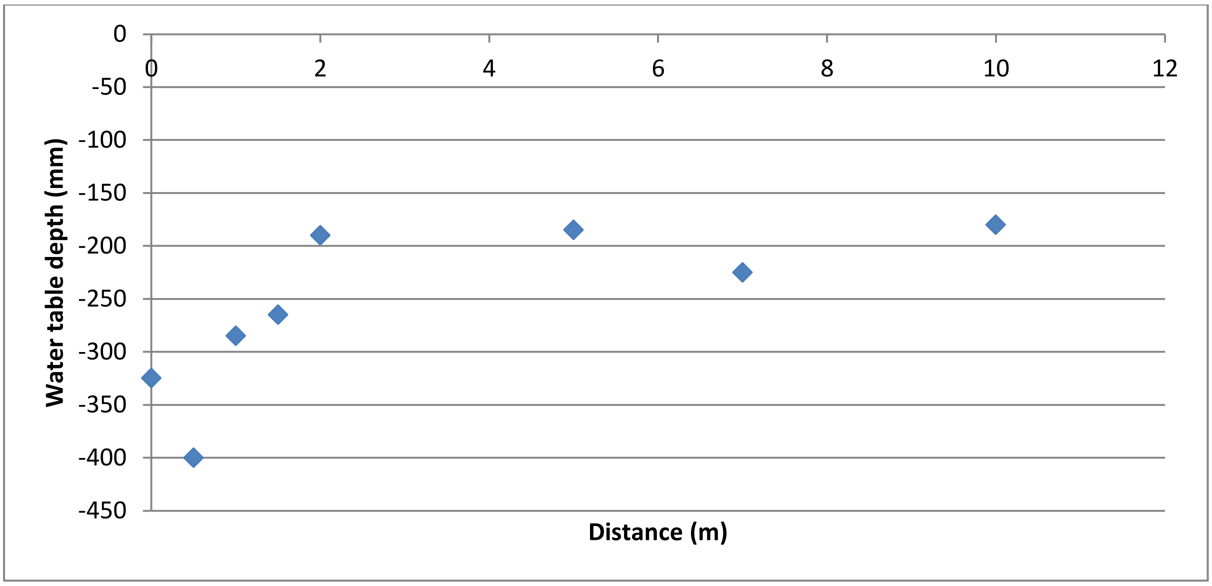

Figure 7.5: Median water table depth along a transect located on an unblocked gully

Using these data it will be possible to calculate the distance of the drawdown effect and the stable interfluve water table away from the gully edge, and after many campaigns, it will be possible to compare the blocked and unblocked gullies for evidence of water table recovery at the blocked sites. In time it may also be possible to note trajectories of water table recovery at the blocked sites by comparing distance of the drawdown effect (as well as the stable water table position) over time.

7.6.2. Site scale (4aii)

Four dipwell clusters were installed; three 'treatment' clusters located on Derwent Moors and one 'reference' cluster located on Moscar Moor. Each cluster consists of one automated and fifteen manual dipwells.

Using the automated dipwell data, it is possible to calculate the monthly mean water table depth for each of the four clusters; this is presented in Figure 7.6 below.

