Natural Capital Laboratory
Year 3 2021/22

End of Year Report

20 November 2022

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1. Introduction

Overview

AECOM, the Lifescape Project, landowners Emilia and Roger Leese, and the University of Cumbria are leading an ambitious, pro-bono research project called the 'Natural Capital Laboratory' (NCL). The project centres around adopting the IUCN CEM Rewilding Principles[1] at Birchfield, a 100 acre estate in Scotland to explore how effective nature-based solutions can be in helping to tackle the climate and biodiversity crises. Alongside the rewilding process, the NCL was set up as an experimental testbed to trial new techniques to quantify, measure, and communicate environmental and social change associated with rewilding. As set out in the Y1 and Y2 reports, the NCL is a collaboration between AECOM, the Lifescape Project, and landowners Emilia and Roger Leese. As of Y2, the University of Cumbria also joined the project team providing academic knowledge and input as well as bringing their expertise leading the IUCN's work on developing rewilding principles. Each member of the collaboration has their own set of aims for the project in Y4 and future years:

- **AECOM** is looking to continue to develop, test, and push forward innovation in environmental and social assessment work in order to develop better ways of collecting data, measuring and valuing environmental and social change, and communicating the findings in engaging ways to stakeholders.
- The **Lifescape Project** is looking to use the NCL as a platform to develop innovative ways of demonstrating how rewilding can be undertaken in practice at a site level, to explore how people can be engaged in rewilding, to understand and demonstrate the impact and value of rewilding work, and to explore how tools and technologies can be used to build the evidence base needed to foster rewilding and conservation projects more generally.
- **Emilia and Roger Leese** are looking to use the NCL project to demonstrate the increase in biodiversity value of the site that may be achieved through restoring the ecosystems and species which used to be there, as well as providing a place for people to re-engage with the environment and cultivate their creativity.
- The **University of Cumbria** is looking to undertake leading scientific research into the impacts of rewilding projects and support opportunities for education and learning for students.

The NCL involves four main workstreams:

- **Rewilding** – managing the site in order to restore habitats, reintroduce lost species, and encourage people to connect with the environment.
- **Data collection** – in order to understand the changes on site, the NCL is being used as a platform for designing and testing innovative approaches for measuring environmental and social change, and evaluating scalability and cost-effectiveness of these. Examples include using drones, AI, and remote sensing to capture, process, and interpret aerial imagery, and quantifying flows of ecosystem services through thermal imaging, camera traps, heart rate monitors, and sensors.
- **Data analysis** – at the core of the NCL are a set of natural, social, human, intellectual, manufactured, and financial capital accounts built around the Corporate Natural Capital Accounting[2] framework. These accounts provide a structured means of organising the data collected on the site and provide the baseline against which the impacts of rewilding may be monitored and evaluated over time.
- **Data communication** – as the data is collected and the accounts are populated, engaging ways of communicating the findings of the NCL are being developed such as virtual reality, video, and interactive digital platforms. These techniques aim to demonstrate the environmental and social benefits of rewilding and potential uses of the technologies being tested to a wider audience than is possible through traditional technical reports.

[1] See https://www.iucn.org/sites/dev/files/content/documents/principles_of_rewilding_cem_rtg.pdf
[2] See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516968/ncc-research-cnca-final-report.pdf

The first year of the project ran from 1 April 2019 to 31 March 2020. Following a six month pause due to the COVID-19 pandemic, the second year of the NCL ran from 1 October 2020 to 30 September 2021. The findings from the first two years were published on the NCL website.[3] The third year has seen the delivery of the following workstreams:

- **Biodiversity monitoring:** Expansion and the installation of data collection equipment (camera traps and audio moths) and analysing the data from the monitoring stations.
- **Baseline fungal surveys:** Development of a baseline survey by David Satori of Rewilding Mycology and understanding of fungal populations to determine their conservation value and contribution to ecological processes on the site.
- **Missing species:** Building toward rewilding of the site, the missing species report by Alan Watson Featherstone explores the feasibility of reintroduction of priority species to the site.
- **Air eDNA** – Working with NatureMetrics to pilot the potential application of air DNA collection, which involves analysing air samples to identify species found on site.
- **Peatland restoration** – Expansion of peatland investigations to understand peat extent and condition and to inform restoration activities in Year 4 (Y4) of the project.
- **Remote sensing**: Using satellite imagery and data to explore more accurate assessment approaches to quantifying the carbon sequestration and storage associated with trees across the NCL site.
- **Soil surveys**: to describe the baseline physical and chemical condition of the soils at the NCL for the purpose of monitoring the effects of rewilding on soil quality.
- **Capitals accounting:** updating the natural, social and intellectual capital accounts for the project to record change against the previous year, and integrating the findings from some of the new Y3 workstreams.

This report provides an overview of the workstreams undertaken in NCL Y3 and presents the key findings of each. Some of the workstream reports have been prepared by collaborators (e.g. Alan Watson Featherstone for the missing species, David Satori for the fungal survey, NatureMetrics for eDNA) with the key discussion and findings presented here in summarised form. The report is accompanied by an updated Digital Natural Capital Account which can be accessed via the NCL website.

The NCL team recognise that we are living in a climate emergency and a core aim of the project is to explore solutions to tackling climate change. As part of this, the project aims to be **carbon negative**, with energy generated on site through solar power, all site visitors adopting a vegan diet, and carbon actively being sequestered through tree planting and peatland restoration. The results of the Y3 natural capital account estimate that the total stock of carbon stored within the site is around 94,000 tCO_2e, while the total emitted during the project's lifetime is around 46 tCO_2e. 23 tCO_2e of carbon emission attributed to the site has resulted from NCL-related travel. The AECOM team travelled to the site in May 2022, with the 13 visiting staff endeavouring to travel to the remote highlands site in as-low-as-possible carbon intensity modes, which included members travelling from the south of England and as far as Belgium using trains, electric and hybrid vehicles, buses and even bicycles. In Y3, it was estimated that the net removals attributable to the project were 224 tCO_2e, excluding the volume of carbon offset credits purchased.

The NCL at Birchfield was the set for the short British horror film, The Lies of our Confines, from writer and director Leon Oldstrong.[4] The film is a fresh and exciting take on both the horror genre and Black youth culture, which seeks to avoid common stereotypes of Black men and boys, marking a departure from Oldstrong's previous films addressing issues that affect the Black community. It was made with a majority Black British cast and crew (and wherever possible the crew was composed of women). This community engagement reflects one of the project's goals to inspire people from all backgrounds to connect with the environment.

Following the success of the first three years of the NCL, the aim is to expand the concept beyond Scotland and set up a network of connected sites around the world aiming to develop and test new solutions to the climate and biodiversity crises. To this end, the NCL team has supported the Western Australian Biodiversity Science Institute, AECOM Australia and Threshold Environmental to set up NCL Australia – a partner site in South West Australia, where baseline surveys are being undertaken.

[3] See https://aecom.com/uk/natural-capital-laboratory/
[4] https://www.leonoldstrong.com/

If you would like to find out more about the NCL, details of the methodologies developed, or you would like to get involved in collaborating on the NCL, you can get in touch with: Michael.aquilina@aecom.com, Vikki.smith@aecom.com, Milica.apostolovic@aecom.com and adam.eagle@lifescapeproject.org.

Figure 1-1: Members of the NCL team on a site visit in May 2022. Credit: Chris Coupland Photography

2. Biodiversity Monitoring

Overview

During Y2 of the project, a pilot approach to remote biodiversity data collection using camera traps and AudioMoths[5] was established. In Y3, the aim was to:

- Continue with the random grid approach for camera and acoustic detection.
- Purchase and install an additional 11 camera traps and supporting equipment (using the same model at each station) so that there are two camera traps per monitoring station and ensuring that all cameras are updated to the agreed naming protocol and using the same options settings.
- Install AudioMoths so that there are one per station (8), ensuring that they all adopt the same configuration file.
- Oversee a site visit every three months to download data to an external hard drive, update the spreadsheet, recharge batteries, and replace memory cards.

Once the data had been collected, a quantitative analysis of the biodiversity at each of the monitoring stations, and the site as a whole, was undertaken. This data also fed into the natural capital accounts for Y3 of the project and provides an ongoing measure of the change in biodiversity over time. In Y3, a total of four site visits were completed for the purpose of this workstream:

- November 2021 - Volker Deecke (Associate Professor in Wildlife Conservation, University of Cumbria)
- March 2022 - Deborah Brady (Lifescape Lead Scientist) and Steven Lipscombe (Lifescape Volunteer)
- May 2022 - Chris White (former Associate Director of Environmental Economics, AECOM) and the wider AECOM team
- August 2022 - Ian Convery (Professor of Environment and Society, University of Cumbria)

Work undertaken in Year 3

Equipment

All equipment was purchased and installed during site visits. Table 2-1 provides an overview of all equipment deployed on site and timeline for data collection.

[5] AudioMoth is a low-cost, open-source acoustic monitoring device used for monitoring wildlife. AudioMoth is not only sensitive to audible sounds but well into ultrasonic frequency range (https://www.openacousticdevices.info/)

Table 2.1: Equipment deployment and data collection at Birchfield, 2021-2022

Monitoring location	equipment	Visit 1 Nov 2021			Visit 2 March 2022			Visit 3 May 2022		Visit 4 Aug 2022	
		Equipment in place	Data removed	equipment installed	Equipment in place	Data removed	equipment installed	Equipment in place	Data removed	Equipment in place	Data removed
00	Camera 1										
	Camera 2										
	Audiomoth										
01	Camera 1										
	Camera 2										
	Audiomoth										
02	Camera 1										
	Camera 2										
	Audiomoth										
03	Camera 1										
	Camera 2										
	Audiomoth										
04	Camera 1										
	Camera 2										
	Audiomoth					no-card corrupted					
05	Camera 1										
	Camera 2										
	Audiomoth										
06	Camera 1										
	Camera 2					no batteries in it					
	Audiomoth										
07	Camera 1										
	Camera 2										
	Audiomoth										
08	Camera 1										
	Camera 2										
	Audiomoth					hadn't been recording					
09	Camera 1										
	Camera 2										
	Audiomoth										

Data collection and processing

Site visit management and data collection was refined during 2021 to 2022. A new Excel spreadsheet was developed for the November 2021 visit to standardise the process. The spreadsheet captures the actions taken, the data removed and storage location of the data.

To ensure consistency of field activity and data extraction and storage, a new system of a pre- and post-visit meeting was implemented. The content varies depending on the familiarity of the data collector with the site and equipment but is designed to cover:

Pre-visit meeting:

- Site orientation and access
- Equipment in use – how to set up, how to extract and how to reset equipment
- Data extraction – process and how and where to store (including actions following visit)
- Spreadsheet – walk through explanation of what and how to capture actions and data

Post-visit meeting:

- Any challenges or difficulties on site
- Data extracted and location of storage
- Equipment left active

Meetings have been attended by the site visitor, Deborah Brady (Lifescape), Volker Deecke (UoC) to specifically cover use of the AudioMoth equipment, and Ciara Beades (Clifford Chance) for records. The method of data storage was addressed during 2021 - 2022. The data is currently removed from the equipment on site and transferred to two hard drives – one of these remains on site as a back-up and one is taken back to the place of work of the data collector for subsequent sharing within the team. This has led to significant logistical challenges and risks as the hard drive has been posted around the UK. This process led to a delay in accessing the data for processing. The decision to centralise the data storage was made with the intention of setting up remote storage of both the raw images and audio data ready for processing and the resulting detection data. AECOM is also currently investigating whether hosting long term remote storage with general access is an option, as data storage and management when a range of people are collecting data has proven a significant challenge.

Data processing was discussed in Autumn 2021 and the stages of processing data were identified and planned. Camera images captured on the traps need to be stored and accessed for processing. Each image needs to be examined to identify species present along with accompanying data such as age, sex (if known), particular behaviours etc. The resulting image data can then be used in analysis. The examination stage can be very time consuming with tens of thousands of images to check with a risk of human error. Species identification can be done in two ways – someone clicking through images or, as is increasingly the case, AI can be used to process images and trained to identify species. The use of AI can support the efficiency and feasibility of the use of this equipment on site and will be explored next year.

Summary of results

Image data from the complete grid was collected in May and August 2022 from the first full equipment set up in March 2022. When this becomes accessible with centralised storage, it can be processed by the student team at UoC, supported by UoC, AECOM and Lifescape. Interim results from data prior to March 2022 and a coarse processing of the data collected in May 2022 give some initial visualisation of species detection. As the data set develops further, analysis will be possible such as accumulation curves, habitat influences and preferences and annual changes in detection.

Auditory data from the complete grid was collected in May and August 2022 from the first full set up in March 2022.

Table 2.2: Species detected from camera trap grid at NCL Monitoring Points

Monitoring point name	Equipment active	Number of images extracted in: March 2022	May 2022	Mammal species detected: Fox	Sika Deer	Red Squirrel	Pine Marten	Badger	Total number of mammals detected
NCL00	Yes	7578	13349	0	3	0	0	0	1
NCL01	Yes	6921	5511	0	3	0	0	0	1
NCL02	No	0	0	0	0	0	0	0	0
NCL03	Yes	0	417	0	2	0	0	0	1
NCL04	Yes	0	103	0	2	2	0	0	2
NCL05	No	0	0	0	0	0	0	0	0
NCL06	Yes	21	312	1	2	1	0	0	3
NCL07	Yes	0	308	0	2	2	2	2	4
NCL08	Yes	60	76	0	3	1	0	0	2
NCL09	Yes	0	6043	0	0	0	0	0	0

Although the data collected in March 2022 was from an incomplete grid, three mammal species were detected over 5 locations from 6 active cameras:

- Sika deer (*Cervus nippon*)
- Red fox (*Vulpes vulpes*)
- Red squirrel (*Sciurus vulgaris*)

A preliminary scan of the images collected in May 2022 indicate the detection of 4 species over 16 locations with 16 active cameras:

- Sika deer (*Cervus nippon)*
- Red squirrel (*Sciurus vulgaris*)
- Pine marten (*Martes martes*)
- Badger (*Meles meles*)

Furthermore, a White-tailed eagle (*Haliaeetus albicilla*), was recorded as flying over the site at the May 2022 visit. Multiple red squirrels were detected at one camera location during the August 2022 visit.

The distribution of camera images was unequal across the site - this is particularly evident once the complete grid was active in May 2022. Early indication is that the eastern more open, clear-felled side is more vulnerable to the unproductive artificial high image count. As the western side is felled this is likely to increase the image count here. The use of AI in filtering the unwanted repetitive (waving grass type) images will become increasingly useful. Although sampling effort has yet to be accounted for, there is an indication that the range of medium to large mammal species is higher on the western wooded side of the site and particularly at the non-conifer monitoring point (NCL07). As data becomes available the required sampling effort could be investigated with species accumulation curves. Variation in species habitat selection could also be investigated as the site changes and matures.

Possible Y4 activities

Over Y2 and Y3 of the NCL project, a team has come together to establish a biodiversity monitoring grid to collect visual and auditory data. With the equipment and data collection method now in place, we can move to investigating analytical approaches; including developing an automated system to investigate bat activity patterns using data from the AudioMoths.

As the site develops, we are compiling a wealth of data and can now progress with defining a method of capturing biodiversity change. The plan is to continue to collate and compile the monitoring data using the established methodology and investigate biodiversity monitoring approaches to define which best suit the NCL site. Capturing a method to quantify biodiversity change at a site level in a way that includes species and can be repeated by rewilding practitioners would pave the way for including this data in work beyond rewilding such as biodiversity net gain projects.

3. Fungal Surveys

Overview

Adding to the baseline biodiversity work being undertaken at the NCL, the diversity of fungi was surveyed between September 2021 and September 2022, and a list of 159 species compiled. Grazing pressure by deer has led to a very high abundance of terrestrial fungi, with a diversity that is significant enough to warrant mycologically-focused habitat management. This section of the report has been written to dovetail with the missing species report produced by Featherstone (2022), offering a mycological perspective on some of the recommended priority species for reintroduction. Furthermore, a list of strategies for enhancing the site's fungal diversity is expanded upon in the detailed baseline fungal survey report[6], and summarised below:

1. Facilitate natural regeneration of the birchwood
2. Increase connectivity within the site to restore natural pathogen dynamics
3. Create deadwood resources where they have been lost
4. Reintroduce the Caledonian pinewood soil microbiome[7]
5. Investigate the reintroduction of Shaggy Parasol fungi alongside the reintroduction of wood ants
6. Use nature-based fungal solutions to tackle unfavourable disease
7. Recreate keystone woodland structures through veteranisation
8. Include fungi in the natural capital accounting of the site

Fungi are staggeringly underrepresented in conservation and biodiversity frameworks, which has resulted in a poor translation into policy and an undervaluing of their importance. This is despite fungi being the most threatened taxonomic group in the UK[8]. They are responsible for the provision of a large array of ecosystem services, in particular nutrient cycling, soil fertility, carbon sequestration and can be a key indicator of habitat condition. Table 3.1 below sets out an overview of the main fungal ecosystem services.

