Ecosystem Services Assessment Report Marches Mosses BogLIFE Project 2016 – 2022

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Credit Stephen Barlow

Restoring Marches Mosses BogLIFE Project (LIFE15 NAT/UK/000786)



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1.0 Introduction

The <u>Marches Mosses BogLIFE project</u> (LIFE15 NAT/UK/000786) is a six-year long project that ran between 1 October 2016 to 31 December 2022. The project's aim was to restore Britain's third largest lowland raised bog encompassing Fenn's, Whixall and Bettisfield Mosses and Wem Mosses National Nature Reserves (NNRs) near Whitchurch, Shropshire and Wrexham in Wales. The LIFE project was led by Natural England working in partnership with Natural Resources Wales and the Shropshire Wildlife Trust. It was financially supported by LIFE, a financial instrument of the European Commission and the National Heritage Lottery Fund.

Lowland raised bogs are defined as, "peatland ecosystems which develop primarily, but not exclusively, in lowland areas such as the head of estuaries, along river flood-plains and in topographic depressions." (JNCC, 2016). They are one of the rarest, and most threatened, habitats in the Europe and are classed as a priority habitat. Within the UK, approximately 94 % of lowland raised bogs have been modified, damaged, or destroyed by human activity. It is projected that further decline is likely to occur through the gradual desiccation of damaged bogs. In favourable condition, lowland raised bogs are a unique habitat which can support a range of specialist plants and animals, including the White-faced darter dragonfly, breeding Eurasian Curlew and a range of Sphagnum mosses.

In the UK there is approximately 6000 hectares of active lowland raised bog habitat (Habitat H7110), of this the Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses complex together comprise 676 hectares. Part of the bog (240 ha) is classed as Habitat H7120 – degraded raised bog still capable of natural regeneration (European Commission, 2013).

The project's aim was to restore the 665 hectares of lowland raised bog at Fenn's, Whixall and Bettisfield Mosses and Wem Moss National Nature Reserves (NNRs), with the ambition to convert areas of degraded bog (Habitat H7120) to active bog (Habitat H7110). This was primarily undertaken through the raising of water levels, removal of woodland and the improvement of water and air quality. Part of the project involved the acquisition and restoration of 63 hectares of land.

1.1 Methodology

The project's effects on ecosystem function has been assessed in terms of the main anticipated impacts on a selected range of ecosystem service indicators relevant to the impact on human wellbeing. These are consistent with Mapping and Assessing Ecosystems and their Services (MAES) (EC 2013, 2014) and the general framework developed by the Common International Classification of Ecosystem Services (CICES) (version 4.3).

Alongside standard statements describing ecosystem service condition, the values 1-5 are also used consistent with the KPI Webtool (Assessing ecosystems and their services in LIFE projects - A guide for beneficiaries) as follows:

Value	Condition
0	Unknown
1	Very poor/bad/non functional
2	Poor/unfavourable
3	Moderate
4	Good/favourable
5	Very good/high

Ecosystem trends are expressed in terms of one of the following descriptors:

- Overall stable
- Deterioration
- Some deterioration
- Improvement and/or deterioration in different locations
- Some improvement
- Improving

A range of data collected during the project has been used to inform this assessment. Sophie Laing, Monitoring Officer, and Robert Duff Project Manager for the Marches Mosses BogLIFE Project who have high level of knowledge of the site and the project actions undertook the assessment presented in this report.

The ecosystem services monitored, the indicators used, data sources/data collected are outlined in Table 1 below:

Service Type	Service description	Indicator	Data source		
Provisioning Service	Provisioning Services				
	Reared animals and their output	Number of livestock	data collected by project staff		
	Fibres	Volume of timber removed	data collected by project staff when timber removed		
	Energy: plant-based resources	Volume of wood removed for energy.	data collected by project staff when wood fuel/chip for biofuel removed		
Regulating Services					
	Maintaining habitats	Area and condition of lowland raised bog and 'lagg' habitats in the site	environmental surveys		
	Maintaining populations	Indicators of size and diversity of invertebrate and bird populations.	environmental surveys		
	Chemical condition of freshwaters	Water quality: pH and conductivity	baseline hydrological survey (conducted under D1) in Year 1 and periodic monitoring (under D2) Year 2 - Year 5		
	Hydrological cycle and water flow maintenance	Hydrology: ground water levels, drainage water flow	Data source: baseline hydrological survey (conducted under D1) in Year 1 and monthly monitoring (under D2) Year 2 - Year 5		

Table 1 The ecosystem services monitored, the indicators used, data sources/data collected

	Air Quality: Maintenance of physical, biological, and chemical conditions NB (not a CICES category)	Air quality: Ammonia deposition	baseline air quality surveys - passive diffuse tube ammonia monitoring (conducted under D1) in Year 1 -5 surveys under D2
	Global climate regulation by reduction of Green House Gases	Amount of carbon stored in peat soils and vegetation	The amount of additional carbon stored, and methane produced to be estimated, using a specialist contractor
	Pest control	Invasive non-native species: cover, species, location and density	
Cultural Services			
	Scientific Knowledge about techniques for bog restoration	Number of people involved in bog restoration technical workshops and/or arranged visits to the site	collected (under D5) by project team.
	Educational - Training/knowledge in bog restoration	Number of people visiting the site in person or remotely (via the website) for purposes of education	data collected routinely by project team on numbers of people visiting for educational purposes (under D5).
	Educational - Training/knowledge in bog restoration	Data collected routinely by project team on numbers of people visiting for educational purposes	data collected routinely by project team on numbers of people visiting for educational purposes (under D5).
	Entertainment	Number of visitors to the site who access it remotely via website	number of visitors (e.g., using webcams) collected via project website (under D5).
	Physical landscape use and experiential use	People who visit the site in person: number of visitors; their perception of the quality of their recreational experience; reason for their visit (e.g., going for a walk, bird watching etc); perceived benefits to well-being; distance travelled.	visitor survey (under D5).
	Existence	Wellbeing arising from nature conservation at the site for volunteers, people who visit the site	surveys of volunteers, visitors, and local residents.

	in person and local	
	residents.	