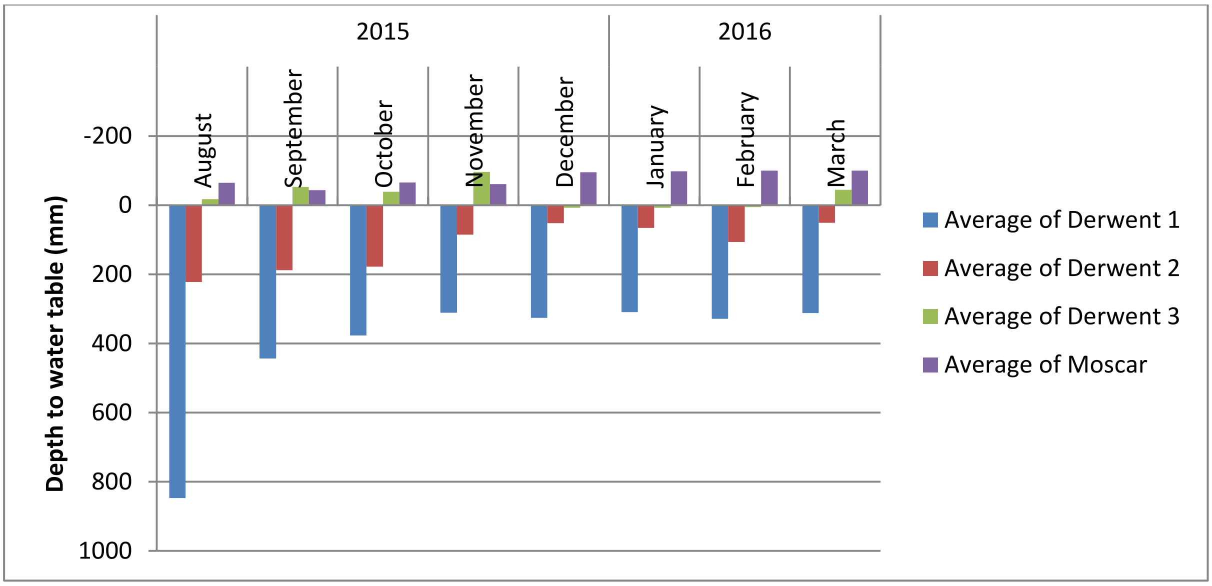

Figure 7.6: Monthly mean water table depth at three treatment sites (Derwent 1, 2 and 3) and one reference site (Moscar)

Using the manual dipwell data it is possible to look for differences in water table depth between years. The results presented below are based on the relative difference between the control site, located on Moscar Moor, and the 'treatment' sites, located on Derwent Moors. This approach eliminates the effect of variability caused by rainfall or temperature, for example, leaving just the effect of treatment. However, in this report two years of baseline data are presented (gully blocking took place between October 2015 and March 2016); therefore we expect the data to be similar, with no significant difference between years.

In 2014, mean water table depth was, on average, 42 mm lower overall at the treatment sites than at the control site. In 2015, mean water table depth was, on average, 37 mm lower overall at the treatment sites than at the control site (Figure 7.7). This is a relative difference of 5 mm. A t-test showed that this was not a significant difference ($t = -0.795$, 21 d.f., $P = 0.435$).

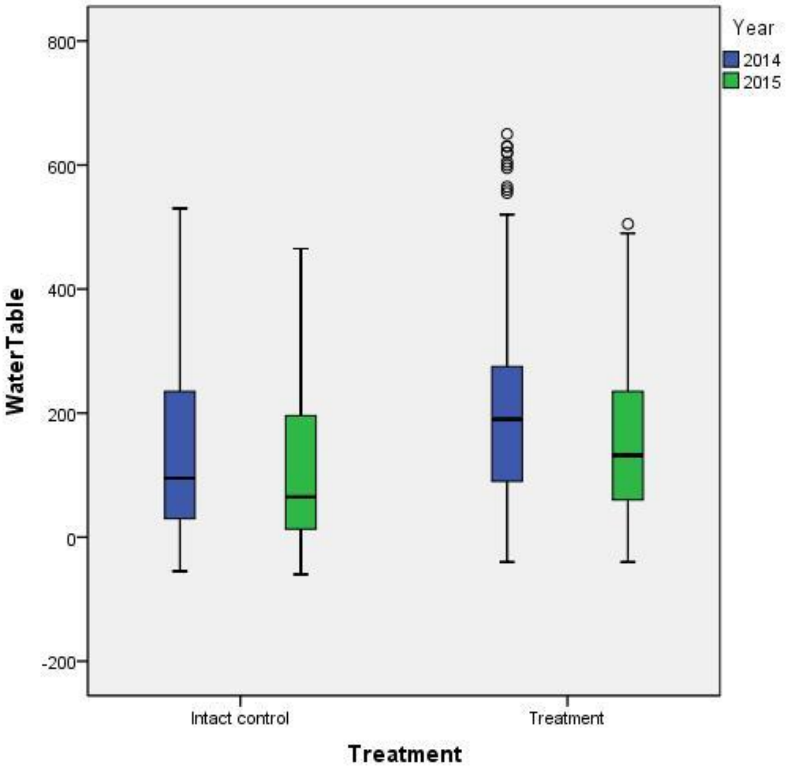

Figure 7.7: Boxplot of water table depth at the control site (Moscar Moor) and the treatment sites (Derwent Moors) 2014 and 2015

7.7. Particulate organic carbon monitoring (4b)

Six TIMS units were deployed between the 4th of February 2016 and the 1st of March 2016. Three of the TIMS units were located in blocked gullies and three in unblocked gullies. The mean value for POC trapped in TIMS units was 3.59 g for blocked gullies and 0.38 g for unblocked gullies.