Table 3.1: Ecosystem services provided by fungi (adapted from Dighton, 2018)

Primary ecosystem service	*Specific role*	*Fungal functional groups*
Soil formation	• Rock dissolution • Particle binding	• Lichens, saprotrophs, mycorrhiza • Saprotrophs, mycorrhiza
Soil quality regulation	• Decomposition of organic residues and nutrient mineralisation • Soil stability (aggregates) • Modification of pollutants	• Saprotrophs, ericoid and ectomycorrhiza • Saprotrophs, arbuscular mycorrhiza • Mycorrhiza, saprotrophs
Primary production	• Direct production • Nutrient provision for flora • Plant yield • Defence against pathogens • Defence against herbivory	• Lichens • Mycorrhiza, endophytes • Mycorrhiza, pathogens • Mycorrhiza, endophytes, saprotrophs • Endophytes
Biodiversity	• Plant-plant interactions • Food source for vertebrates and invertebrates • Population/biomass regulation	• Mycorrhiza, pathogens • Saprotrophs, mycorrhiza • Pathogens
Global climate regulation		• Mycorrhiza, saprotrophs

[6] Satori (2022) Baseline Fungal Survey for Birchfield. Available on request.
[7] Every tree is supported by an underground network of symbiotic fungi which act in concert with beneficial bacteria, nematodes, insects, protozoa, and countless other microorganisms. This is a tree's microbiome, when reintroducing local genotypes of Caledonian forest trees, especially Scots pine, it is important to factor in the translocation of their soil microbiome using samples collected from the organic matter layer of local mature pinewoods and it cannot be assumed that the present soil microbiome at the site is favourable for Scots pine.
[8] DEFRA (2022) Biodiversity terrestrial and freshwater targets: detailed evidence report [online] available at: https://consult.defra.gov.uk/natural-environment-policy/consultation-on-environmental-targets/supporting_documents/Biodiversity%20terrestrial%20and%20freshwater%20targets%20%20Detailed%20evidence%20report.pdf

It is highly recommended to adopt the 3Fs terminology of flora, fauna, and fungi for the purposes of the NCL's biodiversity framework. The adoption of mycologically-inclusive language can be leveraged to improve the site's social capital value by engaging a wider audience through educational materials, fungi forays, academic research, and affiliation with the fungal conservation community. Ultimately, this could help demonstrate the value of rewilding as the most scalable and cost-effective approach to fungal conservation.

Work undertaken in Y3

The initial aim of the of the fungal workstream was to develop a baseline survey and understanding of the fungal populations at the NCL. The workstream, led by David Satori of Rewilding Mycology, had three objectives:

1. To construct a baseline fungal species list for the NCL
2. To assess the species recorded in terms of their conservation interest
3. To deduce the ecological significance of the fungal communities found at the NCL

Three site visits to the NCL were made in the autumn of 2021:

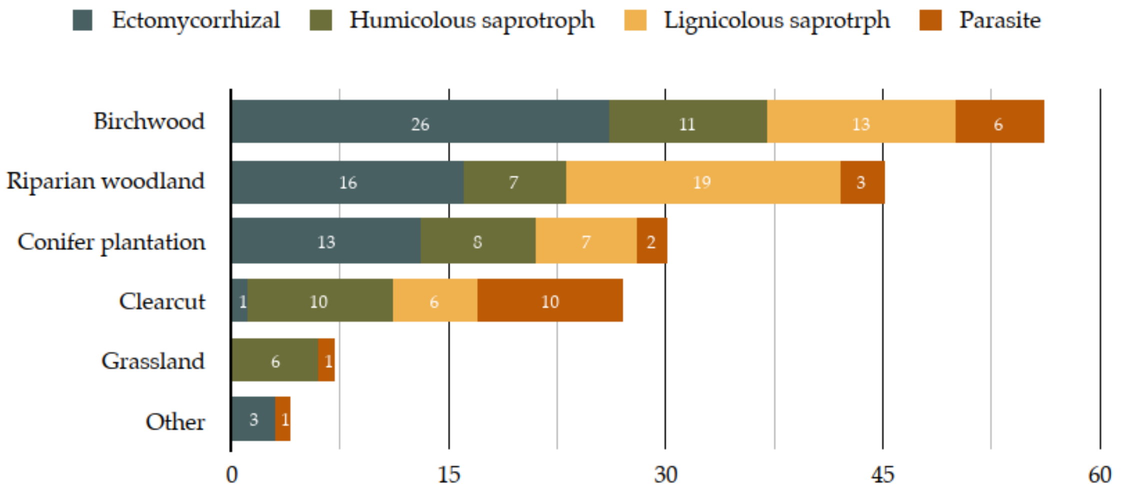
- 21st-23rd September;
- 14th-16th October; and
- 10th-15th November.

This approach was chosen to encompass as much of the succession of autumn fungal fruiting as possible. In addition, a spring survey was carried out on 5 – 8th May 2022 with a specific focus on ascomycetes, followed by a final autumn survey on the 5 – 8th September 2022. A walkover survey approach was taken, with each woodland type (birchwood, conifer plantation, riparian woodland) and other habitats (marshy grassland etc.) studied at least once per visit. Each species was recorded with its field-determined name, habitat, host, and GPS coordinates. Where a species was found in disparate areas across the NCL site, each location was noted. The frequency of occurrence of each fruiting body was recorded according to the DAFOR scale: Dominant, Abundant, Frequent, Occasional and Rare.[9] Species that could not be identified in the field were collected for further microscopic examination. The survey specifically focused on fruit bodies of macrofungi, although some microfungi (such as leaf-associated rusts) were included. A photo gallery of the majority of recorded species is provided within the detailed final report.

In total, 159 species were recorded between 2021-2022. spanning a variety of functional groups, habitats, hosts, and substrates. Ectomycorrhizal fungi, unlike other mycorrhizal types, produce aboveground fruiting bodies. Saprotrophic fungi decompose organic matter and can be summarised as humicolous or lignicolous if they decompose fallen leaves/humus or wood, respectively. Parasitic fungi obtain their nutrition from living plant, animal, or fungal tissue, but do not necessarily always lead to disease of their host. Figure 3-1 provides a summary of fungi by functional group recorded on the site.

[9] Note, with fungi, a genetic individual may produce numerous fruiting bodies in a given locality, whilst its mycelium may span several square metres. Therefore, the DAFOR scale does not indicate the number of individuals of a particular species, but rather seasonality and the overall abundance of fruiting.

Figure 3-1: Number of fungal records by habitat and functional group



The standout mycological feature of the NCL is the mature birchwood. Lichen-draped downy birch is predominant in the canopy, with rowan and eared willow (Salix aurita) interspersed among them and a field layer consisting of ferns, grasses, vaccinium, and large bryophytes that indicate heavy grazing history. Upland birchwood such as that found at the NCL is considered a priority habitat by the UK BAP. However, many of these trees are senescent[10], where young trees are unable to succeed the dying ones. These birchwoods are fragile habitats but have the potential for improvement in order to protect their fungal diversity.

Approximately one-third of the total fungal diversity was found in the mature birchwood, half of which was ectomycorrhizal. There were also observations of small nibble marks on unearthed specimens of the Deer Truffle Elaphomyces granulatus, evidence of red squirrels utilising it as a food source (and, as the name suggests, deer consume them too). The presence of these fungi could improve soil carbon sequestration, seedling establishment, and facilitate the formation of common mycorrhizal networks between seedlings and older trees. In turn, natural regeneration will encourage late-successional fungal communities to develop faster and resemble those of ancient woodlands sooner.

Figure 3-2: Examples of ectomycorrhizal fungi in the birchwood: Lactariuis vietus and Cantharellus cibarius (the prized edible chanterelle)

Source: David Satori, 2022.

In a natural woodland, one expects to encounter a variety of deadwood resources at different stages of decay. The quantity and diversity of deadwood is a major factor influencing the number of saprotrophic fungi that can be supported, and in the birchwoods, there was an observed dearth of coarse woody debris. Apart from a small number of fallen trees, the main sources of deadwood are thin branches. These support several wood decomposers. Once wood decay fungi exhaust their resource, they require new suitable logs to disperse, and these must be within their dispersal distance to maximise the

[10] I.e. in the process of deteroartion where tree cells lose the power of division or growth

chances of successful establishment. Due to their scarcity, the felling of mature birches is not recommended, though natural deadwood recruitment from dying trees will be of benefit to fungi in the medium- to long-term.

Figure 3-3: Examples of wood decay fungi: Mycena galericulata and Stereum reugosum

Source: David Satori, 2022.

Chaga (Inonotus obliquus) was found on a fallen birch log uphill from the cabin (see Figure 3.4) as well as on a standing birch in the riparian woodland. This species shows a strong affinity for birch and the Scottish Highlands are its main region of occurrence in the UK. It is known for its proven medicinal benefits including anti-cancer, anti-oxidant and anti-inflammatory properties. Unfortunately, this has spurred an unprecedented surge in commercial exploitation in recent years with the real threat of over-harvesting this species which takes decades to grow. No attempts have been made at examining the impact of this on wild populations but pressure to place this species under conservation protection is growing[11]. This is an interesting finding as it demonstrates the potential for the site to provide wild food sources (through edible chanterelle) as well as genetic resource and medicinal value (through the presence of Chaga).

Figure 3-4: Chaga growing on a fallen birch

Source: Satori, 2022.

The older mixed conifer plantation yielded a greater number of fungi than the Sitka spruce plantation. In the older stands, sunlight can more readily reach the forest floor, encouraging the growth of mosses which retain moisture better, creating a more suitable microclimate for fungal fruiting. Many fungi require some dappled sunlight to trigger the production of fruiting bodies, so it was unsurprising that the densely-planted Sitka spruce stand did not offer much in terms of records. Most fungal fruiting was along the edges of the stands, and included the ectomycorrhizal Fly Agaric in two varieties *(Amanita muscaria var. muscaria and A. muscaria var. aureola),* Crested Coral *(Clavulina coralloides)* and the Cinnamon Webcap (*Cortinarius cinnamomeus*). The Dusky Bolete *(Porphyrellus porphyrosporus*), considered Near Threatened by IUCN Red List standards was found along a small path and also near the Fechlin River close to the aspen.

It is not an uncommon sight in spruce plantations to see the woody brackets of *Heterobasidion annosum* growing from the base of stumps and living trees. This fungus is considered the most economically important forest pathogen in the Northern Hemisphere, and a specimen was found uphill from the cabin growing on a cut spruce stump near the site's boundary. The fungus spreads when spores land on freshly cut stumps, which germinate and make their way into the roots where they can

[11] Thomas et al (2020) Chaga (Inonotus obliquus): a medical marvel but a conservation dilemma? [online] available at: http://www.sydowia.at/syd72/T14-Thomas-2833.pdf

spread through root grafts into adjacent trees. It was clear that the old, split birches were colonised by H. annosum and are now active hosts of the pathogen from their hollowed bases and root systems. The average age of the birch and the lack of regeneration could potentially put the woodland at risk in the long-term as the disease can persist underground for decades and can lead to higher sapling mortality and lower tree vigour. Scots pine is particularly susceptible to infection, so care should be taken to eradicate the pathogen from the site if these trees are intended to be planted nearby.

Overall, the lower diversity of fungi in the plantations and the disease transfer to the birchwood renders the conifer plantations of low mycological value. Reduction of the area of conifer plantations to facilitate native woodland regeneration would enable an increase in habitat connectivity between the birchwood stands, allowing fungal source populations to expand. Furthermore, considering the total removal of spruce stumps/roots infected by H. annosum (or alternative biocontrol methods) will prolong the lifespan of the ecologically-rich birch trees and improve the chances of birchwood persistence into the future.

The broadleaf woodland along the River Fechlin was another mycologically significant site owing to the greater diversity of trees found here. Adding to the ectomycorrhizal assemblage were Trumpet Chanterelles (*Cantharellus tubaeformis*) and the edible and cherished Porcini *(Boletus edulis*) was also found here, as well as its close relative, the Scarletina Bolete *(Neoboletus praestigiator)*.

Figure 3-5: The prized Porcini and Scarletina Bolete

Source: Satori, 2022.

Saprotrophic fungal diversity was greater here too, owing to the larger quantities of fallen trunks, snags, and overall deadwood biomass that are essential features of natural woodlands. This included the late-stage decomposer and ancient woodland indicator, the Deer Shield (*Pluteus cervinus*),found growing abundantly on fallen birch. The Dusky Bolete *(Porphyrellus porphyrosporus)* was the only red-listed species (Near Threatened) in the riparian woodland.

Figure 3-6: Hygrocybe punicea, a valuable ancient grassland species

Source: Satori, 2022.

The eastern end of the site hosted various grassland fungi. Waxcaps and earthtongues are of great ecological value, preferring unimproved, short-grazed grassland, and it is likely that the meadow waxcap arrived from neighbouring pastures. In fact, the sites surrounding Birchfield host diverse communities of waxcaps, earthtongues, pinkgills, and other ancient grassland species.

Possible Y4 activities

This fungal survey has moved us ahead with our understanding of the site and how to improve biodiversity through a fungal rewilding process. The author's suggested next steps for Y4 are presented below.

A novel and 'bottom-up' approach to rewilding is proposed with the creation of micro-habitats for a wealth of species through cavity creation. Select trees can be inoculated with locally sourced, isolated, and cultured wood decay fungi to create cavities and speed up senescence. This would be a first-of-its kind rewilding trial in Scotland, having only been done previously in English oak and beechwood woodlands.

Cavity creation by fungal inoculation would allow us to bring missing species back to site, increasing biodiversity whilst testing a novel approach to rewilding. Work with 'Rewilding Mycology' to reintroduce fungi for biodiversity improvement through cavity creation would involve:

- identifying suitable host trees;
- sourcing a culture of a wood-decay fungus which could be obtained from local woods;
- isolating selected fungi in a laboratory;
- inoculating chosen trees on site; and
- reporting on process and results.

4. Missing Species

Overview

A number of surveys and data collection exercises were carried out at the NCL in 2020 and 2021, including surveys of the River Fechlin for aquatic species, a Phase 1 National Vegetation Classification (NVC) Survey, Longworth trapping for small mammals, acoustic monitoring for birds, the installation of camera traps for recording larger vertebrates and a survey of plant and leaf hoppers. Amongst the notable species recorded on the site so far are the red squirrel (*Sciurus vulgaris*), pine marten (*Martes martes*), goshawk (*Accipeter gentitlis*) and tawny owl (*Strix aluco*). eDNA analysis of water samples from the Fechlin River revealed the presence of 139 macroinvertebrate species and 6 species of fish, including brown trout (*Salmo trutta*) and the European eel (*Anguilla anguilla*). A breeding bird survey has been carried out on the site, and some limited data about butterflies and dragonflies has also been collected.

Building on some of these findings, Alan Watson Featherstone produced a longlist of 60 species missing from the site, and identified priority species and assessed their potential for their introduction. The report Alan prepared, which is presented in abridged form in this chapter, lists nine priority species for reintroduction:

- Scots pine (*Pinus sylvestris*)
- Sessile oak (*Quercus petraea*)
- Aspen (*Populus tremula*)
- Holly (*Ilex aquifolium*)
- Juniper (*Juniperus communis*)
- Wood ants (*Formica lugubris or Formica aquilonia*)
- European beaver (*Castor fiber*)
- Osprey (*Pandion haliaetus*)
- Freshwater pearl mussel (*Margaritifera margaritifera*)

Work undertaken in Y3

The analysis was made based on other survey work completed at Birchfield to date, several visits to the NCL by Alan Watson Featherstone, and comparisons with other sites of notable biodiversity value in the Highlands. On this basis, a longlist of 60 missing species was identified, based on a combination of several factors, including their role in the ecosystem, their conservation value and ability to assist in ecological recovery, and their rarity and conservation status. Subsequently, nine priority species were identified for potential reintroduction.

It was observed that one of the key challenges in identifying missing species stems from incomplete knowledge of species already present. While substantial progress was made through previous surveys, biodiversity monitoring on site and eDNA results, the data collected is often disaggregated (due to different time points of data collection) and therefore not readily available, meaning that in some cases, assumptions had to be made about certain species.[12] To overcome such challenges, it has been recommended to organise further surveys to identify the extant species diversity for key groups of organisms, especially those for which there is little data at present, or where the existing data is incomplete (e.g. plants, bryophytes, birds, terrestrial invertebrates, etc).

Ecological Potential and Missing Ecological Processes at Birchfield

Because of its overall characteristics and features, the Birchfield site was probably mostly covered with native forest in the past, before human activities had a major impact there. This would most likely have been a mixture of Caledonian Forest typified by Scots pine and associated broadleaved trees, grading into native oakwood featuring sessile oak and its associated species, in sections of the site where the soils are richer. These woodland areas would have been interspersed with wet flushes and, in the flatter area between the road and the River Fechlin, would have given way to peat bog possibly with some stunted bog woodland growing on parts of it. A greater range of native trees species would have been on the site

[12] It is also worth noting that in the course of producing the report on missing species, some additional ones were identified, e.g. lichens.

then and a full range of native birds and mammals would either have been resident on the site or using it at some time during the year.

