Natural Capital Report

Bunloit Rewilding

November 2021

BUNLOIT™

Contents

Foreword

Exponential growth in solutions to the global environmental crisis can justifiably be thought of as societal survival reflexes. The world already knows what one of these looks and feels likes: the solar-solutions revolution, which took off in the mid- to late 'noughties. Prior to its tipping point, investment in solar energy was dominated by concerned individuals and organisations, not the mainstream financial sector. Financial institutions tended to argue that much as a rapid expansion of solarisation was desirable on environmental grounds, solar companies were "uninvestible" absent proof of the technical and economic workability of solar energy. Today, in the face of climate meltdown and biodiversity collapse, the world desperately needs to trigger another survival-reflex revolution, this time in nature-based solutions. Notwithstanding the heady rhetoric of many financial institutions about the imperative for this - the now manifestly existential threat posed to economies by the climate / biodiversity crisis - early investment is following the same pattern as in the solar-solutions revolution.

So where do we go for proof of technical and economic workability for nature-based solutions of the kind that would help release the vast sums of money the financial institutions are sitting on while forests burn and pollinators die?

Helping provide this evidence is one of the main rationales for the Bunloit Rewilding Project. We aspire to provide scientific evidence that will help make business plans based on natural-capital more easily investible by those who stick to the old conservative - now suicidal - ways of big finance. We hope to do this by measuring a baseline of carbon and biodiversity in the varied habitats of the Bunloit estate in Inverness-shire, make interventions to boost carbon sequestration and grow biodiversity, and measure the gains regularly. By doing this, and showing and sharing how we do it, we hope to give all the relevant players in carbon and biodiversity markets (from huge pension funds to local communities) greater confidence in the numbers they are using to write their plans. And give the wider financial sector no excuse for not investing at scale.

Our first year of this work has been thrilling, as you will read, both in the wonders of nature that we are observing, and the sense we have of a contribution to be made in the much-needed acceleration of the nature-based solutions revolution.

I would like to thank all those who have partnered with us in this work, whether from universities, research institutes, nature-conservation organisations, government departments, and technical contractor companies. I won't name them here because you will read about them in the report. The sum of our collaboration, I believe, is so very much bigger than the parts. I extend my heartfelt thanks to all involved for helping this come about, both in the embryonic Bunloit Rewilding team, and our partner organisations.

Dr Jeremy Leggett
Founder and Acting CEO
Bunloit Rewilding

Executive Summary

This report is a summary of the natural capital baselining research undertaken over the last year on the Bunloit estate, near Loch Ness in Scotland, by Bunloit Rewilding - the operator of the estate. Bunloit Rewilding is a new company with a purpose of enabling nature recovery and community prosperity through rewilding.

The Bunloit team has worked with a range of partner organisations to create an inventory of carbon and biodiversity within the highly diverse habitats of the 511 hectare estate. We have used some of the best modelling tools and suppliers available today, including exciting technologies holding the future potential for more accurate measurements, gathered more cheaply and quickly. We have created a baseline of data classifiable within Tier 2 and Tier 3 of the Intergovernmental Panel on Climate Change (IPCC) definitions for estimating greenhouse gas emissions and removals[1]. Through this work, we aim to develop standardised monitoring protocols that can be repeated on a regular basis, to build on the baseline work and quantify the impact of land-management interventions aiming to boost carbon sequestration and biodiversity gain.

Carbon

Our current calculation of the carbon dioxide equivalent (tCO2e) stored within the natural systems of the Bunloit estate is between **845,472 and 1,234,334 tonnes. This is the equivalent of 2% of Scotland's current yearly emissions.** Between 708,778 and 1,097,640 tCO2e is in the peatland and 115,748 (i.e., up to c. 10 times less) in the woodlands of all types, with 20,946 in the grasslands. (Please note that all calculations presented in the report will probably be subject to revision as our scientific programme unfolds, and our understanding grows with it).

The extensive existing woodlands and grasslands of the estate cover some 441 hectares, 86.3% of the estate land area. We calculate that 866 tCO2e / year is being sequestered in them. But meanwhile the open peatlands, which cover c. 70 hectares, or 13.7% of the land area, tell a different story. Based on the data we have gathered so far - absent Tier 3 greenhouse-gas flux measurements, which we plan to begin next year - we calculate a loss of 1,106 tCO2e / year. Satellite-based measurements of peat movements in the last 5 years independently support carbon-dioxide emissions on this kind of scale.

Combining the two gives the unsettling picture of a verdant estate, replete with healthy woodlands, being a net source of greenhouse-gas emissions, with an estimated average net loss of 240 tCO2e / year.

We have two main routes to reversing this most undesirable state of affairs:

- The first is to fell conifer plantations sitting atop the peat, letting the compressed bogs "breathe" again, with healthy moss growing and drawing carbon dioxide down into the wetland, meanwhile planting broadleaves elsewhere on the estate to compensate for the carbon stock loss in the plantations.

- The second is peatland restoration, in particular by blocking drainage channels so as to promote moss growth by retaining water in the bogs.

[1]Tier 2 data are based on the mapping of habitats and the application of standardised tables of emissions data compiled in similar habitats by scientific studies elsewhere. Tier 3 data involve accurately located in-situ measurements.

Based on current data we estimate the reduction in losses from peatland restoration and extra sequestration from new planting at a net saving of 92,350 tCO2e over 100 years. Including carbon stock lost from clear felling activities of 31,603 tCO2e in our calculation (assuming the timber does not end up in long-term storage) **we arrive at a net 60,747 tCO2e saved over 100 years.**

Where we have been able to add Tier 3 actual measurements to our Tier 2 modelling of carbon stocks and flows, we have found higher levels of carbon sequestered in our natural systems than earlier studies in similar terrain might suggest. In particular, Tier 3 modelling of carbon stocks based on intensive, direct sampling of Bunloit soils gives an estimate of 38% (29,002 tCO2e) higher than the Tier 2 modelling based on proxy figures provided by Natural England from measurements elsewhere. Tier 3 soil carbon measurement of previously clear-felled conifer plantation areas suggests 44% higher carbon than in the open grasslands, showing the importance of carbon stocks in woodland soils even after clear-felling.

LIDAR (Light Detection and Ranging) surveys show lower tree numbers within old-growth plantations and woodlands than those projected from the widely-used Woodland Carbon Code (WCC) modelling. Reasons for this could include failed establishment, windblow and previous thinning. However, the data also show that the trees are taller and therefore bigger than the WCC models suggest. Overall, combining these two factors leads to similar estimates of biomass as the Tier 2 WCC calculations, but current existing modelling does not consider biomass and hence carbon within the whole branching structure of the tree. We will be conducting Terrestrial Laser Scanning in the months ahead to assess how much more above ground carbon resides within our broadleaves than current methodologies allow for.

Biodiversity

We do not yet know the methods that policymakers will adopt in effecting the system-change in economic rewards for land management that politicians have promised. But we do know that the options under discussion hinge on as granular an understanding of biodiversity inventory as possible for any tract of land under consideration. Accordingly, we have studied as broad a cross-section of fauna and flora as we could with the resources and time available to us in our first year at Bunloit.

In the course of this work we have discovered that the **Bunloit estate is of international importance in terms of lichen communities, and of regional importance in terms of unimproved grasslands.** NatureMetrics analysed Environmental DNA (eDNA) - nuclear or mitochondrial DNA released from organisms into the environment - to provide an indirect window into fungi and faunal inventories for us. From 42 soil samples, with at least one from each of our representative habitats, a total of 1,168 fungal operational taxonomic units (OTUs) and 352 faunal OTUs were detected. Fungal taxa richness was lowest in the coniferous woodlands and faunal taxa richness was highest in the bogs.

Plantlife UK conducted an initial check of the eDNA data against the ICUN red list of the datasets and **identified several rare and threatened fungi species**. These included *Russula lilacea* and *Clavicorona taxophila*.

A Plantlife specialist team completed a full botanical assessment of the estate, including lichens, vascular plants and bryophytes (mosses and liverworts). They identified 580 separate plant species: 271 lichen species, 155 vascular plant species, and 154 bryophyte species.

Bunloit's lichens are of great interest, with some areas exceeding Site of Special Scientific Interest (SSSI) status. The ancient woodlands below and to the west of the ancient grassland areas have particularly important communities. **An oceanic hazelwood ravine running across the southern sector contains an exceptional rainforest community of great conservation importance.** Such assemblages show that the Bunloit broadleaf woodlands have been in existence for a long time. One resident on the grasslands, the Ballerina Waxcap - (*Porpolomopsis calyptriformis*) is scarce in the UK.

The vascular plant species recorded show that the grassland areas are undisturbed, ancient in origin, and **hold good potential for restoring species richness.**

A survey of 573 individual juniper bushes across the northern part of the estate demonstrates that Bunloit is suffering from the same problem as juniper populations across Scotland, with the population being heavily skewed towards mature plants, and very few young specimens. This indicates heavy grazing pressure.

To assess the fauna we made extensive use of camera traps in a 90 day study period. Estate wide, sika deer are by far the most numerous – accounting for 53% of all classifications. Wild boar classifications came in second at 12%. Other key large mammals on the site are roe and red deer, badgers, foxes and red squirrels.

Based on the point counts and ad-hoc observations, 77 bird species have been recorded to date. Some species e.g., geese (e.g., Canada, Greylag), swans (e.g., Mute) and large eagle species (e.g., White-tailed) were recorded flying over the estate. NBN Atlas records indicate 168 bird species records within 10km of Bunloit and 118 species records within 5km of Bunloit.

At least six bat species of the 10 known to Scotland have been recorded across the estate. Bats have been recorded in all areas sampled.

Repeat surveys of butterflies on transects between June and September showed another picture of struggling species finding refuge on Bunloit. One resident, the Pearl-bordered Fritillary, is a UKBAP Priority species as well as being listed by Scottish Natural Heritage (SNH) as a Species Action Framework (SAF) species. It is also one of the key woodland species identified for action by Forestry Commission Scotland in the Scottish Forestry Strategy 2006 due to its rapid decline. The Comma has only in recent years made its way into the Highlands and has been recorded in low numbers. It is present on Bunloit.

Of the 19 dragonfly and damselfly species in the Scottish Highlands, 11 have been observed on Bunloit by dragonfly enthusiast Larry Templeton. It is likely that the estate is a key dragonfly site in the Highlands due to the presence of the uncommon Northern Emerald and the Brilliant Emerald - **the latter being one of the rarest dragonflies in the Highlands.** The estate has a variety of habitats including small lochans and an abundance of sphagnum bog pools which attracts a variety of dragonfly species. Recent spots by our rangers have also included the elusive Azure Hawker, which makes 12 dragonfly species found so far, of the 19.

The report closes with a discussion of how we hope the ongoing carbon and biodiversity inventory-building we describe will connect to, and add value to, the policy and investment worlds.

Overview of the Bunloit Estate

© Joe Gray

The 511 hectare Bunloit estate on the shores of Loch Ness in Scotland is operated by Bunloit Rewilding Ltd, a new company founded by eco-entrepreneur Jeremy Leggett. Our habitat types include grasslands, peatlands, heathlands and scrub as well as both native broadleaf woodlands and non-native conifer plantations.

The estate has been managed over the past year as an open natural capital laboratory, aiming to create a beacon of hope in the ongoing dual challenges of climate change and the ecological emergency. Our purpose at Bunloit Rewilding is to enable nature recovery and community prosperity through rewilding.

We have four goals:

1. Meaningfully increase carbon sequestration - within our expanding peatlands, grasslands and woodland areas

2. Meaningfully increase biodiversity - through the ongoing creation and enhancement of native, biodiverse habitats

3. Increase local, natural capital employment - via creation of direct jobs on the estate and engagement of local specialist contractors, volunteers and interns

4. Become sustainably profitable - developing natural capital and other income streams to create profitable models that enable us to provide a percentage of profits back into our communities

We believe that these goals will best be delivered through a rewilding-led model, which importantly includes people working with a recovering natural environment.

Research Themes

This report summarises the findings from our 2021 baselining survey of the carbon and biodiversity 'stocks' and 'flows' in the Bunloit estate habitats. It has been conducted aiming to demonstrate that natural capital can be grown verifiably for planet, people, and profit, both in wildland and actively managed land, and with five themes in mind:

- Community Led Delivery - we aim to work with all the communities that we are part of. This includes both our local geographic community, as well as the academic and business communities and networks working to advance the development of natural capital solutions - regionally, nationally and internationally.

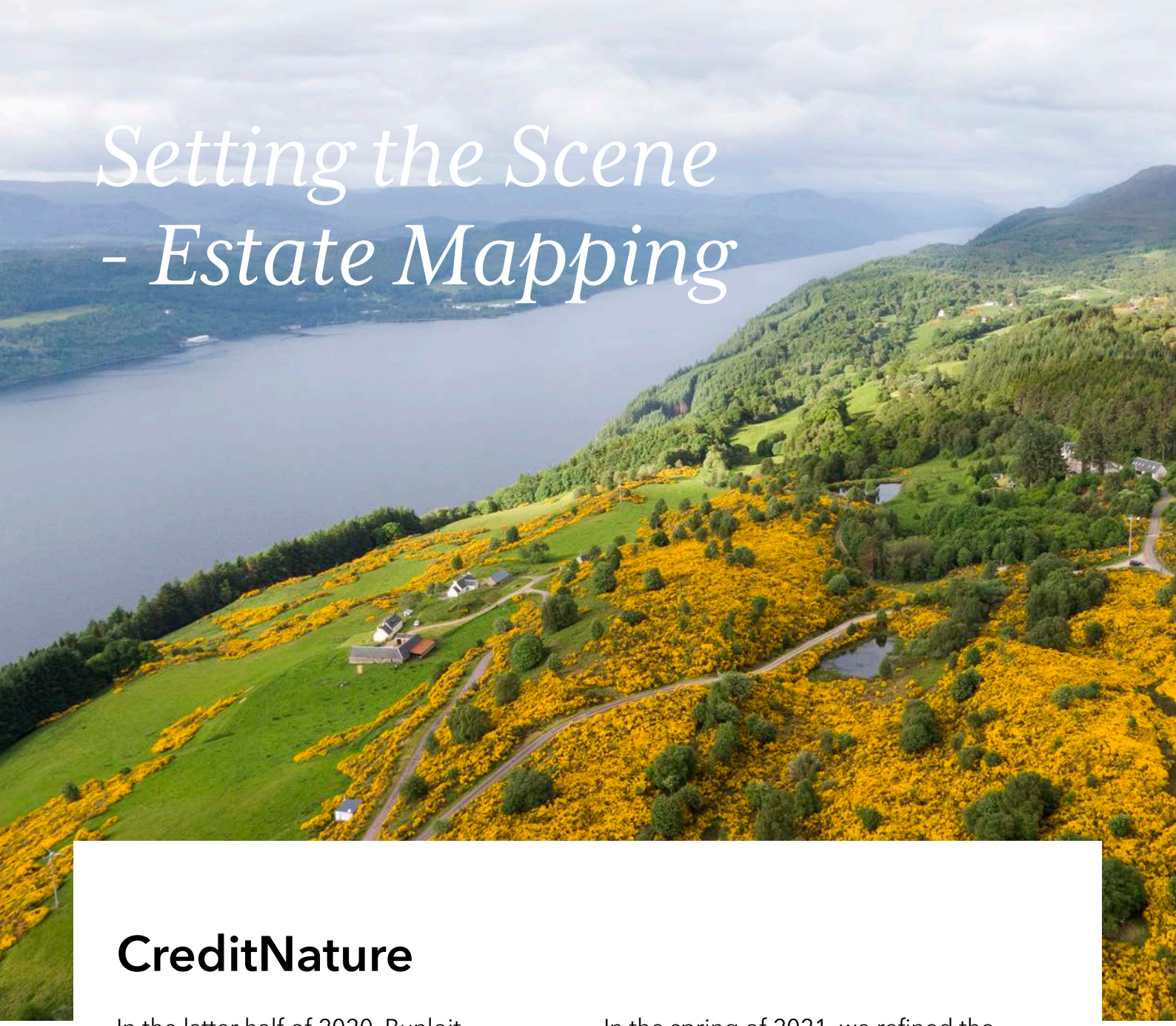
- Nature Led Recovery – We believe that when given a chance, nature can rebound and recover with dramatic results. As such, we aim to undertake as little intervention on the land as possible. However, we also recognise there will be a need to intervene where the collective judgement is that natural recovery may be too slow materially to help in carbon sequestration or biodiversity gain.

- Embracing Innovation and Change – there are multiple new opportunities in technology and innovation that we believe can have dramatic effects on pushing the boundaries of nature-based solutions. From satellite and drone imagery to advances in eDNA testing, we aim to explore all areas that could help drive our impact mission.

- Evidence Based Science – By setting our intention for Bunloit to be an open laboratory for natural capital verification science, we aim to collect a large evidence base that can be accessible to support and drive nature-based solutions research.

- High Quality Credits – Our work aims to produce high-quality evidence-based data on natural capital quantification, and we aim to feed our research outputs into the ongoing policymaking process in government, hoping that we can help the best possible criteria for high quality credits to emerge.

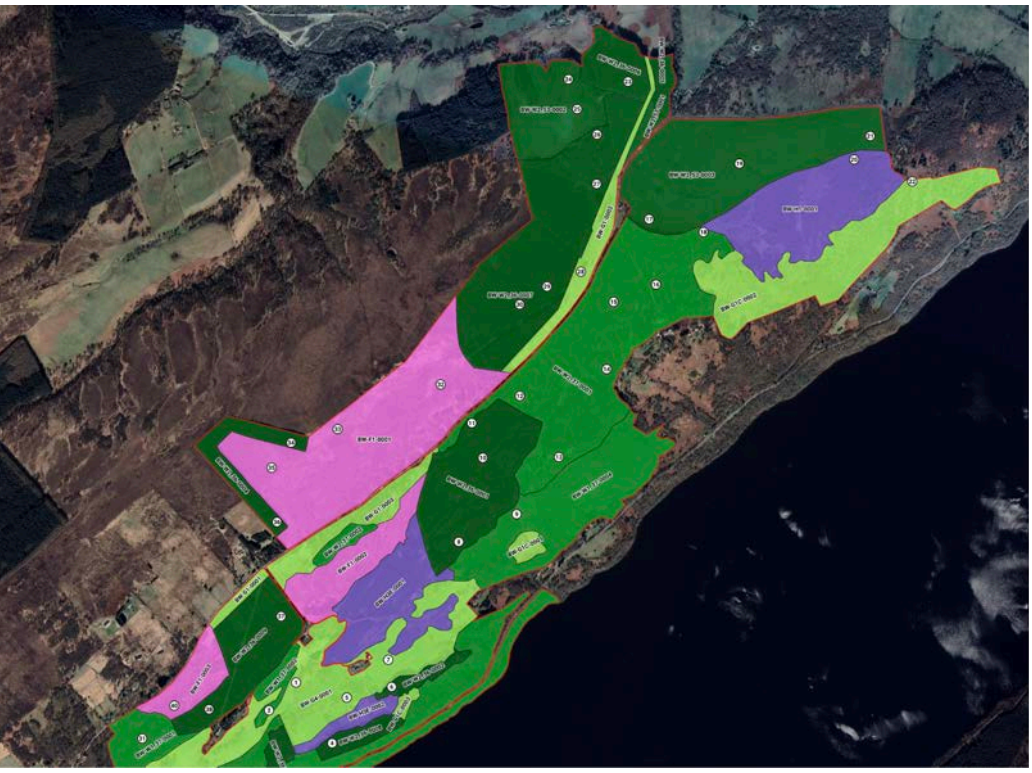
Setting the Scene - Estate Mapping



CreditNature

In the latter half of 2020, Bunloit Rewilding partnered with the rewilding consultancy Ecosulis to begin mapping an ecological baseline on the estate. Called CreditNature, the three-month feasibility study was funded through Innovate UK's Sustainable Innovation Fund and aimed to integrate a range of cutting-edge technologies to create a platform underpinned by real world data, which would enable the development of carbon, biodiversity and rewilding (ecosystem recovery) credits. During this work the estate was classified into five high level habitats which can be seen on the following page.

In the spring of 2021, we refined the mapping process by collaborating with the satellite mapping company Spottitt. Spottitt used an Airbus Pleiades multispectral image (R, G, B, NIR and Pan bands) taken on the 26th of June 2019 to assess Bunloit land cover using their analysis algorithms. Outputs included a Level 2+ UK Habitat Classification and Normalized Difference Vegetation Index (NDVI). Example images are shown on the following pages.