It is important to note that gully blocking and re-profiling works was carried out between the 1st of December 2015 and the 1st March 2016 across Derwent Moors. All gully blocking and re-profiling of gullies included in this study was complete at the time that TIMS were deployed. The higher POC loss from blocked gullies compared to unblocked gullies can be attributed to the disturbance of the peat caused during the work, particularly the re-profiling work which will have disturbed and exposed areas of bare peat. This will have been exacerbated by above average rainfall during February. It is expected that POC loss will reduce over time; this is supported by findings from the Peatland Restoration Project which demonstrated up to a 99% reduction in POC loss from blocked and re-vegetated gullies compared to unblocked and un-vegetated gullies (Crouch et al., 2015).

7.8. Monitoring water quality (4ci; 4cii)

7.8.1. Local scale (4ci)

Water quality was monitored at three paired gully systems (B, H and L) located on Derwent Moors. Within each paired gully system, one gully was blocked (treatment gully) and one remained unblocked (reference gully). Six water samples were collected from each of the blocked gullies, upstream and downstream of gully blocks, located at approximately the top, middle and bottom of the gully. Three samples were collected from each unblocked gully, from approximately the top, middle and bottom of the gully. Water samples were collected weekly during an eight week campaign starting on the 12th of January 2016 and finishing on the 1st of March 2016. Water samples were analysed for absorbance at 400nm using a Spectrophotometer.

7.8.1.1. Absorbance at 400

Absorbance can be used as a proxy for DOC; water samples with a higher concentration of DOC absorb more light than those with a lower concentration of DOC. Overall the mean absorbance at 400nm is lower in water samples collected from blocked gullies (0.339) than unblocked gullies (0.360 - see Table 7.3), suggesting that DOC is also lower in water samples collected from blocked gullies than unblocked gullies.

Table 7.3: Mean absorbance at 400nm of water samples collected from blocked and unblocked gullies

Gully system	Mean absorbance at 400 nm	
	Blocked	Unblocked
B	0.351	0.400
H	0.260	0.254
L	0.389	0.438
Total	0.339	0.360

7.8.1.2. pH

Overall the mean pH was higher in water samples collected from blocked gullies (4.05) than unblocked gullies (3.97) - Table 7.4)).

Table 7.4: Mean pH of water samples collected from blocked and unblocked gullies

Gully system	Mean pH	
	Blocked	Unblocked
B	4.10	3.87
H	4.07	4.11
L	4.00	3.89
Total	4.05	3.97

The results presented above are consistent with Crouch and Walker (2013) who found a significant negative correlation between DOC and pH at moorland edge sites. Rothwell et al. (2007) also found a significant negative relationship between pH and DOC at Upper North Grain.

7.8.2. Site scale (4cii)

Water quality is being monitored at two streams; Ladybower Brook and Rising Clough.

7.8.2.1. Dissolved organic carbon

At Ladybower Brook, DOC was monitored fortnightly between 12th of January 2012 and the 16th of December 2014. No monitoring took place from January until August 2015, when monitoring was resumed on a monthly basis. During this time, DOC ranged from 1 mg/l to 27 mg/l (Figure 7.8). The mean DOC values for each year are shown in Table 7.5.