That combination of pine-dominated Caledonian Forest and oakwood is relatively rare in the Highlands but is evident at Trees for Life's Dundreggan Conservation Estate in Glenmoriston, about 20 km due west of Birchfield. The lower part of that estate lies at a similar elevation to Birchfield and some old oak trees are distributed amongst mature Scots pines and younger birches. In the era that preceded widespread human exploitation, Scots pines and oaks growing in close proximity were likely a common feature at many sites with a comparable elevation and ecological characteristics to Birchfield. Today, examples such as these can provide a template for what restoration efforts at Birchfield can aim for.

The Birchfield site is located about 8 km due south of Inverfarigaig SSSI and shares some important ecological characteristics with it, including the presence of a steep-sided gorge that provides the shade and shelter for a small pocket of temperate rainforest to flourish. Inverfarigaig is noted for the native woodland there, and forms part of the Ness Woods Special Area of Conservation. The native woodland in the gorge area at Birchfield contains many of the same key indicator species (e.g. *Lobaria pulmonaria, Nephroma laevigatum, Pannaria rubiginosa, Peltigera spp., Polypodium vulgare* etc.) for temperate rainforest as those that are present at Inverfarigaig. With appropriate measures for native woodland regeneration and rewilding, the gorge area at Birchfield could rival Inverfarigaig for its ecological importance, albeit on a smaller scale. The section of the River Fechlin that flows through the site has been found to possess high water quality, but a fine sediment issue is prevalent in the lower reaches. In the Y2 report, some improvements that could be made to the river habitat were identified, including six species that could be reintroduced – one of them was identified as a priority species this year as well.

Framing the discussion on the missing species, it is important to note some crucial ecological processes that are currently missing from Birchfield. For species introduction to work, it is important to re-establish those ecological processes that are currently absent, including:

- **Seedling recruitment and successful regeneration of native trees.** There are very few seedlings of native trees growing on the site, due to a combination of factors - the lack of nearby seed sources for some species (e.g. oak, Scots pine); lack of suitable germination conditions for tree seeds; grazing pressure from deer, including the sika deer currently fenced-in within the site.
- **Ecological succession**. Where native trees do occur, along the bank of the River Fechlin and in rides between the plantation blocks, they are almost exclusively pioneer species, such as downy birch, rowan, willows and aspen, and the older trees are dying with no successional species replacing them. In healthy ecological conditions the pioneer woodland they form would be replaced over time by longer-lived and later successional species, including Scots pine and oak.
- **Nutrient retention and cycling**. In a healthy woodland ecosystem, nutrients are largely retained within it, and any nutrients that are lost are balanced by nutrient accumulation through the leaf litter that falls from trees, nitrogen fixation from arboreal lichens that fall to the ground and the action of symbiotic bacteria in the roots of alder trees and bog myrtle (*Myrica gale*). Whilst some of these actions are taking place at Birchfield, the majority of the site is subject to nutrient depletion, due to the past and likely future harvesting of the planted commercial conifers and the removal of their timber.
- **Natural disturbance.** In a healthy forest, heterogeneity of its structure and species composition results in part from the process of natural disturbance. This is provided by events including wind throw of trees creating gaps in the woodland canopy; disturbance of the ground vegetation and soil by large animals such as wild boar (*Sus scrofa*); occasional outbreaks of defoliating insects etc. There is little evidence of these taking place at Birchfield just now, although moles (*Talpa europaea*) are providing some very small-scale localised disturbance of the soil, thereby creating opportunities for seedling germination and establishment.
- **Predator-prey dynamics.** In a healthy woodland ecosystem, the grazing and browsing pressure of deer is limited in its intensity and localised geographic impact by the actions of apex predators such as the wolf (*Canis lupus*) and Eurasian lynx (*Lynx lynx*), creating a dynamic balance that enables some successful recruitment and regeneration of trees and other vegetation to occur. With all the terrestrial apex predators having been extirpated in Scotland for several centuries or more, herbivory by red deer and roe deer in particular, as well as that of introduced domesticated sheep, has prevented substantial tree growth in most areas of the Highlands.

The absence of these processes and species, together with the accidental or deliberate introduction of non-native species and the conversion of diverse natural ecosystems to monoculture plantations for commercial purposes, has created the conditions for non-native species, in some cases at least, to become invasive and/or serious pests. At Birchfield, at least three examples of this can be seen:

- The Sitka spruce that forms the main crop in the commercial plantations on the site is seeding heavily and young regenerating spruces are prolific, especially in the clear-felled former plantation area. Because of the spruce seedlings' unpalatability and prickliness, they are not being eaten by the sika deer inside the fenced enclosure, so they are growing rapidly, whereas any birches and other native tree seeds that germinate are being eaten. Thus, at present, the clear-felled area is heading towards being a new area of Sitka spruce, not a restored native forest.
- The fungal survey carried out by David Satori in autumn 2021 has shown that a pathogenic fungus (*Heterobasidion annosum*) which attacks Sitka spruce has spread to some of the older birches growing near the plantation spruce and 'poses a major risk for the continued health of the birchwood'. The report also indicates that pine species are particularly susceptible to infection, so care should be taken to eradicate the pathogen from the site if the intention is to plant Scots pine nearby.
- The non-native sika deer that have been introduced to the UK have spread widely throughout the country, especially in the north and west of Scotland, and through their ability to interbreed with the native red deer pose a serious threat to the genetic integrity of the latter. They have a preference for conifer plantations, making the site at Birchfield an ideal habitat for them. Their behaviour when disturbed, of hunkering down and hiding in vegetation, rather than running away to higher ground as red deer do, has contributed to the difficulties in attempting to remove them from the fenced clear-felled area at Birchfield. In addition to those located inside the fencing, sika deer must be moving along the road at Birchfield, despite the existence of the deer fences on both sides of it. In November 2021, a dead sika deer was observed in the ditch on the west side of the road, just north of the entrance to the cabin, and is likely to have died from a collision with a car. Its presence there confirms that sika are using the road as an access corridor and illustrates why no suckers from the three large aspen trees on the roadside have been able to grow above browse height (aspen foliage is some of the most palatable of all tree species to deer).

In considering which of the missing species to prioritise for potential return to the Birchfield site, it is important to take account of these ecological processes that are not currently taking place, and to make choices that are informed by their potential role in re-establishing ecological functionality to the site.

The full 'Missing species report'[13] sets out a longlist of species which would be expected to occur if the Birchfield site contained well-developed Caledonian Forest, with its full complement of native species. The list features 60 species and concentrates on some of the most notable and significant ones, as a complete list would be much longer. An indication of this is provided by the 10,000 acre Dundreggan Conservation Estate owned by Trees for Life and situated in Glenmoriston, to the west of Loch Ness and about 20 km. from Birchfield as the crow flies. Although Caledonian Forest only occupies a small proportion of that estate at present, over 4,000 species of plants, animals, birds, fungi and invertebrates have been recorded there, including 10 species that are not known from any other sites in the UK.

Short list of priority species for reintroduction

Because of the present condition of the Birchfield site, the first priority in rewilding it has to be the recovery of natural vegetation communities. This will entail the establishment of native woodland on most of both the recently clear-felled area and the area currently occupied by the spruce plantation, as well as the restoration of the existing area of peat bog near the River Fechlin, see Appendix A.1 for the mapping of the updated Phase 1 habitat survey that took place in Y3. Some key tree species that would comprise the native woodland communities that the site can support are currently missing, so this list of priority species for return to the site is focused largely on them. Once they are successfully re-established, many of the species of invertebrates, lichens and birds etc. that they support should return by themselves, over time.

In the meantime, it may be possible to accelerate the process of ecological restoration by reintroducing some wildlife species, and four possibilities for this are also included here. These are more challenging to reintroduce or translocate, and two species at least – the European beaver and the freshwater pearl mussel – could only be carried forward in close consultation and cooperation with neighbouring landowners and other key stakeholders. One aquatic species, the freshwater pearl mussel, has been included, as the River Fechlin is an important feature at Birchfield, with a completely different ecology to the terrestrial parts of the site. In looking at returning the whole site to an optimum condition of ecological health and full species diversity, the aquatic habitat needs to be accounted for and the freshwater pearl mussel would be a good flagship species for that. Several of the species included in this list are keystone species, and they have been selected because of

[13] Featherstone (2022) NCL Birchfield Missing Species Report. Available on request.

the significant role they play in ecosystems, and the consequent potential benefits they will provide for many other species, thereby assisting and accelerating the overall ecological recovery of the site.

The nine priority species for reintroduction are:

- **Scots pine (*Pinus sylvestris*)**

There are no large or mature Scots pines on Birchfield at present, and there do not appear to be any pines on neighbouring lands which could provide a seed source from which natural regeneration could take place at Birchfield. The recommendation therefore is that some planting of Scots pines is carried out, using trees grown from seed of suitable provenance, with small clusters of seedlings planted out in areas with appropriate soil conditions. The planting should be done at irregular and varied spacing, giving the trees enough space in most cases to achieve a good spreading branching structure. This, combined with leaving significant gaps between the saplings will help to establish a natural-looking forest. It is expected that, assuming the sika deer in the existing clear-cut area are removed, significant regeneration of birch, rowan and willow will occur there of its own accord, helping to create a mixed and varied woodland with the planted pines.

- **Sessile oak (*Quercus petraea*)**

Unless the source and origin of the planted oaks can be identified and confirmed as ecologically appropriate for the site, it is recommended that they all be removed as they are in the wrong soil conditions etc. If they are shown to be of appropriate provenance, it may be possible to transplant some of them to locations where oak would naturally occur at Birchfield. It is very unlikely that oak will recolonise Birchfield naturally in the short to medium term, because of the absence of nearby seed sources (i.e. mature trees) and the resultant lack of opportunities for seed dispersers (e.g. jays, red squirrels) to bring acorns on to the site. The recommendation therefore is that a small-scale planting programme for *Quercus petraea* be implemented, sourcing trees of local provenance for planting in areas of suitable soils (e.g. where bracken is flourishing) and in gaps in between the existing trees in the gorge along the Allt Beag.

- **Aspen (*Populus tremula*)**

Aspen should be treated as one of the priority species for the recovery of native forest to the Birchfield site, as it is a key component of the early successional pioneer woodland community. This will require planting of aspens (given the lack of seed production referred to above), to establish new patches of trees that are discrete from the two existing stands. Propagation can be achieved from root cuttings, with the source material located from a range of different aspen stands in the general area around Birchfield, in order to maximise genetic diversity, the possibility of establishing both male and female aspens at Birchfield and the use of locally-adapted trees. Trees for Life has been propagating aspens for many years and carries out ongoing production of aspen every year at its tree nursery at Dundreggan. Recommendations for planting sites for aspen include establishing additional groups of trees along the bank of the River Fechlin, to provide a future food source for any beavers that move into, or are translocated into, the area. Small groups of aspens from different source stands can also be planted together at selected other locations throughout the site as part of the overall forest restoration process.[14]

- **Holly (*Ilex aquifolium*)**

Because of its relatively sparse distribution in the Highlands and the resultant paucity of seeds being distributed by birds, holly is unlikely to return to the site unaided. It should therefore be included as an integral part of any tree planting programme for forest restoration at the site. Holly saplings should be planted primarily in association with sessile oak. Sufficient numbers should be planted to ensure there are enough male and female trees in relatively close proximity to each other for future pollination and seed production to take place.

- **Juniper (*Juniperus communis*)**

Juniper should be featured in any programme of tree planting for ecological restoration on the Birchfield site, using plants grown from seeds of as local provenance as possible (the juniper stands at Levishie and Dundreggan are potential candidates for this). Planting should be done in areas where Scots pine is also being planted and where birches are either regenerating naturally or being planted. Once juniper is successfully established, it should spread further on the site through the dispersal of its seeds by birds that eat its berries.

- **Wood ants (*Formica lugubris or Formica aquilonia*)**

Although most of the Birchfield site is currently unsuitable for wood ants, due to the density of trees and lack of any understorey in the spruce plantation, as well as the lack of vegetation in the clear-felled area, the strip of native woodland

[14] NB in southwest Norway, where native woodland recovery has taken place spontaneously after the voluntary departure of much of the human population since the beginning of the 20th century, aspen is a prominent component of the young recovering woodland, comprising perhaps 10-20% of the overall tree cover.

along the River Fechlin and in the gorge of its tributary, the Allt Beag, could potentially support wood ants. One of the key determinants of this will be the presence of aphids, especially on the birch trees, as their honeydew is a major food source for the ants. At present, there is no data on aphids on the site, so a prerequisite regarding any wood ant translocation will be to carry out an aphid survey. If the results of such a survey are favourable, then a translocation from a suitable population source could be arranged. Wood ant translocations have been carried out in the Cairngorms National Park and at other sites in Scotland and a translocation protocol for moving wood ant nests has recently been developed (Cathrine, C. & MacIver, C., 2014). Some expert advice will be required regarding the best location, if any, for wood ants to be translocated to at Birchfield, and which of the two common species (*F. aquilonia and F. lugubris*) would be best suited for translocation to the site. However, if a successful translocation can be implemented, the return of a keystone invertebrate species will help to catalyse further ecological recovery at Birchfield.

- **European beaver (*Castor fiber*)**

Although some sections of the River Fechlin at Birchfield are slow-moving, other parts have small rapids and cascades, making them potentially less suitable as beaver habitat. An expert in beaver ecology should be consulted to evaluate whether the site would be suitable to host a translocated group of beavers. Other factors would also have to be considered before any translocation that was deemed ecologically feasible could be implemented. These include consultation with (and obviously the agreement of) neighbouring landowners, as the section of the Fechlin on Birchfield is too small in and of itself to support a beaver population. Potential impacts on the hydro scheme that is in operation on the Fechlin would need to be evaluated and agreement reached with the hydro-power company. In addition, the current lack of successful regeneration of trees such as aspen, willows and alder along the Birchfield bank of the Fechlin, due to overgrazing by deer, would need to be satisfactorily addressed before adding another herbivore with a taste for those species.

- **Osprey (*Pandion haliaetus*)**

Because of its proximity to both Loch Killin and Loch Ness, and its location beside the River Fechlin, Birchfield could potentially be a good site for ospreys to nest at. Although there are none of its preferred nesting trees - mature Scots pines - at Birchfield just now, it is possible that some of the larger spruce trees could form a substitute for Scots pines. An artificial nest could theoretically be constructed on top of a large spruce that was deemed to be suitable for the purpose in the hope of attracting birds to breed there. Given that ospreys are breeding relatively close by, in both Glenmoriston and Glen Affric, an artificial nest site could be enticing for birds dispersing from those sites, as they prefer to breed near other ospreys, and often fish at common feeding sites.

- **Freshwater pearl mussel (*Margaritifera margaritifera*)**

The freshwater pearl mussel is one of six missing species identified for possible reintroduction to the site in the Aquatic Ecology Report. Given the importance of Scotland for this species in a European context, it has been selected from those six as a priority for possible reintroduction in this current report. The AECOM survey indicates a healthy population of brown trout in the Fechlin, which could sustain a reintroduced population of the freshwater pearl mussel, if other relevant habitat features can be shown to be suitable. Because of the small size of the Birchfield site, and the relatively short section of the Fechlin catchment that it contains, any translocation proposals will have to be agreed with other neighbouring landowners and the operators of the hydro scheme on the river. Translocations of freshwater pearl mussels have been carried out previously in Scotland, elsewhere in the UK and in other countries with mixed results. In order to improve the success rate of any future translocations, a protocol for the freshwater pearl mussel was published by Natural England (2016) and this provides important information which could guide any project at Birchfield. The recommendation is to build on the work done already by the AECOM survey and carry out an analysis of the habitat features of the River Fechlin with regard to their suitability for sustaining a translocated population of freshwater pearl mussels, including the constraints that may be applied due to the hydro scheme on the river.

Possible Y4 activities

Please see the ‘Proposed plans for Y4 section under the fungal survey chapter. The findings of the missing species section of the report have contributed to the development of the proposal to inoculate trees with specific fungal species as an initial species reintroduction on the site.

5. Air eDNA Proof of Concept

Overview

Currently environmental DNA (eDNA) techniques are primarily focused on the collection of samples from water and soils, which is highly effective, but also demanding and costly as it requires active effort to collect samples. One of the key workstreams in Y3 focused on piloting a new technique that is receiving increasing attention in relation to its potential application to DNA collection: collection of air samples as a source of eDNA. It has been noted that AirDNA has the potential to be an efficient and cost-effective method for large scale routine monitoring of biodiversity. Over the past few years, several airborne eDNA proof of concept test results have been published[15], which provide DNA trace evidence left behind by a variety of species. In Y3 of the NCL, NatureMetrics, was engaged to deploy a prototype air eDNA system at Birchfield. The plan was to test this approach on site and compare the results with findings from other workstreams focused on biodiversity monitoring. This chapter summarises some of the key findings from the report prepared by NatureMetrics.

Figure 5-1: AirDNA monitoring at Birchfield in July 2022

Credit: NatureMetrics, 2022.