Coniferous Plantation
168.41 ha

Wetland
68.50 ha

Heathland and Shrub
48.35 ha

Grassland
84.69 ha

Woodland
140.39 ha

Total:
510.34 hectares

CreditNature - Bunloit Habitats

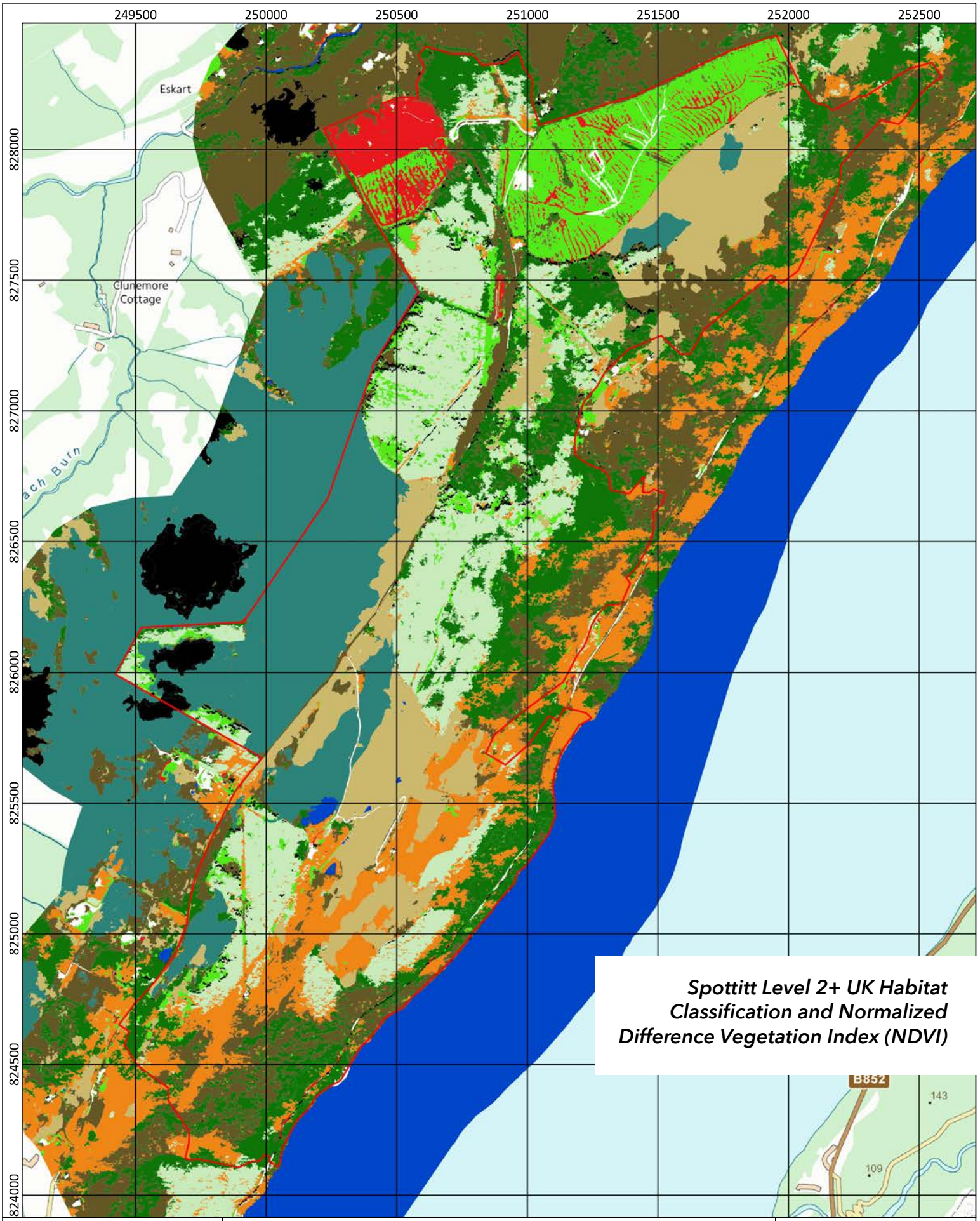
The satellite mapping gave us a more granular insight into the estate land cover (in the summer of 2019) than we previously had obtained from desktop googlemaps assessments and on-the-ground observations. Whilst not 100% accurate (e.g., some bare areas were incorrectly classified as cropland) the assessment gave us a better view of what we were working with on land cover types.

A comparison to the high-level parcels identified in the CreditNature project is shown in the table below.

Over time, the expectation is that as the algorithms better learn how to classify land types, future assessments using this method will become more accurate.

UK Habitat Classification	Spottitt UK Hab Classification *Area in ha*	EcoSulis Classification *Area in ha*
No Data	5.98	
Woodland & Forest	181.49	308.8
Broadleaved mixed and yew (w1)	90.54	84.22
Coniferous plantation and semi-natural (w2)	90.95	165.83
Coniferous felled (w2)		58.75
Sparsely vegetated land (s)	17.36	
Grassland (g)	112.66	84.69
Modified grassland (g4)	53.80	35.65
Un-modified grassland (g1, g2, g3)	58.86	49.04
Urban (u)	3.74	
Cropland (c)	62.72	
River and Lakes (r)	1.00	
Heathland and Shrub (h)	70.13	48.35
Wetland (f)	61.18	68.5
TOTAL area	**516.27**	**510.34**

Bunloit Estate - Satellite Imagery



Spottitt Level 2+ UK Habitat Classification and Normalized Difference Vegetation Index (NDVI)

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Level 2 UK Habitat Classification

Estate Boundary - Simplified

Habitat Classification

- No Data
- Woodland & Forest (w) Broadleaved mixed and yew
- Sparsely vegetated land (s)
- Grassland (g)
- Urban (u)
- Cropland (c)
- Grassland (g) Undefined Level III grassland class
- Woodland & Forest (w) Coniferous (w2)
- River and Lakes (r)
- Heathland and Shrub (h)
- Wetland (f)

0 200 400 m

N

Scale @ A3 - 1:13,000

Drawing number: BUN/003/A
Revision: 1
Date of production: 2021-05-18
Drawn by: JB - Tracks Ecology
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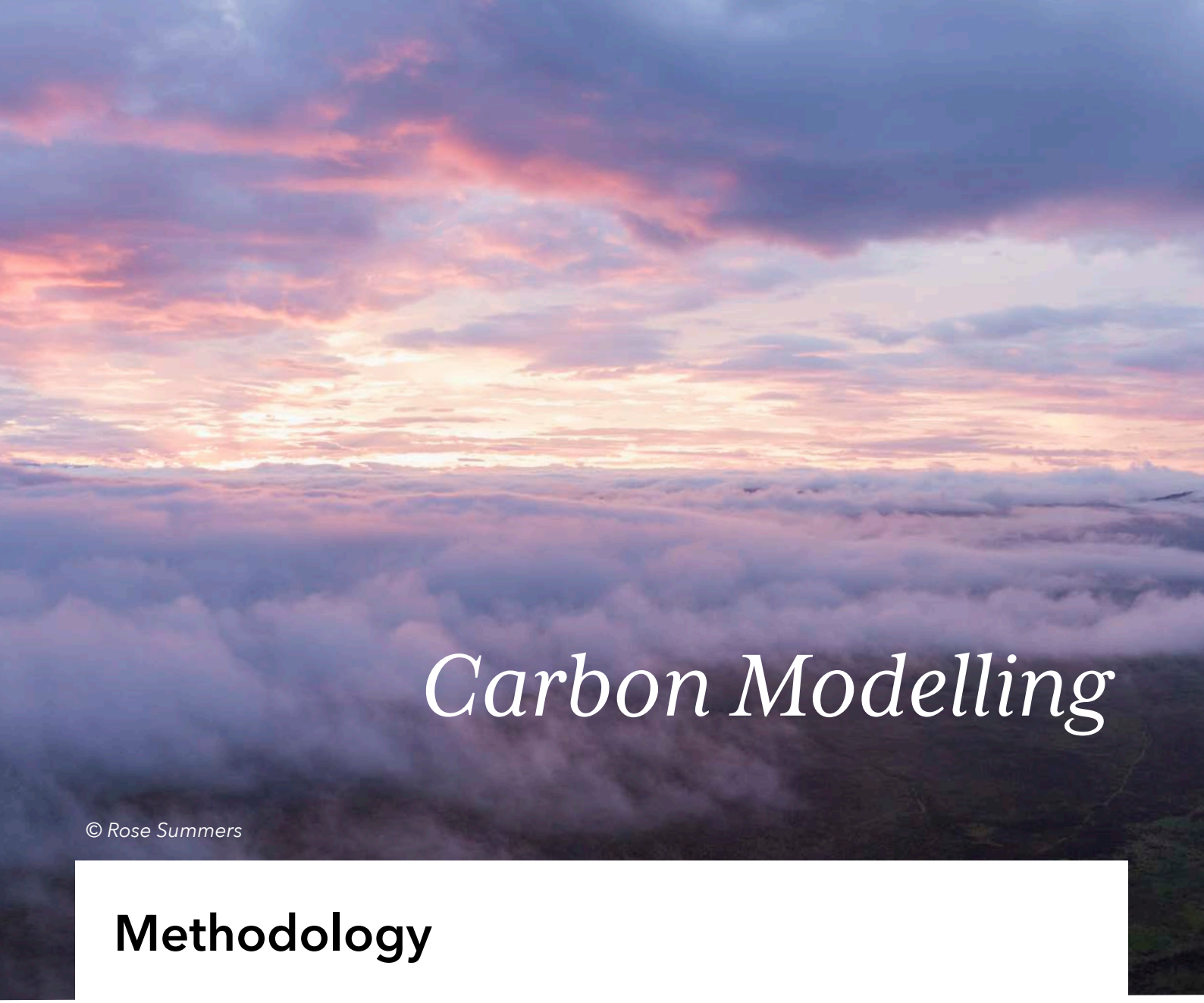


Carbon Modelling

© Rose Summers

Methodology

The Intergovernmental Panel on Climate Change (IPCC) use three tiers of data for estimating greenhouse gas emissions and removals:

- **Tier 1** - basic modelling using default emissions factors for land use types and changes.
- **Tier 2** – modelling methods as in Tier 1, but using country, habitat or area defined emission factors and calculations, identified from case studies and appropriate for the climatic region and land use systems in the country / area.
- **Tier 3** – models and measurement systems repeated over time and driven by high resolution activity data at a fine grid scale, using GIS-based technology systems.

The information presented in this natural capital report uses a combination of Tier 2 calculations, and where possible, actual Tier 3 measurements from a selection of innovative suppliers to provide comparison real-world data. Our methods have included Tier 1 modelling of grasslands using UK-wide emission factors from Natural England, compared to actual measurements of Soil Organic Carbon;

Tier 2 modelling of our woodlands using Woodland Carbon Code models, compared to actual volumetric LIDAR measurements of woodland biomass; and finally peatland calculations using in-situ Tier 3 peat depth measurements to calculate volumes of peat, then extrapolated to tonnes of CO2e, using Tier 2 Highland specific ratios based on research undertaken by the James Hutton Institute, and a conversion factor of 3.67 to convert from carbon to carbon dioxide equivalent (CO2e.)

Due to the modelling methods and technology available, the focus for our initial baseline work has been on a) the above and belowground biomass in our woodland stock, and b) the soil organic carbon (SOC) in our peat and grasslands.

As our research progresses, we aim to gather and apply increasing amounts of Tier 3 data.

The carbon stock (and calculations of future sequestration or 'flows') on the estate is present in four natural carbon pools as follows:

- Aboveground Biomass – biomass within trees and plants
- Belowground Biomass – roots and other plant life in the soil
- Dead Organic Matter – leaf litter and dead branches on the ground
- Soil Organic Carbon – carbon locked up in the soil itself

Bunloit pastures

Grasslands

As identified in the CreditNature project mapping exercise, the Bunloit Estate has around 84 hectares of grassland areas – situated mostly on the south-east facing slopes overlooking the Loch. These are bounded by areas of native ancient oak and birch, and non-native conifer woodlands on the slopes below, with areas of heathland and gorse above.

Our pastures have likely been farmed without the use of chemicals for thousands of years, leading to eruptions of fauna and flora in the spring.

Historical research has shown that the areas have been let for grazing since at least World War Two.

Ecologists from Plantlife led the flora surveys on the estate, reporting that the grasslands are of regional importance, with potential for restoration to become very species-rich. This is discussed later in the biodiversity section of this report.

From a carbon perspective, we initially undertook Tier 2 modelling to calculate carbon stocks and flows using the report by Natural England: NERR094 Carbon Storage and Sequestration by Habitat (2nd). This report - released in April 2021 - summarises the latest scientific evidence base relating to carbon storage and sequestration by semi-natural habitats in the UK.

The bedrock geology under most of the estate is Lower Old Red Sandstone. This is sedimentary bedrock which was formed approximately 398 to 416 million years ago in the Devonian period. In general, the soils are a mixture of peat, gleys, podzols and brown earths with, as would be expected, higher quality soils towards the lower slopes. For our Tier 2 modelling, we used figures from the Natural England report for carbon stock and flux associated with grazed acid grasslands, as shown in the table below.

Grassland Areas	Carbon Stock *(tC ha-1)*	Carbon Flux *(tC ha-1)*
Soil - Grazed Sheep	62.38	
Biomass - *Molinia caerulea* swards under low level grazing (0.9 ewes ha-1 y-1)	5.01	-0.5
TOTAL	**67.39**	**-0.5**

Multiplying these figures by the 84.7 hectares of grasslands identified in the CreditNature estate assessment gives us a total soil organic carbon (SOC) stock of 5,707 tonnes and a drawdown of 42 tonnes of organic carbon sequestered per year. Converting these to carbon dioxide equivalents (tCO2e) by multiplying by 3.67, gives a modelled stock of 20,946 and a flux of 155 tonnes CO2e sequestered per year. Over 100 years this is a carbon drawdown from grasslands of 15,541 tCO2e sequestration.

Tier 3 Modelling - Agricarbon

To undertake a more rigorous analysis of soil carbon, we contracted Agricarbon – a technology startup that **"provides the most accurate high-density soil sampling available in the UK, at a cost of >90% less than manual processes."**

Agricarbon provides granular direct measurements of soil organic carbon stock using SOC% and bulk density analysis, taken from high intensity soil samples collected from the estate. The company uses efficient, mechanical extraction (as shown in the photo opposite), innovative automated sample processing to reduce time and cost and capture a wealth of directly measured SOC% and bulk density data to calculate soil carbon stock.

The map on the following page shows the location of soil cores taken across two large, representative areas of the estate, as well as a small number of additional cores from a third area. A total of 72 cores, of up to 1m depth, were extracted. Each core was divided into 2-3 samples, to allow measurements at different depth horizons, giving a total of 189 samples.

Areas sampled:

Field 1: 7 cores from scrub / heath land near the peat areas

Field 2 (Grasslands): 30.34 ha; 36 cores, 'modified' grassland

Field 3 (Borlum Wood): 40.44 ha; 29 extraction points, clear-felled softwood plantation

The results from Agricarbon are shown in the table on the following page. In total across the 172 samples taken from our grassland and clear-felled areas, a carbon stock has been calculated as 8,386 tonnes of organic carbon, **roughly equivalent to the carbon content of 1,342 mature oak trees**. Multiplying up to tCO2e gives us 31,776 tCO2e across both habitats sampled.

Farm Name	Bunloit
Farm ID	BNB001-T5
Core extraction dates	13 July - 15 July 2021
Sampling event	0

Sampling event 0	Baseline, year 0
Sampling event 1	Resampling 1
Sampling event 2	Resampling 2

Total included area (Ha)*	70.78
Total number fields	2
Average field area (Ha)*	35.39

Terrain type	Strong & gentle inclines
Typical soil type	Podzols
Average soil depth (mm)	406

Total number cores	72
Cores per Hectare	1.0
Total number samples	189
Samples per Hectare	2.7

Total carbon stock (t)	8,386
Mature Oak Trees equivalent	1,342
Tonnes Carbon in mature Oak	*6.3*
Average tonnes carbon / Ha	118.5

Depth Divisions	*cm*	*SOC%*	*Bulk Density*
Depth 1	0 - 15	5.43	0.90
Depth 2	15 - 30	2.38	1.17
Depth 3	30 - 60	1.27	1.40
Depth 4	60+	*N/A*	*N/A*

Using the high-level eco-parcel areas identified via CreditNature for simplicity, and extrapolating from the Agricarbon findings above, this provides the following results for grassland and clear-felled areas:

Habitat	Total Area (ha)	Average Carbon Stock *(tC ha-1) (from Agricarbon)*	Total Carbon Stock *(tC ha-1)*
Grassland	84.7	93.3	7,903
Clearfelled	40.5	134.8	5,453
TOTAL	**125.2**	**228.1**	**13,355**

The summary of grassland carbon findings is as follows:

- Tier 3 modelling based on Agricarbon measurement of carbon stocks in Bunloit soils gives 7,903 tonnes of organic carbon. Multiplied by 3.67, this equals **29,002 tCO2e stored in our soils.** This is 38% more than the Tier 2 modelling using Natural England data from other study sites would indicate.

- A former conifer plantation clear-felled in 2016 shows 134.8 tonnes of carbon per hectare. **This is 44% higher than the open grasslands**, showing the importance of carbon stocks in woodland soils – even after clear fell activities that would have caused a significant loss of carbon to the atmosphere.

- Using Natural England Tier 2 modelling of carbon fluxes, we have estimated a future carbon flux of **15,541 tCO2e drawdown** over a 100-year period.

- A separate 7 cores taken by Agricarbon from areas close to the peatlands gave an **average of 26%** soil organic carbon – showing the higher levels of SOC present in high peat areas.

Semi-ancient Oak Woodland

© Joe Gray

Woodlands

Across the Bunloit estate, we have around 300 hectares of woodlands (60% of the total) – consisting of both ancient native broadleaf woodlands, and commercial non-native conifer plantations. Wooded biomass in the form of trees is a key contributor to carbon sequestration and the fight against climate change. The government recently announced a target of 30,000 ha of new trees being established in the UK every year to 2050, to take woodland cover in the UK from 13 to 17%.

To this end our aim has been to establish the carbon stocks already present in the wooded biomass of the estate, and to estimate future sequestration (fluxes) from the existing and any future woodland areas.

CreditNature - Land Life

The initial Tier 2 desktop assessment was undertaken by a company called Land Life within the CreditNature project. Land Life are a high-tech Dutch reforestation company with a mission to **"reforest the world's degraded land at scale."**

Land Life produced a desktop analysis of the expected carbon stocks within the Above Ground (AGB) and Below Ground (BGB) carbon 'pools' on the estate – essentially the standing biomass in trees and their roots. As they were unable to visit the estate due to travel restrictions, this analysis took the form of a desk-based assessment of the available scientific literature. In this, Land Life assessed carbon stocks of the tree types within our habitats based on the most suitable scientific studies, focusing on the Scottish Highlands where possible. This gave us an indicative range of 44,274 – 197,081 tonnes CO2 (tCO2) for wooded biomass on the estate, as shown below.

Bunloit estate - habitat types

Habitat type	Species / classification	Sum of hectares	Age class
Commercial	Sitka spruce	27.7	21-40
	Scots pine	29.8	21-40
	Mixed conifers	25.3	21-40
	Lodgepole pine	7.4	21-40
	Douglas fir / Sitka Spruce	9.2	41-60
	Lodgepole pine / Sitka spruce	16.9	21-40
Birch woodland	Native broadleaved species	70.6	62-80 & 100+
Oak woodland	Native broadleaved species	45.8	61-80 & 100+
Grazing land	Grazing land	102.9	na
	Common grazings	47.5	na

Estimated carbon stock Bunloit - AGB & BGB

Habitat type	carbon stock (tCO2) lower	carbon stock (tCO2) upper
Commercial	14059	132957
Broadleaved woodland	29629	63071
Grazing land	556	1053

Carbon baseline range Bunloit estate : 44274 - 197081 tCO2

Excl: litter, SOC, DOM

Woodland Carbon Code

Our second stage was to create a Tier 2 model of our woodlands using the Woodland Carbon Code (WCC). The WCC is a credit-based methodology for predicting future carbon stocks and is used in the creation of WCC accredited carbon credits in the UK. In the table below, the WCC standard project calculator has been used to provide an estimate of the carbon currently held in the woodland areas of the Bunloit Estate, by plantation name and planting year. This was created by using species maps from our existing forestry plan, and estimates of yield class and spacing provided by our Head of Forestry. The current stock was estimated at **115,748 tCO2e** – within the middle of the Land Life estimated range - as well as an estimate of future sequestration, at **71,127 tCO2e over 100 years**, should there be no intervention.