Additional in-depth consideration of the cultural and socio-economic impact of the project are contained in:

- Restoring the Marches Mosses BogLIFE Project Final Evaluation Report Evaluation of Impact on Local Communities, Other User Groups and Professional Engagement Final: December 2022 Report by Dr Jane Holland, Jill Hall & Dick Willis of Plantagenet Consulting Ltd;
- Socio-economic analysis of the Marches Mosses BogLIFE Project September 2022 by Matt Georges – Orbital Applied Economics Ltd. for Natural England.

Assessment of Services

2.0 Provisioning Services

2.1 Livestock

A small number of pasture fields on the peatland periphery of the site were seasonally grazed by low numbers of stock, approximately 20 cows and around 30 sheep per year during the project. On several traditionally grazed fields (Section 21, Section 33.3, Section 34.1, and Section 34.2) grazing ceased following their rewetting by peat bunding (Action C3) to avoid the bunds being destroyed by animal hooves. Elsewhere across the site the high density of deep drains and peat cuttings make the greater part of it unsuitable for livestock. Accordingly in terms of this provisioning service it is assessed that the site is poor but stable. Increasing the livestock numbers is not in keeping with the conservation objectives for the bog and is not consistent with the biodiversity goals and other services provided by the site.

Provisioning Services - Livestock		
Cor	ndition	Trend
2	Poor	Stable

2.2 Timber

Plantation forestry removal (Action C2) of Sections 48, 50, 51, 52 and 37 at Fenn's Wood resulted in 7,557 tonnes of timber and brash being extracted off-site and utilised commercially by Clifford Jones Timber group, a leading local processor of timber products. A smaller contract by Redwood Tree Specialists generated 160 – 190 tonnes as woodchip was used for biofuel between 2019 and 2020. Another 180+ tonnes were taken as roundwood timber. Brash has also been used on the project site to create dead hedges and as habitat piles to improve shelter for wildlife including the local adder population.

In summary, measures were taken to ensure as much of the wood cut on site was productively utilised and given a secondary use. The large-scale removal of 90 ha of tree clearance as part of forest to bog restoration and land-use change resulted in a large short-term spike in useable timber production that will not be sustained into the future as most of the cleared woodland areas will not replanted but instead will be reverted to open bog habitat.



Photo of harvested timber stack at Section 48 Fenn's Moss (credit NE)

Overall, more than 8000 tonnes of timber and brash products were extracted and given a secondary use during the project representing a large but temporary short-term increase.

Provisioning Services - Timber		
Cor	ndition	Trend
3	Moderate	deterioration

3.0 Regulating Services

3.1 Biodiversity and Habitat

The Marches Mosses BogLIFE Project site is a NNR, SSSI, SAC and Ramsar site. It is designated based on its rare habitat types (see introduction) as well as it's invertebrate and the breeding bird assemblages. It is also home to a range of rare and specialist bog plants in particular many species of the peat forming Sphagnum mosses.

3.1.1 Habitat and vegetation

As a result of the additional land acquisitions over the last decade and the investment in restoration under the BogLIFE Project, there has been a 96 ha or 10% increase in the area protected and directly managed as part of the National Nature Reserve. The NNR now extends to 764.99ha (583.95 ha lies in Wales and 181.04 ha in England) representing 82% of the designated SAC/Ramsar site. As well as providing greater protection for the site, the larger site enables a more integrated and holistic approach to be enacted in the restoration of its complex hydrology.

A map of broad habitat types (Figure 3.1.1.1) produced of the project site based on aerial photographs taken July 2021 features a mosaic of bog, fen and heath habitats.

Aerial photographic images dated July 2021 were used to produce a map of the broad vegetation types. The results can be seen in **Figure 3.1.1.1**. It was not possible to produce a comparable analysis of it with 2015 drone imagery although visual comparison is possible. The map below does however provide a baseline against which future changes can be assessed against. The target habitats of heath and cotton grass represented by the purple and yellow areas respectfully cover much of the site (37%). It is likely that the areas of Mixed vegetation and water (7.7%), represented by turquoise, will transition into these target habitats. Molinia, one of the species which the project aimed to attempt to control, continues to dominantly cover 22% of the project area according to this method of classification.

Broad Habitat type	Area of habitat (Ha)	% of habitat
Artificial Surfaces	3.30	0.42
Bare Ground	22.21	2.80
Bracken	106.81	13.45
Broadleaved Woodland	46.98	5.92
Cotton Grass	184.04	23.18
Heath	115.16	14.51
Mixed water and vegetation	61.45	7.74
Open Water	9.42	1.19
Other Grassland	44.19	5.57
Purple Moor Grass	175.58	22.12
Scrub	24.74	3.12
Sum	793.88	100.00

Table 2 Estimated % broad habitat cover July 2021- Fenn's, Whixall and Bettisfield and Wem Mosses

Large-scale shifts in habitat from degraded bog vegetation communities to wetter bog vegetation communities appears to be in progress following Action C3 and C4 to rewet large areas of the site. The biggest determinant of the rate of transition to boggy vegetation communities are water table levels which are often affected by the topography and microtopography.



Figure 3.1.1.1 Broad habitat map of Fenn's, Whixall, Bettisfield and Wem Mosses.