Work undertaken in Y3

Methodology

Samples were collected in July 2022 during two time periods (one in the daytime and one at night-time) across three habitat types: the open-felled (OF) area near NCL-00 monitoring station, the peat bog (PB) area near NCL-01, and the conifer plantation (CP) near NCL-06 – see the figure below. A total of 12 samples were collected (2 per time period, per habitat – daytime samples were setup in the morning and left in-situ to run until dusk or until the battery drained, and night-time samples were setup around 20:30-21:30 and left until 08:00 or until the battery drained), after which DNA metabarcoding analysis was conducted.

[15] See for example, https://peerj.com/articles/11030/, https://www.biorxiv.org/content/10.1101/2021.07.26.453860v1, https://link.springer.com/article/10.1007/s41748-021-00219-4

Figure 5-2: Air DNA sampling locations at Birchfield

Credit: NatureMetrics, 2022.

Key findings and conclusions

All samples were successfully sequenced for fungi, and 132 fungal Operational Taxonomic Units (OTUs)[16] were detected across 12 samples. All samples were successfully sequenced for vertebrates; however no target taxa (mammals or vertebrates) were detected in the vertebrate sequencing data.

When it comes to fungi, it was noted that the conifer plantation and the peat bog showed the highest differentiation from one another, and that sample-level richness and treatment-level richness were both highest in the night-time peat bog samples. The conifer plantation habitat demonstrated the greatest difference between its time period with higher richness detected during the day compared to the night.

Figure 5-3: A Taxonomic heat tree showing the number of OTUs across all samples for fungal taxa

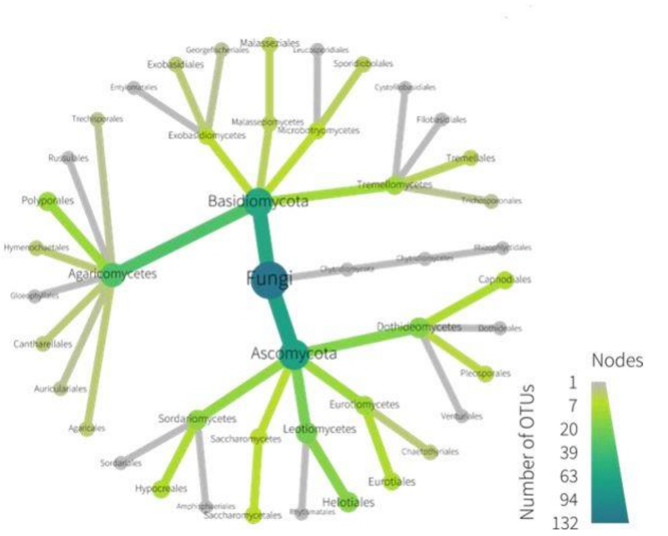


Figure 2. A taxonomic heat tree showing the number of OTUs across all samples for fungal taxa down to the order rank. Each node (the circles) is a taxon and the edges (lines) show hierarchical relationships between taxa. The colour scale and the relative width of the node represent the number of taxa at each level.

Credit: NatureMetrics, 2022.

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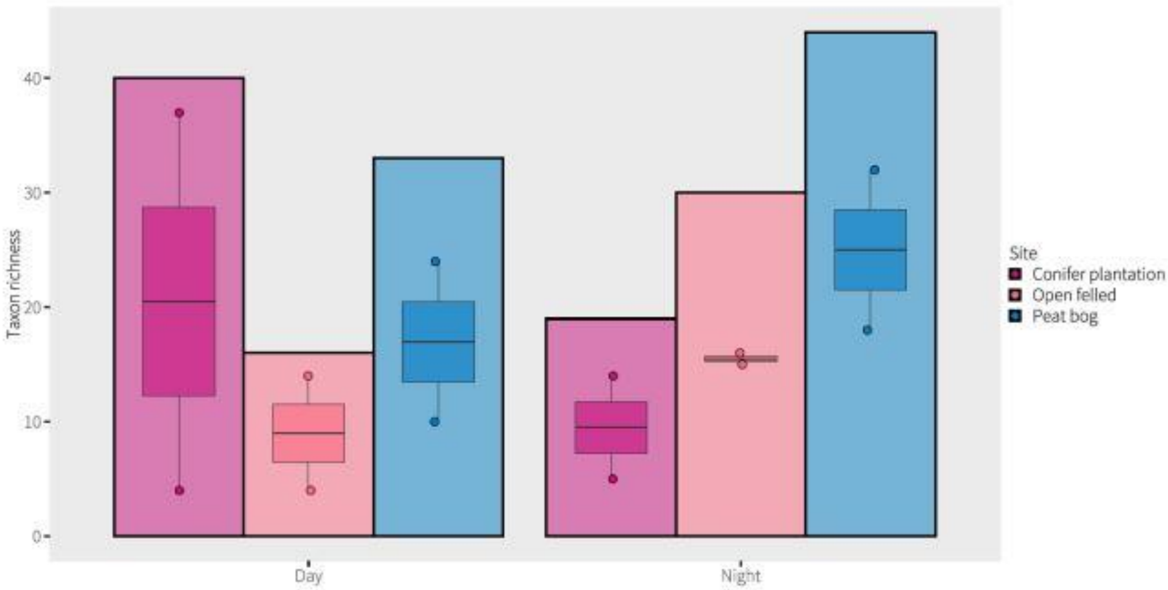
[16] Operational Taxonomic Unit – as analytical category, OUT is approximately similar to species as treated as such in this analysis.

Figure 5-4: Taxon richness (number of OTUs) for fungal communities in each habitat



Credit: NatureMetrics, 2022.

When it comes to vertebrates, the only samples captured were human; wild boar (*Sus Scrofa*) was detected in one of the conifer plantation samples and in one of the peat bog samples. However, this was suspected to be a contaminant from some of the laboratory reagents. While wild boars are present around Loch Ness (most commonly north of the loch) the results obtained during the analysis cannot be used as a confirmation of the wild board presence on site. Interestingly, no deer were detected in any DNA samples, despite their well-established presence on the site.

It is worth noting that the air DNA collection method used was adapted form the most up-to-date scientific literature and based on in-house testing undertaken by NatureMetrics. The technique is however still largely in its infancy, with a lack of testing conducted in natural settings. While laboratory methodology has been selected, it is worth noting that such choice inherently introduces limitations and biases: for example, for each of the target groups, primers were selected that from previous experience capture these targets well – however, these primers will inherently miss taxa and this will be a systematic error. There is not a single primer set that captures all the diversity, and the diversity present in the air makes it impossible to choose one primer set that balances specificity and resolution.

In general, this technique currently does not provide as detailed or comprehensive results as collection techniques from soil or water. As noted above, there are many methodological questions on which clarity will only be obtained after numerous instances of real-world testing; however, it will be important to compare some of the findings from air DNA for fungi with the results of fungal survey to further cross-check some of the results and use them in some of the planned reintroduction work in Y4.

Possible Y4 activities

At present, there are no plans for further eDNA sampling on site in Y4. The focus will instead be on synthetising the results obtained from biodiversity monitoring across all workstreams, and cross-checking results obtained via different techniques to derive some conclusions about their robustness.

6. Peatland Restoration

Overview

Two phases of peat investigation, consisting of peat probing[17], Russian Coring[18] and installation of eight piezometers[19], at the NCL site at have been undertaken.

The Phase 1 investigation was undertaken on 30th March 2021 by David Raeside, Neil Mackenzie and Sean Taylor and consisted of:

- 105 peat probes
- 3 Russian cores; and
- Installation of 6 piezometers

The Phase 2 investigation was undertaken 30th - 31st March 2022 by Neil Mackenzie, Sean Taylor and Daniel Whitley and consisted of:

- 103 peat probes
- 3 Russian cores; and
- Installation of 2 piezometers

The aim of the Phase 1 works was to carry out exploratory fieldwork and data collection to establish peat depth, composition and groundwater level within the southeast of the site, in an area previously identified by ecologists as comprising a degraded peat bog. The aim of the Phase 2 works was to expand the area investigated as part of the Phase 1 works, to determine the extent of peat bog in the lower lying land in the southeast of the site. This information is required to understand peat extent and condition to act as a baseline point of reference to monitor peat regeneration in the future.

Work undertaken in Y3

Peat probing

Peat probing was undertaken to collect preliminary data on peat depths within the generally lower lying area in the south-east corner of the site at Birchfield. The location, in the base of River Fechlin valley, had previously been identified by ecologists as comprising a degraded peat bog. The peat probing, across both phases, involved using 0.9m nominal length rods threaded together, as necessary, to reach the required depth. The peat probes were manually pushed into the ground until refusal, or a granular feel was felt on the rods. The depth achieved was then recorded.

Identifying the approximate peat depths across the area investigated provides an initial benchmark which can be used to monitor how the peat depth develops following regeneration works. In total, 208 peat probes were undertaken, across both phases, typically 20m apart from each other. The fiure below shows the layout of the probing undertaken with the red coloured positions indicating the Phase 1 peat probing and the blue coloured positions indicating the Phase 2 peat probing.

[17] Peat probing is a technique which quickly and accurately determines the depth of peat deposits using a simple probing rod.
[18] Russian coring is a technique used to extract a core of soft sediment from the ground, by driving a steel chamber into the ground, see figure 6.3. the sample is then analysed in a laboratory setting.
[19] A Piezometer is a simple tool used to measure water levels within peatland, to determine existing groundwater levels which informs understanding of peatland condition

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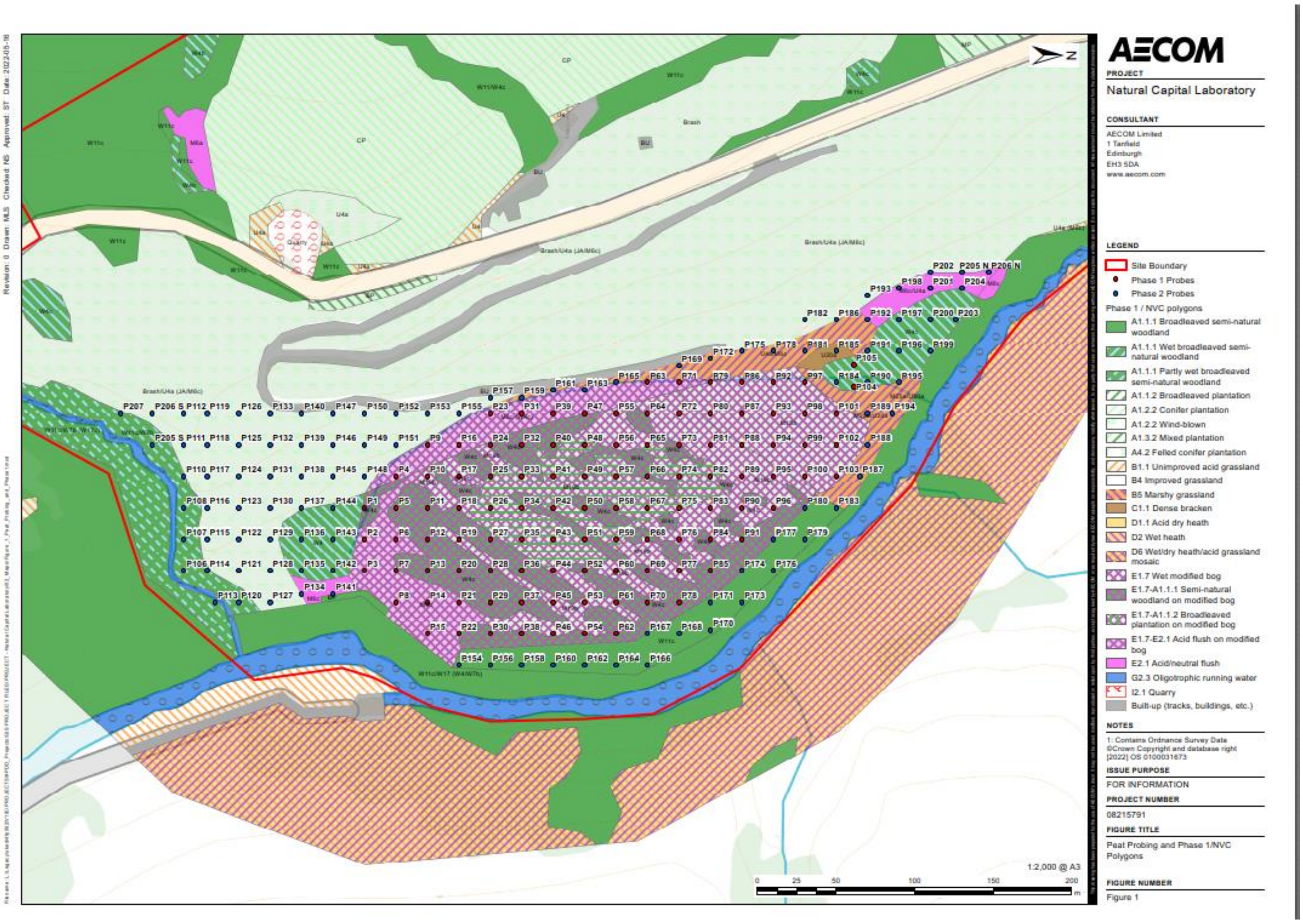
Figure 6-1: Peat probing plan for Y3 surveys

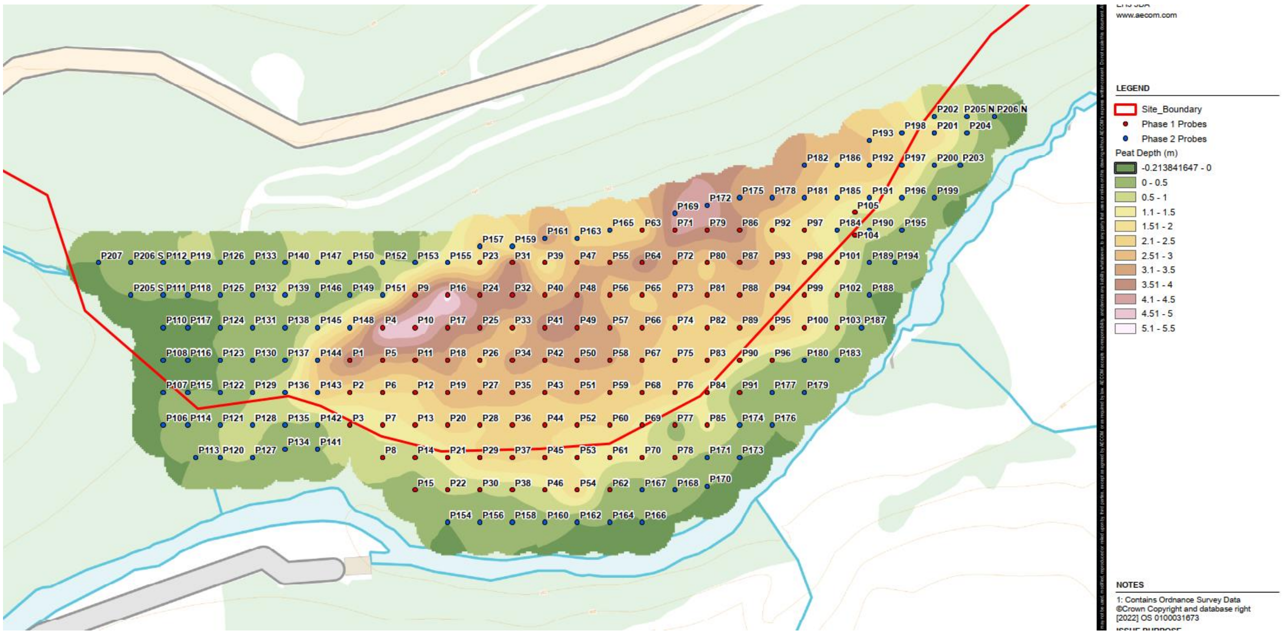


From the peat probing undertaken it was clear that peat exists in greater depths than initially anticipated with estimated peat depths ranging from absent to 5.2m. Figure 6-2 shows the contoured peat depths recorded throughout the site. As highlighted, the shallowest peat depths were typically encountered along the extents of the area investigated towards the River Fechlin and the steep slopes along the west of the site. The deepest peat deposits were typically encountered towards the west of the investigated area along the watercourse and the base of the slope.

The probing indicated that peat may be present in the flat laying area to the west of P207 and P126. This was further corroborated with observations made during the fieldwork potentially indicating peat deposits were present in this higher lying area. It should be noted some of these peat deposits may have been reworked due to the forestry operations in the area.

Based on the results of the peat probing, an approximate area of 6 ha. (59820m^2) of the probed area has been recorded with a peat depth of ≥0.5m. It should be noted that the peat depths recorded by the peat probing are estimates based on refusal of the probe or the feeling of granular material on the rods.

Figure 6-2: NCL Peat extent and depth



Russian coring

In order to determine the type and composition of peat onsite, Russian core sampling was undertaken. The Russian coring involved manually pushing a 500mm long semi cylindrical steel sample chamber with rotating fin into the ground to the required depth using nominal 1.0m long steel rods. The 52mm sample is recovered from the corer by rotating the rod through 180°.