Name	Year	Age	Compartment	Hectares	Current Stock (tCO2e)	Future Sequestration (tCO2e over 100 years)
Clunebeg Wood	2010	11	01a1, 01a4	4.43	216	5,777
Clunebeg Wood	1972	49	01a2/a3/a5/a6/b1/b2	12.31	5885	2,641
Clunebeg Wood	1800	221	01c1, 01c2	2.95	1040	-
Clunebeg Wood	2019	2	01d1	0.76	1	407
Clunebeg Wood	1993	28	02a1	8.34	2957	3,826
Clunebeg Wood	1972	49	03a1, 03a2, 03a3	21.76	8469	5,004
Lon Mhor	1977	44	04a1	7.72	4072	2,756
Borlum Wood	2019	2	05a1-15/b1-4/c1-11/d1-4	31.01	203	31,979
Upper Lennie	1950	71	06a1	39.57	7293	-
Bill's Plantation	1989	32	07a1	25.32	5046	11,206
Bill's Plantation	1950	71	07b1	1.21	831	66
Allt Seileach	1800	221	08a1, 09a1, 10a1	51.62	42866	-
Allt Seileach	1950	71	10a2, 10a3	2.43	1066	7
Allt Seileach	1964	57	10b1, 10b2, 10b3, 10b4	9.25	10498	2,000
Tynaherrick	1950	71	11a1, 13a1	12.2	5352	35
Tynaherrick	1974	47	12a1, 12a2	16.62	17033	5,423
Tynaherrick	1800	221	13b1	6.61	2919	0
				TOTAL	**115,748**	**71,127**

Carbon stock was calculated using the 'Cumulative Carbon Sequestration from lookup tables (tCO2e)' column from each WCC spreadsheet. This provides a 5-yearly estimate of carbon sequestration from planting, between Year 5 and 100, before any buffers are removed. The real age of each Bunloit compartment was rounded to the nearest 5, for example '2010 Clunebeg' is 11 years old and so the 'Age in Years: 10' figure was used. For woodland areas over 100 years old, the maximum sequestration is assumed and so the Year 100 figure is used. To calculate the future sequestration (tCO2e) for each compartment, the current stock was subtracted from the Year 100 figure, assuming that by 100 years the emissions from woodlands are equal to any further sequestration and so create a net-zero balance. The table below shows our model, with the current stock estimates in dark green.

Age in Years	Hectares	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	Current Stock	Future Sequestration (tCO2e over 100 years)
11 (CL 2010 - 01	4.43	57	216	684	1433	1962	2617	3297	3811	4217	4545	4808	5033	5223	5381	5525	5657	5761	5849	5925	5992	216	5,777
49 (CL 1972 - 01	12.31	106	397	1242	2254	3015	3490	4214	4867	5409	5885	6289	6712	7023	7343	7643	7875	8079	8250	8399	8526	5885	2,641
221 (CL 1800 - 01	2.95	6	30	114	339	514	623	713	793	873	952	999	1023	1040	1040	1040	1040	1040	1040	1040	1040	1040	-
2 (CL 2019 - 01d	0.76	1	2	4	9	22	62	132	170	203	235	262	282	301	319	337	353	369	382	395	407	1	407
28 (CL 1993 - 02	8.34	106	406	1287	1977	2359	2957	3604	4156	4598	4942	5246	5551	5788	6010	6220	6396	6530	6635	6716	6784	2957	3,826
49 (CL 1972 - 03	21.76	96	336	1000	2956	4874	4937	5856	6783	7627	8469	9162	9930	10461	11070	11634	12030	12441	12810	13165	13473	8469	5,004
44 (1977 Lon Mho	7.72	42	154	471	1352	2318	2855	3326	3731	4072	4376	4671	4951	5216	5474	5746	5986	6209	6426	6632	6828	4072	2,756
2 (2019 Borlum 0		203	743	2286	5966	9833	12684	15905	18949	21271	23177	24760	26114	27299	28311	29181	29923	30629	31239	31744	32182	203	31,979
71 (Upper Lenie -	39.57	42	208	800	2376	3605	4372	4997	5557	6121	6677	7001	7174	7293	7293	7293	7293	7293	7293	7293	7293	7293	-
32 (1989 Bill's - 0	25.32	102	356	1055	3132	4368	5046	6340	7667	8740	9788	10693	11461	12143	12938	13590	14232	14865	15362	15818	16252	5046	11,206
71 (1950 Bill's - 0	1.21	10	36	110	278	407	504	590	674	723	757	781	800	819	831	846	858	868	880	890	898	831	66
221 (1800 Allt S -	51.62	2513	7614	12810	17357	23209	28189	32270	35362	37063	38677	39610	40570	41300	41620	41977	42199	42412	42580	42731	42866	42866	-
71 (1950 Allt S -	2.43	20	72	221	540	624	709	791	896	978	1027	1040	1060	1061	1066	1073	1073	1073	1073	1073	1073	1066	7
57 (1964 Allt S -	9.25	118	450	1427	2989	4093	5458	6877	7949	8794	9480	10028	10498	10894	11224	11523	11799	12016	12199	12359	12498	10498	2,000
71 (1950 Tyna - 1	12.2	100	363	1108	2709	3134	3558	3972	4497	4908	5155	5220	5320	5327	5352	5387	5387	5387	5387	5387	5387	5352	35
47 (1974 Tyna- 1	16.62	212	808	2564	5370	7354	9807	12357	14283	15801	17033	18018	18863	19573	20167	20704	21200	21589	21918	22205	22456	17033	5,423
221 (1800 Tyna -	6.61	54	196	600	1468	1698	1928	2152	2436	2659	2793	2828	2882	2886	2900	2919	2919	2919	2919	2919	2919	2919	0
																					TOTAL	115,748	71,127

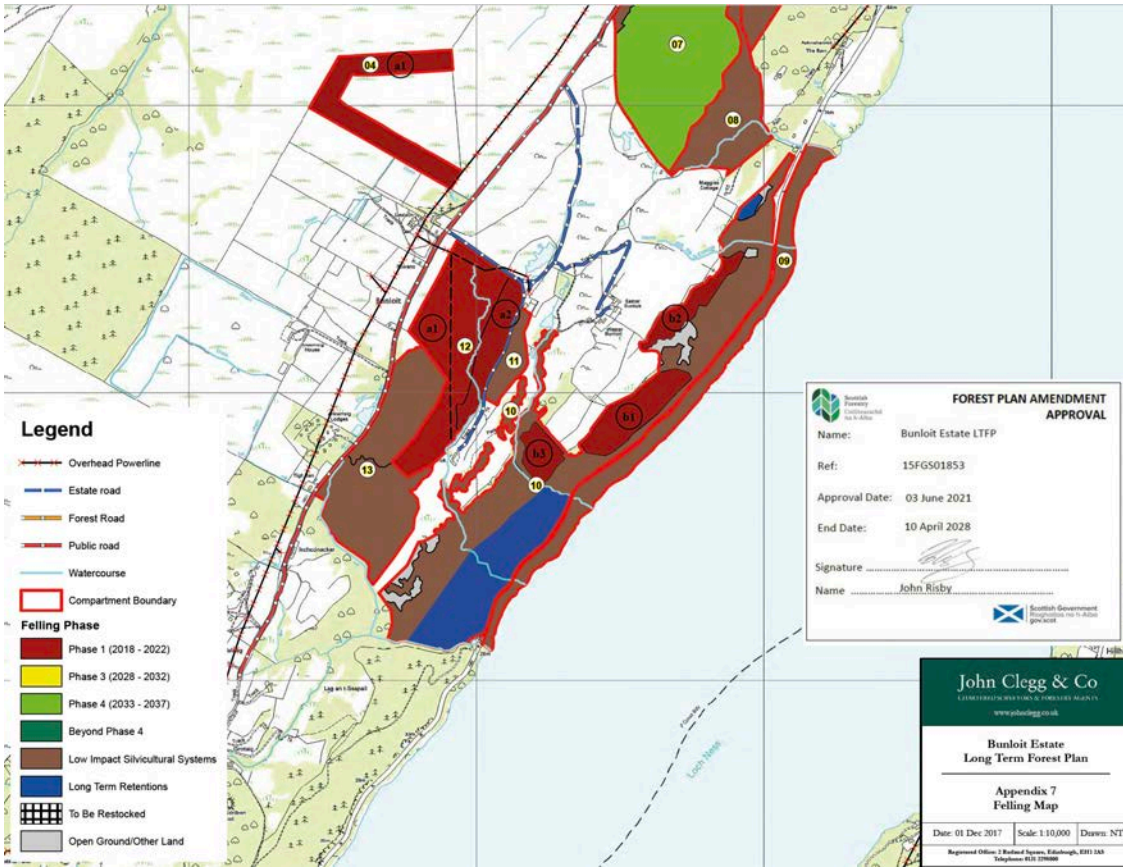
Carbon Losses from Felling Activity

Any intervention that does take place, such as felling, impacts not only current levels of carbon stock held in the system, but also the potential for future sequestration. This therefore needs to be taken into consideration when calculating our overall carbon footprint.

For example, if the 2010-planted section of Clunebeg Wood was felled, the immediate loss of carbon would be 216 tCO2e, however the 5,777 tCO2e of future sequestration that would have occurred over the next 100 years without the intervention would also have to be accounted for. It may be possible to avoid the issue if the felled timber was certifiably keeping the carbon locked up, i.e., if it was used in long-term building, however further investigation is needed here before we can include this in our models.

During initial engagement with specialists, there was a clear consensus that we should remove our non-native conifer plantations as soon as possible. The image below therefore shows part of the Bunloit Estate Felling Plan with Phase 1 (2018-2022) Felling Areas highlighted in red. Approximately 33.6 ha of forest will be felled, specifically lodgepole pine, Sitka spruce and Douglas fir planted between 1964 and 1977.

The estimated total loss of current stock from Phase 1 felling is **31,603 tCO2e, with an addition loss of 10,179 tCO2e future sequestration** (over 100 years). The breakdown by area can be seen in the table on the next page.



Name	Year	Age	Compartment	Hectares	Current Stock (tCO2e)	Future Sequestration (tCO2e over 100 years)
Lon Mhor	1977	44	04a1	7.72	4072	2,756
Allt Seileach	1964	57	10b1, 10b2, 10b3, 10b4	9.25	10498	2,000
Tynaherrick	1974	47	12a1, 12a2	16.62	17033	5,423
			TOTAL	**33.59**	**31,603**	**10,179**

It should be noted that as the trees in the Phase 1 felling areas were planted between 44 and 57 years ago, they have already sequestered much of what can be expected over the course of 100 years, approximately 60%, 84% and 76% of the 100-year figure for Lon Mhor 1977, Allt Seileach 1964 and Tynaherrick 1974 respectively. The remaining sequestration would be slower and not necessarily compatible with best forestry practice. Some of this carbon loss will be made up elsewhere for example by planting new trees onsite as legally required, or as in the case of Lon Mhor by restoring the peat bog on which the plantation currently sits. The table below shows the potential 18,905 tCO2e future sequestration estimated from these restocking projects as required by Scottish Forestry. We have calculated the carbon sequestration using WCC models of mixed native broadleaves, as replacements for the non-native conifers. Where plantations are on existing deep peat, it is assumed that only 50% of the area will need to be replanted elsewhere on the estate so that we can restore the degraded peat.

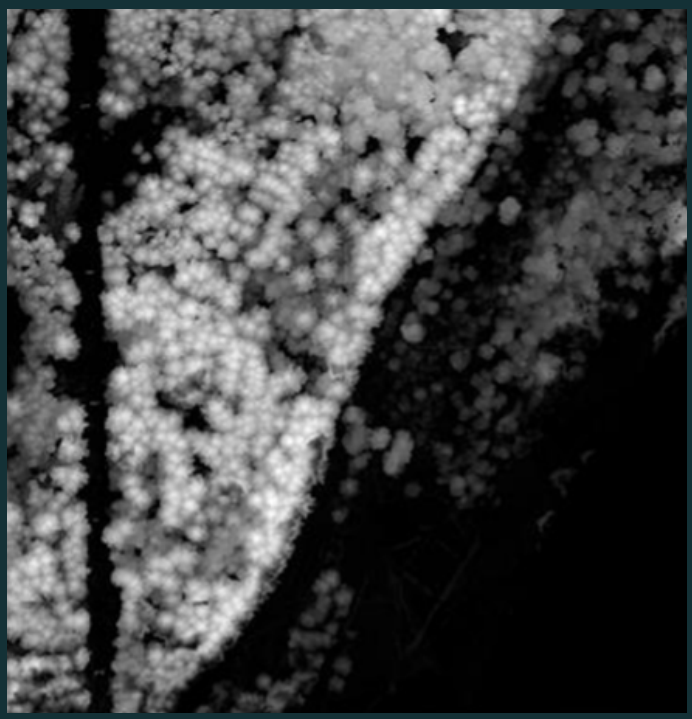
Name	Year	Age	Compartment	Hectares	Current Stock (tCO2e)	Future Sequestration (tCO2e over 100 years)
Lon Mhor + Tynaherrick (50% Replacement)	2021	0		12.17	0	9,051
Allt Seileach	2021	0	10b1, 10b2, 10b3, 10b4	9.25	0	6,879
Gorse Project	2021	0		4	0	2,975
			TOTAL	**25.42**	**-**	**18,905**

Tier 3 Modelling - Climate Systems Exchange (CSX)

For Tier 3 modelling, Climate Solutions Exchange Ltd (CSX Carbon) completed drone surveys of the estate using a DJI M300 airframe, with a P1 45 megapixel camera and an L1 LIDAR unit. Lidar stands for Light Detection and Ranging. It is a remote sensing method that uses light in the form of a pulsed laser to measure ranges. The collected data was then processed through a series of photogrammetry, machine learning and software models to produce an analysis of the above ground biomass within the woodlands at Bunloit.

This analysis has produced a wide variety of results, both anticipated and at times surprising, and informed the prioritisation for the next stage of the data gathering and model improvement – from a Terrestrial Laser Scanning process to be undertaken this coming winter 2021/22.

The machine learning run on the RGB photogrammetry output starts with a tree count of the woodlands. This image on the right being the tree count on a section of the Tynaherrick conifer woodland area.



The most striking initial observation is how many fewer trees there are in the woodlands than would have been anticipated based on expectations of conifer plantation norms. The number of established trees (in this case after 50 years) being less than a third of that which would be planted under current forestry industry standard practice for planting of conifer plantation woodland at 2,500-2,700 stems per hectare. The initial concern was therefore that the carbon store within the woodlands would be much lower than expected from the Tier 2 modelling.

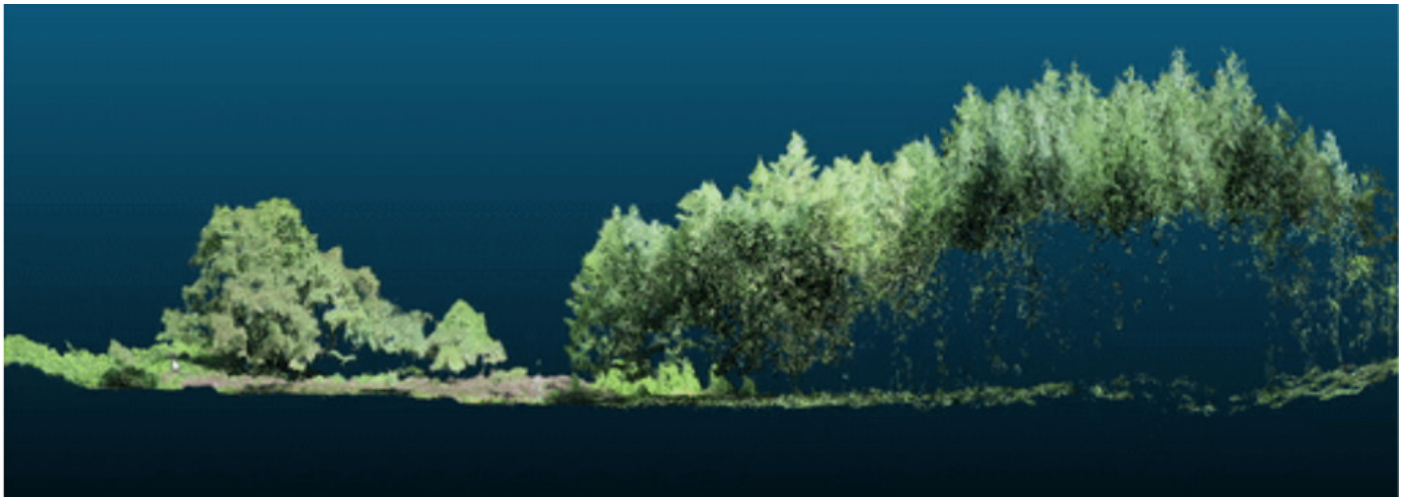
There is also the question of why there is such a 'shortfall' in the number of conifer trees in this instance? Evidence on the ground indicates that failed establishment and previous thinning would be the main reasons for the tree count being less than modelled before the drone surveying commenced.

The next output from the data analysis was the Canopy Height Model, developed from the RGB photogrammetry process, and integrating the LIDAR data. The image on the left being the LIDAR data canopy height model from a section of the Tynaherrick conifer plantation.

What this canopy height model enables us to understand is the wide variety of tree heights within the woodland, and crucially produce a measurement of each individual tree, rather than relying on the 'averages' approach of the traditional forestry mensuration practices, and the handheld ground-based tree height measurement that comes with them.

CSX used this data to establish that the trees in the woodlands at Bunloit are taller than would be modelled under the traditional Woodland Carbon Code system.

The next step in the process is to calculate the volume of these trees, utilising the models created from the photogrammetry output and the LIDAR analysis. This calculation produced a modelled level of above ground biomass rising significantly above the amount that traditional Woodland Carbon Code methodologies would produce for the tree density now known to be in the woodlands. CSX have developed the woodland into a 3D model, as represented in the cross-section image shown below.



Whilst we know the trees are taller than previously modelled, we do now need to confirm whether the trees are bigger than understood within the canopy, and hence confirm the model that the level of above ground biomass, and therefore carbon store, does indeed exceed what the current modelling methodologies would say.

The exciting work that will inform this next stage of the model is the Terrestrial Laser Scanning to be undertaken this winter.

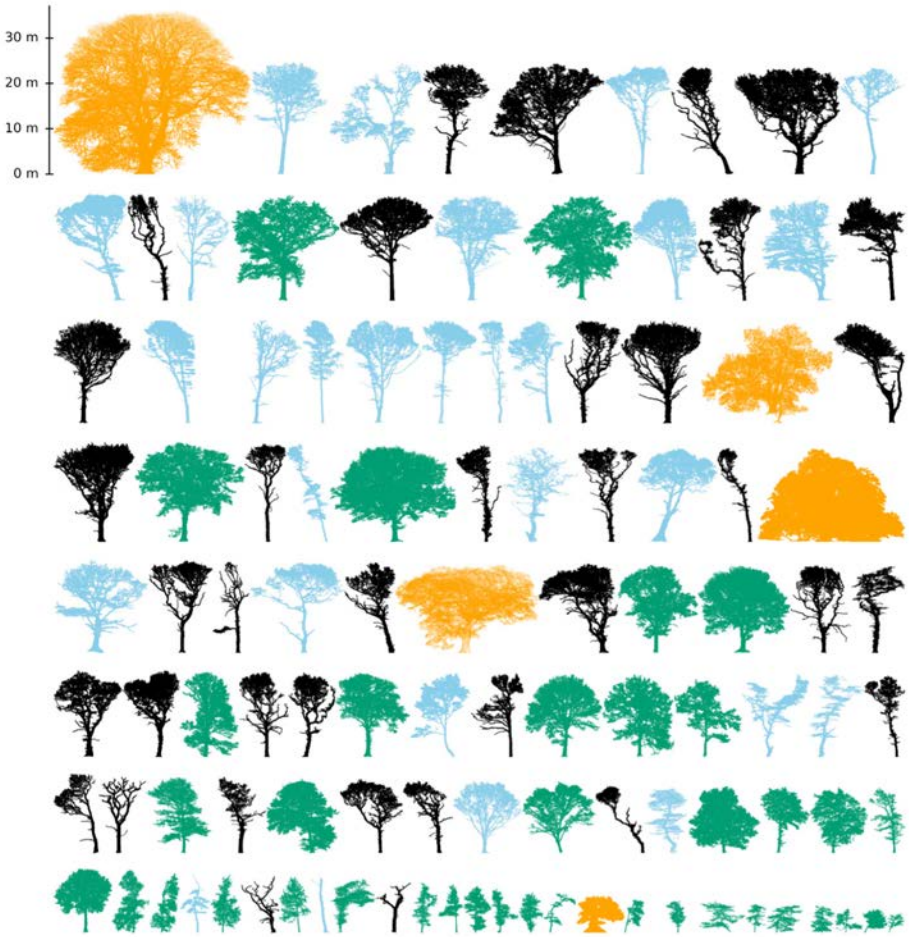
Terrestrial Laser Scanning (TLS) is a non-destructive ground-based, active imaging method that acquires accurate, dense 3D point clouds of object surfaces by laser range finding. 3D measurements of trees are collected in situ and combined with geometric modelling to estimate their volume. Isolating individual trees from a forest point cloud followed by enclosing points with geometric shapes results in a volume estimate of the tree, which can be converted to mass using the wood density. For want of a better description, CSX X-Ray the woodland, as this image below shows.

Moreover, they do this for every tree within a particular survey area, building up a tree-by-tree volume model for the woodland. This will enable us to fully understand where the biomass content is within a tree, and explore just how much biomass, and hence carbon store, is stored within the branching structure of a tree, and hence possibly identify one of the issues behind why current forestry mensuration is underestimating the wood in the trees.