Detailed vegetation monitoring on the uncut areas of the site using multiple quadrats carried out as part of Natural England's Long-Term Monitoring Network in 2016 and 2021 are categorised as NVC vegetation communities M2, (*Sphagnum cuspidatum/recurvum* bog pool community), M18 (*Erica tetralix - Sphagnum papillosum* raised and blanket mire) and M19 (*Calluna vulgaris - Eriophorum vaginatum* blanket mire). All of these vegetation communities are relatable to the target Habitat H7110 – active raised bog (JNCC 2022). Whilst limited in its spatial distribution these survey results are promising signs.

As a result of the impact of peat extraction many of the bog's rare plant species have been lost from large areas of site and are restricted to small vulnerable populations. Following the restoration of favourable habitat conditions, a trial to assist the dispersal of one of site's rarest plant species was undertaken. Bryophyte specialist Des Callaghan, transplanted 10 specimens of *Dicranum undulatum* from an area supporting a healthy population to a new location which was identified as having favourable conditions. The effectiveness of this is being monitored annually (Callaghan, 2020).



Photo of Waved Fork Moss Dicranum undulatum, Bettisfield Moss (Credit Des Callaghan)

As part of a trial to revert pastureland on deep peat to bog habitat, micropropogated plug plants of sphagnum (derived from sphagnum collected from the site and bulked up) and cotton grass species were planted in bunded 'cells' following turf removal (Micropropagation Services (E.M.) Ltd, 2020). Sphagnum plugs were also introduced to some of the de-forested bunded areas to trial whether this treatment speeds up the re-establishment of bog vegetation. As the planting took place in 2021 it is too early to know what the long-term outcome will be in terms of its effectiveness however it should help ensure that key species of sphagna are present in these bare and sparsely vegetated areas.

In 2022, healthy hummocks of the nationally scarce bog moss *Sphagnum pulchrum* were observed on Wem Moss. The bog moss had not been officially recorded at the site for many years and its appearance indicates the return of wetter more favourable conditions as a result of the peat bunding work carried out to increase the wetness of the area (Action C3).

Overall, good progress is evident. There is a marked and discernible shift in vegetation types from drier to wetter vegetation communities following large-scale rewetting works carried across the mosses (Action C3 and C4). The July 2021 broad habitat survey shows this however experience suggest that effects of wetter conditions on vegetation may take between 3- 5 years to manifest themselves.

Notwithstanding, this the vegetation types occurring across the site remain variable as different parts are at different stages of restoration. Consequently, some areas are achieving a good condition whilst others are not. A key determinant of rate of transition is the water level which can be achieved, and this is heavily influenced by the highly modified surface topography and microtopography which varies considerably across the site.

Overall, the habitat and vegetation, taking a conservative view, is assessed as being in a **moderate condition with some improvements.** Even though the target species are widely distributed across

the site, there are still significant areas that would benefit from improvement through Molinia control and/or scrub management.

Provisioning Services – Biodiversity: Habitat and Vegetation			
Cor	Condition Trend		
3	Moderate	Some Improvement	

3.1.2 Birds

The site is important for its bird assemblage. Up to June 2022 179 bird species had been recorded on SAC site (NBN, 2022) and this does not include the Sinker Fields, an area which is known as a local birding hotspot. The restoration of the World's End Fields and the Sinker Fields and the building of the new bird hide is likely to generate further new records for the project site.

Curlew is a particularly important species. The population in Wales is in sharp decline and is estimated to be declining at 5% per year. The 2021 the Wales Action Plan for the Recovery of Curlew estimated the breeding population of Fenn's and Whixall Mosses to be 6-7 pairs of curlew (Gylfinir Cymru/Curlew Wales,2021). This is supported by the results of a survey in 2019 carried out by project volunteers which concluded that the site supported at least 5 breading pairs. This makes it one of the best-known locations for curlew in Wales.



A clutch of curlew eggs on Fenn's Moss monitored by a camera trap (Credit: NE)

During the project annual surveys of nightjar were carried out. Due to the type of the surveys and because the bird is a highly mobile, it proved difficult to arrive at an exact population figure. Without radio tagging it was only possible to confirm that the birds were separate individuals when either they were heard calling simultaneously or they were observed at the same time. Even with these limitations the 2022 and 2021 surveys identified at least two breeding pairs and at least three males. It is highly likely that this is an underestimate. The surveys also helped identify several suspected

nesting areas. This latter information helped inform the timing of planned habitat management works to avoid and prevent unnecessary disturbance.

The 2019 Shropshire Breeding Snipe Survey contains records of drumming and chirping snipe in 2017-2019 at Whixall Moss and represent the first evidence of breeding snipe on the site since 1995 (Smith, 2020). It is considered that the shallow pools often present within the bunded cells provide attractive breeding habitat for snipe.

Overall, based on the bird assemblage, the project site is in good/favourable condition with some improvement.

Provisioning Services – Biodiversity: Birds		
Cor	Condition Trend	
4	Good	Some Improvement

3.1.3 Invertebrates

The White-faced darter dragonfly, *Leucorrhinia dubia*, has spread considerably since the site was designated a NNR in 1991 (Figures 3.1.3.1 and 3.1.3.2) benefitting from the habitat restoration management. During the LIFE Project monitoring indicates the population has remained relatively healthy and stable. It is expected the large increase in *Sphagnum cuspidatum* dominated pools formed following peat bunding work will result in an increase in the dragonfly's population and distribution on site.

A rare caddis fly *Window winged sedge*, <u>Hagenella clathrata</u> is a key feature of the site. Early bunding work in 2018 in Section 17 may have caused areas of the previously suitable habitat for *H. clathrata* (i.e., with large seasonally wet Molinia tussocks) to become overly wet. Since this issue was highlighted by Ian Wallace, the national specialist for the species, care was taken in the remaining habitat to ensure that other known hotspots were avoided. Further surveys were conducted by Ian and Brenda Wallace who offered advice and recommendations on site management for the species.

Although the species' habitat requirements are poorly understood there is a possibility that some of the areas which previously were unsuitable for it through drying out will improve because of the rewetting works. However, *H. clathrata* is not considered to be a very mobile species and so there is considerable uncertainty over whether these areas will be colonised in the future or not. The key conservation priority for the species moving forward is monitoring and maintaining in a suitable condition the existing known habitat patches.

Another rare caddis fly is *Anabolia brevipennis*. Fenn's Moss is the only known location for it in Wales and its presence was confirmed during a survey in 2021 (Wallace, 2021). It is associated with wet woodland. The re-wetting of the site may be helping to improve the wet woodland habitat conditions, but it is too early to say this with certainty. Future targeted surveys are needed to monitor the status and trends of this species.

The Argent and Sable moth *Rheumaptera hastata*, *Ancylis tineana*, a *tortricoid* moth, and *Sterrhopterix fusca*, a *psychid* moth were also highlighted as rare or threatened lepidoptera species at potential risk from the impact of the bog habitat restoration works and particularly the removal of young birch which they all have an association with. Annual targeted surveys were carried out by invertebrate specialist, George Tordoff of Butterfly Conservation (Tordoff, 2017, 2018 & 2022). The abundance of the species recorded varied between survey years. The most recent 2022 survey confirmed that all three species remain present. The Argent and Sable moth however was only

found in very low numbers but because this was the case in all the survey areas including areas where no restoration works had been undertaken, it was considered likely this may be related to the natural population flux rather than habitat change caused by bog restoration management.



Photo of the jumping spider Sitticus caricis (Credit Stephen Barlow)

Spider surveys carried out in 2017 and 2018 by specialist Richard Gallon confirmed that *Sitticus floricola* and *Sitticus caricis* were both present on the site. Fenn's and Whixall Mosses NNR is the only location in the UK where these two species have both been recorded together (Gallon and Burkmar, 2018). *S. caricis* is a UK Biodiversity Action Plan Priority Species and even though more common, *S.floricola* is also very restricted in its national distribution. Both species are bog specialists and *S. caricis* has benefitted from tree removal on other sites (British Arachnological Society 2022). The LIFE Project works appear in line with its known management requirements.

Carorita limnaea was also recorded during these surveys. This is the first time it has ever been recorded in Wales and is the second time it has been found on the NNR. *C. limnaea* is a bog specialist only recorded at two sites in the UK making it an important find for the site. The species requires a wet habitat conditions and should potentially benefit from the rewetting works.

A most well-known butterfly of the Mosses is the Large heath, *Coenonympha tullia* ssp. *Davus*. The presence of a healthy population is recognised as a bioindicator of peatland sites in optimal condition (Osborne *et al*, 2022). Butterfly transect monitoring on site undertaken over 30 years since 1991 by volunteers continued during the BogLIFE project. The records demonstrate how the abundance of this specialist bog species has increased and its distribution has expanded because of progressive bog rehabilitation management. The mean annual count of the butterfly between 1993 – 2001 was 21; between 2007-2014 it had increased to 184 (Butterflies of the West Midlands) and between 2018 and 2021 the mean count was 163 (though the transect routes were altered in 2018). With a further expansion the area of favourable habitat supporting its food plants like Hare's tail cotton grass expected as a result of the BogLIFE rewetting works, the NNR should continue to serve as a resilient regional stronghold for the species.

Overall based on invertebrates the site would be considered very good/high condition but with both improvements and deterioration in different locations.

Provisioning Services – Biodiversity: Invertebrates		
Condition Trend		
5	Very Good	improvements and deterioration in different locations



Figure 3.1.3.1 Map of White-faced darter records (both survey and incidental) pre-1993. Includes data from NBN (*NBN Atlas occurrence download at https://nbnatlas.org accessed on Thu Jun 23 08:19:21 UTC 2022*)



Figure 3.1.3.2 Map of White-faced darter records (both survey and incidental) between 2012 and 2021. Includes data from NBN (*NBN Atlas occurrence download at https://nbnatlas.org accessed on Thu Jun 23 08:19:21 UTC 2022*)

3.1.4 Mammals

Water vole surveys in 2021 of the original Bronington Manor Drain (BMD) showed that there were frequent signs of active water voles in this area (see figure 3.1.4.1). As a result, damming work on the old BMD had to be carried out under a protected species licence and in a manner so as not to harm animal. Signs of water vole have also been recorded in other parts of the periphery of site i.e., in 2017 at Slack's Drain Bridge (Section 56) and in 2022 at Wem Moss and Barnston's North-West (Section 51). These sightings indicate that water vole remain present and may be extending their range.



Figure 3.1.4.1 Water vole records in 2021 along the Bronington Manor Drain.

Baseline static bat activity surveys (Latham, 2017) were undertaken by bat survey specialist, Mark Latham. The seven bat species were identified on site: common pipistrelle, soprano pipistrelle,

Nathusius' pipistrelle, noctule, Daubenton's bat, Natterer's bat and brown long-eared bat. Of these soprano pipistrelle, noctule and brown-long eared bat are UK Biodiversity Action Plan species. Pipistrelles were found predominately on the open moss whereas the other species were mainly detected around the wooded edges of the site. Given this, bat roost checks were carried out in any areas where tree felling took place. Trees that considered to have high bat roost potential were retained where possible. New bat boxes were also erected in areas of mature trees to add to the availability of potential roosting habitat.

Around the edges of the site, badger holes and setts occur occasionally and in carrying out restoration works close to active badger setts mitigation measures were taken to avoid harm and minimise disturbance.

The condition assessment f	for mammals is	moderate and	stable
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Provisioning Services – Biodiversity: Mammals		
Cor	ndition	Trend
3	Moderate	Stable - improvements
		and deterioration in
		different locations

3.1.5 Reptiles

Fenn's, Whixall, Bettisfield and Wem Mosses support the largest remaining adder population in Shropshire and is considered a strong hold for the species nationally (Nigel Hand, Central Ecology 2022).

As adders are sensitive to habitat change, species specific monitoring was carried out during the LIFE Project to help inform decisions regarding avoidance of harm and mitigation. Adjustments were made to peat bunding plans to ensure adder hibernacula were not disturbed or damaged where possible.

The site also supports a healthy population of common lizard.

Condition assessment for reptiles is good/high but with both improvements and deterioration in different locations.

Provisioning Services – Biodiversity: Invertebrates		
Cor	Condition Trend	
4	Good	Improvements and
		deterioration in
		different locations

3.1.6 Invasive Species Management

At the start of the project the following non-native invasive species (NNIS): Himalayan Balsam, New Zealand Pigmy weed (aka Australian Swamp Stonecrop), Rhododendron, Pitcher Plant and Japanese Knotweed were known to occur in isolated locations. Hybrids of Spanish bluebell have also since been identified and added to this list. Fortunately, these species all occur at a low level and are assessed to pose a low short-term risk. Nevertheless, to gain a better understanding of their status monitoring of NNIS was undertaken over the course of the project involving field visits and the

collection of incidental records. This in turn, informed appropriate removal action with further post-treatment monitoring carried out to assess the success of the intervention.



Photo of Japanese knotweed at Section 49 before and after control treatment 2018 (Credit NE)

There was a marked reduction in NNIS on the NNR down from 20 locations in 2017 to 9 locations in 2022 (see figure 3.1.6.1). As the NNIS recorded on site tend to be isolated individuals, the risk of further spread to the point of causing a problem for the conservation of the site is judged to be very low. The monitoring and action to remove NNIS will carry on after the project finishes to ensure the reduction trend continues.

The condition assessment for the site based on the control of non-native invasive species would be good/favourable and improvement.

Provisioning Services – Biodiversity: Invasive Species		
Condition Trend		Trend
4	Good	Improvement



Figure 3.1.6.1 Map of Non-Native Invasive Species occurrences on the NNR and whether they have been treated.

3.2 Hydrology and Air Condition Assessment

3.2.1 Hydrological levels and Flow rates

Analysis of the extensive water level monitoring results was carried out by both the BogLIFE team and by Dr Sam Leader, a hydrologist. Bettisfield Moss was the first area to undergo large scale bunding. The initial findings for Bettisfield Moss show that it is significantly wetter compared to before the bunding, beyond what would be explained by differences in annual weather patterns (Leader, 2020). It is expected that in many of the more recently completed bunded areas a similar improvement will result. However, for the areas bunded in 2020 and 2021 it is too early to say for certain what the overall effects will be, as not enough time has passed between the works being completed and the data being analysed.

Monitoring results show more of the rain fall is held in place on the Mosses for longer with the cell and contour bunds and dams acting together to filter and slow the flow offsite. The flow of water leaving Fenn's Moss measured at the main control weirs were substantially lower in 2019 compared with before the project started in 2015. As result the peak flows of the watercourses downstream at times of flooding downstream will be lessened. In addition, the slow filtration of water through Mosses also helps keep the River Dee and River Roden that much cleaner too.

The condition assessment for the water tables would be moderate but improving.
Provisioning Services – Hydrology and Air Condition Assessment: Hydrological

Provisioning Services – Hydrology and Air Condition Assessment: Hydrological			
levels and Flow rates			
Cor	Condition Trend		
3	Moderate	Improvement	

3.2.2 Water Chemistry

Under the BogLIFE Project several surveys were undertaken to investigate water quality issues and where appropriate action was taken to tackle these.

Ground First (2019) carried out a water quality assessment of Furber's former scrapyard to understand the contamination risk to the local water courses and the SAC. The assessment identified the former car breakers yard as a source of localised pollution, but this was found to largely contained within the yard area itself. Since the remediation of the scrap yard (Action C5) was completed there have been no signs that the clean-up works caused any increase or further mobilisation and spread of pollution in the surrounding areas. Time-series data show that the levels of pollutants are reducing over time at locations sampled away from the scrapyard. In 2019, many were at or below the detectable limit. The retention of the concrete apron on the yard is thought to be helping contain in-situ any pollutants beneath it in a state of low mobility. Specialist advice considers containment of the pollutants under the concrete apron and elsewhere under a soil cover layer as an appropriate remediation approach for the site given the circumstances and risks.

Thirty years ago, pig slurry spilled onto Wem Moss for several years from a nearby farm. The extent to which this episode continues to affect the edge 'lagg' zone of Wem Moss was unknown. To investigate this a water quality assessment was carried out by Stantec Ltd, a specialist contractor (Stantec, 2018). They found that most of the contaminants tested for were found in their highest levels along the eastern edge of the site coincidental with the location of the pig slurry incident. The

central 'lagg' area also showed elevated nutrients levels but there was otherwise a decline from east to west across the site. Overall, the effects of the incident continue to impact Wem Moss and are likely to be affecting its vegetation.

However, it is likely that bunding carried out at Wem Moss will help to reduce the effects of the high nutrients on the core bog area. Some evidence to support this was found in the pH and conductivity survey (Walters, 2022). pH levels were lower within the bunded areas compared to the nearby 'lagg' area, a finding which supports the notion that the bunds help to reduce the spread of nutrient rich water.

pH and conductivity surveys were also carried out elsewhere around the NNR on target ditches and drains associated with elevated nutrient levels. The most notable one of these was the old Bronington Manor Drain (BMD). This carried mineral rich water from the adjoining farmland across a portion of the bog until a new large-scale 3 km diversion route was created to send the water around the northern edge of the NNR instead. Following this diversion pH levels dropped in the old, dammed BMD. This is a positive indication that the diversion is working and conditions in the old BMD are reverting to those associated with peat bog conditions.

The overall condition assessment for water chemistry would be moderate with some improvement.

Provisioning Services – Hydrology and Air Condition Assessment: water chemistry		
Condition Trend		Trend
3	Moderate	Some Improvement

3.2.3 Ammonia

Fenn's, Whixall, Bettisfield and Wem Mosses are exposed to higher than recommended concentrations of aerial ammonia (NH3). The recommendation for the protection of bryophytes and lichens is an annual mean below 1 μ g NH3 m⁻³. This was exceeded at each of the site's four monitoring stations between 2017 – 2022 (Tang *et al*, 2022). However, it is worth noting that there was a reduction in 2021 particularly at the most north westerly monitoring point, which consistently recorded the highest concentration of ammonia during the project. The levels here fell significantly from 3.4 to 2.3 μ g NH3 m⁻³ but still twice the recommended level. The decrease in the concentration here coincided with the closure of the nearby aluminium smelting plant. The ammonia concentrations on the NNR will be monitored after the LIFE project so it will be possible to see if the reduction in levels continues.

The condition assessment relating to ammonia/ air quality would be poor/unfavourable but with some minor improvement.

Provisioning Services – Hydrology and Air Condition Assessment:		
Ammonia		
Condition Trend		
2	Poor	Improvements and
		deterioration in
		different locations

3.3.3 Global climate change regulation through greenhouse gas reduction

There are different ways of estimating carbon greenhouse gas emissions from a peat bog including direct measurement or indirect methods based on models that in part rely on other published emission factors. To estimate the amount of greenhouse gases emitted from Fenn's, Whixall, Bettisfield and Wem Mosses, Professor Fred Worrall, Durham University applied the Durham Carbon Model (Worral, 2022). Using this method, it was estimated that the BogLIFE Project site was a net carbon sink in 2016 with a predicted additional marginal improvement by 2022. The estimated total sink size went from -4.2 ktonnes CO_{2eq}/yr to -4.3 ktonnes CO_{2eq}/yr as a result of the works already completed by the LIFE project. It is thought that this could reach an estimated sink size of -5.2 ktonnes CO_{2eq}/yr with the development of a comprehensive sphagnum moss vegetation community cover. It is likely that the higher and more stable water tables achieved during the LIFE Project will result in a continued development of bog vegetation and size of the sink will continue to increase. He also estimated the amount of carbon stored in the Fenn's, Whixall and Bettisfield Mosses SAC to be 1,183,000 (± 99,000) tonnes C. This is the equivalent to annual greenhouse gas emissions of just over 4 million UK citizens.

Other research on site (Creevy *et al*, 2020) involved direct measurement of greenhouse gas emission fluxes relation to the restoration of previously forested areas back to bog. The researchers found that restoration to bog habitat is effective in returning the carbon sink function of areas damaged by commercial forestry although this took over 10 years to achieve. The most important factor determining the reductions in greenhouse gas emissions was the vegetation composition, with a sphagnum cover with other vascular plants the most effective. The sphagnum plug planting trialled on parts of the recently cleared and restored ex-forestry area in combination with rewetting may help to speed up the return of the carbon sink function to these areas.

The condition assessment in relation to global climate change regulation through greenhouse gas reduction would be good/favourable with some improvement

Provisioning Services – Global Climate Change Regulation Through		
Green House Gas Reduction:		
Condition Trend		
4	Good	Some Improvement

4.0 Cultural Services

4.1 Scientific - Knowledge about techniques for bog restoration

Over the duration of the project 25 events were held in person or online, specifically covering technical aspects of the restoration. These included:

• IUCN UK Peatland Programme Annual Conference presentation & visit, poster in 2016, 2020 & 2022;

- Hosting NE's England Air Quality Network visit;
- Shared Nitrogen action Plan workshop (6/07/2018);
- Hydrological restoration webinar (9/03/2020);
- Presentation to the 16th International Peatland Congress (5/5/2021);
- Presentation to a Eurosite webinar on peatland restoration (3/11/2021);

• article published in the e-newsletter of Chartered Institute of Ecology and Environmental Management (CIEEM) - the Ecological Restoration & Habitat Creation Special Interest Group (2021)

The Project Conference on the 20th of July 2022 entitled 'Restoring Lowland Peatland for Biodiversity & Carbon: Lessons from the Meres and Mosses' was a hybrid event held at Harper Adams University and attended by 70 people. The end of the project provided a timely opportunity to engage and open up the conversation between farmers, environmental land managers, financial institutions and conservation organisations in support of the restoration of the variety of lowland peatlands found across the Meres and Mosses landscape within which the BogLIFE Project lies. The conference covered the achievements of the BogLIFE Project but also explored best practice in terms of lowland peatland restoration for carbon and local nature recovery.



Field trip to the Marches Mosses BogLIFE Project by delegates from IUCN Peatland Programme annual conference 2017

In terms of the Shared Nitrogen Action Plan (SNAP) an initial workshop with key stakeholders was held in July 2018 to introduce the SNAP and share knowledge. In 2021 a SNAP coordinator was appointed and together with the local Catchment Sensitive Farming (CSF) officer engagement work was started with local farmers to raise awareness of the issue and to promote available grants and incentives. The National Farmers Union have remained a key partner throughout the SNAP pilot. These are early days but the feedback from stakeholders is positive and policy makers are becoming aware of the value of the site-focused coordination approach involved through SNAPs. NE has expanded the number of pilot SNAPs to four and SNAPs were cited in the UK Government's Clean Air Strategy 2019 as an example of innovation and leadership.