A sample description was recorded along with a Von Post and Moisture evaluation of the peat. Three Russian cores were undertaken as part of the Phase 1 works, with a further 3 Russian cores undertaken as part of the Phase 2 works. The Russian cores were undertaken at selected locations to understand peat composition and where possible, prove substrate.

The detailed results of the Russian coring are set out in the Peat Investigation report, the below figure provides a sample resile from position P16.

Figure 6-3: Russian core sample P16 1.0m to 1.5m

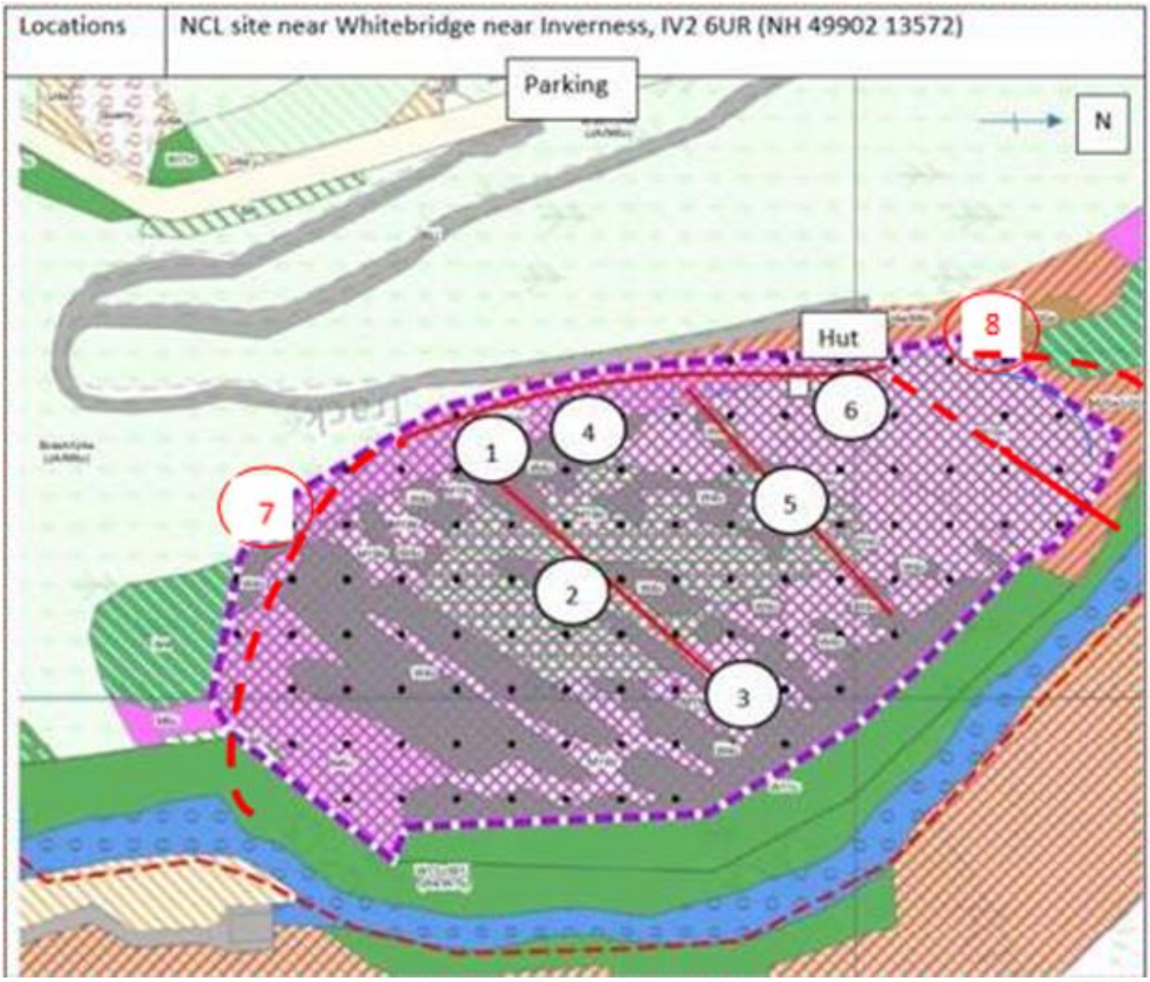
Piezometer installation and monitoring

A piezometer is a tool used to measure water levels within peatland, to determine existing groundwater levels which informs understanding of peatland condition. For instance, heavily eroded peatlands are characterised by a predominantly low water table, with lower water storage capacity than intact peatland.

In Phase 1, six 19mm ID piezometers were installed at selected locations across the site in order to determine existing groundwater levels. The locations were chosen based partly on areas where the peat was observed to be deepest and also close-by to where water was observed in drainage ditches. Figure 6-4 sets out the locations of the piezometer installations. Two ditches were observed onsite (north and central red lines in the figure below) which were oriented SW-NE and which run in the direction of the River Fechlin. A further ditch runs along the western boundary of the degraded bog area, which was also the location of some of the thickest peat deposits.

The presence of groundwater is essential for peat regeneration, as well as for monitoring changes in groundwater levels throughout the regeneration period. In Phase 2, a further two piezometers were installed in some of the newly probed areas in order to extend the area of monitoring to the north and south of the main peatland area.

Figure 6-4: Location of piezometers

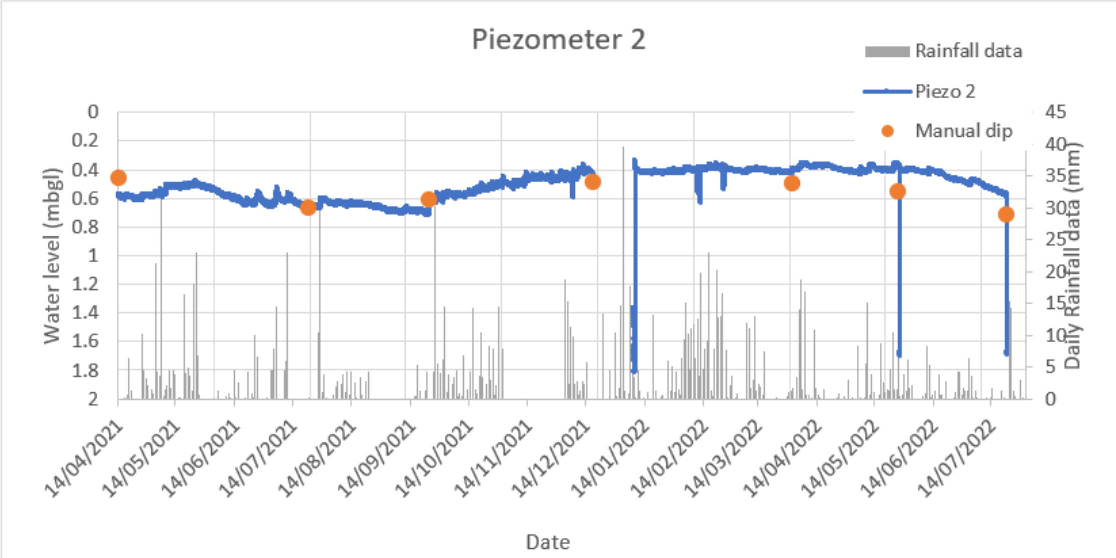


In Phase 2, additional drainage routes identified along the top of the peatland topography (red dashed lines – shown in Figure 6-4) provide possible flow paths to the river. This may result in surface water runoff from above the road being diverted away from the peatland. It is less likely that the groundwater system is similarly affected, but these drains could be important if it is decided that the peatland is too dry.

Water level data collected from the piezometers has now been recorded for a period of 13 months, including a winter recharge period. The pattern of responses in all piezometers is broadly similar with a recharge period from October through to March, with recessions in spring and summer. An example of groundwater measurements made at Pz 2 is shown below in Figure 6.5. Note how the logger data and dip data follows a similar trend.

The response of water levels (plotted on left hand axis) to rainfall (plotted on the right hand axis) is quite clear in the figure below. The location of this piezometer approx. 3m from the Middle Drain (halfway down the site) means that the influence of the drain is less distinct than for some other piezometers.

Figure 6-5: Water levels in Piezometer 2



Possible Y4 activities

Following on from the peat surveying and groundwater monitoring, it is recommended the results are reviewed to understand the baseline conditions for the peat and determine the best course of action to promote regeneration of the peatland.

Depending on whether a larger peat area is required to be proven, a further peat probing exercise could be undertaken to the west and southwest of P126 on the flatter lying ground at top of the slope leading to the proven lower lying peat bog. Observations made during the Phase 2 works indicated peat may be present here, however, due to time constraints the Phase 2 works could not incorporate probing within this area.

The groundwater monitoring has given us picture of the response over a fairly dry winter (2021/22). To build up a full picture, then continuation of this monitoring over the coming winter (2022/23) is advised. During this period, it would also be advisable to align all the Pz's to an ordnance datum so that an accurate groundwater level map can be produced and against which future changes might be compared.

In order to restore the peatland, alterations will be required to the network of drainage ditches presently running across the site. When planning this, consideration should be given to the best practice guidance provided by Scottish Renewables/SEPA[20] and from examples from other peatland restoration schemes in the area.

[20] Scottish Renewables & Scottish Environment Protection Agency (SEPA) (2012) *Developments on Peatland – Guidance on the Assessment of peat volumes, reuse of excavated peat and the minimization of waste.*

7. Remote Sensing

Overview

The objective of this workstream was to explore a new way to quantify the carbon sequestration of trees across the NCL site. While existing systems and calculations for quantifying carbon predominantly rely on canopy coverage as the basis for their assessment, the objective of this workstream has been to produce a more accurate assessment by using the existing AECOM methodology that relies on the National Tree Map (NTM) dataset from Bluesky and looks at the correlation between tree heights and stem diameters based on AECOM's large database on detailed BS5837 surveyed trees. The additional data on the tree heights and stem diameters obtained on site has been used to inform a model, in combination with canopy coverage, that can produce a potentially more accurate assessment of carbon sequestration of trees.

Work undertaken in Y3

Methodology

Initially, a baseline using iTree Canopy Assessment was established: this industry-accepted tool allows identification of forest canopy benefits such as carbon sequestration, air quality regulation, etc. Following this assessment, as it was determined that NTM dataset from Bluesky does not encompass all of Scotland (only England and Wales), it was decided to use another product, ProximTREE, which derives tree positions, height and size using an alternative methodology. This dataset was then run through an existing system derived from AECOM's High Tree Assessment work that uses AECOM's own internal database of over 70,000 detailed surveyed trees in order to look at the correlation between a tree's height and stem diameter size, resulting in the mapping set out in Figure 7-1, where the darker points represent taller trees. From this an additional attribute for each tree – approximate stem diameter – could be applied to the dataset, which would be crucial for the next step – the production of the carbon model.

Figure 7-1: Estimates of tree height on site

Next, a methodology for a baseline survey to establish ground-truthing of trees across the site was established. This involved splitting the site into distinct tree groups, within which individual trees and quadrants would be established. The data from these surveys would then be used to inform the carbon model. The project team made a site visit to Birchfield in May 2022. The team members present were briefed and split into groups. The first group utilised Trimble tablets with a bespoke survey form to capture 50 individual trees across the site. This included the following for each tree:

- fixing metal tree tag with corresponding tree ID;
- blue spray-painting spot below tag to assist in locating trees in future;
- measurement of the individual tree's stem diameter (using stem diameter tape);
- measurement of the individual tree height (using Clinometer); and
- photographing both the tree and its tag

The second group set out quadrants within each identified tree group across the site and measured the number of individual tree stem positions within that quadrant.

Figure 7-2. Examples of the ground truthing surveys

Carbon model – assumptions

Tree carbon was calculated as half of the tree's mass – mass is calculated by multiplying volume by density. The volume of a tree is calculated by assuming its shape is a long cone defined using its height and radius. This assumption is likely more reasonable for some species than others and will require further testing in the future.

Tree identification and height estimates can be done reasonably well. The first step is in this process is locating trees to understand where and how many you may have on a piece of land; this can be done using machine learning approaches. Synthetic Aperture Radar (SAR) data can estimate the altitude of a tree canopy, subtracting a digital terrain map will then give a tree height. The resolution of remote sensing data is usually too coarse to estimate tree widths. We therefore inferred these values using a statistical model. Typically, these models work in the opposite direction with height being inferred from width. This is an easier challenge to address as trees reach a maximum height but will continue to grow wider. Therefore, from a certain width you will have a good idea that a tree has reached its maximum height, but from a certain height it will be unclear what the width of the tree is. The current work around for this is to impose a maximum width of 150cm. The model for width-height was derived using a Bayesian model fit to the AECOM dataset of tree measurements. The tree carbon model can be applied across a parcel of land in which trees have been identified and heights estimated to give a prediction of total carbon on a site.

Results

iTree Canopy Assessment

Table 7.1: Tree benefit estimates: Carbon (English Units)

Description	Carbon (T)	CO_2 Equiv (T)	Value (GBP)
Sequestered annually in trees	80.63	295.63	£18,505
Stored in trees (Note: this benefit is not an annual rate)	2,024.81	7,424.31	£464,730

Source: i-Tree Canopy Assessment Report

National Tree Map Dataset

The ProxmiiTREE dataset provided good correlation with the ground truthing height data from the individual tree measurements. When compared to aerial imagery and site walkover, it also appeared to have a good coverage for identifying tree canopy extents. However, in dense woodland, it was apparent that it could not be relied upon to quantify a number of individual trees on its own. This finding was based on comparing the distribution of individual points and canopies from the dataset against the results of the group quadrant ground truthing. Therefore, going forward it should be used as an effective dataset to understand tree heights and overall canopy coverage area.

Ground Truthing – Site Walkover

The measurements for the 50 individual ground truthing trees are shown in the table below.

Table 7.2: Individual tree ground truthing schedule

Tree Tag Number	Tree Height (m)	Stem Dia (mm)	Latitude	Longitude	x	y
1	9	230	57.186447	-4.488446	249703	813372
2	15.1	490	57.186252	-4.488606	249693	813351
3	10.5	425	57.185835	-4.489119	249660	813305
4	11.4	240	57.185577	-4.489555	249632	813278
5	21.9	620	57.186699	-4.487587	249756	813398
6	23.1	480	57.186476	-4.487709	249748	813374
7	22.3	345	57.186234	-4.487211	249777	813346
8	22.1	420	57.185941	-4.486853	249797	813312
9	11.6	330	57.18698	-4.488634	249694	813432
10	9.4	200	57.187323	-4.488875	249681	813471
11	7.1	380	57.187698	-4.48916	249665	813513
12	18.8	315	57.187844	-4.48939	249652	813530
13	19.2	295	57.187042	-4.489079	249667	813440
14	23.7	310	57.187062	-4.489188	249661	813442
15	21.2	430	57.187612	-4.491075	249549	813508
16	11.3	325	57.187633	-4.491206	249541	813510
17	9.3	114	57.187631	-4.491616	249516	813511
18	12.3	410	57.187718	-4.49224	249479	813522
19	10.5	385	57.188279	-4.491229	249542	813582

Tree Tag Number	Tree Height (m)	Stem Dia (mm)	Latitude	Longitude	x	y
20	25.5	60	57.188459	-4.49156	249523	813603
21	12	21	57.188618	-4.49204	249495	813622
22	22.9	450	57.188913	-4.491674	249518	813654
23	9.5	180	57.189174	-4.492237	249485	813684
24	14.7	200	57.189713	-4.491917	249507	813743
25	14.7	240	57.190023	-4.492487	249473	813779
26	12.6	170	57.19094	-4.492136	249498	813880
27	24.3	330	57.191083	-4.491166	249558	813894
28	22.5	540	57.191296	-4.490857	249577	813917
29	6.3	26	57.188608	-4.490804	249569	813618
30	8.7	205	57.189052	-4.490654	249580	813667
31	7.7	140	57.183913	-4.486039	249838	813085
32	12.5	470	57.183968	-4.485404	249877	813090
33	7.5	450	57.184263	-4.485218	249889	813122
34	4.3	130	57.184862	-4.484907	249910	813188
35	11.1	230	57.185458	-4.48364	249989	813251
36	6.5	190	57.185474	-4.483686	249987	813253
37	6.6	150	57.186351	-4.483428	250006	813350
38	9.9	155	57.186701	-4.482828	250043	813388
39	6.4	140	57.187266	-4.484088	249970	813454
40	8.7	240	57.187918	-4.483719	249995	813525
41	5.7	160	57.188452	-4.484682	249939	813587
42	10.5	280	57.188902	-4.48606	249857	813640
43	14.4	450	57.189522	-4.487397	249779	813712
44	7.5	215	57.19049	-4.487591	249771	813820
45	12	260	57.191085	-4.487608	249772	813886
46	8.5	220	57.191755	-4.487931	249756	813962
47	10.8	305	57.192482	-4.488994	249694	814045
48	5.1	100	57.192714	-4.489342	249674	814072
49	9.3	165	57.192714	-4.490061	249631	814073
50	7.7	145	57.186349	-4.486914	249795	813358

Carbon model

The ProxmiiTREE dataset produced a list of trees and heights over the site. We estimated their width using our previously calculated model. From this we could estimate the total carbon in these trees. This gave a total carbon measurement from across the site of 7155 tonnes. The model used above requires more ground truthing to understand the accuracy of the model, in particular how accurate the conical model is. The ProxmiiTREE appears to not identify every tree and so this estimate is likely to be a lower limit estimate. The model currently assumes the tree density is similar to that of a sitka spruce wood and so likely underestimates the amount of carbon stored by the site's broadleaved trees. A more appropriate model should be derived for different types of trees – either in a broad category or individual species.