The conclusions gained from the CSX Tier 3 modelling of our woodlands on the Bunloit Estate is as follows:

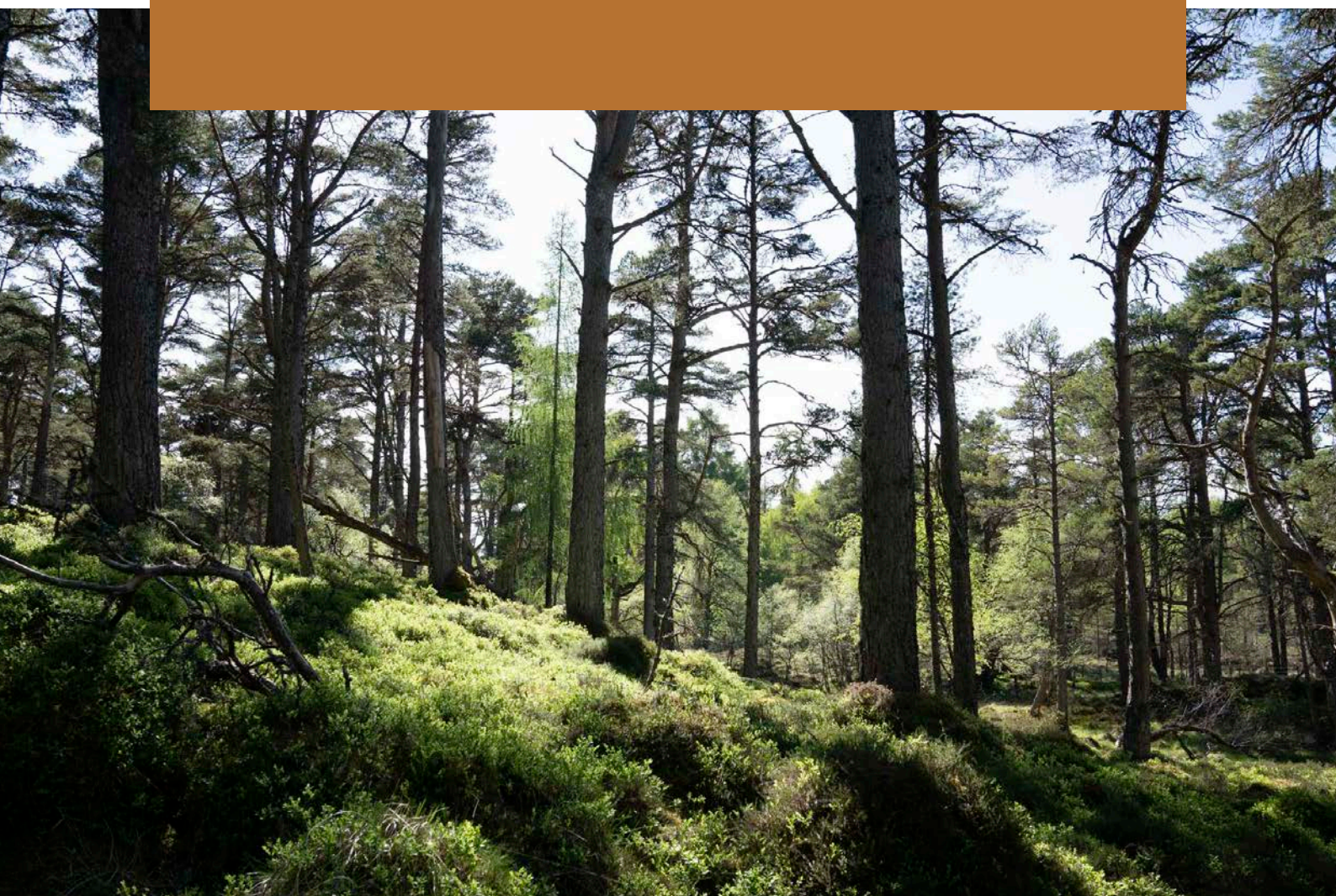
- Actual tree establishment within old-growth plantations and woodlands is much less than the numbers of trees projected from the Woodland Carbon Code modelling. Reasons for this could include failed establishment, windblow and previous thinning.
- However, initial data suggests that the trees are taller and therefore bigger than the models suggest – larger amounts of CO2 in the atmosphere may have aided tree growth.
- Overall, combining these two factors leads to similar biomass, and therefore carbon models as the Tier 2 WCC calculations.
- However, current existing modelling does not consider biomass and hence carbon within the whole branching structure of the tree. Following TLS to create these more accurate models, we expect to see significantly larger amounts of above ground carbon – specifically within broadleaves - than current methodologies allow for.

The image below shows an example modelling of individual trees within a Bunloit woodland, which will be used for TLS scanning this winter.



Overall, a summary of our findings from estimating woodland carbon stocks is as follows:

- Our WCC Tier 2 calculations have shown a current existing estimated stock of **115,748 tCO2e** as well as an estimate of future sequestration of **71,127 tCO2e over 100 years.**
- The estimated total loss of current stock from Phase 1 felling is **31,603 tCO2e,** with an addition loss of **10,179 tCO2e future sequestration** (over 100 years).
- However, restocking requirements should create a future 18,905 tCO2e, leading to a **net increase in future sequestration of 8,726 tCO2e.**
- Tier 3 modelling **has shown that there are less trees with more volume** than the Tier 2 model – leading to similar carbon stock for existing plantations.
- Future TLS scanning work is expected to show significantly larger biomass - and therefore carbon - due to modelling of full branching structures in broadleaf trees.



The smallest of 3 peatlands on the estate

Peatlands

In their report "Carbon Storage and Sequestration by Habitat 2021", Natural England identified that peatlands are the largest carbon stores within the UK. When in a healthy condition they soak up carbon slowly but can go on doing so indefinitely. Peatland soils can be over 10 metres deep, holding huge carbon stocks that have developed over many millennia.

Carbon held in the deep peat soils of fens and raised bogs can hold eight times as much carbon as the equivalent area of tropical rainforest.

The Bunloit estate has around 70 hectares of open peatlands (13.7% of the total land area), with a similar area of shallower peatlands under conifer plantations. All these peatland areas are degraded in some way: by plantations compressing them, burning of heather, historical draining and peat cutting. These processes release large amounts of stored carbon.

Peatland Depth mapping

To assess the volumes and condition of the carbon stocks within the peatland, we engaged with a range of peatland specialist organisations – these included Peatland Action, The Peatland Code, The University of Highlands and Islands and The James Hutton Institute.

Supported by these partners, we undertook a peatland depth mapping exercise at the end of May 2021. A group of volunteer students from Glasgow University spent a few days on site working with our in-house team of rangers to map peat depths across the estate using measuring rods.

The resulting depth measurements were interpolated using GIS software to calculate a peat volume of 1,159,242 m3 – as shown in the image on the next page.

PEATLAND DEPTH MAP

SITE NAME:
Bunloit Estate

GRANT NUMBER:
N/A

CONTRACTOR DETAILS: In-House

DATES OF SURVEY:
26th - 27th May 2021

TOTAL NUMBER OF POINTS SURVEYED:
174

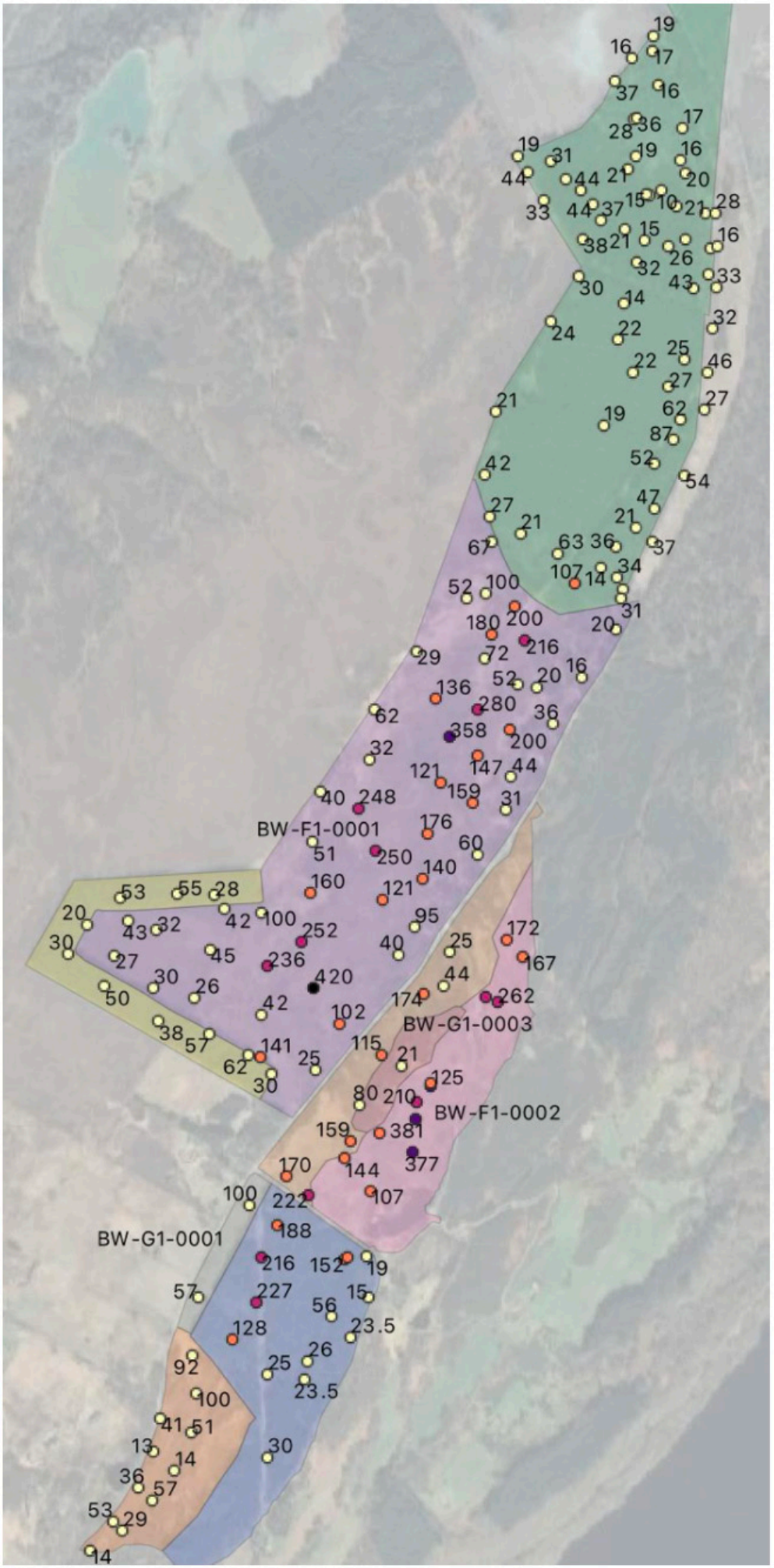
GENERAL WEATHER CONDITIONS:
26th - overcast, warm, dry
27th - sunny, warm, dry

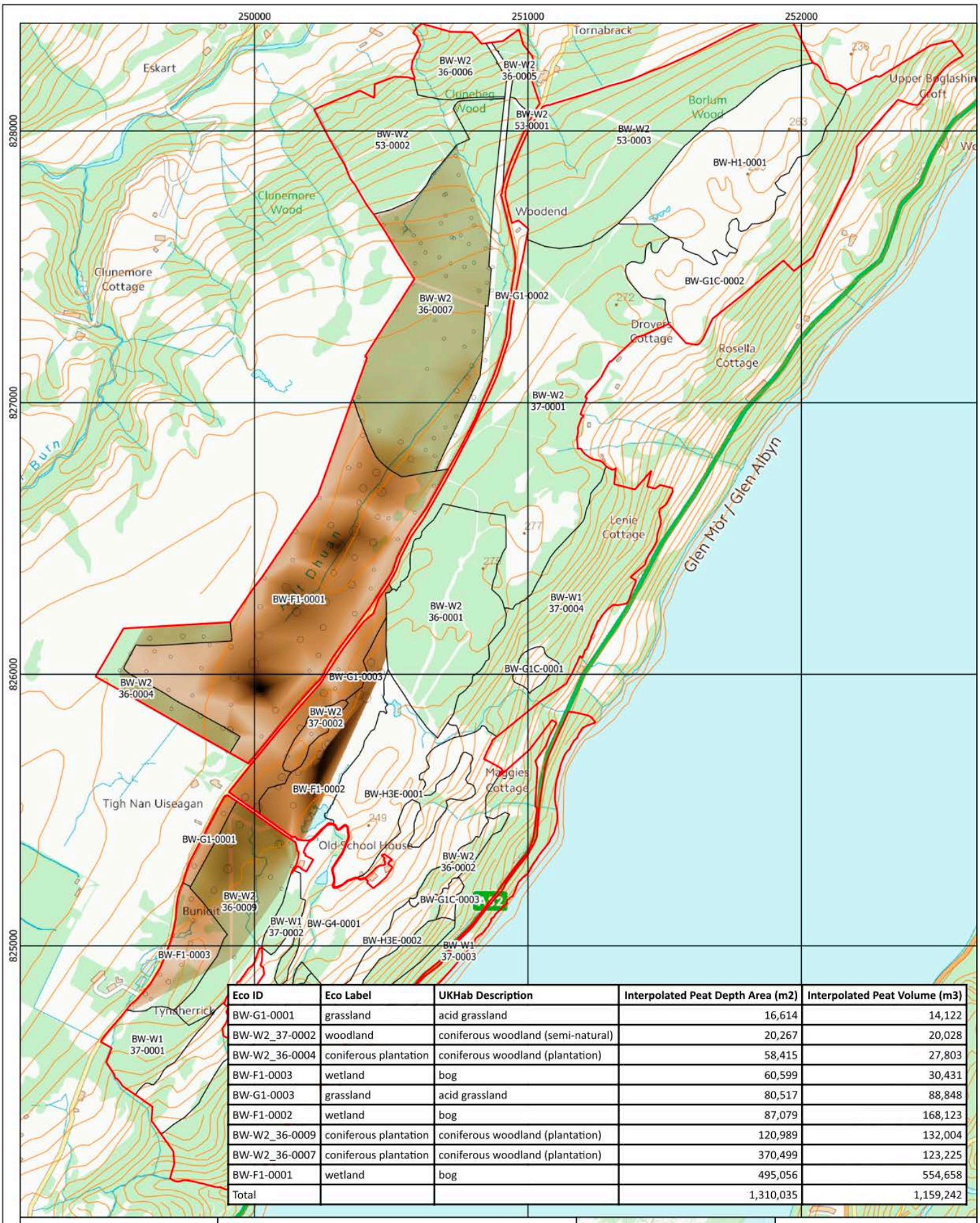
KEY:

Sample Peat Depth Point (cm)
- 10 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 420

BW-F1-0001
BW-W2_36-0004
BW-F1-0002
BW-F1-0003
BW-W2_36-0007
BW-W2_36-0009
BW-G1-0001
BW-G1-0003
BW-W2_37-0002

Google Satellite





Eco ID	Eco Label	UKHab Description	Interpolated Peat Depth Area (m2)	Interpolated Peat Volume (m3)
BW-G1-0001	grassland	acid grassland	16,614	14,122
BW-W2_37-0002	woodland	coniferous woodland (semi-natural)	20,267	20,028
BW-W2_36-0004	coniferous plantation	coniferous woodland (plantation)	58,415	27,803
BW-F1-0003	wetland	bog	60,599	30,431
BW-G1-0003	grassland	acid grassland	80,517	88,848
BW-F1-0002	wetland	bog	87,079	168,123
BW-W2_36-0009	coniferous plantation	coniferous woodland (plantation)	120,989	132,004
BW-W2_36-0007	coniferous plantation	coniferous woodland (plantation)	370,499	123,225
BW-F1-0001	wetland	bog	495,056	554,658
Total			1,310,035	1,159,242

Bunloit Rewilding

Peat Depth Survey and Interpolated Volumes

BUNLOIT™

Estate Boundary
Eco Land Parcels

Interpolated Peat Depth
0.0
1.0
2.0
3.0
4.0

Peat Depth Samples (m)
0.1 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.2

0 200 400 m

N

Scale @ A3 - 1:12,500

Drawing number: BUN/020/A
Revision: 1
Date of production: 2021-07-10
Drawn by: JB - Tracks Ecology
Projection: British National Grid EPSG:27700

Working with peatland specialists from The James Hutton Institute and the University of the Highlands and Islands, the peatland volume was converted into organic matter using bulk density values, taken from the scientific literature from studies in the Scottish Highlands. The ranges used were:

- The National Soil Inventory for Scotland - 0.129 g / cm3
- A Joss Radcliffe Study of Highland soils - 0.88 g / cm3 (average)

These figures gave a range of organic matter calculations of 204,027 to 299,084 tonnes, of which approximately 50% is organic carbon (C). This figure, likely to be conservative, is taken from the report 'Carbon stocks in Scottish peatlands' (Chapman et al., 2009). Finally, the organic carbon was converted to tonnes of carbon dioxide equivalent (CO2e) by multiplying by 3.67 to give a final range of **748,778 to 1,097,640 tonnes of CO2e stored in the Bunloit peatlands.** Based on a rate of peat accumulation of c. 1 mm a year – the deepest point of our peatlands would be over 4,000 years old.

Separately to the mapping work, a student from the University of Highlands and Islands - Rhiannon Stewart - also completed a dissertation paper assessing the condition of the peatlands on the estate, and attributing emission factors to these. Within this paper, and following fieldwork on site in December 2020, peatland condition was classified into four land types:

- Forest (on Peatland)
- Heather dominated bog – drained
- Grass dominated bog – drained
- Rewetted bog

Using emission factors from the report 'Implementation of an Emissions Inventory for UK Peatlands' by the Centre for Ecology and Hydrology on behalf of the Department for Business, Energy, and Industrial Strategy (BEIS), the current flux is calculated at **1,106 tCO2e / year emissions** under current state, with a range of 952 - 1,881 tCO2e / year, as shown below. The report used is the most up to date and comprehensive assessment of GHG emissions from UK peatlands.

Land uses	Area on Estate (ha)	net total emission for land use (tCO2 eq yr^{-1})	
		Emission factor	Estate
Forest	91.94	9.91	911.1254
Heather dominated bog - drained	49.51	3.4	168.334
Grass dominated - drained	7.93	3.4	26.962
Rewetted bog	0	0.81	0
Estimated total estimated emissions			1106.4214

Rhiannon then calculated a range of possible future emission scenarios arising from interventions on the peatland – which include clear-felling of plantations, and then restoration and rewetting peatland areas. Three different scenarios were developed showing min, max and medium restoration impacts on emissions.

Land uses	Area on Estate (ha)	Net total emission for land use (tCO2 eq yr^{-1})	
		per 1 ha	Estate
Forest	0	9.91	0
Heather dominated bog - drained	49.51	3.4	168.334
Grass dominated - drained	7.93	3.4	26.962
Rewetted bog	91.94	0.81	74.4714
Estimated total estimated emissions			269.7674

The scenarios were based on the range of possible values from the Emission Factor Inventory - high being where the highest emissions were used and low where the lowest emission were used. In all scenarios, the constant was that restoration was guaranteed to bring emission reduction. The magnitude of those emission reductions is more difficult to constrain for two reasons: the "starting state" was necessarily assumed and assigned a category of emission that may or may not be truly representative of the actual GHG processes on the ground. That is because the degradation is largely a legacy of past land use, rather than more recent, ongoing damage. Second, there is a high variation in empirical data underlying the emission factor, as revealed by the scenario. It is likely that the emission reduction will fall somewhere within this range and supports the need for restoration and management activities that aim to improve the peatland condition.

Using the mid-range scenario (as shown in the previous page) showed yearly emissions of **269.76 tCO2e / year - a reduction of 809.24 tCO2e / year.** It should be noted that the range of possible emission scenarios was from a min. 18 to a max. of 3,723 tCO2e/ year. Clearly, there is a need for Tier 3 actual measurement data going forward in order to reduce the uncertainty range.

Tier 3 Modelling - Terra Motion

For the Tier 3 modelling of peatlands – we worked with Terra Motion to explore assessing carbon loss through satellite measurements of land motion.

In healthy peatlands, the surface responds seasonally to changes in water and gas volumes by rising and falling, a phenomenon known as "bog breathing". When averaged over time, the surface motion of a healthy peatland shows net uplift, because of mass gain. In contrast, the surface of a degraded peatland shows a net collapse, indicative of loss of mass and therefore carbon. Therefore, if we can measure the long-term trend of a bog surface, we can estimate the associated emissions.

Terra Motion Ltd have developed a novel technique called the APSIS™ method, which they used to measure the surface motion of the Bunloit estate over a five-year period using historical data from the Sentinel-1A satellite. The APSIS™ method can estimate the long-term trend in motion over the entire peat area and, from this, they were able to estimate emissions from the areas eroding the most.