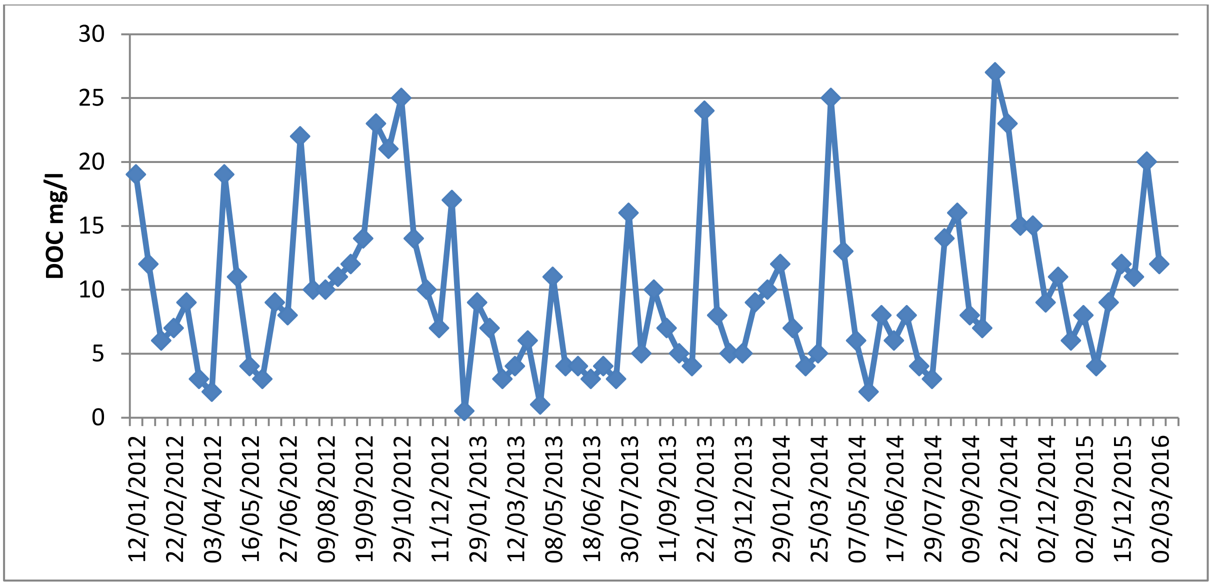

Figure 7.8: DOC concentrations in Ladybower Brook between January 2012 and March 2016

Table 7.5: Mean DOC concentrations in Ladybower Brook between January 2012 and December 2015

Ladybower Brook	**2012 (n = 26)**	**2013 (n = 24)**	**2014 (n = 24)**	**2015 (n = 5)**
Mean DOC (mg/l)	12	7	11	8

At Rising Clough, DOC was monitored fortnightly between the 7th of October 2014 and the 16th of December 2014. No monitoring took place from January until August 2015, when monitoring was resumed on a monthly basis. During this time, DOC ranged from 9 mg/l to 46 mg/l (Figure 7.9). The mean DOC in 2015 was 24 mg/l (n = 5), three times greater than the concentration found in Ladybower Brook during the same period. This is consistent with Crouch and Walker (2013), who found that the concentration of DOC in stream water from moorland edge sites was three times greater than at the bottom of the sub-catchment.

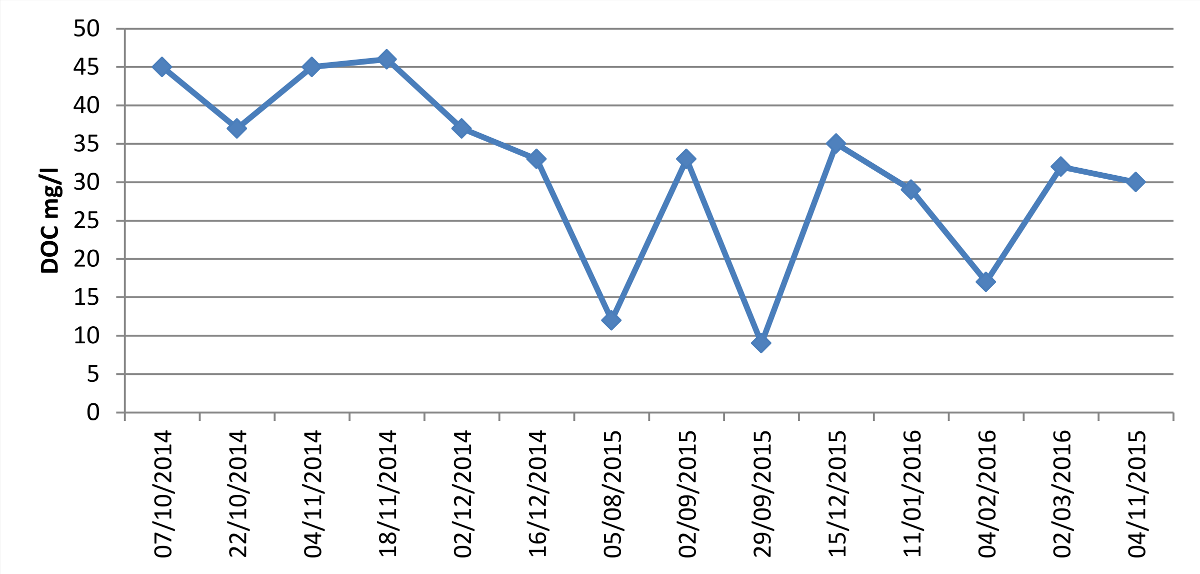

Figure 7.9: DOC concentrations in Rising Clough between October 2014 and March 2016

7.8.2.2. Colour

At Ladybower Brook, colour was monitored monthly between the 12th of January 2012 and the 16th of December 2014. No monitoring took place from January until August 2015, when monitoring was resumed on a monthly basis. During this time, colour ranged from 27 HU to 600 HU (Figure 7.10). The mean colour values for each year are shown in Table 7.6.

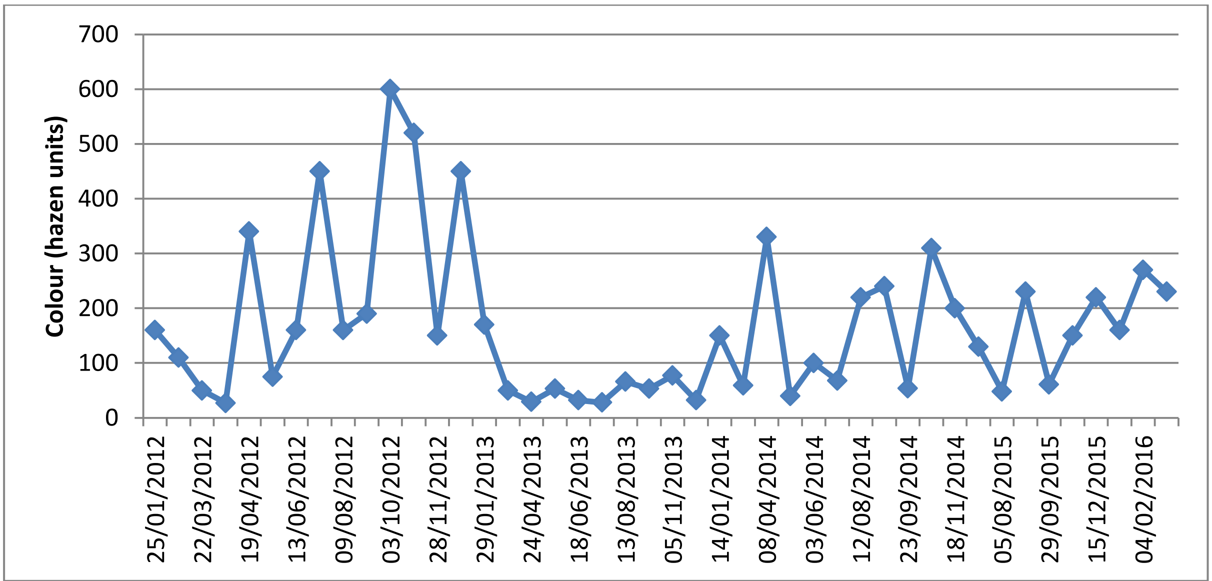

Figure 7.10: Colour concentrations in Ladybower Brook between January 2012 and March 2016

Table 7.6: Mean colour concentrations in Ladybower Brook between January 2012 and December 2015

Ladybower Brook	2012 (n = 13)	2013 (n = 11)	2014 (n = 12)	2015 (n = 5)
Mean colour (hazen)	230	95	158	142

At Rising Clough, colour was monitored monthly between the 7th of October 2014 and the 16th of December 2014. No monitoring took place from January until August 2015, when monitoring was resumed on a monthly basis. During this time, colour ranged from 210 HU to 930 HU (Figure 7.10). The mean colour in 2015 was 572 HU, approximately four times greater than the concentration found at Ladybower Brook during the same period. Crouch and Walker (2013) found that the concentration of colour was 2.9 times greater at moorland edge sites than at the bottom of the sub-catchment.

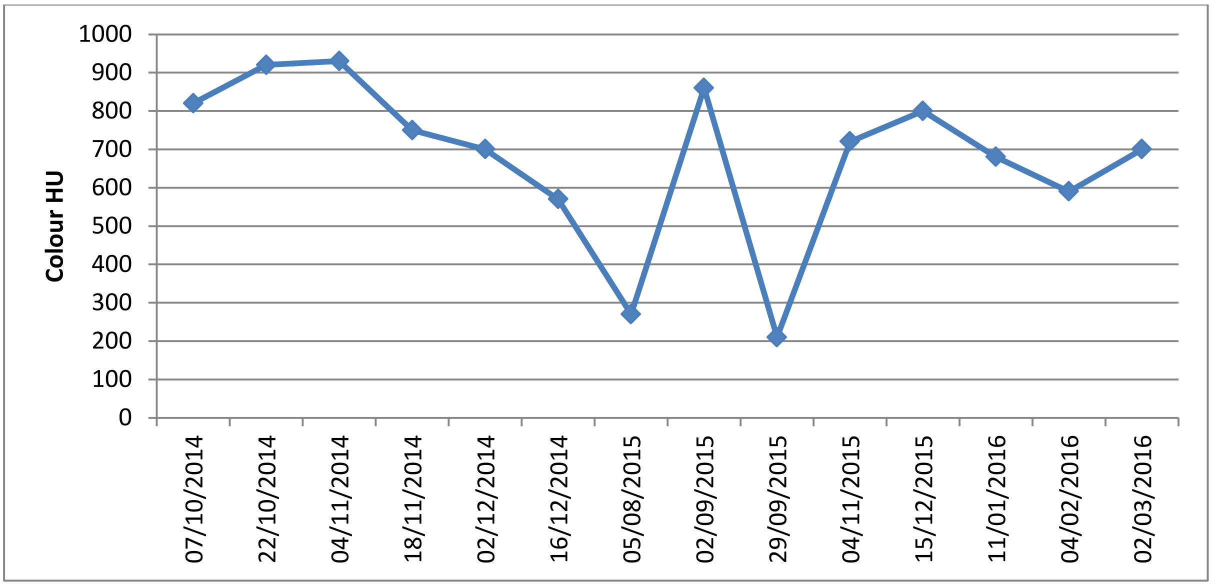

Figure 7.11: Colour concentrations in Rising Clough between October 2014 and March 2016

7.9. Monitoring rainfall and water flow (4d)

The set-up of the water flow station was completed in February 2016. There are no water flow results to present at this stage. A rain gauge has been purchased. This will be installed after the bird nesting season, at the request of the landowner.

8. Proposed monitoring plan for 2016/17

Monitoring activity	Calendar	Objective
Site scale water quality monitoring at Rising Clough and Ladybower Brook	Ongoing every four weeks	4cii
Water flow monitoring at Rising Clough (downloads and manual calibration)	Ongoing every four weeks	4d
Automated water table monitoring (downloads and manual calibration)	Every four weeks (this will recommence after the bird nesting season at the request of the landowner)	4aii
Install rain gauge and carry out rainfall monitoring (downloads)	Every four weeks (this will start after the bird nesting season at the request of the landowner)	4d
Pre restoration footpath monitoring	July 2016	2a
Vegetation monitoring	July – August 2016	1b, 1c and 3c
Grouse survey	July – August 2016	3b
Manual water table monitoring (local and site scale)	Week commencing 26th September – week commencing 12th December 2016	4ai and 4aii
POC monitoring	November 2016	4b
Breeding bird survey	April – June 2017	1a and 3a

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