Conclusions and next steps

The ProxmiiTREE dataset proved to be an effective dataset for demonstrating tree heights and canopy coverage. The team were notified at the time of procuring the data that a full National Tree Map standard dataset would be available for Scotland within the next 6-12 months. Once this dataset is available it would be interesting to procure the data for the NCL area and make a comparison to the ProxmiiTREE to ascertain whether it is more effective for quantifying individual tree numbers and also how canopy coverage and tree height measurements compare.

When based upon the NTM dataset, the carbon model has the potential be immediately utilised within AECOM's existing Arboricultural High Level Tree Assessment service that already procures and uses the dataset to demonstrate spatial constraints for design optioneering and planning. It has the potential to provide a live insight into the potential carbon and environmental impacts of tree removals to allow for more effective design work during early stages of a development and before biodiversity net gain calculations are started. This could prove invaluable for large infrastructure projects that involve potentially significant tree loss and where tree loss is a particularly contentious issue.

Possible Y4 activities

The carbon model could be integrated into AECOM's newly developed biodiversity net gain and natural capital accounting tool, BioInstinct to improve estimates of existing carbon stocks. Currently this is done using assumptions about carbon density over area and habitat classifications. However, the density of trees in an area can vary with a potentially large impact on total carbon, particularly in cases such as plantation forests.

The model will need to be verified in the field. Additionally, it will need to be built upon to improve the uncertainty measurement, in particular accounting for missing trees from the dataset. For now, this method is likely best at showing that the data is consistent or not with a claimed amount of carbon rather than giving a precise estimate of total carbon.

As another outcome of this year's work, 50 ground truthing tree positions were plotted to a map that formed the basis for the design of a social value poster, see Appendix A.1. This sets out how visitors to the Birchfield site can be involved in capturing data on the trees and share it with the team to understand how the trees change over time and further refine the carbon model. The data will also be used to assess how different individuals' measurements compare. The intention is that the social value poster will form the beginnings of further social engagement at the Birchfield site and with the NCL concept.

8. Soil Surveys

Overview

The aim of this work was to describe the baseline condition of the soils at the NCL for the purpose of monitoring the effects of rewilding on soil quality. Baseline conditions have been defined by key physical and chemical properties that can be linked to soil quality in a UK forestry context. These soil quality indicators were selected to enable quantification of ecosystem services, such as soil carbon storage, and provide a measure of functional capacity with regards to forest ecosystem productivity and environmental quality. Table 8.1 summarises the soil properties included in this study and their relationship to soil quality and function.

Table 8.1: Soil properties and the rationale for inclusion in the soil baseline study

Soil quality indicator	Relationship to soil quality and function
Physical	
Texture	Influences water and nutrient retention.
Soil bulk density	Indicator of soil compaction, rooting ability, aeration, drainage and nutrient uptake. Required to convert carbon concentrations to stocks i.e. mass per unit area basis.
Penetration resistance	Indicator of soil compaction, rooting ability, aeration, drainage and nutrient uptake.
Chemical	
Soil organic matter (SOM), soil organic carbon (SOC) and total nitrogen (TN)	Soil organic matter is vital for many soil functions by providing food for microorganisms, promoting aggregation, improving physical structure, enhancing soil water infiltration and holding capacity and reducing erosion. Soil carbon storage contributes to climate change mitigation. C:N ratio provides an indicator for the decomposability of organic matter and thus soil biological activity.
Permanganate oxidisable carbon (POXC) or 'active' carbon.	Provides an early indicator for management-induced changes in carbon stocks. Also provides a measure of soil biological activity and nutrient cycling.
Cation exchange capacity (CEC)	An indicator for a soil's capacity to supply nutrients.
Available phosphorus (P), potassium (K) and nitrogen (N)	A measure of plant available concentrations of major nutrients can indicate changes in soil fertility and help to explain ecosystem productivity.
pH	Affects availability of nutrients and influences biological processes and productivity.

Work undertaken in Y3

Soil survey areas

Firstly, a review of available data for the site was undertaken, including published soil mapping, aerial photographs and the National Vegetation Classification (NVC) survey mapping carried out on site in 2019. Based on the available information, a soil sampling regime was proposed consisting of six survey areas to target the six main established vegetation types present at the site: (1) semi-natural broadleaved woodland; (2) Sitka spruce; (3) Norway spruce; (4) Serbian spruce; (5) a felled area with some established birch; and (6) a recently felled area awaiting restocking.

A site reconnaissance visit was carried out on the 21st and 22nd of April 2022 to assess the condition of the vegetation, confirm and record the boundaries of each survey area using a handheld GPS, and to conduct preliminary soil sampling and profile observations to confirm published soil mapping information. The soil sampling regime was subsequently finalised using the revised boundaries recorded during the reconnaissance survey.

Soil sampling

The fieldwork for the baseline soil study was carried out 16th - 22nd May 2022. Within each of the six survey areas, 25 soil sampling locations were selected using a systematic grid sampling approach, as set out in Figure 8.1.

At each sample location, soil was collected using a 10 cm diameter Edelman auger. The soil profiles were separated into the litter, organic and mineral layers to a minimum depth of approximately 40 cm and composited accordingly for laboratory analysis. Thickness of the litter and organic horizons were measured to the nearest 0.5 cm for each soil auger sample. Composite samples were taken at fixed depth layers that included the organic layer and the 0 – 10, 10 – 20 and 20 – 40 cm of mineral soil layers, with the exception of peaty gley soils where the rooting depth is restricted by anaerobic conditions and the top 20 cm of the mineral gley horizons was sampled.

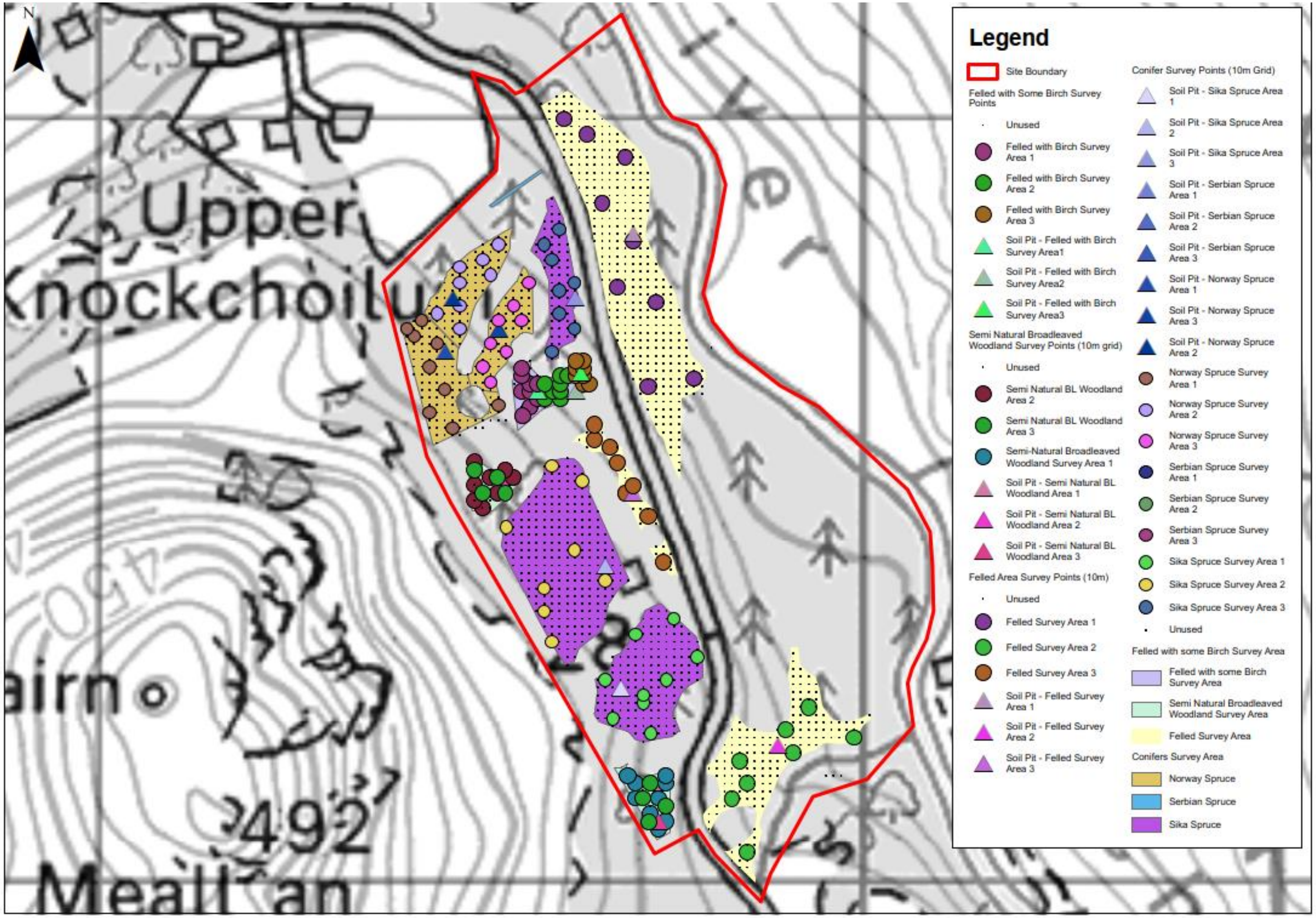
Three hand-dug soil pits were also excavated at randomly selected locations within each survey area and the thickness of the litter and organic horizons measured to the nearest 0.5 cm on all faces of the soil pits and overall mean thickness of each horizon calculated. Soil pits were located in the upper, middle and lower end of the grid to account for changes in topography. Soil bulk density samples were collected by inserting 100 cm^3 stainless steel rings into the middle of each horizon in the wall of each soil pit. The mean soil bulk density per horizon was used to calculate soil carbon stocks.

Litter density was calculated by measuring the depth of the litter horizon and excavating an area of 25 cm x 25 cm adjacent to the three soil pits within each vegetation type. Harvested litter was weighed at the laboratory to calculate the wet and oven-dried weights. The compaction level of the soil was also measured using a cone penetrometer, with four measurements recorded adjacent to each soil pit. Table 8.2 sets out the soil physical and chemical characteristics that were analysed from the soil samples.

Table 8.2: Soil analytical methods

Parameters	Results (and units) provided by laboratory	Analytical method
Physical		
Particle size distribution	% sand, silt and clay	Laser diffraction method
Soil bulk density / litter density	Total fresh weight (g) Total dry weight (g)	A known volume of fresh sample is weighed, oven dried and re-weighed
Chemical		
Carbon and nitrogen	% total carbon % total nitrogen % soil inorganic carbon % soil organic matter	Total C and N: Dry combustion Inorganic C: acidification with orthophosphoric acid and dry combustion Soil organic matter: Van Bemmelen factor of 0.58 to convert soil organic carbon to organic matter
POXC	Active carbon (mg/kg)	Oxidation with Potassium Permanganate
Mineral nitrogen	Nitrate-N (kg/ha) Ammonium-N (kg/ha)	Extraction with Potassium Chloride
CEC	Cation exchange capacity (meq/100g)	MAFF RB427 Standard Method for Temperate Regions – Extracted with Ammonium Acetate
Available P	Available P (mg/l)	Sodium bicarbonate extractable (Olsen's P)
Available nutrients	Available K (mg/l) Available Mg (mg/l)	Extraction with Ammonium Nitrate
pH	pH units	Measured in water [1:2.5]

Figure 8-1: Systematic grid sampling approach for soil sampling



Results – Soil physical properties

According to the national map of Scotland, the soils at the site are mapped at the association level as Arkaig[21]. Soil parent material has a major influence on the physical and chemical properties of a soil and soil associations represent a high-level grouping of soils that developed on the same or similar parent material.

The soil landscape at the site can also be differentiated *broadly* according to soil map units, which represent a generalised soil type or ‘complex’, based on a limited number of repeated landforms and usually comprising more than one particular soil type, and more *precisely* by soil series, which are groupings of similar soils based on key characteristics such as texture, parent material, colour and mineralogical characteristics. According to the published soil mapping, the western part of the site is located within soil map unit 23, described generally as peaty gleys with three component soil series: Badanloch (peaty gleys), Blanket Peat (peat) and Kildonan (peaty podzols). The eastern part of the site is located within soil map unit 27, described generally as brown earths with two component soil series: Aberscross (brown earths) and Gordonbush (humus-iron podzols). Field observations of soil samples generally agreed with the soil mapping, with the exception of brown earth soils encountered within the broadleaved woodland survey areas in the west of the site. Brown earth soil formation can be expected under semi-natural broadleaved woodland, due to the rapid decomposition of plant residue and recycling of nutrients.

The majority of soils at the site exhibited coarse textures, which is considered typical for Arkaig soils, with sandy loam and sandy silt loam soils being the most commonly assigned texture classes. Ten samples exhibited >50% coarse fragment volumes, most of which were gravel sized fragments although brown earth soils in the broadleaved woodland and felled areas and peaty podzols in the Sitka spruce survey area also contained cobbles and boulders. Such a high stone content is likely to have a considerable impact on soil hydraulic properties, evapotranspiration and water balance processes which warrants further investigation.

Soil bulk density varied with soil type and depth. Similar trends of increasing bulk density with depth were observed between the peaty gley soils beneath the Serbian spruce and Norway spruce, which increased from 0.28 g/cm^3 in the 0 – 10 cm organic layer of both soils to 0.55 g/cm^3 and 0.59 g/cm^3 in the 0 – 20 cm mineral layer of the Serbian spruce and Norway spruce, respectively. A similar pattern was observed with brown soils on the site. Bulk densities in the peat layers ranged from 0.09 to 0.28 g/cm^3, with generally higher bulk densities in shallow peat layers of peaty gleys and peaty podzols than the deep peat encountered within the felled area with birch.

As expected, soils profiles with a greater proportion of mineral material, i.e. brown earths and peaty podzols, had higher bulk densities than the soils with a greater proportion of organic material, i.e. peaty gleys and deep peat. The results of the analysis of the soil physical properties are set out in Table 8.3 where bulk densities and coarse fragment volumes are presented as mean values for each soil sample depth (n = 3). Soil compaction measurements are presented as mean values for each vegetation type (n = 12). Particle size distribution and soil texture classes are shown for each soil sample composited by depth increment (n = 1).

[21] Scotland’s soils (2022) National soil map of Scotland [online] available at: https://soils.environment.gov.scot/maps/soil-maps/national-soil-map-of-scotland/

Table 8.3: Soil physical properties

Vegetation type and soil sample depth	Predominant soil type	Bulk density (g cm^3)	Coarse fragment volume (%)	% sand	% silt	% clay	Texture class (SSEW)	Soil compaction measurement (average depth to 300 psi)
Semi-natural broadleaved woodland								
Litter layer (average thickness of 1.5 cm)	Brown Earth	0.02	-	-	-	-	-	30 – 38 cm
Organic horizon (average thickness of 5 cm thick)		0.63	60	22	55	23	Clay Loam	
Mineral horizon 0-10 cm		0.77	60	36	48	16	Sandy Silt Loam	
Mineral horizon 10-20 cm		0.85	81	63	31	6	Sandy Loam	
Mineral horizon 20-40 cm		0.81	60	46	42	12	Sandy Silt Loam	
Sitka spruce								
Litter layer (average thickness of 1.5 cm)	Peaty Podzol	0.07	-	-	-	-	-	22 – 30 cm
Organic horizon (average thickness of 6 cm thick)		0.18	34	-	-	-	Peat	
Mineral horizon 0-10 cm		0.67	60	45	42	13	Sandy Silt Loam	
Mineral horizon 10-20 cm		0.85	16	49	38	13	Sandy Silt Loam	
Mineral horizon 20-40 cm		1.08	35	61	32	7	Sandy Loam	
Norway spruce								
Litter layer (average thickness of 3 cm)	Peaty Gley	0.02	-	-	-	-	-	>45 cm
Organic horizon 0-10 cm		0.28	33	-	-	-	Peat	
Organic horizon 10-20 cm		0.34	42	57	37	6	Sandy Loam	
Organic horizon 20-30 cm		0.35	45	58	36	6	Sandy Loam	

Vegetation type and soil sample depth	Predominant soil type	Bulk density (g cm^{3})	Coarse fragment volume (%)	% sand	% silt	% clay	Texture class (SSEW)	Soil compaction measurement (average depth to 300 psi)
Mineral horizon 0-20 cm		0.59	70	70	25	5	Sandy Loam	
Serbian spruce								
Litter layer (average thickness of 3 cm)	Peaty Gley	0.02	-	-	-	-	-	>45 cm
Organic horizon 0-10 cm		0.28	41	-	-	-	Peat	
Organic horizon 10-20 cm		0.35	33	48	42	10	Sandy Silt Loam	
Organic horizon 20-30 cm		0.35	35	42	44	14	Sandy Silt Loam	
Mineral horizon 0-20 cm		0.55	75	55	34	11	Sandy Loam	
Felled area with some birch								
Litter layer (average thickness of 0 cm)	Deep Peat	0.00	-	-	-	-	-	>45 cm
Organic horizon 0-10 cm		0.09	0	-	-	-	Peat	
Organic horizon 10-20 cm		0.13	0	-	-	-	Peat	
Organic horizon 20-30 cm		0.13	0	-	-	-	Peat	
Organic horizon 30-40 cm		0.28	0	-	-	-	Peat	
Felled area								
Litter layer (average thickness of 0.5 cm)	Brown Earth	0.00	-	-	-	-	-	30 – 38 cm
Organic horizon (average thickness of 3 cm thick)		0.36	60	51	39	10	Sandy Loam	
Mineral horizon 0-10 cm		0.68	51	26	49	25	Clay Loam	
Mineral horizon 10-20 cm		0.76	42	15	55	30	Silty Clay Loam	
Mineral horizon 20-40 cm		0.83	60	16	54	30	Silty Clay Loam	

Results – Soil chemical properties

Table 8.4 presents laboratory results for key soil chemical properties. Total soil organic carbon (SOC) stocks for the survey areas ranged from 96 to 296 t/ha and varied with soil type and depth. SOC stocks decreased in the order of deep peats > peaty gleys > peaty podzols > brown earths. As expected, the organic (deep peat) soil type beneath the felled area with birch had the highest SOC stocks (296 t/ha), followed by the organo-mineral soils (peaty gleys beneath the Norway spruce, 289 t/ha, and Serbian spruce, 281 t/ha, and the predominantly peaty podzols beneath the Sitka spruce, 158 t/ha) and, lastly, the mineral soils (brown earths beneath the felled area, 138 t/ha, and broadleaved woodland, 96 t/ha).

Litter layer SOC stocks only accounted for between 0 and 3% of total SOC stocks, with the lowest proportion at the felled areas, from which little or no litter was recovered, and the highest at the Sitka spruce areas, which also had the highest litter density. SOC stocks were generally higher in organic / peat layers, with a mean of 61 t/ha, than in mineral soil layers, with a mean of 41 t/ha. Organic soil layers accounted for the majority of carbon in the peaty gleys beneath the Norway spruce, 75%, and Serbian spruce, 74%, which had an organic layer thickness of approximately 30 cm. However, mineral soil layers accounted for the majority of carbon in the predominantly peaty podzols beneath the Sitka spruce, 79%, and the brown earths beneath the felled area, 90%, and broadleaved woodland, 71%, which had organic layer thicknesses of approximately 6, 3 and 5 cm, respectively. The relatively low proportion of SOC stocks in the organic layer of the peaty podzols is likely to be due to:

1. the organic layer at the site is relatively thin for this soil type, which can range from 5 to 45 cm deep;
2. the presence of a humus-enriched illuvial mineral soil; and
3. the composite soil obtained for the Sitka spruce also contained soil sampled from a survey area that was characterised as brown earths which typically have lower SOC stocks.

As expected, SOC stocks were significantly positively related to soil C:N ($P = 0.01$), indicating that SOC accumulation relates to lower rates of decomposition. The lowest C:N values and SOC stocks were observed in the broadleaved woodland, which typically have lower SOC stocks than coniferous forests in Scotland and higher rates of decomposition due to litter quality and higher microbial / faunal activity in the soil.

Soils ranged from extremely acidic to strongly acidic, which is typical for Arkaig soils, and this varied with soil type and depth. The deep peat beneath the felled area with some birch and the peaty gley beneath the Norway spruce had the lowest pH, with both soil profiles exhibiting a mean pH of 4.4, while the brown earth beneath the broadleaved woodland had the highest pH, with a mean pH of 5.3 for the soil profile.

Table 8.4: Soil chemical properties. All results are shown for each soil sample composited by depth increment (n = 1). Soil inorganic carbon was reported as <0.1% in all samples, therefore, TC (%) values are equivalent to SOC (%).

Vegetation type and soil sample depth	SOC (%)	SOC stocks (t ha^{-1})	TN (%)	C:N	POXC (mg/kg)	Nitrate-N (kg/ha)	Ammonium-N (kg/ha)	pH	Available P (mg/l)	Available K (mg/l)	Available Mg (mg/l)
Semi-natural broadleaved woodland											
Litter layer (average thickness of 1.5 cm)	48.8	1.49	1.47	33:1	-	-	-	-	-	-	-
Organic horizon (average thickness of 5 cm)	19.7	26	1.31	15	2329	0.33	4.14	5.3	4.6	40.5	32.8
Mineral horizon 0-10 cm	5.6	17	0.36	16	833	0.70	3.58	5.3	3.8	26.6	22.7
Mineral horizon 10-20 cm	11.3	18	0.78	14	1519	0.02	1.51	5.3	3.4	22.6	15.8
Mineral horizon 20-40 cm	5.0	32	0.29	17	653	0.10	4.62	5.3	3.2	20.8	15.6
Sitka spruce											
Litter layer (average thickness of 1.5 cm)	50.2	4.95	1.35	37:1	-	-	-	-	-	-	-
Organic horizon (average thickness of 6 cm)	38.2	29	1.23	31	4806	0.13	5.75	4.5	5.6	22.1	95.6
Mineral horizon 0-10 cm	11.2	30	0.46	24	1036	0.04	2.74	4.9	8.0	19.4	24.6
Mineral horizon 10-20 cm	5.7	41	0.26	22	795	0.08	1.93	4.8	6.0	15.3	32.3
Mineral horizon 20-40 cm	3.8	53	0.17	22	504	0.12	2.72	5.1	6.2	16.9	17.4
Norway spruce											
Litter layer (average thickness of 3 cm)	50.4	3.41	1.55	33:1	-	-	-	-	-	-	-

Vegetation type and soil sample depth	SOC (%)	SOC stocks (t ha^{-1})	TN (%)	C:N	POXC (mg/kg)	Nitrate-N (kg/ha)	Ammonium-N (kg/ha)	pH	Available P (mg/l)	Available K (mg/l)	Available Mg (mg/l)
Organic horizon 0-10 cm	43.3	81	1.67	26	4724	0.15	12.30	4.1	6.0	21.4	104.0
Organic horizon 10-20 cm	40.0	79	1.59	25	3669	5.81	42.37	4.3	5.8	20.2	50.0
Organic horizon 20-30 cm	29.6	57	1.23	24	3023	5.13	16.29	4.4	6.2	21.4	47.8
Mineral horizon 0-20 cm	19.4	69	0.80	24	2149	3.01	9.41	4.6	5.8	17.7	22.6
Serbian spruce											
Litter layer (average thickness of 3 cm)	51.8	3.49	0.77	67:1	-	-	-	-	-	-	-
Organic horizon 0-10 cm	47.8	79	1.70	28	3792	0.17	8.01	4.2	4.4	38.7	53.2
Organic horizon 10-20 cm	33.5	79	1.41	24	3023	0.29	6.57	5.0	5.2	42.9	92.8
Organic horizon 20-30 cm	22.1	50	1.04	21	2320	0.20	12.93	5.3	4.6	45.9	124.0
Mineral horizon 0-20 cm	25.2	69	1.19	21	1503	0.07	3.91	5.8	3.8	55.2	100.0
Felled area with some birch											
Litter layer (average thickness of 0 cm)	-	-	-	-	-	-	-	-	-	-	-
Organic horizon 0-10 cm	40.0	37	1.74	23	4503	0.49	8.96	4.4	5.8	37.5	170.0
Organic horizon 10-20 cm	45.3	61	1.89	24	3375	0.51	8.63	4.4	6.4	38.3	200.0
Organic horizon 20-30 cm	47.4	62	1.87	25	3269	0.52	12.11	4.3	5.0	20.2	191.0
Organic horizon 30-40 cm	48.9	137	1.93	25	2468	0.57	58.46	4.4	4.4	15.3	187.0
Felled area											
Litter layer (average thickness of 0.5 cm)	33.6	0.03	1.38	24:1	-	-	-	-	-	-	-

Vegetation type and soil sample depth	SOC (%)	SOC stocks (t ha^{-1})	TN (%)	C:N	POXC (mg/kg)	Nitrate-N (kg/ha)	Ammonium-N (kg/ha)	pH	Available P (mg/l)	Available K (mg/l)	Available Mg (mg/l)
Organic horizon (average thickness of 3 cm)	31.5	14	1.36	23	2925	0.02	1.92	4.7	5.4	31.8	60.8
Mineral horizon 0-10 cm	11.8	39	0.64	18	1454	0.05	1.25	5.0	4.4	34.6	20.4
Mineral horizon 10-20 cm	9.4	41	0.49	19	803	0.06	1.61	5.1	4.4	36.3	18.1
Mineral horizon 20-40 cm	6.7	44	0.32	21	825	0.10	1.91	5.1	4.2	36.7	17.0

Possible Y4 activities

It is proposed that a repeat sampling event be carried out after five years of rewilding to assess changes in important soil conditions that are linked to forest ecosystem productivity. Even with intensive sampling, changes in certain soil characteristics such as soil carbon stocks can be difficult to detect in the short-term without significant changes to soil inputs. Unlike SOC stocks, which includes all forms of organic carbon in the soil, such as microbial biomass, recently decomposed plant matter and stable humus, POXC responds more rapidly to changing inputs and has been employed in this study to serve as an early indicator for changing soil carbon dynamics.

Due to budget constraints, it was not possible to include all the physical and chemical soil parameters that are considered important as soil quality indicators in a UK forestry context, however, this study represents an important first step towards incorporating soil within the natural capital accounting framework. It is recommended that additional sampling and analysis be carried out as soon as possible to supplement this baseline dataset with other important characteristics such as: acid neutralising capacity, to determine buffering capacity against acidification; acid cations including H^+ and Al^{3+}, which are important for accurate CEC measurement in acidic soils and assessment of Ca:Al ratio; and the available water capacity, to determine the ability of the soil to store and provide water to plant roots.

9. Natural Capital Accounting

Overview

Following the development of a baseline natural and social capital account in Y1, a digital natural capital account and additional intellectual account were developed in Y2. The aim for Y3 was to build further complexity into the capitals accounting process, using outputs from the survey work to add granularity to the accounts. Specific activities included:

- Updating the multi capitals accounts to reflect new environmental valuation literature;
- Undertaking further ecological site survey (see Appendix A1) and BNG assessments using the new Biodiversity Metric 3.1[22]; and;
- Estimating carbon impacts of project travel.

Under this workstream, the AECOM NCL team also managed the overall NCL project and brought together this report. The following sections set out the results of the capitals accounting work undertaken in Y3 and some areas of further work that could be potentially undertaken in Y4.

Work undertaken in Y3

During the 2021/22 there were some interesting changes to the status of natural capital assets on site, and these have been reflected in the asset account:

- **Ecosystems:** Additional walk over surveys in June 2022 identified a significant change in habitat type due to the rewilding process. The key change has been the transition of 12.5 ha of felled plantation woodland to acid grassland, which provides a demonstration of natural habitat re-establishment occurring. Remote sensing and aerial imagery also helped capture minute changes in habitat classification such as the broadleaved woodland on the edge of the River Fechlin being recategorised as part of the river bed.
- **Species:** Further breeding bird and butterfly/dragonfly surveys were undertaken as part of the ecological walkover surveys; however no significant additions were noted to the species on site. The key changes in respect of species were the 192 fungi identified through the fungal survey work (see section 3), including the IUCN red listed Dashy Bolete.
- **Freshwater:** Extensive freshwater surveys were undertaken in Y2 of the project, as such the Y3 focus was on other aspects of the site.
- **Soils:** Extensive soil baselining and further peatland surveys have provided important updates on soil type and condition. Incorporating this data into the natural capital accounts is a potential key activity for Y4t.
- **Atmosphere:** The remote sensing work has provided updated, site-specific estimates of the carbon stored in woodland vegetation; this is reflected in the increase from an estimated 6950 t/CO_2e to 7447 t/CO_2e stored in vegetation between the Y2 and Y3 accounts as a result of improved assessment approach. Additionally, an increase in carbon emissions has been estimated due to further areas of degraded peatland being identified as well as increased site visits following the easing of pandemic-related travel restrictions.

[22] Natural England (2021) The Biodiversity Metric 3.1 [online] available at: http://publications.naturalengland.org.uk/publication/6049804846366720

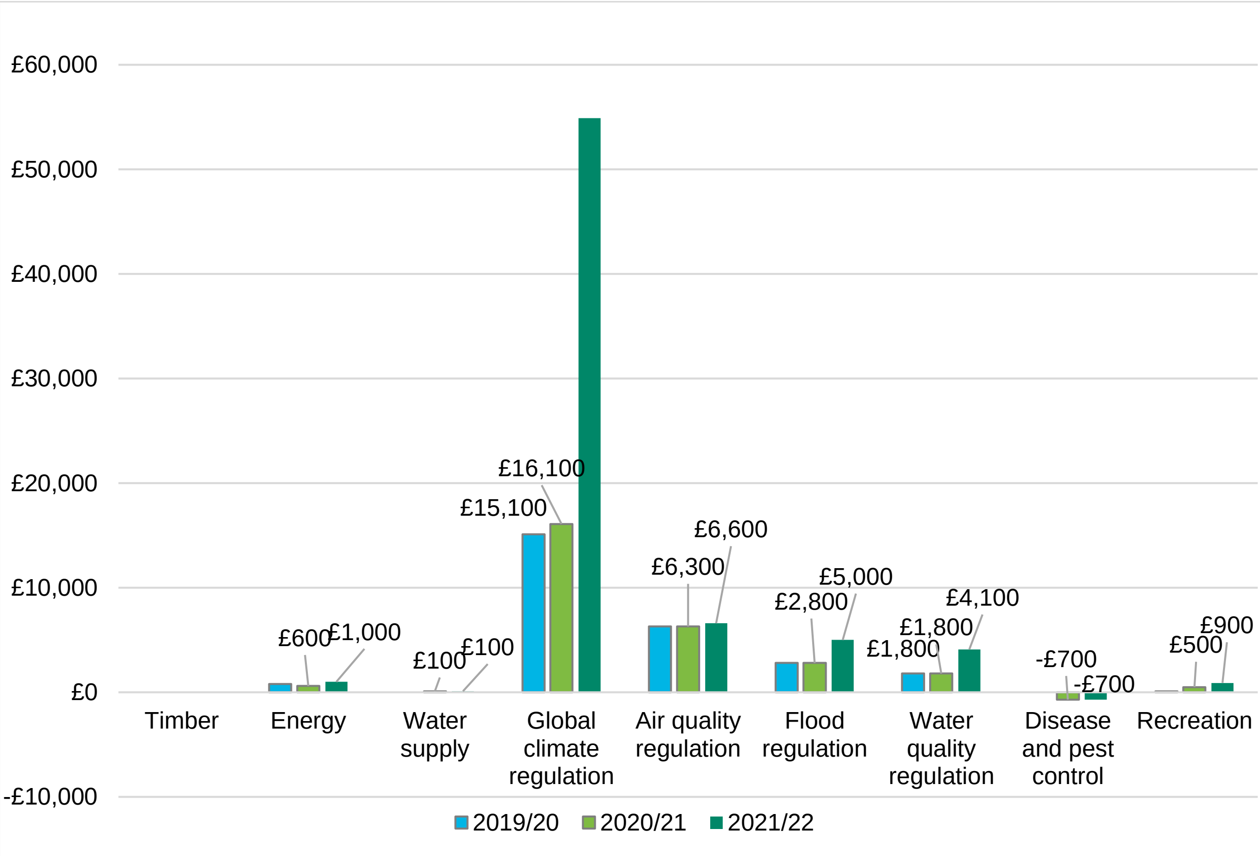
Figure 9-1: Summary of natural capital asset account

In terms of the physical and monetary flows accounts for the NCL in Y3, there was a noticeable change in water quality regulation, due to the increase in blanket bogs, raised bogs and fens habitat identified through the further ecological surveys undertaken. The identification of these wetland habitats also provided for an increase in our assessment of the provision of flood regulation, as wetlands provide a key service in terms of filtering pollutants. The most notable change evident in the monetary flow account, set out in Figure 9.2, is the sharp rise in the value of climate regulation. In physical flow terms there has been little change with carbon sequestration rates from land being estimated at 299 t/CO_2e sequestered per year, while emissions from site travel have increased from 1 to 18 t/CO_2e per year between Y2 and Y3 records. Instead, the increase in climate regulation value can be explained by a significant increase in carbon prices.

There were also increased numbers of recreational visits to the site, principally due to the reduced risk of COVID-19, encouraging people to holiday. The rewilding process has resulted in some natural changes to habitats, most prominent is the transition of felled plantation woodland to acid grassland. Despite a large increase in biodiversity units delivered by freshwaters, wetlands and floodplains, the transition and reclassification of woodland habitats has resulted in a net decrease of 20.08 biodiversity units across the site as a whole. Changes in the number of biodiversity units on site has also been influenced by the use of Biodiversity Metric 3.1, whereas for Y2 the Metric 2.0 version was used.[23]

In total, the annual natural capital value of the site was estimated to have increased by approximately 133% from £30,800 in Y2 to £71,900 in Y3. It should also be noted that this does not include the value of biodiversity, which is estimated to be approximately £3.9 million based on Defra's estimated value of £11,000 per biodiversity unit.[24] However, given that this figure has not previously been reported in end of year reports it has not been included in the account.

Figure 9-2: Annual value of ecosystem services at the NCL (2021 prices rounded to the nearest 100)



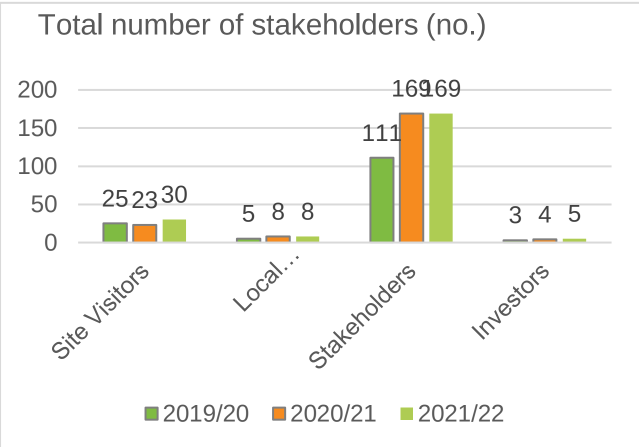
[23] Natural England (2021) The Biodiversity Metric 3.1 [online] available at: http://publications.naturalengland.org.uk/publication/6049804846366720
[24] IEMA (2018) 'IEMA Briefing on the DEFRA Net Gain consultation' & 'Full costs of biodiversity net gain revealed'

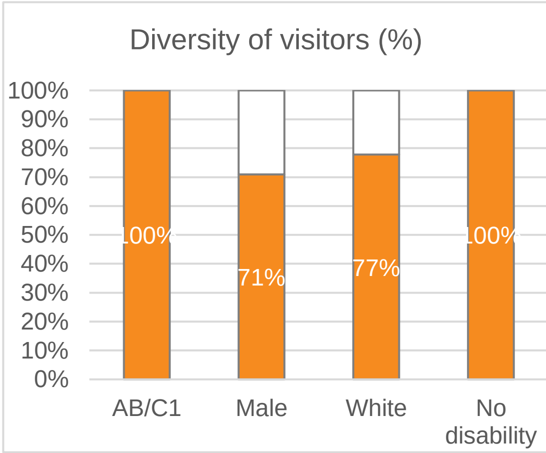
Social capital account

With regards to the social capital account, efforts were made to improve the structure and consistency of the account framework and expand on the detail where possible. In terms of the main changes to the asset account:

- **Site visitors:** the number of visitors recorded in the social capital account was based on the number of people who completed the site survey. Therefore, despite an actual increase of 82 visitors between Y2 and Y3 (from 138 visitors in Y2 to 220 in Y3), the social capital account takes into consideration the response from the 30 visitors who completed the feedback form, which represents a 20% increase on Y2 numbers. Importantly we have seen an increase in the diversity of people visiting the site, in Y2 92% of the survey respondents were 'White' in Year 3 the proportion was 77%, with 19% of visitors identifying as 'Black/African/Caribbean/Black British' and 3% as 'Mixed/multiple ethnic groups'. There is still a long way to go in terms of visitor diversity, particularly in terms of socio-economic status and gender representation, only 29% of survey respondents were female, while 71% identified as male.
- **Local communities:** no change in the engagement of local communities' engagement was reported, this is seen as an area for improvement and exploration of social value and local engagement is a priority for consideration in Y4.
- **Stakeholders:** It is estimated that the number of people engaged with the project grew exponentially, this is due to visibility at COP26 through the UKGBC Virtual Pavilion[25] as well as several published articles and presentations.
- **Investors:** there was no change to the investment structure and AECOM continued to fund the lab through its third year, together with funding of the site management activities by the landowners, and in-kind contributions from the Lifescape Project and University of Cumbria.

Figure 9-3: Overview of social capital account



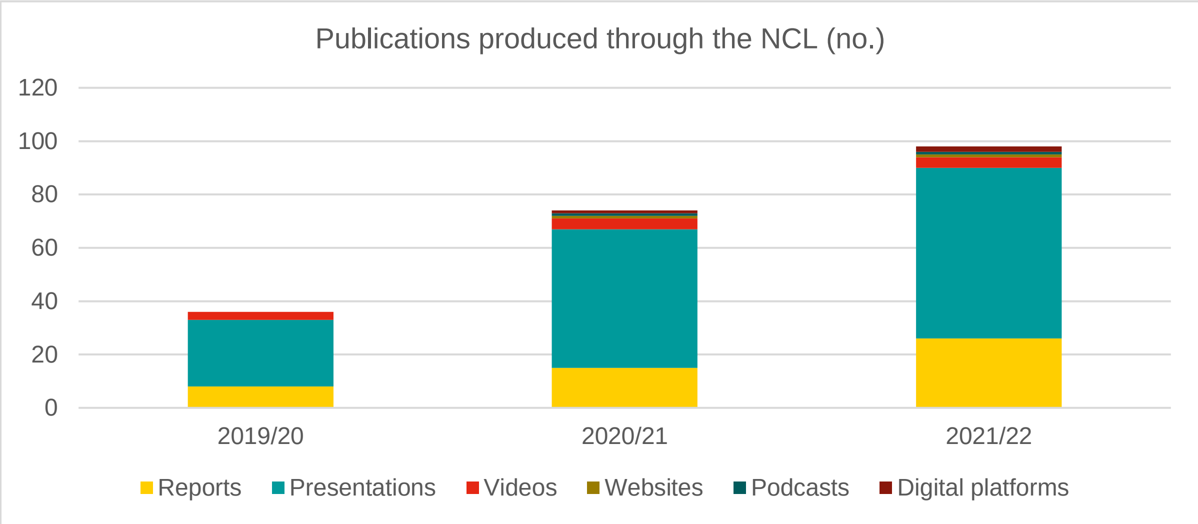


Intellectual capital account

In terms of the asset account, there has been a steady increase in the number of NCL-related publications in Y3, in terms of reports, presentations, videos, websites, and digital platforms. Furthermore, the NCL received important recognition in terms of the number of awards won in Y3. However, it should be noted that intellectual capital accounting is a new and evolving area and there are many gaps (e.g. around data assets); the initial account provides a starting point to think about how this value can be measured in quantifiable terms going forward.

[25] UKGBC (2021) CO26 Built Environment Virtual Pavilion [online] available at: https://virtualpavilion.co/

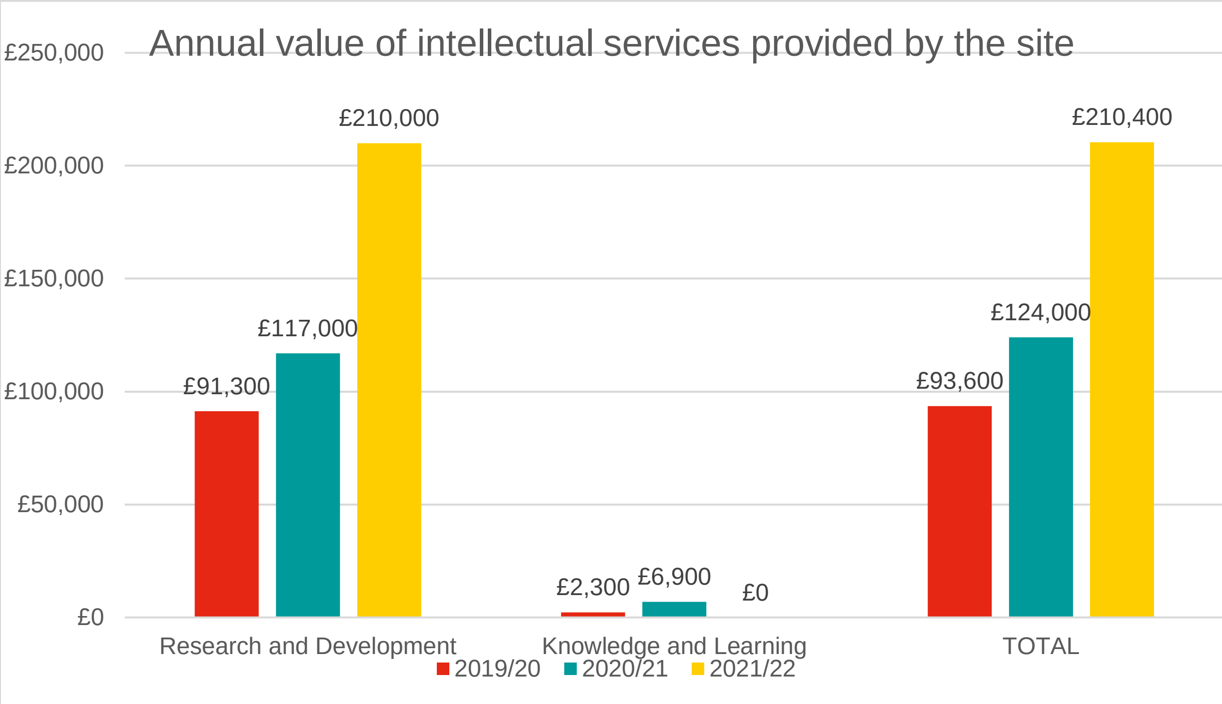
Figure 9-4: Summary of intellectual capital account asset register



In terms of physical and monetary flows, a key addition to the account was beginning to track the return on investment generated through the project via innovations which assisted AECOM to win new business. It was estimated that the total number of contracts were supported by NCL outputs increased from 9 contracts in Y1 to 10 in Y2 and a further 10 have been recorded in Y 3, with an increase in value from around £117,000 to £210,000 in total revenue, between Y2 and Y3. Therefore despite the quantity of contracts being consistent across Y1-Y3, the size and value and therefore scale of impact of the NCL has increased.

In total, the intellectual capital value was estimated to have increased by around 70% from £124,000 to £210,400 per year from Y2 to Y3.

Figure 9-5: Intellectual capital account monetary flows



Possible Y4 activities

One of the key successes of the NCL has been the development of the natural capital account using site specific data to support the quantification and valuation of ecosystem services delivered by the site. As workstreams collect richer and more detailed and complex data this provides an opportunity to evolve the account to use this data to give a much more accurate picture of the of the environmental changes that are occurring on site to inform future rewilding activity. The biodiversity monitoring and remote sensing workstreams provides unique opportunities to test and develop new quantification and valuation methods with respect to soils, pest and diseases, carbon stock of habitats and species, all of which can inform future AECOM client work and tools such as BioInstinct. The AudioMoths and digital workstream outputs will be used to add audio datasets to the interactive mapping and to develop further engaging media material that can be added to the digital account platform. Additionally, the development of social capital metrics in the proposed 'Public engagement and social value' workstream will result in outputs that can support the delivery of a digital natural *and* social capital account, through this workstream.

10. Next Steps

Overview

This section provides an overview of the aims and activities for Y4 of the NCL.

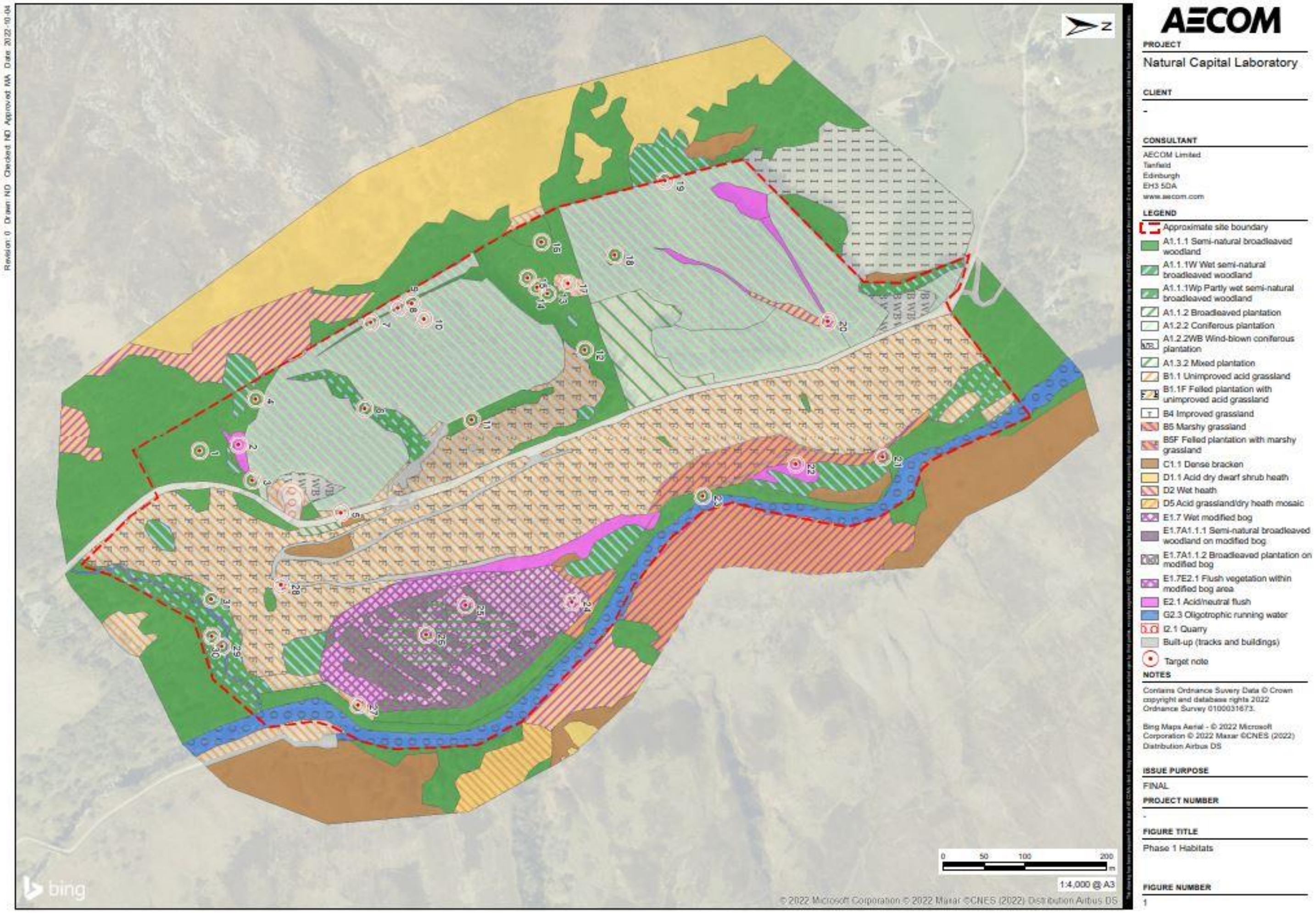
Aims

All project partners have a commitment to sharing the results of this project and engaging with other organisations to help tackle the climate and biodiversity emergencies. One of the objectives of the project is to expand the concept beyond the site in Scotland aiming to develop new solutions to the climate and biodiversity crises.

The proposals for Y4 workstreams are still under consideration. A number of proposals have been brought forward, building on the findings from the Y3 work and the following three principles: innovation; restoration and growth and partnerships:

- **Remote sensing:** Further the development of the remote sensing carbon modelling work to better account for carbon storage and sequestration rates of woodland habitats.
- **Social value and public engagement:** A programme of engagement with local communities is proposed. This will feed into the development of site-specific social value metrics to quantify social value impact of the project.
- **Capitals accounting:** Replicate the capitals accounts to capture impacts over Y4 and extend the breadth of the accounts to include new data streams and new forms of capital, including the outputs of the social value work stream above.
- **Peatland restoration:** Building on work undertaken in Y1 – Y3, a combined team from AECOM are proposing to deliver a peatland restoration trial. By focusing on a small area where peatlands are already present alongside the River Fechlin, the aim will be to put in place measures to block the existing drains on site and thereby create the conditions for the peatlands to recover.
- **Biodiversity monitoring:** With the equipment and data collection method now in place we can move to investigating analytical approaches.
- **Species reintroduction:** A novel and 'bottom-up' approach is proposed with the creation of micro-habitats for a wealth of species through cavity creation. Select trees can be inoculated with locally sourced, isolated, and cultured wood decay fungi to create cavities and speed up the natural process of breaking down decaying and deadwood.
- **Deer management:** At a site level the high density of sika deer present on the NCL site is significantly hampering the rewilding process, evident by the damage caused to saplings planted in Y1 - Y2. Vegan ethics are central to the site and culling is not the default approach. Alternatives, such as spraying of Trico, lowering deer fencing in a specific area to habituate the deer to leave the site and additional alternatives are being trialled.

A.1 Y3 Phase 1 habitat mapping



A.2 Remote sensing tree measuring poster