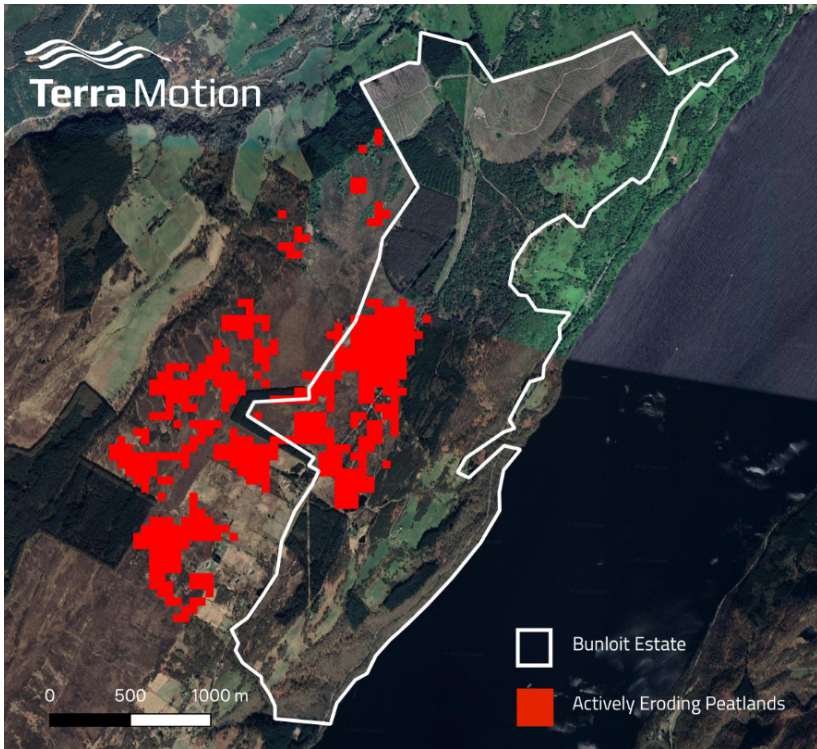
In the UK, there are many sources of land motion, from geohazards such as landslides to groundwater abstraction. In rural areas, the land may also be subject to change due to agricultural and forestry practices. Therefore, TerraMotion initially only considered those areas of land classified as peatlands by the EU CORINE land cover map. The mapping is reliable but does not consider peat areas covered by grass, forest or used for agriculture. On a UK-wide basis, about one-third of peatland areas are excluded, much of these being fens and lowland bogs. In our case plantations on peatland areas were excluded.

The results of the 5-year motion survey for the Bunloit estate and surrounding areas are shown in the image below. The resolution of the survey is 50m. The red areas represent peatland areas that are consistently subsiding at a large rate (0.5cm/year) over the observation period and therefore are classified as 'Actively Eroding'.

This classification aims to align with the methodology used by the UK Peatland Code – which attributes different emission factors for different peatland conditions, ranging from Actively Eroding, Hagg/Gully to Near Natural.

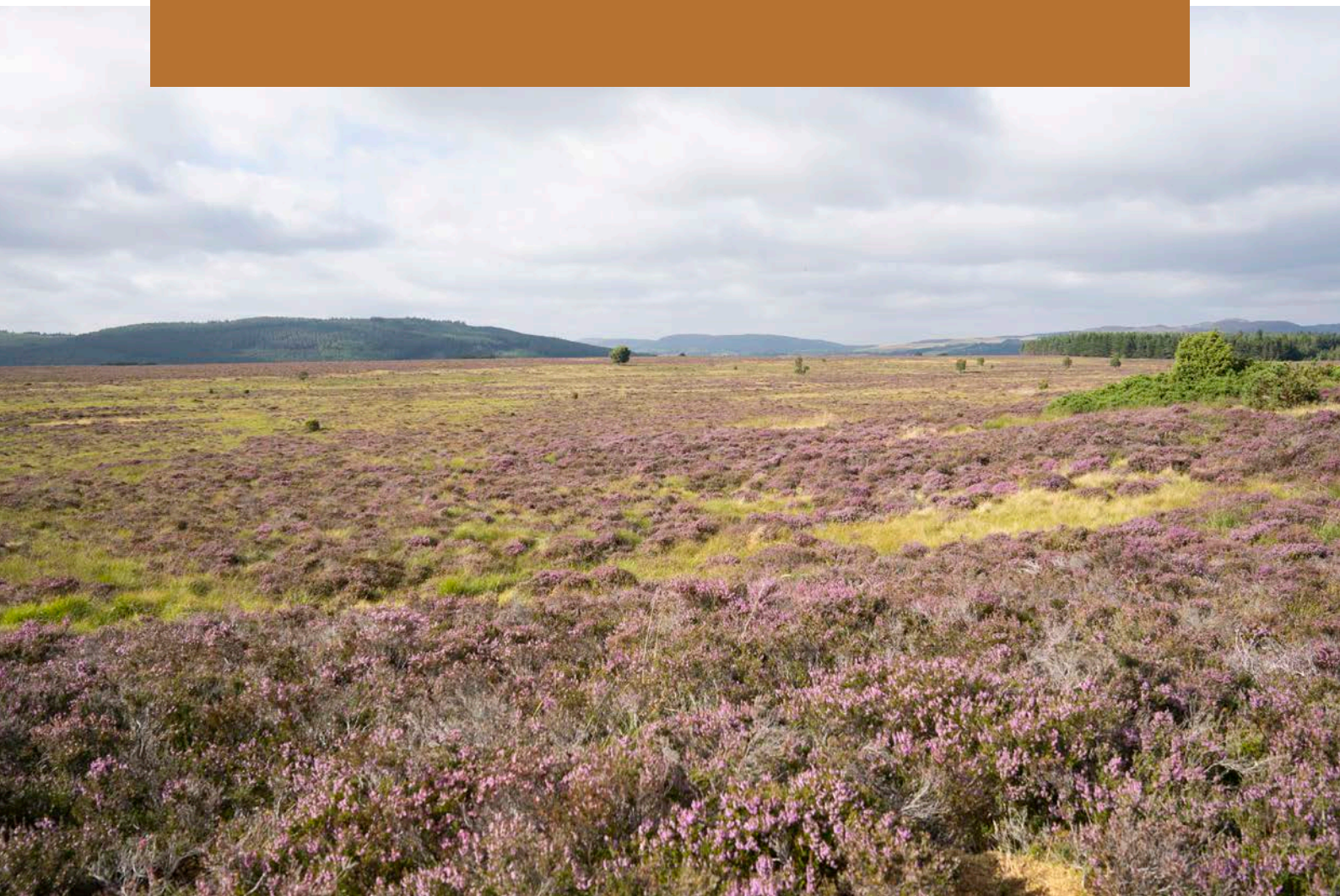
From these results, Terra Motion reached the following conclusions:

- A total of **47 hectares** are observed to be actively eroding within the Bunloit estate
- Using emissions factors from the Peatland Code, Terra Motion estimate that there was an average net loss of **1,067 tCO2e/year** from these areas during the last 5 years



A summary of our findings from estimating peatland carbon stocks is as follows:

- Our **peatland areas are the largest carbon stocks on the estate** – with a range of 708,778 - 1,097,640 tCO2e stored in the peatland soils.
- This is up to **10 times the amount of carbon stored within the woodland** areas.
- However, they are **also our largest carbon source** - with calculations of carbon flux showing a mid-range scenario of **1,106 tCO2e / year** emissions in their current state.
- Tier 3 observations from satellite measurements of land motion have **supported the assessment of yearly carbon losses**, coming in slightly lower than estimates, albeit from a smaller area.
- Satellite measurements are however unable to assess losses from plantations on peatlands – so we can expect higher emissions when these areas are factored in.



240

We have an estimated average net loss of

tCO2e/year

We can save an estimated net of

60,747

tCO2e over the next 100 years

Carbon Modelling Summary

The Tier 2 carbon model of the Bunloit Estate is shown in the table below. The key headlines are as follows:

- We have a calculated 845,472 – 1,234,334 tonnes of carbon dioxide equivalent (tCO2e) stored within the Bunloit estate – **equivalent to 2% of Scotland's annual carbon emissions**

- 708,778 - 1,097,640 tCO2e is in the peatland and 115,748 (i.e., up to c. 10 times less) in the woodlands of all types, with 20,946 in the grasslands

- **We have an estimated average net loss of 240 tCO2e / year via:**

  866 tCO2e / year sequestered from existing woodlands and grasslands

  1,106 tCO2e / year lost from Peatlands via drained and forest areas

- We are seeing 38% more carbon in actual measured stocks in soil, compared to Tier 2 modelling taken from Natural England reports

Habitat Type	Tier 2 Modelled Stock *(Tonnes Co2e)*	Tier 3 Modelled Stock *(Tonnes Co2e)*	Tier 2 Future Fluxes *(Tonnes Co2e over 100 years)*
Woodland	115,748	TBC - CSX LIDAR	-71,127
Peatland	708,778 – 1,097,640	N/A	110,600
Grassland	20,946	29,002 (38% uplift)	-15,541
TOTAL	**845,472 - 1,234,334**		**23,932**

Considering our research to date, and the universal advice to remove the conifer plantations and restore peatland areas for both carbon and biodiversity reasons, an updated projection of stocks and fluxes is shown below.

We can save an estimated net of 60,747 tCO2e over 100 years from:

- Clear felling plantations atop the peat plus increasing sequestration via broadleaf replanting

- Peatland restoration - reduced emissions from restoring and rewetting degraded peat

Based on current data we estimate the reduction in losses from peatland restoration and extra sequestration from new plantations at a net saving of 92,350 over 100 years. Including carbon stock lost from clear felling activities of 31,603 tCO2e in our calculation (assuming the timber does not end up in long-term storage) we arrive at a net 60,747 tCO2e saved over 100 years.

Habitat Type	Tier 2 Modelled Stock *(Tonnes Co2e)*	Tier 3 Modelled Stock *(Tonnes Co2e)*	Tier 2 Future Fluxes *(Tonnes Co2e over 100 years)*
Woodland	84,145 (**-31,603**)	TBC - CSX LIDAR	-79,853 (**-8,726**)
Peatland	708,778 – 1,097,640	N/A	26,976 (**-83,624**)
Grassland	20,946	29,002 (38% uplift)	-15,541
TOTAL	**813,869 - 1,202,731**		**-68,418 (-92,350)**

Biodiversity Modelling

© Joe Gray

Methodology

The second key area of focus for our initial baseline of the Bunloit estate has been mapping biodiversity in all its forms across the varied habitats. By its very nature, the term biodiversity encompasses the entire web of life, and so is more complex than the four pools of carbon we have been monitoring. Most of the data collection is also therefore at Tier 3 level – i.e., actual in-field surveys. From discussions with UK-wide specialists and local ecologists, we decided to collect the following high level data sets to provide a picture of the state of biodiversity on the estate:

- eDNA and a Tier 2 Biodiversity Net Gain assessment via the CreditNature project

- A complete floral community assessment via Plantlife:

  - Vascular plants
  - Lichens
  - Bryophytes (mosses and liverworts)

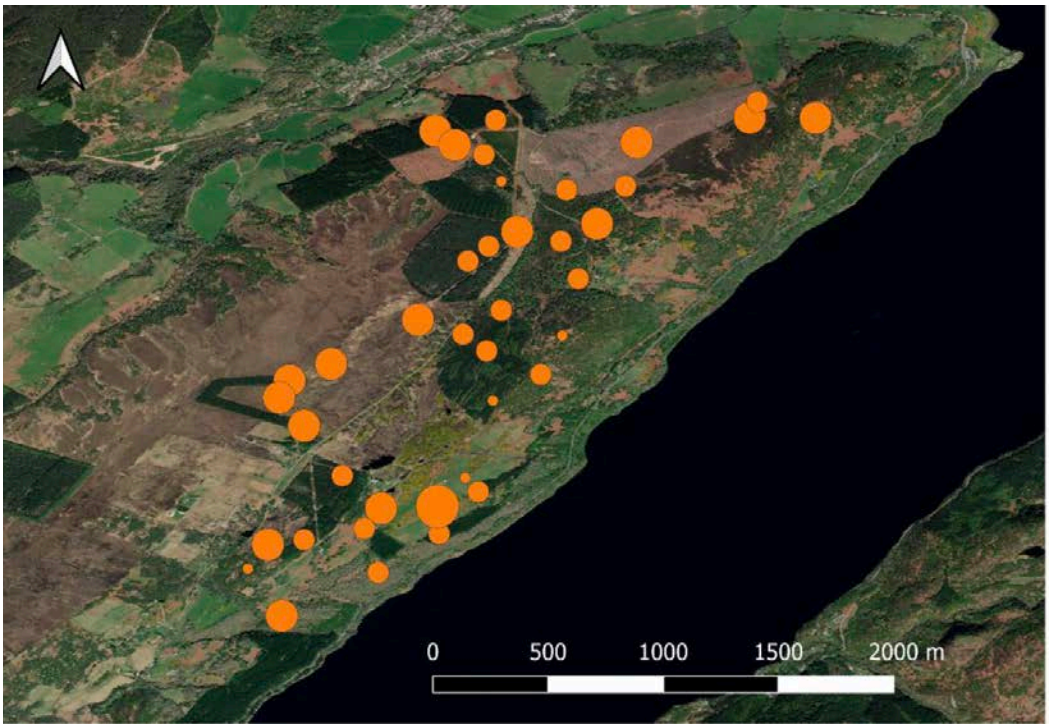
- Species surveys with local ecologists Wychwood Environmental and Dan Puplett, plus camera traps from NatureSpy. These were:

  - Large mammals - via camera trapping and tracking
  - Small mammals (non-flying) - box camera traps
  - Bats (ultrasonic acoustic surveys)
  - Birds (visual/acoustic)
  – point counts (Breeding Bird Surveys will be conducted in Spring 2022)
  - Amphibians & Reptiles - targeted refugia-based surveys.
  - Insects - transect surveys for butterflies, pollinator surveys and moths

eDNA and Biodiversity Net Gain

Within the initial CreditNature project, we worked with NatureMetrics – who are an innovative UK biotech company that provide commercial sampling kits to monitor soil and water biodiversity via DNA. Environmental DNA (eDNA) is nuclear or mitochondrial DNA released from an organism into the environment. Scientists have lately developed innovative techniques to detect this DNA in water and soil samples at very low concentrations - a potentially game-changing development for biodiversity inventory-building.

NatureMetrics provided kits and analysis for 42 soil samples - looking at the eDNA of fungi and fauna. At least one sample was collected for each of our representative habitats. Diversity metrics were then created from the DNA lists identified - an example of fungi diversity across the estate is shown on the figure below.



Soil Fungi

Shannon's Diversity Imdex

1 - 2

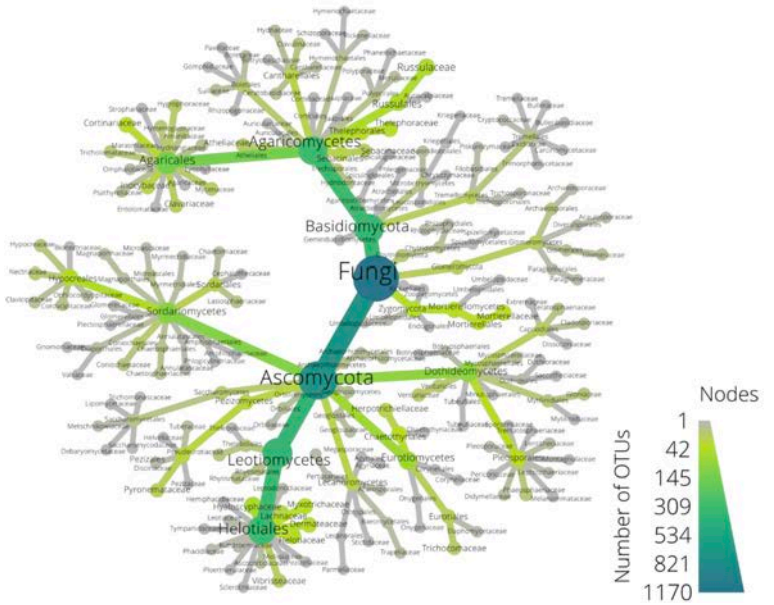
2 - 3

3 - 4

4+

Target	Number of OTUs	Phylum	Class	Order	Family	Genus	Species
Fungi	1,168	98.9%	92.8%	84.3%	66.2%	47.9%	28.2%
Fauna	352	99.7%	89.2%	90.9%	82.1%	45.2%	22.7%

The eDNA results provided some interesting initial results. The figure below shows a taxonomic heat tree visually showing the number of units across all samples for fungal communities, with an extract from the Nature Metrics summary report:



A total of 1,168 fungal operational taxonomic units (OTUs) and 352 faunal OTUs were detected across the samples. Fungal taxa richness was lowest in the 'coniferous woodland – semi natural' habitat and faunal taxa richness was highest in the bog.

Samples collected from the bog and 'modified grassland' habitats had distinct fungal and faunal community compositions. While the three categories of coniferous woodland habitats appear to have similar soil communities, 'broadleaved mixed and yew woodland' and 'coniferous woodland – semi natural' differed from each other.

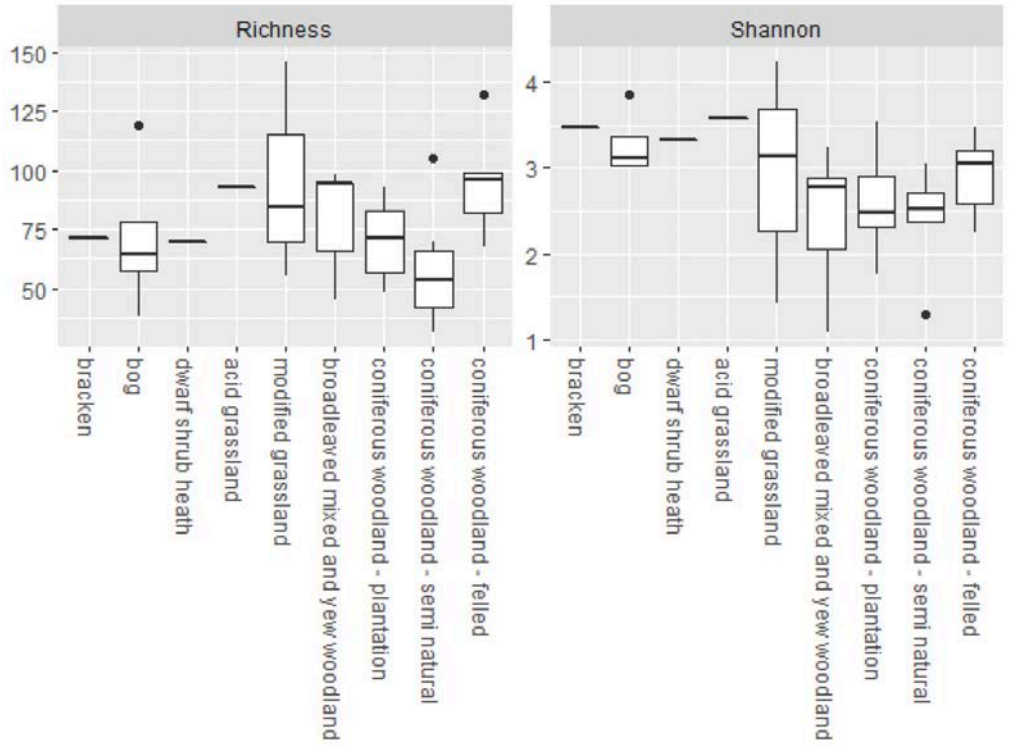
The eDNA analysis corroborated what we had been told by many of the conferees in our initial 12 months of discussions. i.e.:

1. Coniferous woodlands (our non-native plantations) had the lowest biodiversity richness and diversity within both fauna and fungal soil samples

2. Our peatlands and grasslands have the highest and most distinct biodiversity in the soil samples

This can be seen in the visuals of the fungi DNA testing as shown in the graphic below. Interestingly, the clear-felled plantation in Borlum Wood on the far right shows a high level of fungi diversity. This can be attributed to the fact that the clear-felling has caused a lot of disturbance, and the parcel is now in flux which is creating opportunities for increased biodiversity (at a fungal level at least).

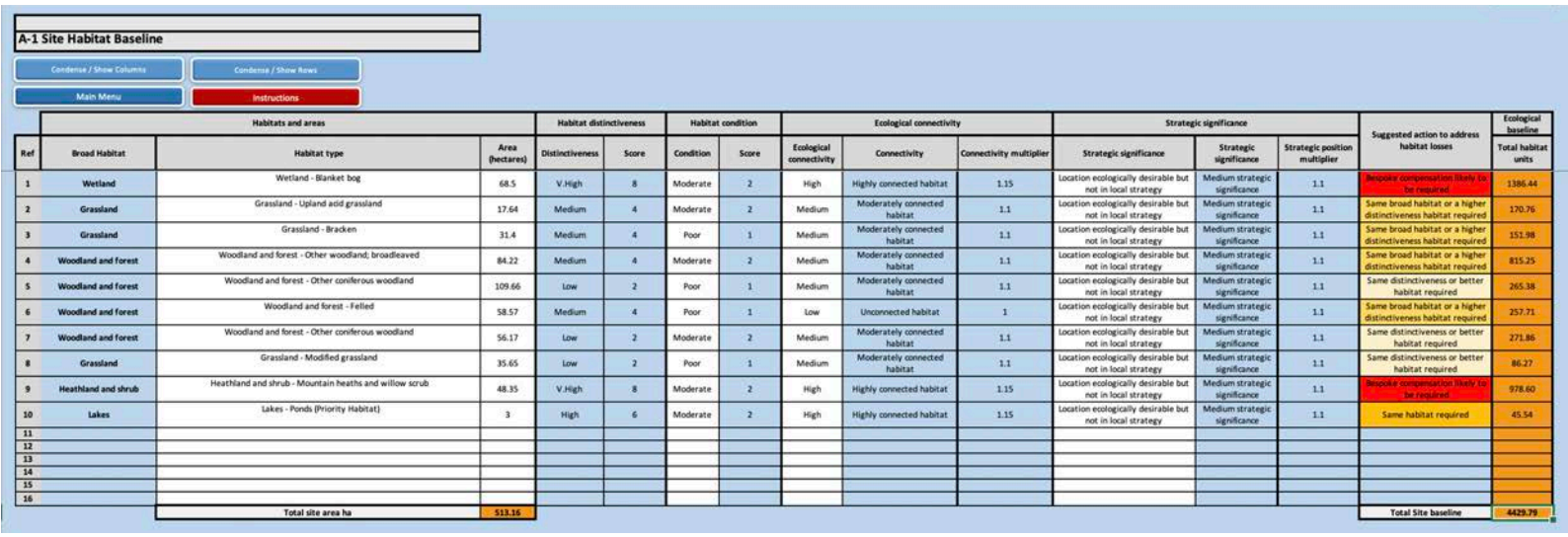
We also had some interesting feedback when we sent the eDNA data to Plantlife UK, who are leading on plant surveys at Bunloit. An initial check against the ICUN red list of the datasets identified several rare and threatened species. These included fungi *Russula lilacea* and *Clavicorona taxophila* on our grasslands.