The condition assessment in relation to education is assessed as good with some improvement.

Cultural Services - Scientific - Knowledge about techniques for bog restoration	
Condition	Trend

4	Good	Some Improvement
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4.2 Education and Training

An integral part of the project involved education and training in peatlands and wildlife. This was delivered in several ways. 28 volunteers attended certified training courses. This included forestry first aid; chainsaw use; 4x4 off-road driving; safe use of excavators; safe use of pesticides; and managing and preventing wildfires. Seven full-time traineeships were supported by a stipend from Shropshire Wildlife Trust. Each trainee was hosted by the project team for 12 months. They received a mix of in-house training and certificated training provided by various learning providers as well as an opportunity to gain experience in peatland conservation and nature reserve management. All the trainees have subsequently gone on to work in the conservation sector.



Primary school children on an educational visit to the Mosses (Credit Paul Harris)

There have been school visits from 10 schools and other engagement through the John Muir Award scheme involving over 500 children. Significant numbers of secondary and tertiary stage students have also visited the Mosses including 600 A-Level Biology students from Shrewsbury College, and a number of groups from the Field Studies Council. In addition, students from Derwen College have made several trips to the tower and the bird hide at Charles Sinker Fields via the canal, transported by boats provided by the Lyneal Trust.

Table 2 Summary of Education and training carried out during the Marches Mosses BogLIFE Project

Educational, awareness and training	number of people visiting the site in person or remotely (via the website) for purposes of education

1.2 Presentations and talks at local village halls/community buildings for local community and stakeholders to explain the project and engage in heritage/ecological value of the site	Target: Total of 10 events, 200 people total. ACHIEVED 33 events for 986 people
1.2 Local group support children/young people - this age group are not currently engaged, but there is an interest in using the Mosses more for sessions. Work with young people groups to encourage use of Mosses, engagement activities	Target: 5 Groups engaged. ACHIEVED 7 groups engaged involving 206 children and young people directly, 19 adults
1.3 Guided site visits - expert led guided walks to explore bog restoration. Variety of specialists walks such as birds, plants and natural history	Target: 10 per year (50 total), 20 people on each = 1,000 people total ACHIEVED 48 events for 4,059 people and 1 self-led leaflet in production
 1.4 Educational visits - John Muir Award University visits - Trips will be subsidised 	Target: 18 training sessions, 30 teachers or TAs trained, specific sessions to complement the curriculum and use the Mosses as a curriculum topic for a whole term. ACHIEVED 23 training sessions for teachers 88 teachers or TAs engaged
1.5 Educational visits - revised targets to - 10 schools engaged and 300 children.	Target: 10 schools, 300 children engaged. ACHIEVED: 10 schools, 23 training sessions, 88 teachers / TA's / AT's, 500 children
School / college engagement in addition to the original action plan	13 events for 600 people ACHIEVED: 13 events for 463 people

The opportunity to engage trainee teachers with the Mosses was a key aim of BogLIFE and an early link was established with what was then the North Shropshire Teaching Alliance (which was made up of 19 schools). A decision was made to focus on developing and delivering training for Associate Teachers (AT's), trainee teachers on the school direct PGCE and placed in various schools across Shrewsbury and North Shropshire. The intention was to use the Mosses as a location to persuade them at the start of their careers that outdoor learning is important and will benefit their learners and their own mental health & wellbeing. Visiting the Mosses allowed them to take part in a wide range of outdoor activities that they then gain the confidence to deliver as they progress through their careers. In the process, they are also able to learn about peatlands and their importance, globally and locally, as a rich habitat and an important player in the fight against climate change.

The condition assessment in relation to education is assessed as good with some improvement.

Cultural Services - Scientific - Educational - Training/knowledge in bog restoration			
Cor	Condition Trend		
4	Good	Some Improvement	

4.2 Entertainment - Remote Access to the site

There are many ways in which people can engage with the site these include 6 self-led or online walks which have been used by approximately 3,200 people. The website also achieved 3,000 viewings per year, with 2,000 direct hits by 2021 (George, 2022).

Social media was highlighted as an important way in which people learnt more about the site and the Project (Plantagenet, 2022). The Marches Mosses BogLIFE Project had 1,964 Facebook and Twitter followers as of August 2021.

Table 2 Summary of remote access by people through the website and social media during theMarches Mosses BogLIFE Project

Entertainment - Remote Access to the site	Number of visitors to the project who access it remotely via website
Access through website /social media.	Target: 3,000 viewings per year 2,000 direct hits
	5,000 consistently following project by 2021.
	Web posts: 142
	Web visitors: 31,781
	Facebook followers: 934
	Facebook reach: 7,200
	Twitter followers: 1,157
	Twitter impressions: 167,611

Other media forms can reach much broader audiences with a single episode of BBC Springwatch in which the Mosses were featured, reaching an estimated audience of 3 million people. The site has also featured in both local and national newspapers.

The condition assessment in relation to remote access to the site is assessed as good with some improvement.

Cultural Services - Entertainment - Remote Access to the site				
Cor	Condition Trend			
4	Good	Some Improvement		

4.3 Physical landscape use and experiential use and Existence of the Project site

The new ways for people to be able access and appreciate the Mosses have proved popular. There has been a big jump (70%) in visitor numbers since the start of the project. A big hit has been the new 5 m high Mammoth Tower which allows visitors to gain a birds-eye view of the bog whilst at the same time finding out about peatlands and carbon storage. The creatively designed new bird hide overlooking the Sinker's Fields is equally valued by families and bird watchers alike. Added to this is much improved and innovative interpretation signage, walking trails and new online information and leaflets improving the visitor experience.



Photo of the Mammoth viewing tower displaying art banners celebrating the landscape of Mosses produced by Wem Youth Club and local artists (Credit Stephen Barlow)

A survey of visitors and local householders carried out between 2018 and 2020 resulted in 402 questionnaire returns. The main reasons people visit the site are walking, enjoying the peaceful landscape and to see wildlife. The graph below shows the benefits respondents felt they gained from a visit to the Mosses – the figures are shown in percentages. Overall, a sense of wellbeing, a break from everyday life and getting or keeping fit were cited by more than half of respondents. There was a noticeable increase between 2019 and 2022 in the percentage of respondents identifying a sense of well-being as benefit of visiting. Spending quality time with family and friends was another important benefit that was highlighted by just under 50% of people. Overall, it is evident that the Mosses provide positive experiential services valued by visitors and the local community.



Photo of a family visiting the Mosses (credit Paul Harris)



Figure 4.3.1 Bar chart of results from visitor and resident survey (Credit Plantagenet, 2022)

Another way of experiencing the Mosses includes as a volunteer with the project. In total 291 people volunteered and helped with conservation management and monitoring over the duration of the project. It amounted to 2,362 days of their time with an estimated value to the project of 275,327€.

The condition assessment in relation to remote access to the site is assessed as good with some improvement.

Cultural Services - Physical landscape use and experiential use and					
Exi	Existence of the Project site				
Cor	Condition Trend				
4	Good Some Improvement				

5.0 Conclusion

The assessment of ecosystem services was undertaken by the BogLIFE Team using best available information. It is worth noting that some provisioning services were greater under the drained degraded peatland conditions prevailing before the project. These included extractive activities such as fuel and growing soil media derived from peat extraction, livestock and timber production. Following the implementation of habitat restoration in the 1991 the levels of these provisioning services has declined as many of the output products became incompatible with the ecological and hydrological state required for the bog habitat to meet favourable conservation condition mandated by the site's legal Ramsar, SAC and SSSI protected status.

Notwithstanding this, the evidence available indicates that the project has positively affected a range of regulating and provisioning services. Habitats, species, hydrology, water quality, greenhouse gas emission reduction and invasive species show positive improvement trends. An exception is air quality where the trend is poor.

Similarly, the evidence available indicates that the project has positively affected a range of relevant cultural services described above reflecting the impact the project's communication, public engagement, education and training programmes.

Service description	Indicator	Data source	Condition Score	Condition	Trend	
Provisioning Services						
Reared animals and their output	Number of livestock	data collected by project staff	2	Poor	Overall stable	
Fibres	Volume of timber removed	data collected by project staff when timber removed	3	Moderate	Deterioration	
Energy: plant-based resources	Volume of wood removed for energy.	data collected by project staff when wood fuel/chip for biofuel removed	3	Moderate	Deterioration	
Regulating Services						

Table 4 Summary of the ecosystem services assessment of the Marches Mosses BogLIFE Project

Maintaining habitats	Area and condition of lowland raised bog and 'lagg' habitats in the site	environmental surveys	3	Moderate	Some Improvement
Maintaining populations	Indicators of size and diversity of invertebrate population	environmental surveys	5	Very Good	Improvements and deterioration in different locations
Maintaining populations	indicators of size and diversity of bird population	environmental surveys	4	Good	Some Improvement
Chemical condition of freshwaters	Water quality: pH and conductivity	baseline hydrological survey	3	Moderate	Some Improvement
Hydrological cycle and water flow maintenance	Hydrology: ground water levels, drainage water flow	baseline hydrological survey	3	Moderate	Improvement
Air Quality: Maintenance of physical, biological and chemical conditions NB (not a CICES category)	Air quality: Ammonia deposition	baseline air quality surveys - passive diffuse tube ammonia monitoring	2	Poor	Improvements and deterioration in different locations
Global climate regulation by reduction of Green House Gases	Amount of carbon stored in peat soils	The amount of additional carbon stored and methane	4	Good	Some Improvement

	and vegetation	produced to be estimated, using a specialist contractor			
Pest control	Invasive non-native species: cover, species, location and density	Baseline and repeat field surveys	4	Good	Improvement
Cultural Services					
Scientific Knowledge about techniques for bog restoration	Number of people involved in bog restoration technical workshops and/or arranged visits to the site	Collected (under D5) by project team.	4	Good	Improvement
Educational - Training/knowledge in bog restoration	Number of people visiting the site in person or remotely (via the website) for purposes of education	data collected routinely by project team on numbers of people visiting for educational purposes	4	Good	Improvement
Educational - Training/knowledge in bog restoration	Data collected routinely by project team on numbers of people visiting for educational purposes	data collected routinely by project team on numbers of people visiting for educational purposes	4	Good	Improvement
Entertainment	Number of visitors to the site who access it remotely via website	number of visitors (collected via project website).	4	Good	Improvement

Physical landscape	Focusing on	Visitor surveys	4	Good	Improvement
use and	people who	-			-
experiential use	visit the site				
	in person:				
	number of				
	visitors;				_
	their				
	perception				
	of the				
	quality of				
	their				
	recreational				
	experience;				
	reason for				
	their visit				
	(e.g. going				
	for a walk,				
	bird				
	watching				
	etc);				
	perceived				
	benefits to				
	well-being;				
	distance				
	travelled.				
Existence	Indicator:	Surveys of	4	Good	Improvement
	wellbeing	volunteers,			
	arising from	visitors, and			
	nature	local residents			
	conservation				
	at the site				
	for				
	volunteers,				
	people who				
	visit the site				
	in person				
	and local				
	residents				

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