In the same project, Ecosulis also produced a desktop Biodiversity Net Gain assessment - using the English DEFRA Metric v2.0 - as a similar model is yet to be launched in Scotland. As this was undertaken during lockdown, no site visits were undertaken and the initial assessment of our habitats was based on drone imagery, NatureMetrics data and conversations with the site team.

The image below shows the summary of the desktop analysis. This considered most habitat types as moderate or poor condition. The DEFRA Metric uses an assessment of habitat distinctiveness, area, condition and strategic significance to calculate a habitat unit for each parcel, and a suggested management action. This led to a site baseline of 4,429 habitat units, as shown in the last column in the image below.

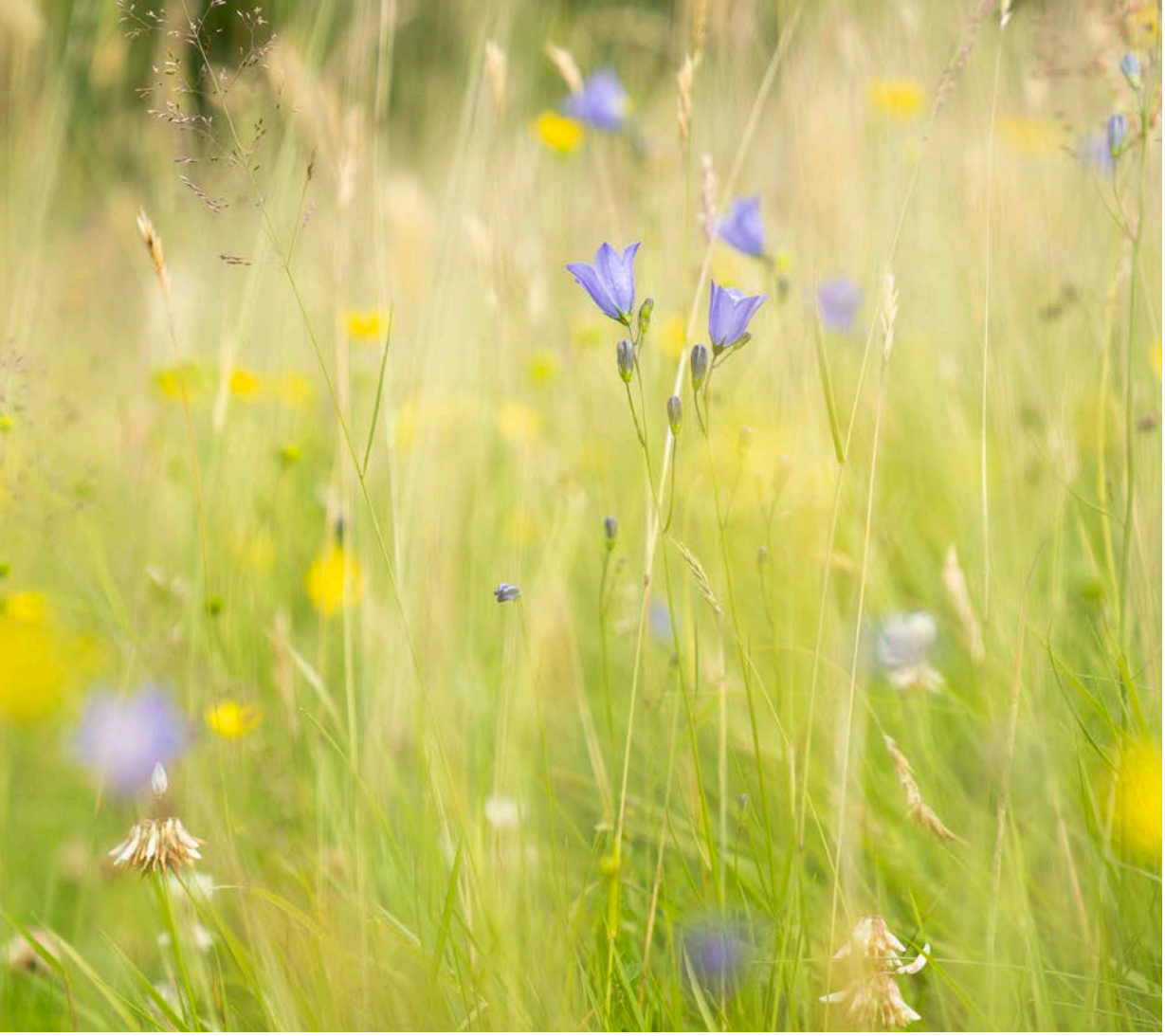
This high-level work identified the wetland peatbogs and heathland and shrub habitats as highly distinctive – and therefore worth more in terms of biodiversity units. There has since been a 3.0 version of the metric, with a different scoring process so it will be interesting to see whether the site has increased or decreased in units. Initial feedback from other rewilding entities who have explored this, is that the new metric doesn't put much value in scrubland as it is considered a transition habitat, although actual measurements show these areas are high in biodiversity value.



A-1 Site Habitat Baseline

Condense / Show Columns | Condense / Show Rows | Main Menu | Instructions

	Habitats and areas			Habitat distinctiveness		Habitat condition		Ecological connectivity			Strategic significance			Suggested action to address habitat losses	Ecological baseline
Ref	Broad Habitat	Habitat type	Area (hectares)	Distinctiveness	Score	Condition	Score	Ecological connectivity	Connectivity	Connectivity multiplier	Strategic significance	Strategic significance	Strategic position multiplier		Total habitat units
1	Wetland	Wetland - Blanket bog	68.5	V.High	8	Moderate	2	High	Highly connected habitat	1.15	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Bespoke compensation likely to be required	1386.44
2	Grassland	Grassland - Upland acid grassland	17.64	Medium	4	Moderate	2	Medium	Moderately connected habitat	1.1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same broad habitat or a higher distinctiveness habitat required	170.76
3	Grassland	Grassland - Bracken	31.4	Medium	4	Poor	1	Medium	Moderately connected habitat	1.1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same broad habitat or a higher distinctiveness habitat required	151.98
4	Woodland and forest	Woodland and forest - Other woodland; broadleaved	84.22	Medium	4	Moderate	2	Medium	Moderately connected habitat	1.1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same broad habitat or a higher distinctiveness habitat required	815.25
5	Woodland and forest	Woodland and forest - Other coniferous woodland	109.66	Low	2	Poor	1	Medium	Moderately connected habitat	1.1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same distinctiveness or better habitat required	265.38
6	Woodland and forest	Woodland and forest - Felled	58.57	Medium	4	Poor	1	Low	Unconnected habitat	1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same broad habitat or a higher distinctiveness habitat required	257.71
7	Woodland and forest	Woodland and forest - Other coniferous woodland	56.17	Low	2	Moderate	2	Medium	Moderately connected habitat	1.1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same distinctiveness or better habitat required	271.86
8	Grassland	Grassland - Modified grassland	35.65	Low	2	Poor	1	Medium	Moderately connected habitat	1.1	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same distinctiveness or better habitat required	86.27
9	Heathland and shrub	Heathland and shrub - Mountain heaths and willow scrub	48.35	V.High	8	Moderate	2	High	Highly connected habitat	1.15	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Bespoke compensation likely to be required	978.60
10	Lakes	Lakes - Ponds (Priority Habitat)	3	High	6	Moderate	2	High	Highly connected habitat	1.15	Location ecologically desirable but not in local strategy	Medium strategic significance	1.1	Same habitat required	45.54
11															
12															
13															
14															
15															
16															
		Total site area ha	513.16											Total Site baseline	4429.79



Flora

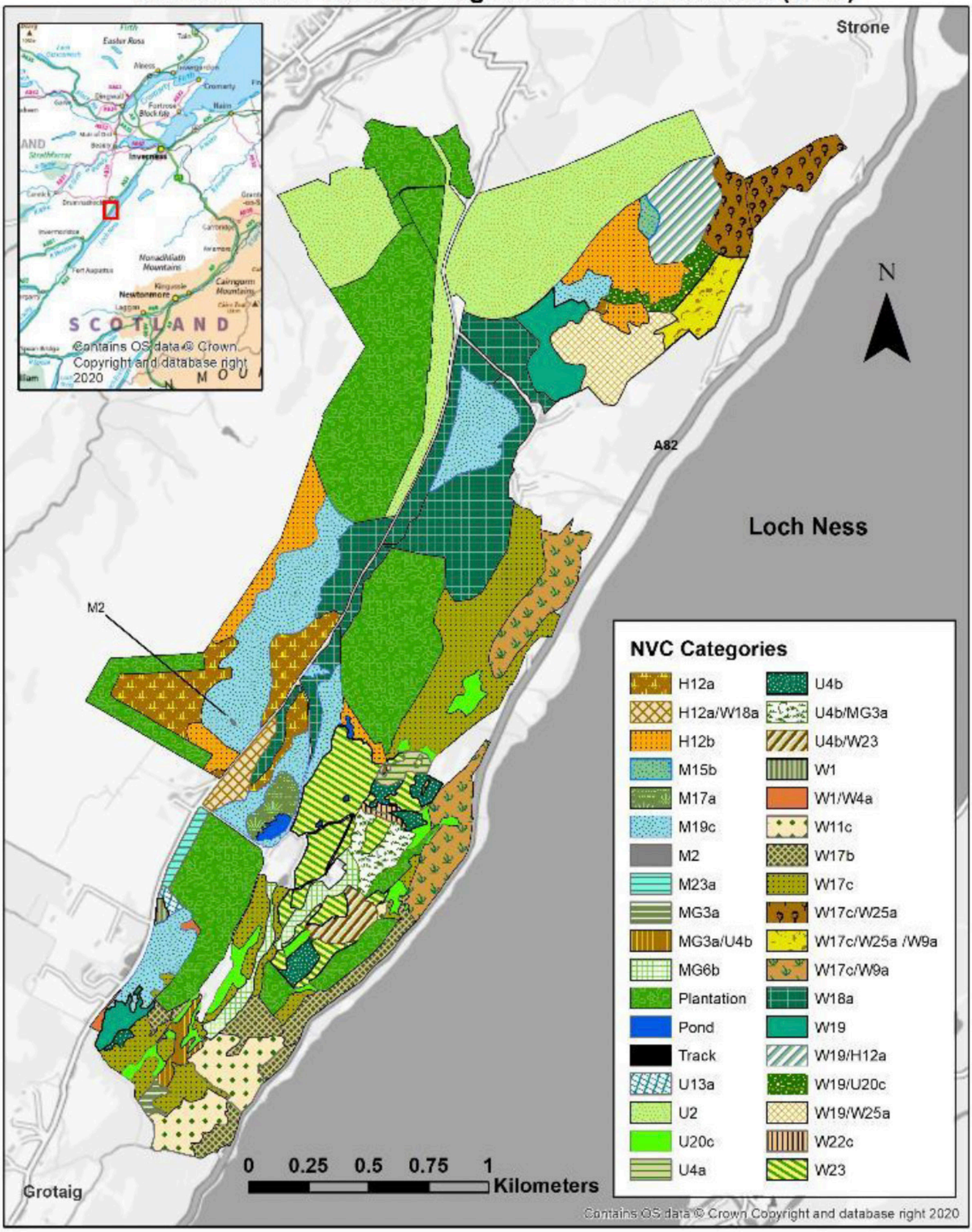
For floral surveys, we engaged Plantlife to carry out a comprehensive botanical survey of the Bunloit Estate. Plantlife are the 'Wild Plant Conservation Charity' – with a focus on lasting positive change for wildflowers, plants and fungi. Across the summer of 2021, the Plantlife specialist team completed a full botanical assessment of the estate - including lichens, vascular plants and bryophytes (mosses and liverworts). **They identified 580 separate plant species across the estate.**

During the survey period, Plantlife specialists assessed the estate's floral population using the National Vegetation Classification (NVC) as the standard descriptive medium to identify the various vegetation communities on site. The results of these surveys show a mosaic of different plant communities across the estate - as shown in the map on the following page.

Where suitable, surveys were aligned with and fed into national databases. For example, all lichen records generated were submitted to the British Lichen Society National Database, which subsequently make their way on to the National Biodiversity Network's Atlas.

In addition to the fieldwork and analysis, the Plantlife GIS team interrogated the Botanical Society of Britain and Ireland database for field records from the Bunloit estate over the last ten years. 300 individual records were available here.

Bunloit Estate National Vegetation Classifications (NVC)




271
Lichen Species


154
Bryophyte Species
(mosses and liverworts)


155
Vascular Species

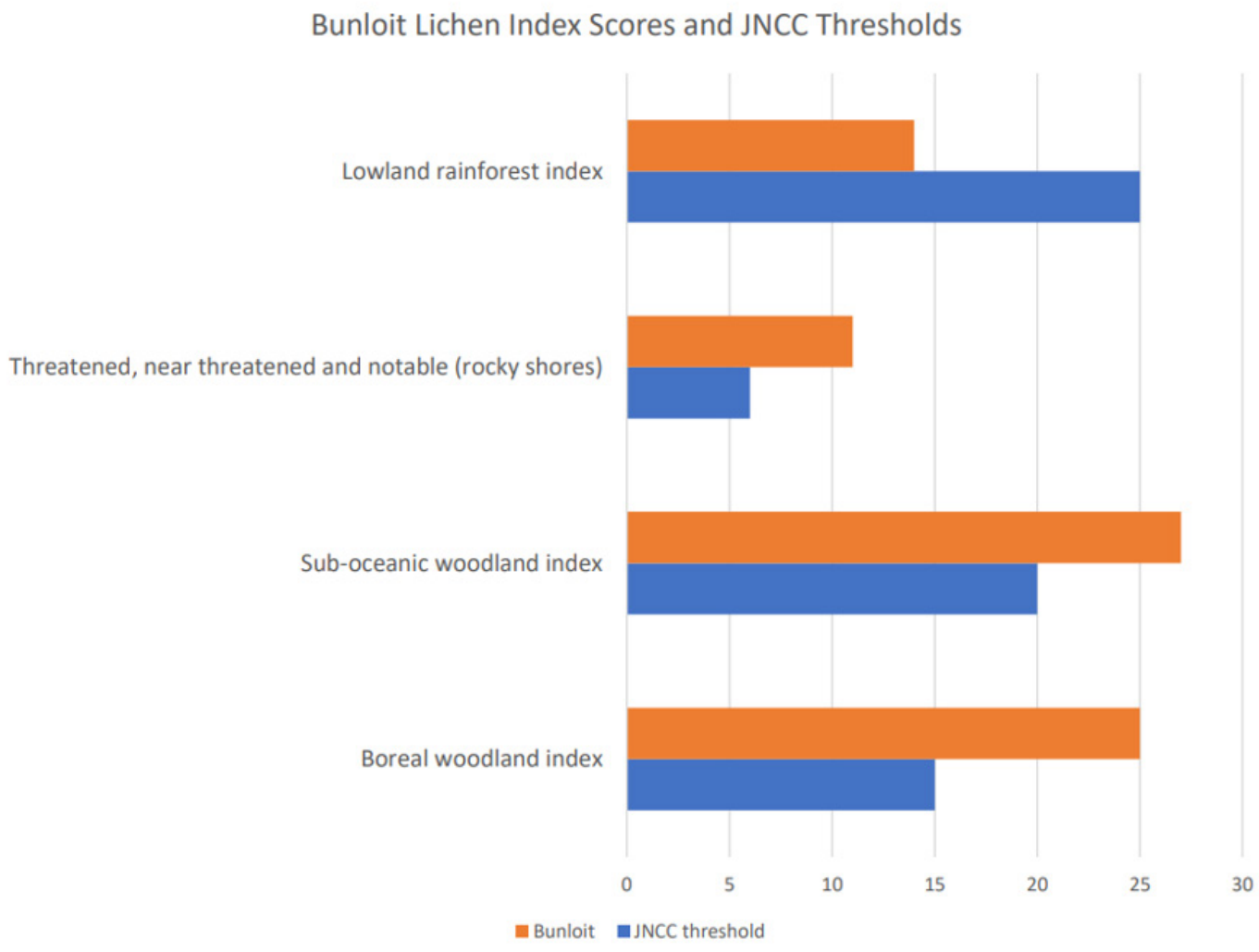
Flora - Lichens

Of the three high level groups surveyed, the lichens were the most interesting. According to the British Lichen Society "A lichen is not a single organism; it is a stable symbiotic association between a fungus and algae and/or cyanobacteria. Like all fungi, lichen fungi require carbon as a food source; this is provided by their symbiotic algae and/or cyanobacteria, that are photosynthetic."

Lichen assemblages are evaluated using habitat indices, designed to measure lichen diversity in a consistent way, using species strongly associated with high quality and long continuity of habitat.

Sites of Special Scientific Interest (SSSIs) are the very best examples of habitat and species assemblages in the country and are afforded protection in Scotland under the Nature Conservation (Scotland) Act 2004. They are selected using strict criteria defined by the Joint Nature Conservation Committee.

As can be seen in the image above, it was found that the site far exceeds the SSSI thresholds based on its lichen feature alone. The Lowland Rainforest Index (LRI score of 14) was also applied (despite Bunloit being outside of the rainforest zone), as microclimatic conditions in Area 3 on the map below have resulted in well-developed rainforest communities.

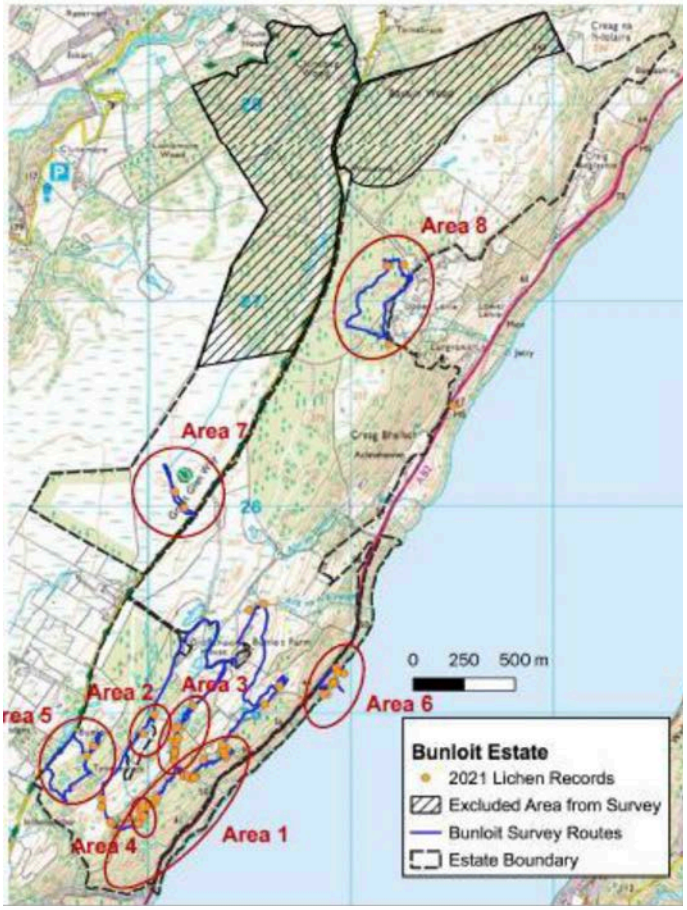


The map opposite provided by Plantlife shows the areas of most interest in lichen communities. Specifically, the areas of ancient woodlands below and to the west of the ancient grassland areas have particularly important communities – such as Area 3 already mentioned. This is a high-quality oceanic hazelwood ravine of great conservation importance. Shelter and humidity from the ravine, plus high light levels from the west, has resulted in the development of an exceptional rainforest community.

The identification of this important lichen community has led to a slight change in the felling plan when discussed with the Forestry team. While noting that removal of non-native conifer plantations in these areas will be beneficial for floral communities, a strip along the edge of the plantations will be left to continue to shelter the ravines with these rare communities.

The results of the Plantlife lichen survey have shown our estate woodlands and ravines are packed full of lichens, with species which indicate significant continuity, meaning that these woodlands have been in existence for a long time. The specialists stated it was

Map 3: A map of the Bunloit Estate provided by Plantlife Scotland prior to the survey, indicating the Estate boundary, 2021 survey routes, lichen records & different areas.



"quite extraordinary to find a hazel dripping with so many lichens that you can't even see its trunk." The photo below shows hazels and ash trees festooned with tree lungwort (*Lobaria pulmonaria*) and green satin lichen (*Lobaria virens*).


© Alistair Whyte - Plantlife

Flora - Bryophytes

For bryophytes, a total of 154 species were found. These totals are not particularly high by Scottish Highland standards, but they still indicate a bryophyte flora of at least moderate richness. The bryophyte floras of these survey areas (and the plant communities in these places) indicate that the soils are mainly acidic but locally more neutral to base - enriched. Species totals are not expected to be as high here as in sites that are further west (where there are more oceanic species, reflecting a wetter and more equable climate) or where base-rich rocks and soils are more extensive.
The richest part of the survey area for bryophytes is the wooded ravine of the Grotaig Burn at the southern end of Area 1 on the previous map, where there is a good range of habitats with rocks at varying distances from the stream, trees, logs and steep banks, all in a humid setting. **This ravine is the only place where the oceanic liverworts *Cololejeunea microscopica*, *Lejeunea lamacerina* and *Plagiochila spinulosa* were found in this survey.**

Flora - Vascular Plants

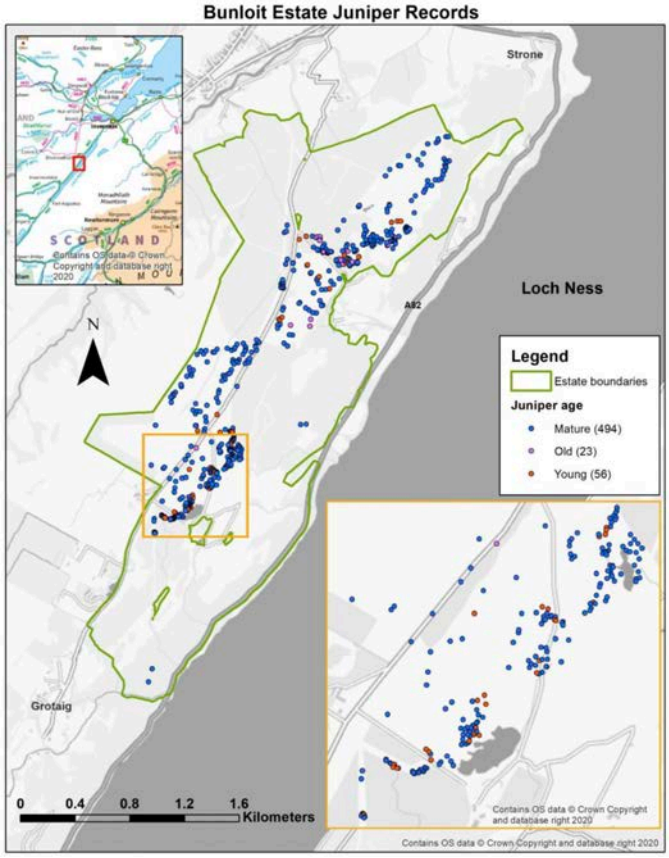

© Alistair Whyte - Plantlife

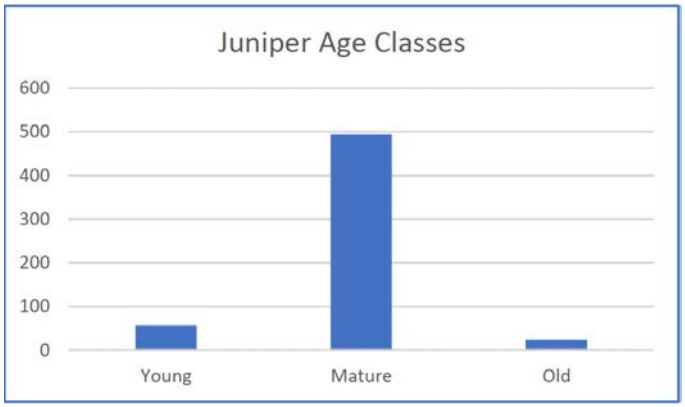
Finally, a total of 155 vascular plant species were recorded. Aspen, an important tree species, was found during these surveys, and it was identified that the grassland areas are unimproved, ancient in origin, and hold good potential for restoring species richness. The picture on the left shows a Ballerina Waxcap - (*Porpolomopsis calyptriformis*) which are scarce in the UK, and even rarer in Europe, meaning that this country is one of the most important places for them.

According to Plantlife UK Ballerina Waxcaps don't cope well with disturbance, or the 'improvement' of grasslands through the application of fertilisers. This means that they are only found in undisturbed grasslands which have likely been in existence for a very long time. **Finding this species at Bunloit was a clue that the grassland habitat here is undisturbed, and therefore extremely important.**

The Bunoit Estate also has a lot of Juniper bushes, and so Plantlife selected this plant as a key indicator and carried out a survey of the condition of these bushes within the northern section of the estate. This was both because Juniper is a very important species at Bunloit in its own right, and a crucial component of several of the habitats, but also because it is a good indicator of the condition of the wider habitat, and an indicator of grazing pressure.

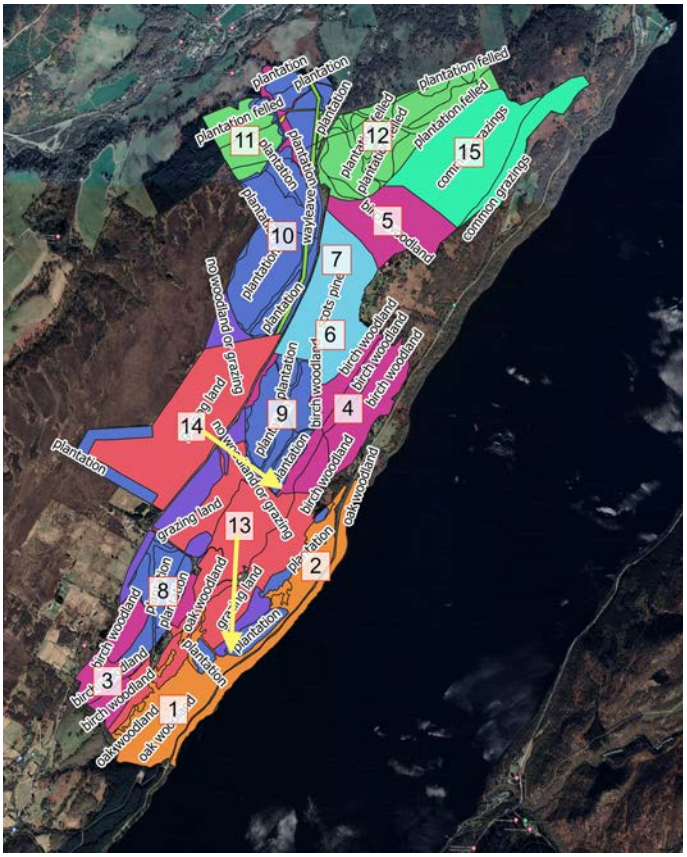
The survey of 573 individual juniper bushes demonstrates that Bunloit is suffering from the same problem as juniper populations across Scotland, with the population being heavily skewed towards mature plants, and very few young specimens being found - as shown below. This indicates heavy grazing pressure, a point considered further in our final section on fauna surveys.





Sika Deer

Fauna - Camera Traps

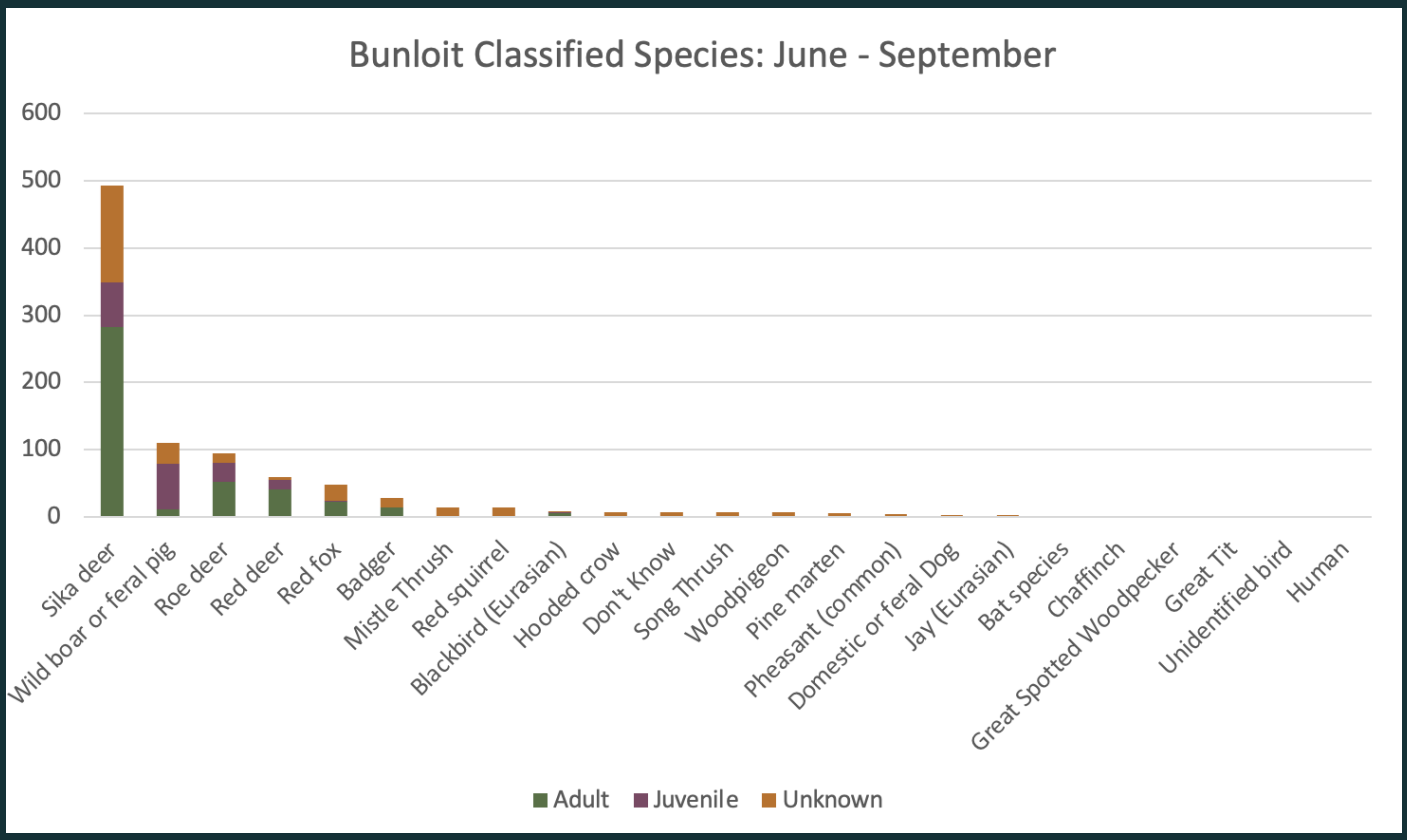


The dictionary definition of fauna is “all the animals that live wild in a particular area” and so we have worked with a selection of organisations - including several local ecologists - to survey and map the species present within the Bunloit estate.

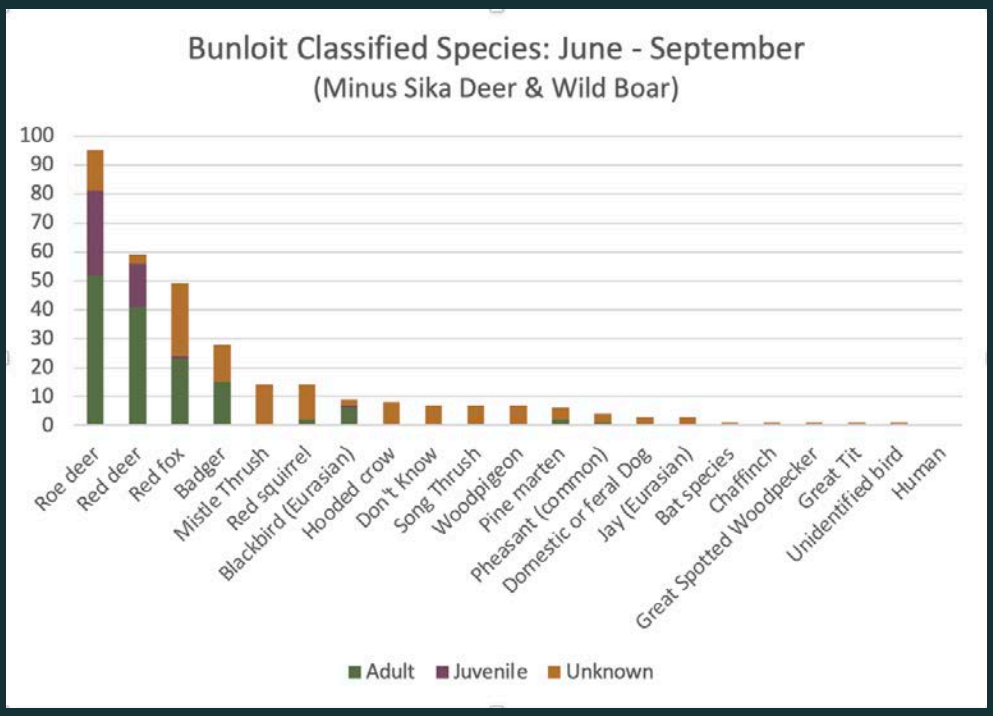
In the first instance, we obtained fifteen camera traps from NatureSpy - a non-profit organisation that aims to research and protect wildlife whilst engaging local communities, using the most advanced wildlife watching tech available. For us, this was the Browning Recon Force Elite HP4 camera trap, which our in-house ranger team installed across the estate in May 2021 - as shown in the diagram above. The NatureSpy team helped design the ideal placement of the cameras across the estate and attended site in May to help with their distribution and setup.

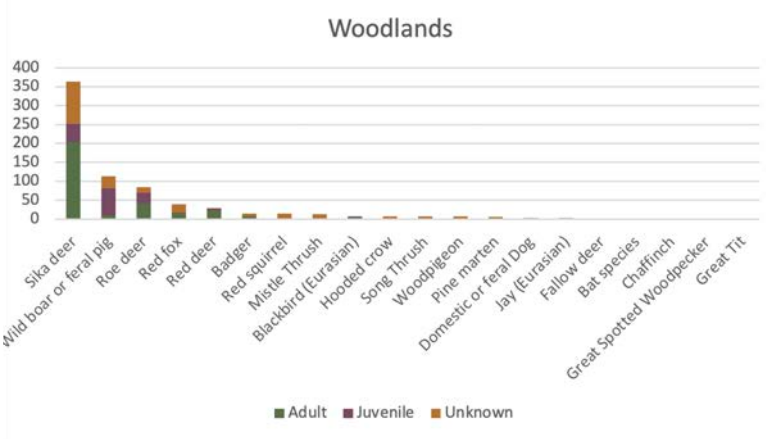
These camera traps are movement triggered, recording a 20-second video of the animal that triggered them. Data was then collected after a period of 90 days (1,350 camera traps days). Previous inventory studies from NatureSpy have shown this period to be enough to detect 60-70% of species within a study area. The collected sequences were then uploaded to a citizen science platform called MammalWeb - where citizen scientists classify each sequence according to standard species lists. Some example shots are shown below.

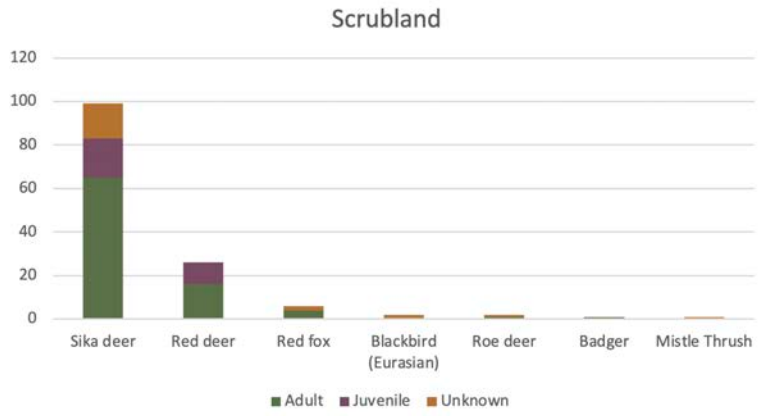
Through the 90-day period, 859 sequences have been classified via MammalWeb, which has given us a good initial snapshot of the animal species present on the estate, and where they are. Importantly, the MammalWeb portal enables spotters to identify whether the images are of an adult or a juvenile (or unknown). The estate-wide picture is shown below, with sika deer being by far the most numerous – accounting for 53% of all classifications during this time. Wild boar classifications came in second at 12% of overall classifications. However, 62% of the wild boar were classified as juvenile. Some of the reasons for this could be that wild boar piglets are easier to classify – but it also shows how much faster boar breed than other species - even deer.

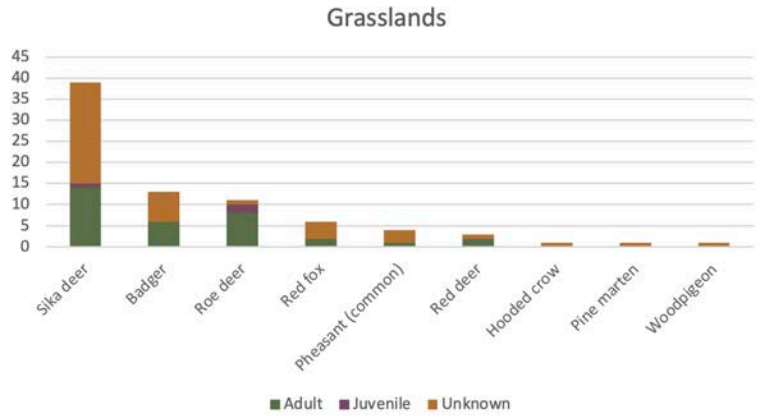


Removing sika deer and wild boar from the data set shows the other key large mammals on the site are roe and red deer, badgers, foxes and red squirrels. There is also a long tail of lower density bird, bat and other animal species present.









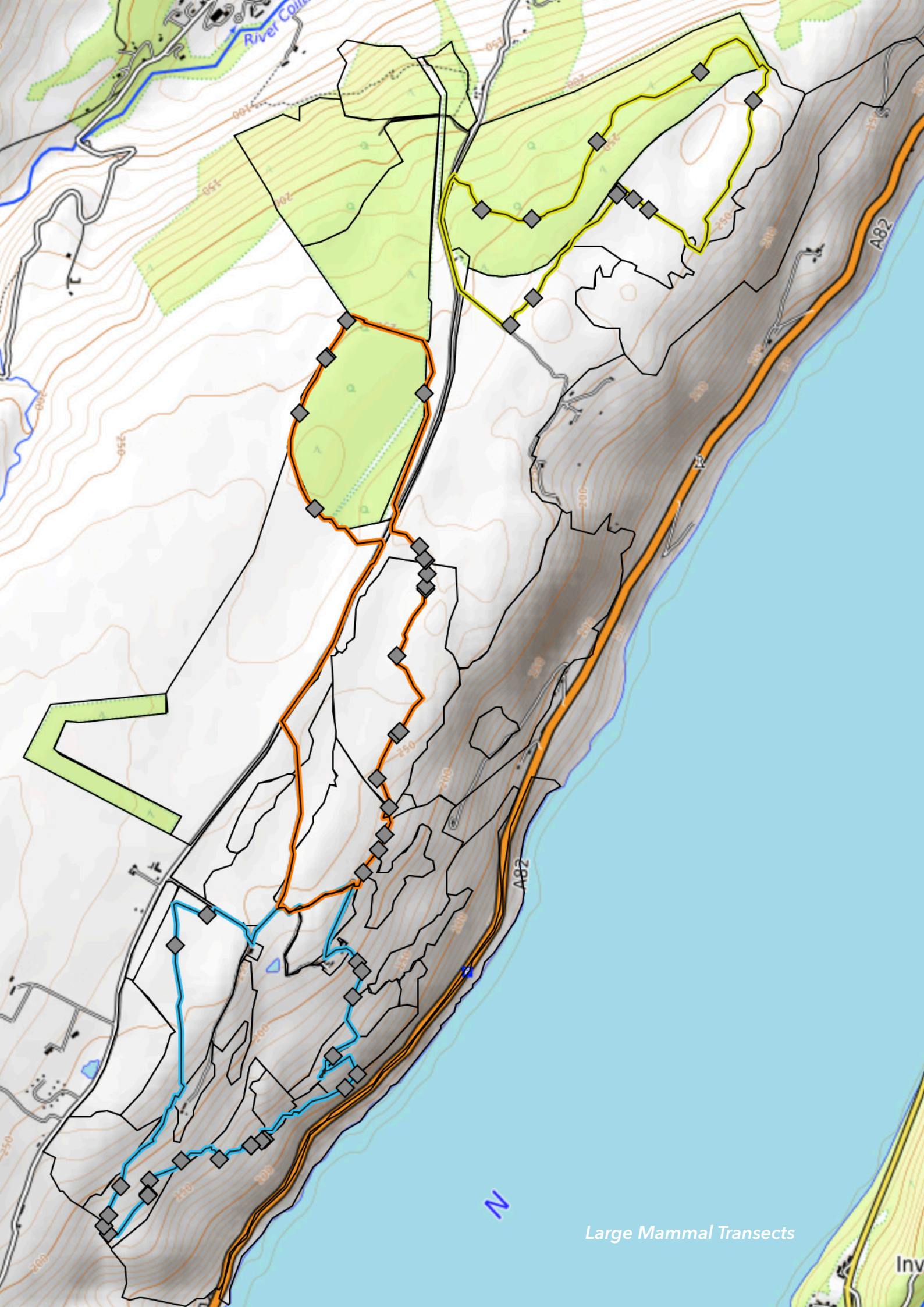
Filtering the dataset by broad habitat types starts to show us what species are where, with the woodlands having the largest species numbers - both overall and in diversity of species. This is then followed by scrubland and finally grassland, with the overall volume of biodiversity decreasing in proportion to the amount of cover available.

Our main species - sika - is present in all habitat types, reflecting the amount of this species we have on the estate, and its flexibility in grazing choices.

The second largest volume of species spotted, wild boar, are only to be found in the woodland areas - reflecting their shy nature, preferring to stay in areas of good cover.

These findings from the camera trap surveys were also backed up by tracking observations undertaken by a local nature guide and expert Dan Puplett. To complement the camera traps, Dan established three transects covering different parts of the estate, adding up to 13.8 km in total - as shown below.

Working with volunteer students who joined for a 4-week period over the summer, Dan undertook large mammal sign monitoring, whilst providing the students field training on how to recognise a range of tracks and signs, and about mammal ecology and behaviour. Our hope is that eco-tourist visits will be able to join these surveys in the future, adding another level of citizen science to the project data collection process.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Large Mammal Transects

Fauna - Ecological Surveys

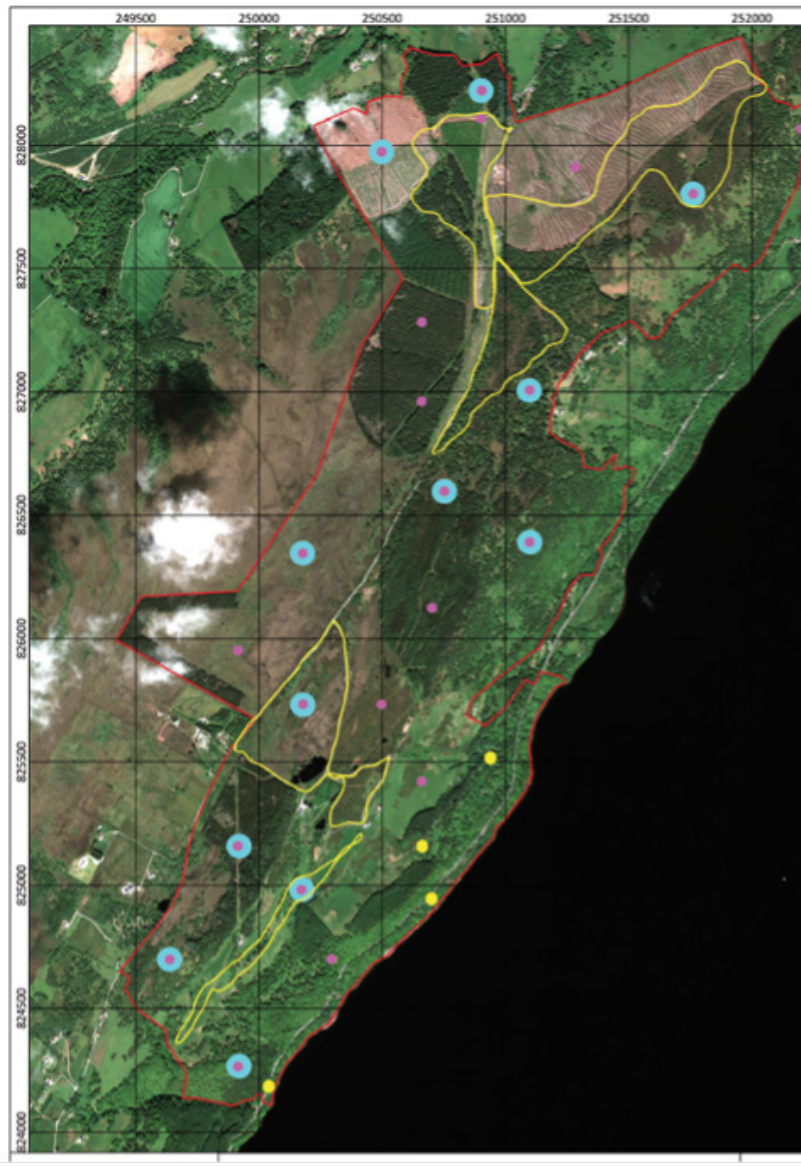
Finally, we engaged with local ecologists Wychwood Environmental, who worked with our volunteer students to lead a range of other surveys across the estate covering small mammals, bats, birds, amphibians & reptiles and insects (pollinator surveys and moths).

All surveys were completed between June and October 2021. This does not necessarily cover the full optimum survey season for each taxonomic group and so several surveys will be ongoing. Surveys were conducted across twelve different habitats, sometimes using a transect method, which moved between habitats during the same survey period, as shown in yellow lines on the image opposite.

The main habitats surveyed included: deciduous woodland (oak, birch & mixed) and coniferous woodland (Sitka spruce, larch, Scot's pine & mixed), clear felled areas, grassland, wet heathland, moorland and wetland. This covered the main habitat types present within our estate boundary.

The survey approach was structured to maximise species diversity capture and to ensure they are easily repeatable in both space and time, offering a range of ongoing monitoring options.

The following preliminary results have been developed - with further analysis to be undertaken over the winter/ spring period, following completion of surveys across this time.



Birds – Sampled by 10-minute static, fixed distance (c.50m) point counts, repeated 9 times in different locations within each habitat type. At least 108-point counts have been completed to date.

Global Summary - Based on the point counts and ad-hoc observations, 77 bird species have been recorded to date. Some species e.g., geese (e.g., Canada, Greylag), swans (e.g., Mute) and large eagle species (e.g., White-tailed) were recorded flying over the estate. All over species recorded should be considered to have a territorial or habitat dependence on the estate.

NBN Atlas records indicate 168 bird species records within 10km of Bunloit and 118 species records within 5km of Bunloit. These include several 'single' records and cover all seasons. Note our survey has covered June - October 2021.

Habitat Summary - Based on the point count data, 58 species were recorded across 12 habitats. Species richness between habitat types ranged from 14-35 species. Individual point count records range from 3-18 species.

The most diverse habitats were the heathland, mixed deciduous woodland and birch woodland. The least diverse were the clear fell, Scot's pine woodland and moorland. No species were recorded across all habitats.

The table below shows a summary by habitat, for:

1. Species richness (i.e., number of species in each habitat)

2. Richness range (min and max species counts on the lists)

3. Number of bird families recorded

We will be continuing to survey birds through the winter and spring breeding season to create a full picture of species on the estate over the year.

Habitat	Species Richness	Richness Range	Families
Clearfell	14	5-11	9
Sitka Plantation	17	4-12	9
Mixed Coniferous Plantation	18	6-13	8
Scots Pine Woodland	13	5-10	9
Larch Woodland	17	7-12	8
Birch Woodland	23	8-14	14
Oak Woodland	21	6-13	11
Mixed Deciduous Woodland	29	7-17	14
Moorland	15	3-9	8
Wetland	23	7-13	10
Wet Heathland	32	8-18	17
Grassland	27	9-15	15

Geese Migration

Bats – Sampled via transect walks and static detection (following BCT methods[2]). Transect surveys were completed seasonally along four different routes. Static detectors were rotated around 16 monitoring points.

At least six species (of the 10 known to Scotland) have been recorded across the estate. Bats have been recorded in all areas sampled. The records include all four species known to be present (based on NBN Atlas records).

Habitat Summary - Common pipistrelle (*Pipistrellus pipistrellus*) and soprano pipistrelle (*P. pygmaeus*) were recorded in all twelve habitats sampled and are by far the most numerous and widely distributed bat species on the estate.

Noctule and Leisler's are amongst the rarest bat species in Scotland[3], but were recorded in select habitats - as shown in the table below. Brown long-eared (*Plecotus auritus*) along with Leisler's were the least recorded.

Species	Habitat Type											
	Clearfell	Sitka	Mixed Coniferous	Scots Pine	Larch	Oak	Birch	Mixed Deciduous	Heath	Moorland	Wetland	Grassland
Common Pipistrelle	1	1	1	1	1	1	1	1	1	1	1	1
Soprano Pipistrelle	1	1	1	1	1	1	1	1	1	1	1	1
Notcule	1	0	1	1	0	1	0	0	0	0	0	1
Leisler's	0	0	1	0	0	0	0	0	0	0	0	1
Brown Long-eared	0	0	0	0	0	1	0	0	0	0	0	1
Natterer's	0	0	1	1	0	0	0	1	0	0	0	0
Daubentons	0	0	0	0	0	1	0	0	0	0	1	1

Summary Table: Presence (=1) / Absence (=0) data by habitat sampled

[2]https://www.bats.org.uk/resources/guidance-for-professionals/bat-surveys-for-professional-ecologists-good-practice-guidelines-3rd-edition

[3]https://www.nature.scot/plants-animals-and-fungi/mammals/land-mammals/bats

Reptiles & Amphibians (Herps) – Sampled using multiple artificial refugia (c.24) in each habitat area, totalling 288 refugia across 12 habitats.

Global Summary - At least six species have been recorded across the estate. Whilst 10 species are known to Scotland, based on NBN Atlas records (within 5km of Bunloit) only 3 reptile species and 5 amphibian species have been recorded. Based on the current survey, reptile and / or amphibian species have been recorded in at least 9 of the 12 habitats sampled (see table below).

Habitat Summary - Amphibians (either common frog and / or common toad) have been recorded in all habitats sampled, with common toad recorded in all habitats surveyed. Whereas reptiles (common lizard or slow-worm) were only recorded in 9 of the habitats sampled. Frequency of occurrence and relative abundance varied between habitats. Relative abundance and encounter rates were lower in the clear-fell and coniferous habitats compared to other habitat types.

Species	Habitat Type											
	Clearfell	Sitka	Mixed Coniferous	Scots Pine	Larch	Oak	Birch	Mixed Deciduous	Heath	Moorland	Wetland	Grassland
Common Frog	1	1	1	0	0	1	1	0	0	1	1	1
Common Toad	1	1	1	1	1	1	1	1	1	1	1	1
Smooth Newt	0	0	0	1	0	0	0	0	1	0	0	0
Palmate Newt	0	0	0	0	0	0	0	0	0	1	1	0
Slow-worm	1	0	0	0	0	1	0	1	0	0	0	1
Common Lizard	1	1	1	0	0	1	1	1	1	0	1	1

Summary Table: Presence (=1) / Absence (=0) data by habitat sampled

Small Mammals – The small mammal fauna was targeted using adapted camera traps[4]. These were deployed for at least 3 days in 10 different locations within each of the 12 habitat types. These resulted in 30 trap nights per habitat and 360 trap nights across the estate.

Global Summary - At least six species of small mammals have been recorded to date across the estate. Non-target mammal species also recorded include pine marten, badger and red squirrel. This is comparable to the species known to be present (based on NBN Atlas records). Several bird species were also recorded, and these are being integrated into the global bird data set.

Habitat Summary - The most common species encountered were rodent species, namely wood mice and voles (bank and field). These were recorded across most habitats, with wood mice recorded in all habitats surveyed. Shrews and weasel are less common. Watervole and hedgehogs are known to be present in the local area but have not been detected on the estate to date.

Species	Habitat Type											
	Clearfell	Sitka	Mixed Coniferous	Scots Pine	Larch	Oak	Birch	Mixed Deciduous	Heath	Moorland	Wetland	Grassland
Wood Mouse	1	1	1	1	1	1	1	1	1	1	1	1
Bank Vole	1	0	0	0	0	1	1	1	0	1	1	1
Field Vole	1	0	1	0	0	0	1	1	1	1	0	1
Common Shrew	0	0	1	0	0	0	0	1	0	1	0	1
Pygmy Shrew	0	0	0	0	0	0	0	0	1	0	0	0
Weasel	0	0	0	0	0	0	1	0	1	0	0	0
Red Squirrel	0	0	1	0	0	0	0	1	0	0	0	0
Pine Marten	0	1	1	1	0	1	0	1	0	0	0	0
Badger	0	0	0	0	0	1	0	1	0	0	0	0

Summary Table: Presence (=1) / Absence (=0) data by habitat sampled

[4]https://www.mammal.org.uk/2021/01/camera-trapping-for-small-mammals/

Butterflies – Four butterfly transects were completed twice each month (June -September), following an adapted version of the Butterfly Conservation transect survey method[5].

Data was collected over four 3km transects across the estate. These transects will continue to be monitored annually - with a fifth suggested route to be added, leading from the upper slopes of Bunloit farm down an old drover's track.

Species of note:

- **Pearl-bordered Fritillary** - This is a UKBAP Priority species as well as being listed by Scottish Natural Heritage (SNH) as a Species Action Framework (SAF) species. It is also one of the key woodland species identified for action by Forestry Commission Scotland in the Scottish Forestry Strategy 2006 due to its rapid decline.

  This uncommon species is located on south-facing slopes of the estate where bracken is present, however bracken has become very dense which is likely to reduce the presence of violet (the caterpillars food source) and therefore negatively impact the existing population of butterflies. Bracken control will reverse this trend.

  Suitable habitat is often characterised by violets growing in shallow bracken litter (<15cm depth) and low to medium bracken density (<c20 fronds m2), in sunny, sheltered locations. Steep south-facing sites are important. Bracken control should not be undertaken in areas of currently suitable habitat[6].

- **Scotch Argus** - This is the most common butterfly across the estate in August. A count of 135 butterflies was recorded over a 400m section of acid grassland (where purple moor-grass - the caterpillars food plant - dominates) sheltered between plantation and Scots pine woodland.

- **Comma** - This species has only in recent years made its way into the Highlands and has been recorded in low numbers. Caterpillars feed on elm and nettle which are uncommon across the estate and therefore management to increase these species would improve numbers.

[5]https://butterfly-conservation.org/in-your-area/surrey-and-sw-london-branch/transects-wcbs
[6]https://scotland.forestry.gov.uk/images/corporate/pdf/PBFSRDPadvice.pdf

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Following the butterfly surveys, we have identified a selection of intervention opportunities that can enhance conditions for Lepidoptera (butterflies and moths) on the estate. These include:

- **Further Study** - Transect surveys were not started until mid-June and therefore early flying species such as Green Hairstreak and Dingy Skipper were not recorded or were only seen in low numbers, such as Orange Tip and Chequered Skipper. Transect surveys will start in April next year.

- **Borlum Wood** - This part of the estate is very exposed and butterfly numbers are low. As trees regenerate sheltered areas will increase and so should butterfly numbers. Rides along the main track that cut through the felled section of Borlum Wood could be maintained by preventing Sitka/pine trees from growing within at least 10m either side of the track.

- **Meadow Areas** - Meadows have suffered from bracken and gorse encroachment. The control of this - through ideally natural processes - will improve habitat for butterflies by increasing the area of acid grassland.

- **Wet Heath Areas** - Shelter from the plantation to the south is where the highest number of butterflies are present. Very few butterflies were observed in the open section of wet heath, but this may improve with regeneration, creating pockets of shelter.

Dragonflies - Local dragonfly enthusiast Larry Templeton has been undertaking species surveys on the Bunloit Estate for several years. There are 19 dragonfly and damselfly species in the Scottish Highlands, of which Larry has seen 11 at Bunloit. While this includes many common species – such as the Common Blue Damselfly or the largest Highland species Golden Ringed Dragonfly, Larry particularly notes the rare Brilliant Emerald. These are medium sized dragonflies with emerald abdomen, apple green eyes and yellowish face, which can be found patrolling the lochans on sunny July and August days - see image opposite.

It is therefore likely that Bunloit is a key dragonfly site in the Highlands due to the presence of the uncommon Northern Emerald and the Brilliant Emerald – being one of the rarest dragonflies in the Highlands. The estate has a variety of habitats including small lochans and an abundance of sphagnum bog pools which attracts a variety of dragonfly species. Recent spots by our rangers have also included the elusive Azure Hawker, which makes 12 dragonfly species found so far at Bunloit with at least 2 other species that might be expected in the area. Further surveying and pond dipping work is planned for next summer - including potential school visits, with the hope of adding more species to the spotted list.


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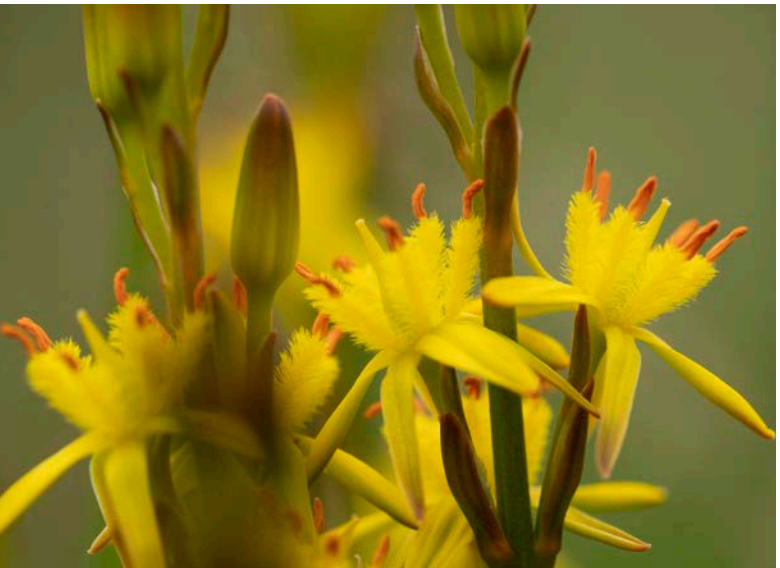

Conclusions

We hope this report provides a good start in illustrating how carbon and biodiversity can be quantified at a granular level, using an array of scientific techniques, on a plot of mixed-habitat land measured in the hundreds of hectares. How the data we have collected can begin to be translated into policymaking, in support of government objectives in addressing the climate- and biodiversity crises, is beyond the scope of the report but will be addressed in a further Bunloit Rewilding report in 2022.

Meanwhile, on the Bunloit estate, scientific monitoring will continue, with the aim of regular reports updating our inventories of natural capital and assessing the impacts of interventions we make. We will present annual revisions of the whole story to future climate summits.

At the time of writing, November 2021, these interventions have begun. Responding to near-universal expert advice to remove monoculture plantations, because of their suppression of biodiversity and carbon sequestration, we have begun felling five plantations on the south of the estate, including two atop peat. Once this process is complete, the impact will be assessed as effectively as our funding allows.

In terms of potential for enhancement of carbon sequestration, the report shows how important both satellite-based and drone-based remote sensing is, especially when backed by ground truthing. This work will continue and be expanded in 2022. We also aim to complete a programme of peatland restoration in 2022, and hopefully have first results to present in our 2022 Natural Capital report at COP27.

Our interventions on biodiversity include the protection and enhancement of important lichen and grassland habitats. These include leaving protective screens of conifers above the extraordinary lichen-rich ravine described in the report, and exploration of natural control for bracken on grassland areas.

Further interventions will include creation of new wood pasture habitats across the site, restoration of former areas of oak plantation to open grazed old-growth woodlands through patchy thinning and glade creation, and development of a herbivore grazing guild which builds in grazing level diversity to reflect the diversity of habitats and their condition, and to increase soil carbon in grassland.

All the above findings and recommendations are under active consideration by the team and supporting partners within the next stage of the Bunloit estate land management plan, and care is being taken to allow natural processes to take the lead where possible. We are aware that for some rewilding advocates, our portfolio of activities and plans to date may look intervention-heavy. But the design of our work has been guided by multiple expert conferees both within the institutions we are partnered with and beyond, and we believe our actions are consistent with our definition of rewilding, in that they aim to help nature to recover to the extent that all the Bunloit landscape can eventually become as close as possible to a former natural state.

We hope the evidence shines through in our report that the process of returning to the natural state we seek will render the landscape quantifiably better at sequestering carbon and building biodiversity than the current estate. Our aim is to use that process to help make nature-based solutions more investible than they seem to be today, quicker than would otherwise have been the case.

We also hope that in so doing we can provide a beacon for hope that humankind can ultimately not just survive but prosper as we arrest climate meltdown and reverse biodiversity collapse.

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Many thanks to our partners

The Bunloit team would like to thank the numerous supporting partners, specialists, sub-contractors, volunteers, and well-wishers who have helped us to get to this initial stage of understanding of natural capital within the Bunloit estate. These include the following: