MOUNTAIN WOODLAND ACTION GROUP

Scrubbers' Bulletin 15

Scrubbers' Bulletin no.15
Spring 2023

The Bulletin of the **Mountain Woodland Action Group** -
a partnership of individuals supported by their organisations

The current members of the group are:

Phil Baarda	NatureScot
David Blair	Cairngorms Connect
Mick Drury	individual member
Isobel Filor	John Muir Trust
Diana Gilbert	individual member
John Holland	Scotland's Rural College
Nicola Hunt	Borders Forest Trust
Peter Lowe	Woodland Trust Scotland
David Mardon	individual member
Richard Mason	Royal Society for the Protection of Birds
James Rainey	Trees for Life
Rodney Shearer	individual member
Richard Thompson	Forest and Land Scotland
Andrew Warwick	National Trust for Scotland
Sarah Watts (Chair)	Stirling University/Corrour Estate
Alistair Whyte	Plantlife

Earlier issues of the Bulletin may be found at:
http://www.msag.org.uk/publications.html

We are most grateful to the authors for their contributions to this issue, and we're always keen to receive articles for future editions. Please contact **http://www.msag.org.uk/contact.html** for more information and submission details.

This issue was compiled by:

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Photos are by the individual authors, unless otherwise stated. Cover photo: *planted downy willow with Creagan a' Choire Etchachan in the background* | credit: Phil Baarda

Contents

MWAG is now on Twitter!

@MontaneWoodland

https://twitter.com/MontaneWoodland

After our launching tweet in January 2021 we gained over 500 new followers in under three days! We will be tweeting updates from group members, along with plenty of photographs and facts about mountain woodland habitats and restoration action. We're now at 832 followers. Let's make that 1,000…!

Update from the Chair | Sarah H. Watts

MWAG new chair introduction

I am incredibly excited to be taking on the role of Chair of the Mountain Woodland Action Group. Over 25 years Diana Gilbert and members have created an experienced advocacy collective which combines research interests and practical knowledge with that of effective on-the-ground action. No other body collates or offers support and advice to individuals or organisations wishing to undertake conservation action specifically at the altitudinal treeline. In fact, the MWAG has been instrumental in shaping the course of my own career by providing inspiration, guidance and networking opportunities during the last twelve years.

I was introduced to mountain woodland restoration in 2010 on my very first day as a volunteer ecologist at Ben Lawers NNR. While studying for my BSc in Ecological Sciences at the University of Edinburgh I was keen to gain some practical survey experience. I joined NTS property staff for Site Condition Monitoring of restored montane willow scrub at a high-altitude exclosure on Meall Garbh. I learned to identify mountain, downy, eared, dark-leaved and woolly willow, and we made measurements in the sunshine surrounded by a wonderful diversity of bird and insect life. I could tell that this was an extraordinary habitat and something which we needed more of in Britain.

Further reading and experience led me to understand that trees and shrubs are key structural features of mountain environments but populations have become highly fragmented and restricted. Montane scrub communities are particularly vulnerable to overgrazing and burning. However, treelines are vitally important for improving soil nutrient retention, controlling surface run-off and reducing the severity of extreme events such as floods, landslips and avalanches. Restoration of mountain woodland therefore holds economic value through water regulation, shelter provision and climate change mitigation. The habitat is important in its own right as a component of upland biodiversity, and also has potential to support a wide range of associated flora and fauna including rare and specialist species. See more in the paper *The benefits of mountain woodland restoration*.

My summer of volunteering at Ben Lawers left such an impression that I was inspired to write my 3rd year Applied Ecology and Environmental Management essay on *Montane Willow Scrub in Scotland.* I achieved an exceptionally high 1st class grade and realised that I was on to something special. I still keep this document in my desk draw and marvel at how it led me on the journey to drafting my own PhD proposal years later. Much of the literature reviewing I did for this piece of work was of articles in past issues of the Scrubber's Bulletin; one of the many reasons I am so enthusiastic to support its delivery going forward.

After graduating from my undergraduate degree I was employed at Ben Lawers as the seasonal ecologist from 2013-2020. I continued monitoring restored montane scrub and grew even more obsessed with arctic-alpine flora, particularly the diminutive and under-appreciated rarity *Sagina nivalis* (snow pearlwort). I also became increasingly excited by applied ecological research; carrying out fieldwork and data analysis to study the outputs of restoration action and publishing several scientific papers in the process. I wanted to pursue this further and develop my own PhD project, and what better topic than montane woodland restoration, given the years of experience I had

amassed at Ben Lawers. I am incredibly grateful to Diana Gilbert and members of the MWAG who so willingly engaged with my project proposal and suggested avenues of research that would be most useful to inform the group's work.

My PhD is part-time and since January 2021 I have worked as the Conservation Manager at Corrour in Lochaber. I spent much of summer 2021 surveying for populations of rare montane tree species on the Estate and was delighted to discover far more than existed in the botanical records. The presence of some downy and whortle-leaved willow provides more than enough justification to embark on our own mountain woodland restoration project. It is focusing on supplementary planting of these rare species, in conjunction with maintaining large herbivore densities that are low enough to facilitate natural tree regeneration across the open hill. We have produced a long-term strategic restoration plan and work on seed and cutting collection began in earnest in Spring/Summer 2022. I am looking forward to updating you on our progress in the next Scrubbers' Bulletin. My new job at Corrour also provides a unique opportunity for me to implement the findings of my own PhD project into conservation action; certainly motivation to deliver high quality research!

Mountain woodland restoration is a very long-term commitment. It takes a lot of fieldwork to map populations, time to collect seed and cuttings, more time to grow saplings in a nursery and even more time and patience to wait for them to reach maturity on the hill. This process benefits from staff continuity and knowledge retention by highly motivated individuals who are willing to devote potentially decades of their career to achieving conservation management objectives. But the outcome of such dedication is landscape-scale ecological restoration; a goal definitely worth striving for. The MWAG has played a key role in facilitating this occupational longevity. There has been significant long-term membership continuity since its conception in 1996, with individuals who have delivered pioneering restoration projects continuing their involvement to support the next generation of environmental land managers such as myself. This is testament to the passion that mountain woodland restoration can invoke in us.

Our work is made richer and more contextually relevant by collaborative knowledge exchange, scientific research projects and outreach partnerships. I am looking forward to working with the group to facilitate promotion of treeline ecotone habitats by further collating and articulating evidence for restoration action. I hope that through wider dissemination we can continue to inspire more communities, environmental managers and landowners to value and protect the unique resource that mountain woodland and scrub represent.

References

Watts, S. H. and Jimp, A. S. (2020). The beneftis of mountain woodland restoration. Restoration Ecology 30(8), e13701. Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1111/rec.13701

Sarah H. Watts is a plant ecologist with a strong focus on upland vegetation, restoration ecology and applied science. She is the Conservation Manager of Corrour in the Scottish Highlands and is currently researching her part-time PhD entitled *Improving outcomes in montane woodland restoration.* From 2013-2020 she worked as an ecologist for the National Trust for Scotland at Ben Lawers NNR.

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Mountain woodland action group – the last 25 years… | Diana Gilbert

In 1996 when, I admit, I had my arm twisted to set up a group (the Montane Scrub Action Group), I was feeling daunted and not a little out of my depth. A few years earlier in the pre-Millennium optimism I'd punted a "Montane Scrub Restoration Project" proposal into the first Millennium Forest for Scotland (MFS) application round with little expectation that it would be successful. To my surprise early in 1996 not only was the project accepted but it also meant I had a conference to organize to launch it.

Having, by that time met the montane willow gurus, David Mardon and Richard Marriott, I was persuaded that the most effective way to further the cause of the absent treeline would be an "action group". We would share experience and develop best practice but, perhaps most importantly, collectively we would promote the habitat to statutory bodies to achieve recognition of its absence and improve national-level support. Simon Pepper was enlisted to work on me and we all subsequently persuaded Michael Scott, then Plantlife Scottish Officer, to take on the role of chair, while I would manage the group.

The conference, opened by Simon Pepper (WWF Scotland & MFS Board Member), reviewed the state of knowledge about Montane Scrub (MS) in Scotland at that time. Many eminent biologists spoke on their particular subjects including Des Thompson (SNH, MS ecology), Keith Bland (MS invertebrate fauna), Ro Scott (SNH, MS distribution), Alison Hester (Macaulay LURI, Herbivory) and Tim Clifford (Caledonian Partnership, on restoration best practice). All the papers were subsequently provided in a conference report (Gilbert, Horsfield & Thompson, 1997; now available at the National Library of Scotland (https://digital.nls.uk/pubs/e-monographs/2020/216663504.23.pdf).

And so our first meetings started in 1996, hosted by SNH at Battleby. The additional group members were Sandy Payne, SNH, Rob Soutar, FE, David Mardon, Property Manager Ben Lawers, NTS, Ian Hulbert, SAC Kirkton, Brian Staines, ITE and Tim Clifford, Caledonian Partnership. All people who had a clear interest in and some knowledge of montane scrub in Scotland. Soon we were joined by Philip Ashmole, from BfT; and Ro Scott, Deer Policy Officer, SNH replaced Sandy. We had also launched this publication *The Scrubber's Bulletin* in the first winter (all issues available on the MWAG website (http://www.msag.org.uk/publications.html).

For the Millennium we provided the content of an SNH Scotland's Living Landscape Series booklet – *Montane Scrub*[1] expertly crafted by Michael from the material provided by group members, in particular David Mardon. In addition, through the MFS project, Neil Mackenzie had collated all the existing records for the constituent MS tall shrub species, and high altitude woodland remnants. This information provided the justification and evidence to approach the agencies with suggestions that it was time to explicitly include this "ecotone" in their landscape management strategic planning and incentive programmes. In 2005 the group hosted a Study Tour for key policy makers, including the influential Andrew Raven (Chair, Deer Commission of Scotland) John Henderson (Assistant Chief Agricultural Officer, Scottish Executive), Bob McIntosh, (Chief Executive Forest Enterprise) &

[1] https://www.webarchive.org.uk/wayback/archive/20210501110957mp_/https://www.nature.scot/sites/default/files/2017-06/Publication%202002%20-%20Montane%20Scrub.pdf

Ian Jardine (Chief executive, Scottish Natural Heritage). One day was spent at Ben Lawers discussing the restoration work there, pioneered by David Mardon and ongoing since the 1980's. On the second we visited Creag Fhiachlach, walking up through forest zone Caledonian pine to a very rare Scottish altitudinally-limited woodland, to experience a tall-woody ecotone lost from the majority of Scottish upland landscapes & discuss how its return would contribute to ecosystem health and services.

Since that time we have seen an incentive for expansion or creation of treeline woodland (including montane scrub) appear in 2014 with the introduction of the "Low Density" option within the Woodland Creation incentive. It was and continues to be a relatively limited incentive but it does exist and has been used by land managers in most relevant regions in Scotland. There is still much to do before treeline woodlands are fully recognised for the benefits they can bring to the upland ecology and landscape, in terms of their contribution to supporting the indigenous biodiversity and their enhancement of the visual and recreational value of our uplands. For a more expansive essay on the benefits of mountain woodland see: https://onlinelibrary.wiley.com/doi/pdf/10.1111/rec.13701 .

The group is now entering a new phase with my handing over the reins of the group as Chair, as of Spring 2022, to Sarah Watts. Over the 25 year life of the group the membership, as expected, has fluctuated with changes in the staff of different supporting organisations, and as we all get older! (Table 1). I'm sure those still on the group would like to join me in sincerely thanking all those who have retired from active involvement for their outstanding contributions, in particular Rob Soutar and Philip Ashmole (below). I have certainly benefitted from their extensive knowledge, experience and, endless questioning over the years

Rob Soutar (left) | **credit: Andrew Jarrott;**
Philip Ashmole (centre, and right) | **credit: Phil Baarda / Diana Gilbert**

Diana Gilbert, PhD, is an Upland ecologist with 30 years' experience working in the Highlands focussing on upland vegetation, particularly montane scrub, treelines and upland woodland. She initiated the MWAG in 1996. Since then, she has undertaken specific montane scrub research and continues to survey & advise on upland vegetation ecology.

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Table 1 – previous and current MWAG participants *[this is compiled to the best of our knowledge – please get in touch if amendments are needed]*	
Plantlife	Michael Scott (1996 – 2005)
	Deborah Long (2006 – 2016)
	Davie Black (2016 – 2017)
	Alastair Whyte (2018 – present)
Scottish Agricultural College / Scotland's Rural College	Ian Hulbert (1996 – 2002)
	John Holland (2002 – present)
Forest Enterprise/Forest & Land Scotland	Rob Soutar (1996 – 2017)
	Richard Thompson (2012 – present)
Institute of Terrestrial Ecology	Prof Brian Staines (1996 – 2003)
Scottish Natural Heritage / NatureScot	Sandy Payne (1996)
	Ro Scott (1997)
	Angus Macdonald (1998 – 2002)
	Jenny Bryce (2003 – 2006)
	Phil Baarda (2006 – present)
National Trust Scotland	David Mardon (1996 – 2009)
	Dan Watson (2009 – 2012)
	Andrew Warwick (2012 – present)
Macaulay Land Use Research Institute	Alison Hester (1998 – 2013)
Farming & Wildlife Advisory Group	Bruce Lowe (2002 – 2006)
Trees for Life	Adam Powell (2002 – 2008)
	Mick Drury (2008 – 2021)
	James Rainey (2021 – present)
Mountaineering Council of Scotland	Keith Miller (2003 - 2012)
	Hebe Carus (2012 - 2014)
Cairngorms Connect	David Blair (2019 - present)
Borders Forest Trust	Hugh Chalmers/Philip Ashmole (2006 – 2020)
	Nicola Hunt (2020 – present)
Highland Birchwoods	Diana Gilbert (1996 – 2002)
	Phil Baarda (2003 – 2006)
	Billy Bodles (2006 – 2018)
John Muir Trust	Mike Daniels (2019)
	Isobel Filor (2020 – present)
Woodland Trust	Andrew Campbell (2012 – 2018)
	Alasdair Firth (2018 – 2019)
	Peter Lowe (2020 – present)
Alba Trees Ltd	Rodney Shearer (2017 – 2019)
University of Stirling / Corrour Estate	Sarah Watts (2020 – present)
Royal Society for the Protection of Birds	Richard Mason (2019 - present)
Individual members	Diana Gilbert (2002 – present)
	David Mardon (2009 – present)
	Mick Drury (2021 – present)
	Rob Soutar (2017 – 2019)
	Rodney Shearer (2019 – present)

Treeline woodland restoration in the wild heart of Southern Scotland | Nicola Hunt

Treeline woodland cover in the uplands of Southern Scotland is virtually non-existent and only remains in small isolated fragments and individual trees as a result of centuries of burning and grazing. This absence has given native woodland restoration charity, Borders Forest Trust (BFT), great impetus to re-establish these montane trees and shrubs as part of its landscape scale ecological restoration initiative, *Restoring the Wild Heart of Southern Scotland.*

The Wild Heart covers 3,100 ha of BFT's largest three landholdings in the Central Southern Uplands - Carrifran Wildwood, Talla & Gameshope and Corehead & the Devil's Beef Tub. The restoration of native woodland and treeline woodland is a priority in these areas along with other upland habitats such as blanket bog and heath.

Treeline woodland restoration at Carrifran began back in 2007 and now after more than 15 years of work, established areas of willow scrub are thriving. Building on the work carried out at Carrifran, restoration effort has more recently been focused on BFT's other Wild Heart Sites at Corehead & the Devil's Beef Tub and Talla & Gameshope.

Talla & Gameshope is BFT's largest site which spans more than 1840ha and connects with Carrifran to the south. Over 60% of this land sits at 600m asl or above, which makes it particularly suited to upland habitat restoration including treeline woodland. An initial National Vegetation Classification survey carried out by Stuart Adair identified suitable planting areas for the initial planting and work so far has been directed to these areas. Some of this planting has connected directly into treeline planting carried out at Carrifran enabling the habitat to expand across both sites to create a more significant continuous area of scrub. Since its purchase in 2013, more than 62ha of the site has now been planted with treeline woodland and there is scope for plenty more. Species planted in the treeline so far include Downy willow, Dark-leaved willow, Tea-leaved willow, Eared willow, Grey willow, Dwarf birch and Juniper.

Corehead, covering 640ha, is similar in size to Carrifran and is comparatively lower lying than Talla & Gameshope. Despite this lower altitude it still has considerable potential for supporting substantial areas of treeline woodland. Higher elevation planting started with Dwarf birch above the Tweedhope Valley in 2012 and these small trees are now flourishing into scrub and last year produced their first collection of seed. Planting then moved further east to Whitehope Heights and the slopes of Hartfell Shoulder, where 38ha have now been planted with Downy Willow, Dark-leaved willow, Tea-leaved willow, Dwarf birch and Juniper, at around 600m asl. Recent land management changes at Corehead to remove sheep grazing in favour of habitat restoration, created opportunities for further treeline woodland restoration above an area proposed of native woodland planting. In autumn 2021, Diana Gilbert and Isobel Filor undertook a habitat survey to assess site suitability for mountain woodland planting on tops of the hills recently released from grazing at the western end of the site. While the area surveyed, around 450m asl, is comparatively lower than the height conventionally associated with the treeline woodland, it was considered that the lack of woodland cover and high levels of exposure suited the surveyed area better to a shrub community at this stage rather than

taller tree species. The survey identified suitable areas for planting treeline zone willows including Dark-leaved, Tea-leaved, Downy and Whortle-leaved along with Dwarf birch and Juniper and this work is planned for 2023, funding permitting.

Volunteer tree planting at Stirk Craig

BFT inherited all three of the Wild Heart sites severely denuded of woodland cover with only individual trees and small stands clinging to inaccessible outcrops on the hill sides. Through planting, native woodland is now returning to the lower slopes and valleys and the montane scrub to the treeline zone above to create a more complete woodland ecotone. Across these sites more than 660ha of native woodland and 130ha of treeline woodland has been planted and is now establishing across the landscape to create a habitat capable of supporting far richer biodiversity than the treeless land that existed there before.

Involving people in woodland restoration, including mountain woodland, is a fundamental part BFT's ethos. Volunteer activities enable people to connect to our environment and to make a positive contribution towards its improvement and management whilst undertaking physically rewarding tasks. Providing this opportunity to involve people in woodland restoration is as important as getting trees in the ground and is an integral part of BFT's work. The majority of montane trees at Wildwood and many at the other sites were planted by numerous hardy volunteers who braved working tough conditions at over 600m asl to help bring this missing woodland habitat back to the landscape. High planting camping weekends were a major feature in the BFT calendar but sadly Covid very much hindered this activity over the last 2 years. Instead we have relied upon the hardiness of the Treesurv contractor planting team who have endured challenging conditions to reach and plant high

up on our sites. As we move past Covid, it is hoped to resume volunteer planting activity high up on the Wild Heart sites and provide these unique volunteering opportunities again.

Stirk Craig volunteers

Sourcing suitable trees for planting is always a challenge due to the lack of parent trees and tree species in the south of Scotland. As many plants as possible as sourced locally including from BFT volunteers collecting seeds and cuttings for growing on and also from the Cree Valley Woodland Volunteers who have annually provide us with around 3,000 *Salix lapponum*. However due to the lack of seed trees and to avoid a genetic bottle neck, we often have to look elsewhere in Scotland for planting stock figuring that is is better to have the species albeit from a more distant provenance than not at all. Also, to build resilience against the uncertain impact of climate change, increasing genetic diversity may possibly be a good thing.

Funding for the treeline woodland restoration work in recent years has come from a range of sources. NatureScot has been a major supporter, awarding grants from the Biodiversity Challenge Fund and Nature Restoration Fund in recognition of the biodiversity value of the treeline woodland being created. Woodland Trust Scotland has also been significant supporters of this work along with international not for profit organisation, One Tree Planted, and corporate sponsors Walter Scott. Costs are high when working in remote and challenging environments and BFT are grateful to receive financial support from funders to facilitate this work.

Volunteers planting on Games Castle, Carrifran above Rotten Bottom blanket bog │credit: Mark Golding

Volunteers planting, Carrifran │credit: Mark Golding

Hartfell screefing

BFT is now looking forward to the next 5 years of treeline woodland restoration work on our Wild Heart sites. This is largely being developed through participation as a partner in a regional National Lottery Heritage Fund project called Destination Tweed being led by the Tweed Forum. Part of BFT's involvement in this project will be to carry out an extensive habitat survey of Talla & Gameshope to identify suitable treeline woodland planting areas that will form the basis for a 5 year planting plan to be delivered largely with the help of volunteers across the site. Advance planning on this timescale will also help in the procurement of suitable species for planting rather than being reliant on what species are available when funding is secured. Alongside the new planting will be the ongoing maintenance of the recently planted trees across 130ha of the Wild Heart sites to ensure they establish into a healthy treeline woodland habitat to support wildlife in the Southern Uplands of Scotland.

Scrub at Carrifran
(top left & top right)

Screefing at Hartfell
(bottom right)

Nicola Hunt has been with Borders Forest Trust for over 20 years and has worked in a number of roles leading to the Head of Land Management where she heads up the team managing BFT's landholdings and native woodland outreach work. Part of her duties include developing plans for the restoration of treeline woodland on BFT's sites.

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Natural capital and montane scrub restoration | Matthew Hay

Climate breakdown and the global loss of nature have brought into sharp relief the shortcomings of an economic system that treats environmental costs as externalities. Acceptance that the status quo is unsustainable and seriously jeopardising the long-term stability of both economies and societies across the globe is now widespread. One reaction to this has been to broaden the scope of 'value' as a concept, to widen the net beyond monetary worth and to consider the non-financial capital that is implicated in real world decisions.

There are many different sources of value, or capital, that our economies rely upon. Human capital, social capital and natural capital are now all being scrutinised by mainstream actors as we collectively shed the mistaken dogmas of 20th century economics.

Adopting a natural capital approach

In Scotland, land managers are being strongly encouraged to embrace a 'natural capital approach' if they aren't doing so already. This involves thinking holistically about the stocks (such as forests, peatlands, lochs, mountains) and flows (such as carbon sequestration, nutrient cycling, water storage, food production) of natural capital in their care.

There are two main upshots of adopting a natural capital approach. Firstly, it enables far greater understanding of the impact of land management decisions on an estate's long-term sustainability. Logging a forest may yield an economic return but accounting for the value lost in terms of carbon sequestration and biodiversity for example, and expressing those losses in monetary terms, reveals the true impact of logging the forest. Now, of course, most land managers have always known, intuitively, that there will be non-financial value lost when they extract from a natural asset. But accounting for that loss and expressing it in monetary terms allows a more meaningful comparison to be made. If logging the forest generates £10,000 in timber income but that same forest's ecosystem services are valued at £100,000 it might make a land manager think twice before sending in the harvesters!

This leads to the second upshot, which is that more ecosystem services are now being monetised, in effect pricing in what were previously just valuations into the real economy. The best example of this is currently found in the voluntary carbon market, where the emission reductions or carbon sequestration potential of a woodland creation or peatland restoration project can be accredited and sold to a willing buyer.

Debates are raging as to whether the monetisation of nature is ethical or even helpful. But a majority of people now recognise the reality that if we don't find ways to incorporate nature into our economic system its decline will continue much as it has done over the last century.

And so the race is on, to create new natural capital markets and products. Ecosystem services can be tokenised and sold, with greater efforts to disclose nature-related dependencies and risks hopefully creating an investment case for private-sector finance to flow into nature recovery.

What is the value of having a flourishing population of Capercaillie in Scotland's pinewoods? The ecological and cultural benefits these magnificent birds provide are hard to quantify in monetary terms and do not provide land managers with a financial return.

Capercaillie │
Credit: Eoghain MacLean/NatureScot

So, where does montane scrub fit into a natural capital approach? Well, in several ways…
Firstly, as land managers begin to appraise their estates more holistically, they are understanding that many of the habitats they care for are degraded and fragmented. Historical baselines can be used to illustrate the progressive loss of woodland, for instance, which represents a real loss of natural capital over time. Likewise, habitats above the treeline are valuable for the many ecosystem services they provide, as well as being important components of Scotland's biodiversity in their own right.

Historic maps provide insight into how woodland cover has changed over time, with deforestation widespread and ongoing for hundreds of years in the Highlands of Scotland. │ Map reproduced with the permission of the National Library of Scotland.

Perhaps more interestingly, with a voluntary market for woodland carbon now up and running, many land managers are turning their attention to native woodland creation because of the potential economic rewards. Planting trees or allowing woodland and scrub to naturally regenerate at last has a financial underpinning and many a bare hillside is being assessed to see if it could be turned over to woodland creation.

But selling carbon credits is not a straightforward commodity transaction, because the businesses buying credits have multiple motivations for partaking in this nascent market. Whether it's for ESG targets, marketing or simply to demonstrate their environmental awareness to customers or stakeholders most businesses put huge stock in the narrative surrounding the carbon credits they buy. This 'charisma' is all important and strongly influences the price a credit can be sold for.

One result of this, is that land managers looking to generate and sell carbon credits have a powerful incentive to differentiate their offering. Often they do this by enhancing the other ecosystem services their project is delivering. A native woodland with fantastic public access for local communities trumps one that offers no recreational amenity. Likewise, a project that is more than just tree planting, but actually involves the restoration of an entire suite of habitats 'from glen to ben' is likely to command a premium for the carbon credits it sells. Herein lies the motivation for montane scrub restoration.

Dwarf birch provides beautiful displays on Scotland's peatlands and moors in the autumn. This species is small and slow growing, meaning it has limited carbon sequestration potential. It has aesthetic and ecological value though, especially to montane species like grouse and mountain hares.

Dwarf Birch (Betula nana) | **credit: Lorne Gill/NatureScot**

What next for natural capital?

Carbon markets and the 'offsets' they produce understandably have their detractors. These are imperfect systems currently, which yoke private finance for nature to the continued emission of greenhouse gases. The credits they supply also have the potential to be exploited and fuel greenwash. But no-one operating in this market thinks we have arrived at where need to yet, and a huge amount of work is underway to improve the function and integrity of carbon markets at both ends of the supply chain.

What these markets have done, however, is opened the door to payments for ecosystem services, laying the foundation for regenerative practices to become profitable instead of relying on public money or philanthropy.
For montane scrub restoration to become widespread, its many benefits need to be quantified and buyers for those ecosystem services secured. To my mind, the most obvious path to success here is through the creation of biodiversity markets. But these will need to be kickstarted by government action as much as by private sector leadership. They will also eventually need to be complemented by increased public funding for the maintenance of the habitats that are created and restored.

There is a long way to go yet on our collective natural capital journey. But the potential is there for incentives to be put in place that compel land managers to be the agents of nature recovery and to bend the curve of nature loss in Scotland and elsewhere.

Matthew Hay is a former weather forecaster, turned natural capital consultant. As a director of the charity Reforesting Scotland, Matt has long advocated for greater woodland cover across Scotland, especially in the uplands.

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The restoration of downy willow and mountain woodland on the uplands of Lakeland | Pete Barron & Simon Webb

This article intends to reflect and update on a piece produced by Simon Webb from Natural England (NE) in 2008 for the then MSAG Scrubbers' Bulletin (issue 7: https://www.msag.org.uk/uploads/4/0/7/3/40732079/scrubbers_bulletin_7.pdf)That article outlined our first tentative steps in identifying the remaining Downy Willow scrub on Helvellyn and understanding the challenges in restoring montane scrub in the Lake District. Since 2008 the work has steadily continued, and both the partnership and our aspirations have broadened.

We have made considerable progress with re-populating the higher reaches of the Helvellyn massif with montane willows and in particular Downy Willow, and more recently have expanded this work into other key locations in the Lake District fells.

Red Tarn and the Helvellyn Cliffs │credit: Pete Barron

To recap, in 2007 there were 22 identified Downy Willow bushes, most of which were female with only a couple of potential males across a large area of crag, in three separate coves (corries), making onsite natural reproduction virtually impossible.

At the start of restoration work some plants were grown from seed but the practicality of gathering seed from a small population with the critical timing, staff availability and weather implications all drove the decision to propagate from cuttings to expand the population. The tipping point was a few years in a row making multiple trips to Helvellyn to collect soggy catkins in the rain and having very few fertile seed for our efforts.

Whilst this might limit the number of willows we can produce in a year it is reliable and simple. We have considered the impact of genetic drift in this process and accept that re-population from seed

would be genetically better, but we have used a technique that is well suited to our resources and our ultimate aim is to produce enough parent plants on site so that sexual reproduction can happen in the wild. We have seen this happening over the past few years.

A further consideration has been to stop the use of vine weevil control as the Vinil treatment is a systematic noenicitinoid and planting willows with this systemically in them could kill mountain bees or other pollinators. We therefore prefer to take the risk of losses, and these have not been a problem as detailed below. As elsewhere, 'vole years' can also be a risk with voles present right up to summit level at 950m.

Downy Willow: an original survivor Helvellyn │credit: Pete Barron

It is important at this stage to understand that the work since 2008 has expanded into a partnership approach across parts of the Lakeland fells with work being undertaken, expertise and resources being shared and results often being very much a 'team effort' through the work of the John Muir Trust (JMT) and NE on Helvellyn, United Utilities (UU), NE and JMT at Thirlmere, RSPB at

Haweswater and Mardale, UU, NE and National Trust in the Wild Ennerdale project and the restoration of Hardknott Forest at the top of the Duddon valley (FE and Leeds University). This has been coupled with many scrub creation projects in the high fells through the Agri environment schemes led by NE, including the fencing and restoration of the high altitude oakwoods at Young Wood on Skiddaw and Keskadale in the Newlands Valley.

The last decade has therefore seen a big push to restore mountain woodland and the involvement of many partners from the voluntary, academic and statutory sectors. Those 22 shrubs on Helvellyn through the efforts of many have now increased significantly. Much of this planting has been completed by a small group of dedicated individuals and volunteers.

Success: planted Downy Willow spreading across the crag │credit: Pete Barron

To improve the future viability of the predominantly female remnant population of Downy Willow male stock was donated from The Merrick (Thank you FC Scotland) and males therefore introduced into the planting. The annual routine we now follow is of early spring cuttings from ex-situ or “captive” male plants from Merrick and ex-situ female plants from Helvellyn. A good number of these ex-situ donor plants are maintained at many locations, mostly the private gardens of dedicated individuals and community volunteers. Planting is undertaken in September and early October. We will

probably supplement our females from Scotland at some point as we think inbreeding is a bigger threat than loss of local genetic distinctiveness, and that 22 females from Helvellyn and 8 males from Merrick is not a wide enough genetic base for montane scrub across the Lake District.

Downy Willow 2 years old (left); About to go planting with MWAG support! (right) │credit: Pete Barron

Some 2000 willows have now been planted on the Helvellyn crags alone. Absolute survival rates have not been assessed with accuracy, access is difficult and time consuming, but those of us who have been involved throughout the last 15 years can clearly see that survival rates are good and planted cuttings are now, after roughly a decade, spreading across those crags and seeding, we look forward to identifying our first self-seeded Downy Willow!

We plant the Downy Willow cuttings generally above 800m and initially had to be very careful about the location to avoid browsing by sheep. Although this is still a consideration, we are now much more relaxed about the planting location as NE have worked closely with graziers and their agri-environment agreements which has reduced grazing pressure on the crags along with stock reduction by neighbours and off wintering, the only issue to be resolved is sheep encroachment from the Thirlmere valley to the west. In due course we of course hope to see the willows thriving on the damp areas below the crags and on beck-sides where they belong, we still hold that as the future aspiration and goal.

We have perhaps used a different method for growing the plants as we have largely avoided nursery growing to date although this may change as we upscale the planting, instead we have gone for establishing community growing groups, firstly in the Helvellyn area with committed local people. Following the success of our work on Helvellyn with community growing this approach has now expanded to other parts of Cumbria and we are in the business of helping each other with experience, cuttings and planting effort. A major plus factor in the community growers is the

involvement of local people, who we train and advise, and who contribute to direct nature recovery in their own back yard. It works, and we now have some expert growers working with staff from NE and JMT increasing the production of these montane species.

As the work has progressed its aspiration has broadened. This is a classic example of having the same committed people working on a project over many years and we have been fortunate in that regard with the key players in Lakeland keeping positions of influence on upland management. We have expanded the work on Downy Willows with restoration of other willow species such as Dark Leaved Willow, rare in Cumbria, Tea Leaved Willow and an equally rare cross between the two (Salix x tetrapla). In addition, we have some montane populations of eared willow on both Helvellyn and High Street and these are easy to propagate and make welcome additions both high up and on scrub restoration at lower altitude. We also intend to widen the planted species to include Betula nana and purple willow. Neither of these are montane species but are part of restoring diversity and colour to our impoverished uplands. It was the success of purple willow at Carrifran that opened our eyes to the potential of that species in the uplands – in Cumbria this is seen only in the lowlands.

The two authors have also been responsible for driving forward a programme of work on English arctic alpine plants. The Lake District Arctic Alpine Restoration Programme has involved systematic survey, life cycle analysis and, where required, hands on re-introductions or population supplementations. Populations of alpine saxifrage, shrubby cinquefoil, and alpine cinquefoil have all been supplemented and we now have a larger alpine saxifrage population than the one recorded here by Derek Ratcliffe in the 1950s. New populations of oblong woodsia and pyramidal bugle have been planted and it is great to see these species successfully re-established. Work on mountain avens is also underway and alpine mouse-ear is just starting.

Arctic-alpines: successful community growing │credit: Pete Barron

Our approach has therefore expanded from montane scrub to improve the robustness and variety of our upland flora across the Lakeland Fells. Again, our community growers have been invaluable here, propagating both rarer arctic alpines and more common tall-herb species, although the Woodsia growing was led by RBGE.

Summary and conclusions

The work on restoring montane scrub in the northern Helvellyn coves, which are managed by JMT, has been successful although not yet complete. We are delighted to see thousands of thriving willow plants and both male and female catkins on plants we have established. Our original 2008 objective of preventing the local extinction of Downy Willow in England now seems rather conservative and unambitious!

We have now started planting montane willows, including Downy Willow, on the western side of Helvellyn and on the cliffs of High Street. The other willow species are being planted widely and there is considerable appetite for more willow planting across the Lake District mountains. The success of Helvellyn has been central in showcasing the possibilities and getting other organisations to start similar work on their own land.

Tall herb and Arctic-alpine assemblage, Helvellyn │credit: Pete Barron

In England the Nature Recovery agenda in the uplands is helping progress restoration of a range of mountain habitats – tall herb, montane scrub, upland grasslands and heath. Likewise, the arctic alpine plants which characterise both tall herb stands and lime-rich chasmophytic vegetation on cliffs, are slowly expanding with intervention by propagation and planting where needed. Because of the degraded nature of most of our habitats and species-populations, this work is quite hands on and significant intervention is often needed. There is now a wider group of individuals and organisations who share these objectives and there is good progress in restoring some valleys and mountains. There also remains resistance to change and high numbers of sheep remain a barrier to Nature Recovery in some locations.

The community growers groups have been remarkably successful, both in producing quality material (willows and arctic alpines) for restoration planting and in engaging local communities with restoration of nature close to their homes. There is an active Cumbrian network exchanging advice, support, donor plants and seeds.

We continue to take inspiration from Scottish restoration projects - the work at Carrifran, the ambitious Trees for Life work, the reduction of herbivores in Glen Feshie and wider and the community involvement that is typified by the way JMT manage their land.

Pete Barron has spent 23 years as a Lake District National Park Ranger, being involved in NNR management, Osprey recolonisation, raptor protection, peat restoration, and upland management in the round - with a passion for restoration of mountain woodland and flora in Lakeland. He's currently working for John Muir Trust and the Lake's local communities growing montane species.

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Simon Webb is a nature recovery advisor for Natural England in the Lake District. He has led the Lake District Arctic Alpine Recovery project since 2005 which includes a raft of montane species including willows and dwarf birch. He is also part of the Wild Ennerdale partnership and leads on other landscape scale nature recovery projects with a range of key partner organisations.

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First observations of regeneration occurring at restored montane willow scrub, Ben Lawers NNR │ Sarah H. Watts

The long-term goal of mountain woodland and scrub restoration projects should be the creation of viable populations which are self-sustaining through natural regeneration (Mardon, 2000; Montane Scrub Action Group, 2016). Treeline conservation work in Britain typically relies on planting to kickstart habitat creation because existing relict populations of rare montane tree species are usually restricted to very small, isolated and declining fragments. Recent restoration projects may not yet contain enough mature trees to permit seed production on a large enough scale, and recruitment cannot occur if suitable regeneration niches are lacking.

Montane willow seeds are viable for less than a week and need bare soil for germination (Sullivan, 2002; Mardon, 2003; Shaw *et al*., 2010). In the unstable upland environment these microsites can be generated by frost heave, solifluction and landslips. Such events are frequent at Creag an Lochain, Ben Lawers NNR; one of the reasons why the National Trust for Scotland selected this site for pioneering habitat restoration work over three decades ago (Mardon, 2000). After large herbivores were excluded in 2000 there has been a reduction in soil disturbance and the ground flora has shifted towards a community of taller species where light availability is a limiting factor (Watts *et al*., 2019; Watts, 2020). This change will increase competition from surrounding vegetation and reduce the availability of bare ground for seed germination, thereby accentuating the importance of landslip sites for potentially creating new opportunities for regeneration.

***Salix lapponum* (downy willow) seedlings growing at a landslip site at Creag an Lochain, Ben Lawers NNR**

I have been carrying out ad hoc monitoring for regeneration at the planted montane willow scrub at Creag an Lochain since 2014. My work has included searching landslip sites for seedlings, with the hypothesis that they would be the first places for natural regeneration to occur. Abundant seed production at the site has been ongoing since at least 2009 (Andrew Warwick, personal observation). On 27th May 2021, I found several *Salix lapponum* seedlings growing in a landslip, which were approximately 2-3 years old and within 10 m of mature, planted shrubs (Photo C.1). More were subsequently observed throughout the summer; all in stabilised landslips that have already been colonised by other pioneer vegetation, particularly acrocarpous bryophytes. Further survey work for my PhD in 2022 discovered over 230 individual seedlings across the site.

These *Salix lapponum* seedlings are the first evidence of regeneration from planted, restored montane willow scrub in Britain. They represent the next generation and a significant milestone in conservation management towards achieving self-sustaining populations of this threatened species. I hope that my observations can provide encouragement to more recent or planned restoration projects by demonstrating that natural regeneration of Nationally Scarce montane willows can be facilitated by supplementary planting, as long as we are patient. I will be studying seedling establishment in more detail during my PhD research, to further understand how we can enable and promote it.

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An investigation into indicators for good montane woodland restoration sites by an early-career ecologist │ Gus Routledge

It's been a wee while since I carried out my dissertation project for my Honours degree in Countryside Management at Scotland's Rural College. The day I handed in the paper copy my friend said, in relation to the newly emerging pandemic, "Wouldn't it be funny if this was the last day we had in college." And it was, as the threat of COVID-19 temporarily shut down our way of life. Shortly after that we all plunged into a new way of living but what held firm, for me anyway, was nature and that helped me get through those mundane lockdowns.

It was also nice to be able to look back at previous adventures, and I'm in the fortunate position of having a dissertation project that was just that; an adventure.

Montane scrub woodland (MSW) had long been of particular interest to me, this "Cinderella habitat" that offers to show us how much we're missing out on in the uplands, so many ecological interactions lacking from our Highland landscape. How do we restore this? A question that many reading this will likely have asked, so I decided that would be the basis for my Honours project. I figured that the methods for restoration are pretty well established, but where is best to restore our scrub to? With help from my friend Andy McMullen, we came up with a couple of ways of looking at the vegetation found in and around existing MSW and use this to find currently open vegetation communities on our hills that offer the most ready-to-go sites for MSW establishment, or where might offer the greatest chance of success. Indicators, if you like, and in hindsight this word should probably have been included in the project title.

On my course, it's standard to do a literature review, as is the case for most if not all science-based courses. This was a thoroughly enjoyable experience. Many factors were brought to my attention in terms of MSW establishment and ecology and I ended up getting a bit carried away, including 134 references in my paper, the guidance for our project suggesting we should have at least 12. Many of the ideas and theories that I discovered will be well understood by those involved in the MWAG but I'll highlight a few of my favourites:

- **The effect of mutual shelter.** The first trees/shrubs to establish will have a hard time of it but once they do, they offer so much in terms of shelter, seed source, establishing mycorrhizal networks. One of my favourite lines from a paper I read: "With a medium-density tree barrier… the wind speed was reduced to 20% of the original force at distances beyond the barrier three to five times the height of the tree." (Pears, 1967).

- **The effect of having a mycorrhizal network already set up**. I particularly enjoyed the fact I'd read this paper by Hesling & Taylor (2013) on bearberry sharing ectomycorrhizal partners with tree species when I came across this interaction being played out right in front of me in the Cairngorms, not far from the famed Creag Fhiaclach.

Photo 1: I found myself lost amongst the juniper a few times, then remembered I just needed to stand up.

- **Woodland indicator species**. Finding woodland indicators in open landscapes was nothing new to me, but I hadn't really thought about exactly what type of woodland this might be, depending on where I found those indicators. I'm sure wood-sorrel *Oxalis acetosella* would be quite happy to move out of the boulder scree and beneath the lush canopy of some downy willow *Salix lapponum*. Overall my understanding of what MSW is and what grows with the shrubs & trees themselves was greatly expanded.

- **Productivity.** The lack of productivity in the Scottish uplands was really brought home to me when I was reading some of the papers, in particular the fact that annual vegetation productivity beneath Icelandic birchwoods is four times higher than that of the open, sheep-grazed countryside elsewhere in Iceland (Jonasson, 1992), the latter being similar to much of

our deer forests, grouse moors & sheepwalk. On top of this, many plants can't grow in the exposed, relatively harsh conditions offered by our moors & grassland, but montane *Salices* have been shown to have a nurse effect on some species of tall-herb (Dona & Galen, 2007).

In terms of site selection, I did have my eye on a few, Corrie Kander being one of them which I initially visited with Andy to assess suitability but the scrub there was not particularly accessible. Thus, I settled on the juniper *Juniperus communis* scrub at Creag Fhiaclach (CF) (Photo 1) and some eared/grey willow *Salix sp.* scrub at Craigdilly SSSI in the southern uplands (Photo 2). The latter was not at particularly high altitude but it was the best I could find for carrying out my research.

Photo 2: The view from the eared willow scrub of Craigdilly SSSI, giving a stark picture of what our hills have lost

What were my methods then? My career that I was, at the time, ecological consultancy in which I was undergoing a shift away from birds and protected species to botanical/habitat surveys and where best to cut my teeth in the National Vegetation Classification (NVC) than my Honours project? So the idea was to do an NVC survey of existing sites of MSW but ignore the canopy species, and input my data into a software developed by the Centre for Ecology & Hydrology called the Modular Analysis of Vegetation Information System, or MAVIS for those who know her on a personal level. This would then churn out the NVC communities that my data showed the closest affinities with. Despite not including the canopy species in my data, many of the communities identified were woodland ones, which is encouraging both for me as a data collector and those who developed the software, but not useful for my project. I figured out a workaround though and the results are as below…

The other method fortunately used the same data (% coverage of all plant species within 2x2m quadrats, 20 quadrats for each site) but used Ellenberg values. For those that don't know, Ellenberg values are assigned to all higher plants, and in the UK five of the seven values are used (temperature and continentality not being suitable in our oceanic climate). Salinity was also not useful for my study thus I was left with light, soil moisture, soil pH and soil fertility. These values show the environmental preferences of the species, so the soil moisture value for bell heather *Erica cinerea* is 5 whereas that of the bog-dwelling cross-leaved heath *Erica tetralix* is 8.

Through weighted averaging I calculated the Ellenberg values for each quadrat. This means that the soil moisture value for *Calluna* with a coverage of 40% would contribute more to the quadrat's overall soil moisture value than that of *Goodyera* that has a coverage of <1%. From this, I then averaged all the quadrat Ellenberg values to get Ellenberg values for each site. These values were remarkably similar, with the pH and fertility values being higher at CD than CF, highlighting the difference between the deciduous willows and coniferous junipers.

As a result the Ellenberg values for MSW as a whole turned out to be: light 6, soil moisture 6, soil pH 2 or 3, and soil fertility 2 or 3 as well.

These values could then be compared to the values of individual plant species to, hopefully, find a species that would be a good fit as an indicator for sites where MSW would be best established. I went through the whole list of plants in Hill *et al.*'s (1999) paper and identified all the plants showed some degree of similarity with the values I'd come up with. The list of species is as below. Green shows a perfect match, yellow shows the value is +/- 1 from the MSW value, and red shows it's >1 from matching up with the MSW value. I tried placing the most comparable ones at the top of each section for ease of reading

Wood crane's-bill was frequent beneath the willows of Craigdilly SSSI

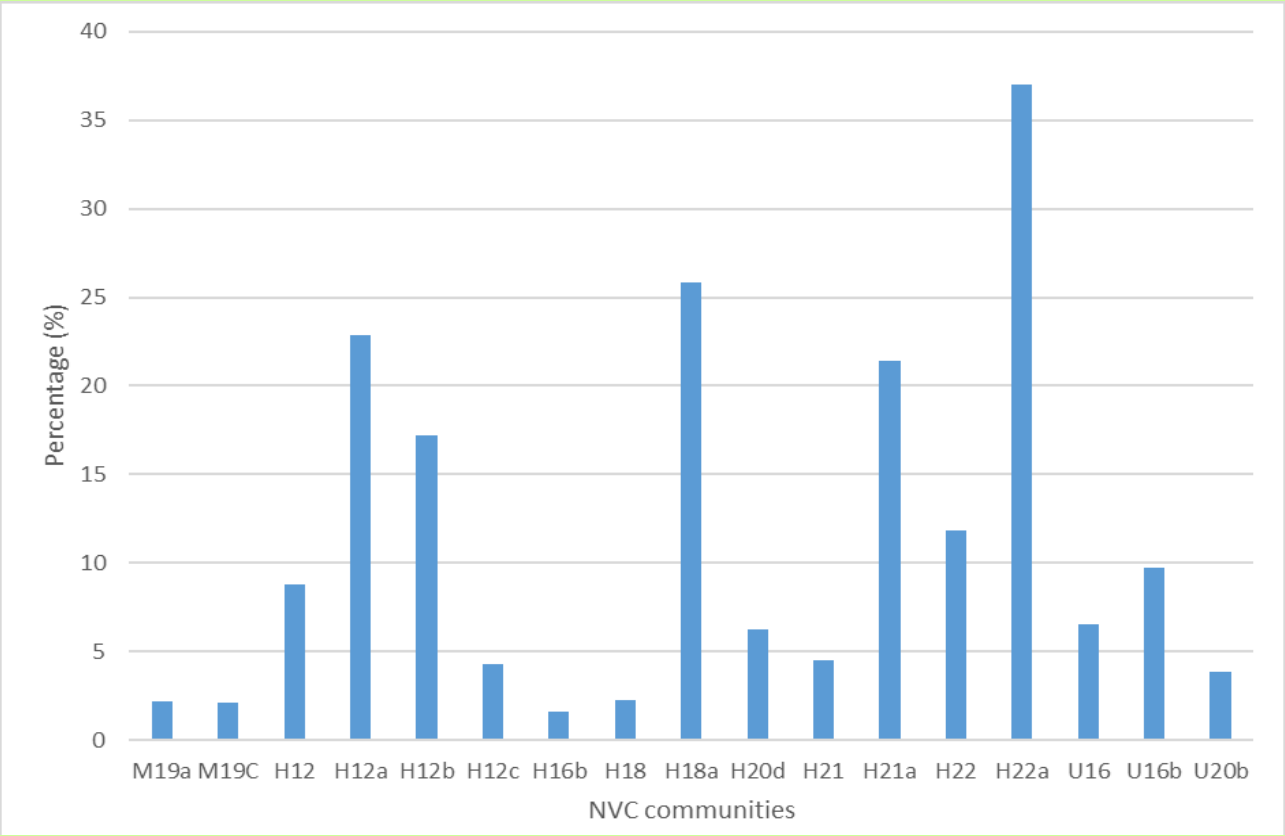

Figure 1: Chart showing the average percentage similarity of open habitats identified by MAVIS from the CF quadrat data.

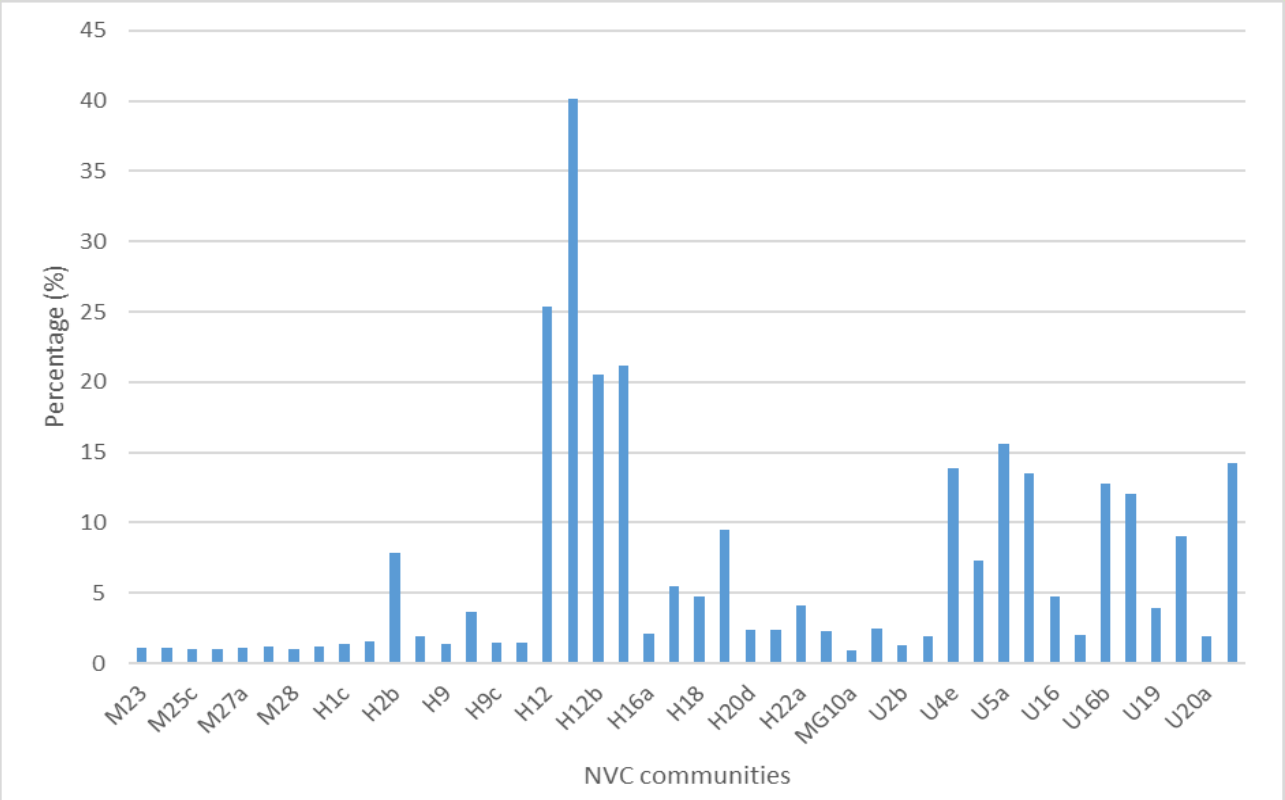

Figure 2: Chart showing the average percentage similarity of open habitats identified by MAVIS from the CD quadrat data.

Table 1: Table comparing the Ellenberg values for the quadrat data with the values for vascular plants

Species	Light	Moisture	pH	Nutrient status	
MSW values	**6**	**6**	**2/3**	**2/3**	
Galium saxatile	6	6	3	3	**Indicators of a specialist & generalist nature.**
Holcus mollis	6	6	3	3	
Lycopodium annotinum	6	6	3	3	
Vaccinium myrtillus	6	6	2	2	
Athyrium distentifolium	6	6	3	4	
Homogyne alpina	6	6	4	2	**Open heathland plants and woodland ferns.**
Cornus suecica	6	6	1	2	
Oreopteris limbosperma	6	6	4	3	
Hypericum pulchrum	6	5	4	3	
Lathyrus linifolius	6	5	4	3	
Deschampsia flexuosa	6	5	2	3	
Pteridium aquilinum	6	5	3	3	
Vaccinium vitis-idaea	6	5	2	2	
Arctostaphylos uva-ursi	7	5	2	2	
Agrostis canina	7	7	3	3	
Erica cinerea	7	5	2	2	
Cryptogramma crispa	7	5	2	3	
Dactylorhiza maculata	7	7	3	2	
Diphasiastrum alpinum	7	5	2	2	
Euphrasia micrantha	7	5	2	2	
Hymenophyllum wilsonii	5	5	3	3	
Nardus stricta	7	7	3	2	
Potentilla erecta	7	7	3	2	
Blechnum spicant	5	6	3	3	
Calluna vulgaris	7	6	2	2	
Carex binervis	7	6	3	2	
Danthonia decumbens	7	6	3	2	
Dryopteris aemula	5	6	2	3	
Athyrium flexile	7	6	3	4	
Empetrum nigrum	7	6	2	1	
Gnaphalium sylvaticum	7	6	4	3	
Platanthera bifolia	6	6	6	2	
Goodyera repens	5	5	3	2	**Mainly plants with a more continental & pinewood character.**
Melampyrum sylvaticum	4	5	2	2	
Dryopteris expansa	7	6	3	2	
Huperzia selago	7	6	2	2	
Luzula multiflora	7	6	3	3	
Pinus sylvestris	7	6	2	2	
Trientalis europaea	5	6	3	3	
Ulex gallii	7	6	3	2	
Vaccinium uliginosum	7	6	2	2	
Gnaphalium norvegicum	7	6	4	3	
Cicerbita alpina	6	6	6	6	**Fairly specialist plants of often base-rich ledges.**
Saxifraga cernua	6	6	7	1	
Saxifraga nivalis	6	6	7	3	
Cerastium arcticum	7	6	4	2	
Sedum rosea	7	6	6	3	
Oxyria digyna	7	6	5	3	
Saussurea alpina	8	6	5	3	

Melampyrum pratense	5	5	2	3	**Selected ancient woodland indicators identified by Crawford (2009).**
Polypodium vulgare	5	5	4	3	
Gymnocarpium dryopteris	4	5	4	4	
Primula vulgaris	5	5	6	4	
Phegopteris connectilis	4	6	4	4	
Oxalis acetosella	4	6	4	4	
Anemone nemorosa	5	6	5	4	
Orthilia secunda	5	5	5	3	
Populus tremula	6	5	5	6	
Polystichum aculeatum	5	5	7	5	
Equisetum sylvaticum	5	8	5	5	
Quercus petraea	6	6	3	4	**Deciduous trees**
Sorbus aucuparia	6	6	3	4	
Betula pendula	7	5	4	4	
Betula pubescens	7	7	4	4	
Betula nana	7	8	1	1	
Salix arbuscula	8	5	7	2	**Montane willows, showing the clear difference between calcicolous willows and the acidic sites studied.**
Salix aurita	7	8	4	3	
Salix lanata	8	6	7	3	
Salix lapponum	8	6	6	3	
Salix myrsinifolia	6	8	5	4	
Salix myrsinites	8	5	6	2	
Salix phylicifolia	7	8	5	4	
Salix repens	8	7	6	3	
Salix reticulata	7	6	8	3	
Tsuga heterophylla	6	6	3	3	**Non-native conifers and Rhododendron**
Pseudotsuga menziesii	6	6	4	4	
Rhododendron ponticum	5	5	3	3	
Picea sitchensis	7	7	2	2	
Picea abies	7	6	3	4	

Table 1 (cont): Table comparing the Ellenberg values for the quadrat data with the values for vascular plants

I also carried out a Detrended Canonical Correspondence Analysis that didn't really reveal anything, which was a bit frustrating given the fact I had to read the book every time I came back to that particular methodology in order to bend my mind around how it worked. Fortunately it means I don't have to try to explain it here though.

If you're interested in seeing my full analysis of what the data means then my email is below and I'd be happy to send you my full dissertation, however I'll briefly summarise what the data showed me.

There were some interesting little suggestions from the NVC data, such as picking up a few snowbed communities that provide shelter to species in winter in a similar way to MSW. Some communities have been noted before as being preferable for MSW establishment such as those dominated by great wood-rush *Luzula sylvatica*, especially where tall-herb communities are also

found. Quite a few of the communities identified are also noted by Averis *et al.* (2004) as existing at

Craigdilly has a richer understory than at Creag Fhiaclach, with great wood-rush, tall herbs & wood-sage abundant

The Ellenberg value approach also threw up some interesting suggestions. I'd like to give myself a pat on the back for predicting that interrupted clubmoss *Lycopodium annotinum* might be a good indicator, but it's hardly a difficult one to make if you've been to the juniper scrub at Creag Fhiaclach and seen just how abundant it is. This is also sometimes noted to be a minor snowbed species, but is well-known on the continent as a species of woodland, unlike here in Scotland where it is most frequently encountered in open habitats. Ferns are also noteworthy but their presence beneath the canopy of the juniper and willow scrub is probably more a sign that these species prefer damper, sheltered habitats, but this could suggest we establish MSW nearer places where shelter may have afforded refuge for species that will gladly move into said MSW once it's established.

It's worth noting how many generalist species of our hills have been identified here. Combine this with the very broad range of communities identified by the NVC approach and I feel the bottom line is that our hills could support MSW communities across a far wider range of environs than at least I had realised before undertaking this project. I don't know why but I'd envisaged them being somewhat restricted to certain places. With greater experience now I can see that there's no reason for our hills not to be covered in the stuff, other than unsustainable grazing/browsing levels and

muirburn, and now that those things have been underway for so long we also have to combat the lack of seed source.

Another thing worth noting is that the lack of a match for typical species of montane willow, such as downy *Salix lapponum*, is largely due to the underlying geology of the two sites I studied. One was the typically botanically uninspiring granite of the Cairngorms and the other was the slightly more botanically rich mix of sandstone, mudstone & siltstone of the Southern Uplands, where the likes of limestone bedstraw occurs. So the large amounts of red in the table are largely due to the fact I was studying acidic sites. Perhaps the same study could be carried out on downy willow or mountain willow *Salix arbuscula* sites if there are any sites extensive enough to give robust results.

Creag Fhiaclach: Grey willow seedling, one of a small number of broad-leaved trees seeking to establish themselves here now browsing levels are reduced (left); Abundant oak fern, interrupted clubmoss & *Sphagnum* beneath juniper scrub (right).

It's perhaps a bit of a boring, stuck-record sort of conclusion but this is, I feel, the simple fact of the matter. Until we see huge changes in the way our uplands are managed, MSW *will* be restricted but not by ecological factors. The more I experience Scotland's countryside, the clearer it is to me that this is the most sensible way forward in ecological restoration. It's by no means the easiest, as we're all aware, but if we truly wish to restore our montane woodlands to allow them to function naturally then we need to facilitate it. I'm enlightened by visits to the likes of Cairngorms Connect, Mar Lodge Estate and Corrour Estate where I can see the processes of regeneration getting going. Those wee pioneering willows providing a bit of shelter for a couple rowans and a birch that will struggle upwards to begin providing a seed source for Scotland's future montane woodlands that will spread

their broken, open canopy across the landscape. Allow our sensitive montane woodlands to flourish again and our trampled blanket bogs, overgrazed flushes, exposed liverwort heath and a whole host of other habitats will see the benefit as well.

Craigdilly SSSI: A rich mosaic of willow scrub, rowans, birch, burnet-rose, dwarf shrubs & herbs.

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Mapping the effects of climate change on montane woodland species in Scotland │ Rachel M. Robinson

Introduction

A lot of effort and money goes into reforesting projects, and if the climate is potentially unsuitable in 40-60 years' time then what can we do right now that will 'future proof' these projects? It is widely accepted that climate change poses challenges to the persistence of plant life, especially plants that have a narrow ecological niche. Climate change has the potential to eliminate vulnerable species from our landscape permanently and thus if preventative action is delayed there are potentially devastating results.

Many of the species that make up the montane woodland communities are highly specialised to deal with the harsh conditions of high altitudes. Temperatures are forecast to rise, with heat waves becoming more likely, along with summer droughts and increase in winter rainfall (UKCP, 2018). Montane woodland is especially sensitive to climate change since their migration is restricted geographically (Tejedor Garavito *et al*., 2015) My undergraduate thesis reviewed and critically analysed the current context and considered how a changing climate will affect montane woodland species by creating climate envelopes for a selected range of species which were tested through MaxEnt software.

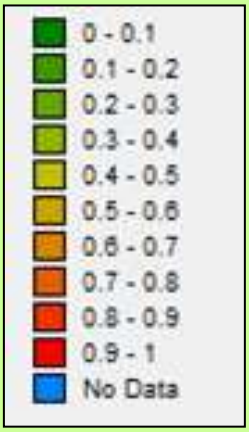
Methods

Using climate envelope mapping coupled with Maximum Entropy, I was able to cautiously predict the geographical distribution of 7 montane woodland species native to Scotland: *Juniperus communis* subsp*. nana, Salix herbacea, S. lanata, S. lapponum, S. myrsinites, S. reticulata and Sorbus rupicola*, under current and future climates in Scotland.

Global distribution data was obtained from Global Biodiversity Information Facility (GBIF) and supplemented with data from BSBI (Botanical Society of Britain & Ireland). Bioclimatic data was downloaded from the DIVA GIS website as 19 files representing a specific aspect of the current climate. Future climate data, downloaded from WorldClim, was used to represent the potential future climate scenarios. The time period this data represents is 2061-80.

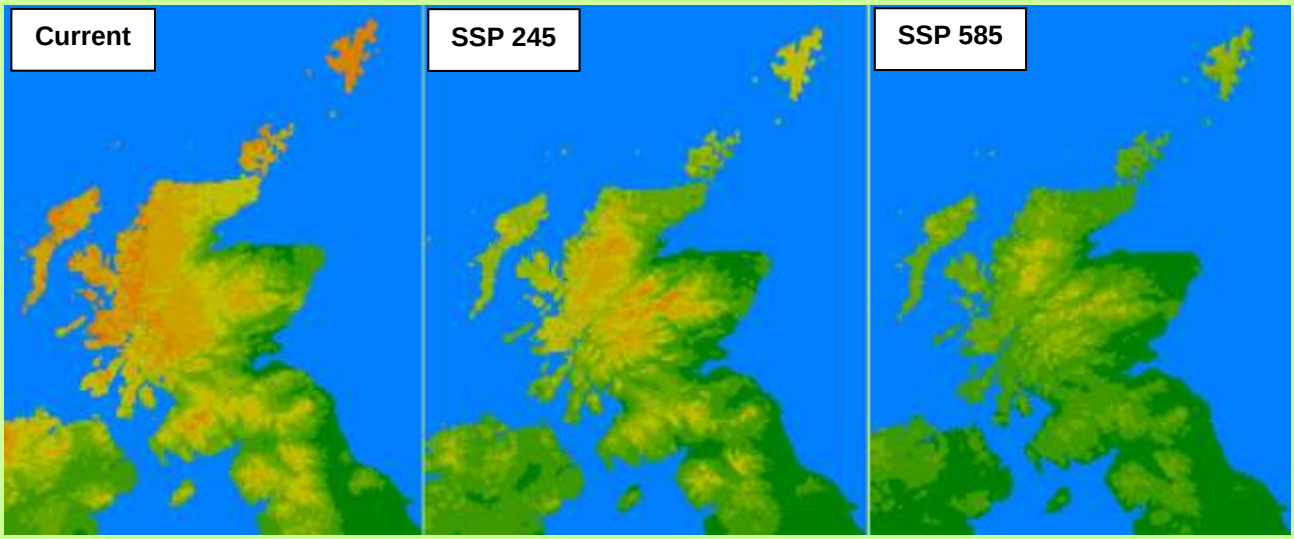
There are five available scenarios for this climate model that represent the various ways that the climate may evolve with lack of climate policies and international efforts to halt climate change, referred to as Shared Socioeconomic Pathways (SSPs). I chose two for this study: SSP 245 representing a medium emissions scenario and SSP 585 representing a medium-high emissions scenario. Hausfather (2019) explains these scenarios very comprehensively in their article on CarbonBreif.org (linked in the references) (Hausfather, 2019).

Using a maximum entropy algorithm applied through MaxEnt software, each climate envelope could be tested. For each species, the model was trained with the current climate data - with MaxEnt displaying the distribution of that species under those climate parameters. The MaxEnt output displays a legend that ranges from red to dark green. The warm tones represent an ideal climate for the species being mapped, and the green areas highlight areas that have an unsuitable climate for the plant being mapped. For the purposes of this thesis, any score of 0-0.4 was deemed an inappropriate climate, a score of 0.4-0.6 was deemed a somewhat suitable climate and a score of 0.6-1 was deemed as an ideal climate for the given species.



Results by Species

Juniperus communis subsp*. nana*



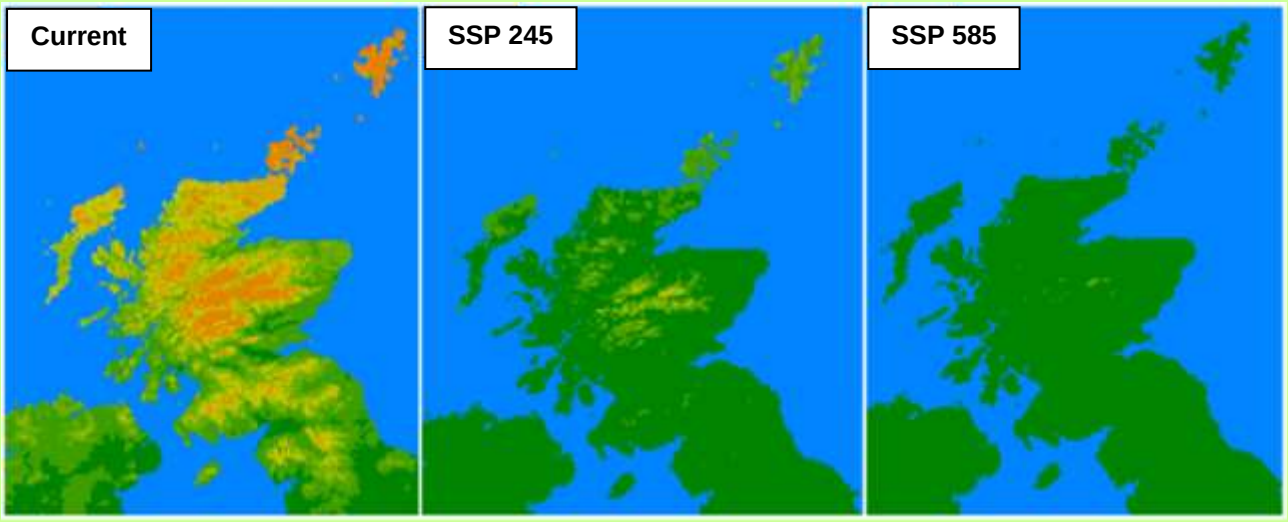
**Distribution maps for *Juniperus communis* subsp. *nana* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80**

The three variables that most contributed to the climate model were Precipitation of Driest Quarter, Precipitation of Warmest Quarter and Mean Temperature of Warmest Quarter. Under the current climate, *J. communis* subsp*. nana*'s most favourable climate is located on the North West coast of Scotland, mainly in the Highlands and the entirety of the Outer Hebrides. Suitable climate is also located in the Orkney Islands, the Shetland Islands, Argyle and Bute, and parts of Stirling, Perth and Kinross. Suitable climate, albeit less ideal, also creeps into the East coast such as in Aberdeenshire, and the Scottish Borders. The climate is generally unfavourable throughout Angus, and Lothian. Generally, much of Scotland's current climate is suitable for J. *communis* subsp. *nana*.

By 2061-80 under SSP 245 the climate shifts from the west coast towards the inlands. The Orkney Islands and the Shetland Islands, favourable under the current climate, become largely unfavourable under SSP 246. The same pattern can be seen in Argyle and Bute. Favourable areas remain in the

south of the Highlands, North Perth and Kinross and West Aberdeenshire with some scattered areas of fragmented suitable areas through South Lanakshire and the Scottish Borders.
By 2061-80 under SSP 585 most of Scotland has an unfavourable climate for *J. communis* subsp. *nana*. Scattered areas remain somewhat suitable through West Aberdeenshire and parts of the highlands, but mainly in the Cairngorms.

Salix lanata



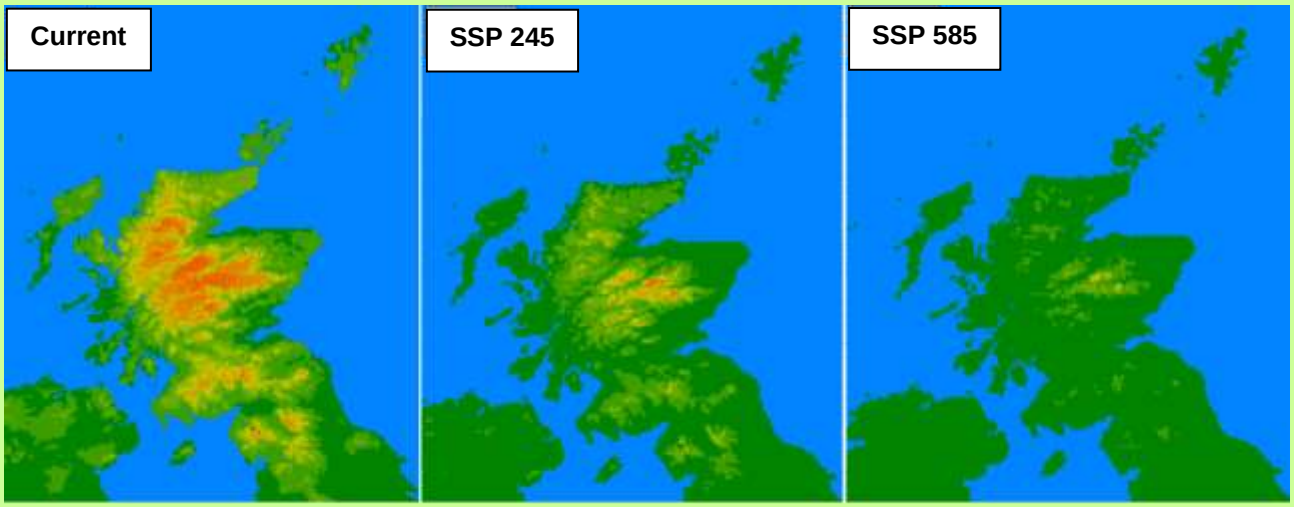
Distribution maps for *Salix lanata* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80

The variables that most contributed to the climate model were 10 (Mean Temperature of Warmest Quarter), 14 (Precipitation of Driest Month) and 5 (Max Temperature of Warmest Month).
Under the current climate, the majority of Scotland displays a suitable to ideal climate for *S. lanata*. A clear hot spot can be seen in the Cairngorms National Park, with other areas showing an ideal climate in the Orkney and Shetland islands, as well as throughout the Highlands as well as the Isle of Harris and scattered areas from South Ayrshire and Dumfries and Galloway in the west to the Scottish Borders in the east.

By 2061-80 under SSP 245 the map of the climate is visibly changed from that of the current climate. The only suitable areas for *S. lanata* remain in the Cairngorm National Park. The Orkney Islands and Shetland Islands, whilst favourable under the current climate, become largely unfavourable under SSP 246 with a score of 0.1-0.3.

By 2061-80 under SSP 585 the map of the climate is extremely bleak. >95% of Scotland has a score of 0, with a fragmented scattering of areas with a score of 0.1-0.3 around the Cairngorms National Park.

Salix lapponum



Distribution maps for *Salix lapponum* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80

The variables that most contributed to the climate model were 14 (Precipitation of Driest Month), 1 (Annual Mean Temperature) and 18 (Precipitation of Warmest Quarter).

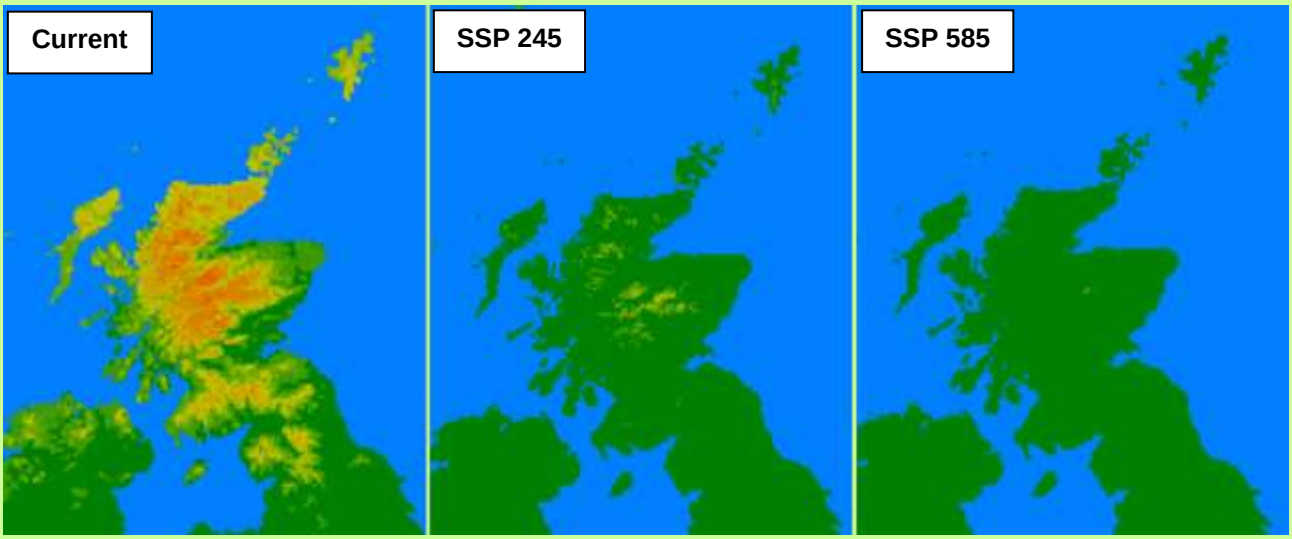
Under the current climate large areas of Scotland are ideal for *S. lapponum*. These areas are mainly seen throughout the Highlands, Aberdeenshire, Perth and Kinross as well as a strip from Argyle and Bute in the West to small areas of the Scottish Borders in the East.

By 2061-80 under SSP 245 the climate in Scotland is depicted as largely unfavourable, with >90% of Scotland showing a score of 0-0.3. Then small areas that remain favourable are found scattered throughout the Highlands and fragmented areas around Eastern Dumfries and Galloway. There remain hotspots around the Cairngorms National Park with a score of 0.5-1, however when compared with the map of the current climate the decrease in this area is evident.

By 2061-80 under SSP 585 the areas throughout the Highlands that remained somewhat suitable in the SSP 245 scenario are now mostly unsuitable. This pattern can also be observed with the fragments around Dumfries and Galloway. Whilst there remain areas of the Cairngorms that still have a score of 0.5-0.8, this area has reduced substantially.

Salix myrsinites

The variables that most contributed to the climate model were 10 (Mean Temperature of Warmest Quarter), 4 (Temperature Seasonality (standard deviation *100)) and 11 (Mean Temperature of Coldest Quarter).



Distribution maps for *Salix myrsinites* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80

In the present time map, most of Scotland is shown to represent a climate that would be considered very suitable for *S. myrsinites*. Most of the Highlands would provide the ideal climate, as well as areas of Perth and Kinross, Abedeenshire and a strip from South Ayrshire in the West to South Lanarkshire and into parts of the Scottish Borders. The Orkney and Shetland Islands have a somewhat suitable climate for *S. myrsinites*, as well as the Outer Hebrides to the west of Scotland. By 2061-80 under SSP 245 the climate suitable for *S. myrsinites* in Scotland has visibly changed. The areas that remain somewhat suitable are clustered in fragments around the area of the Cairngorms National Park as well as some areas in the Highlands. >90% of Scotland has a score of 0.

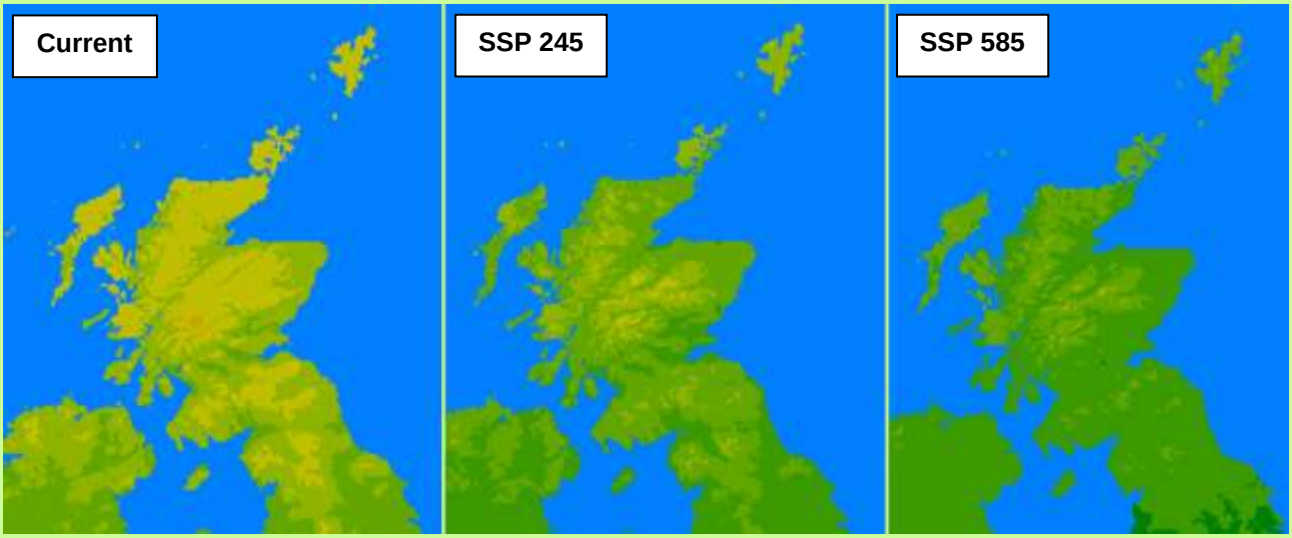
By 2061-80 under SSP 585 the climate in Scotland is mostly unfavourable for *S. myrsinites*, with >95% of Scotland showing a score of 0.

Salix reticulata

The variables that most contributed to the climate model were 14 (Precipitation of Driest Month), 10 (Mean Temperature of Warmest Quarter) and 5 (Max Temperature of Warmest Month).

Under the current climate, Scotland largely represents the score bracket 0-0.5. There are small fragments of areas that represent a score of 0.5-0.6 in the highlands and the most northerly point of the Shetland Islands. A score of 0.3-0.4 can be observed throughout the highlands, Aberdeenshire, Moray, and North Perth and Kinross, suggesting the climate in these areas is somewhat suitable for *S. reticulata*.

By 2061-80 under SSP 245 the climate, Scotland largely represents the score bracket 0-0.3. There are fragments of areas with a score of 0.4-0.5 mainly concentrated around the Highlands and Aberdeenshire, with some concentrated areas around the Cairngorms National Park and around Creag Meagaidh.

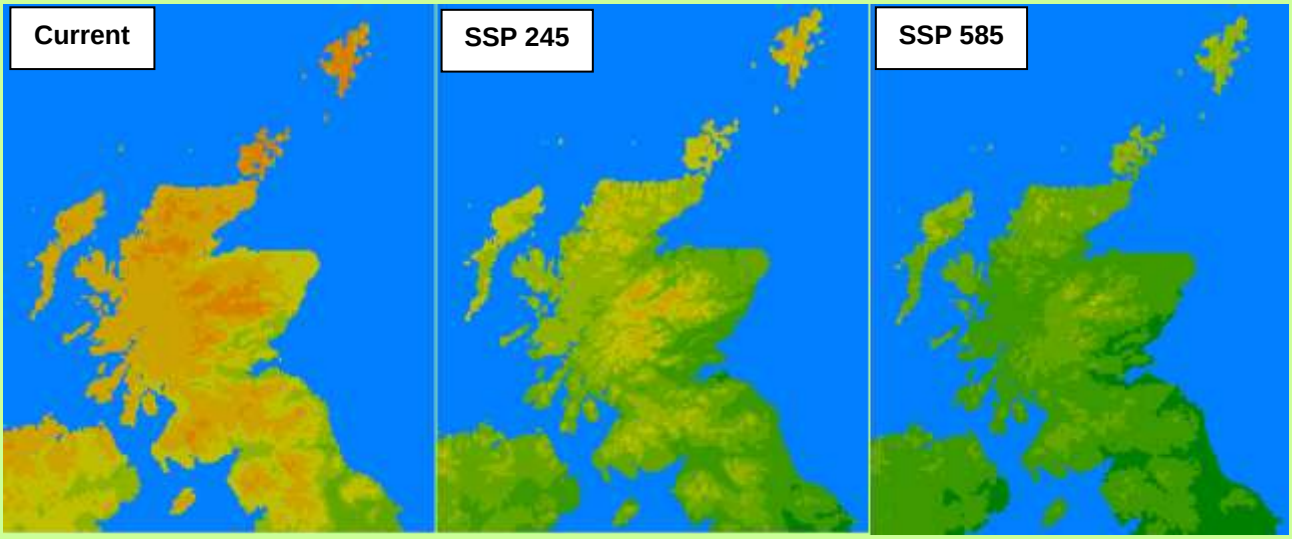


Distribution maps for *Salix reticulata* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80

By 2061-80 under SSP 585 the climate in Scotland fits into the score bracket of 0-0.4, suggesting that the climate will be largely unfavourable for *S. reticulata*.

Salix herbacea

The variables that most contributed to the climate model were 5 (Max Temperature of Warmest Month), 14 (Precipitation of Driest Month) and 7 (Temperature Annual Range (BIO5-BIO6)).

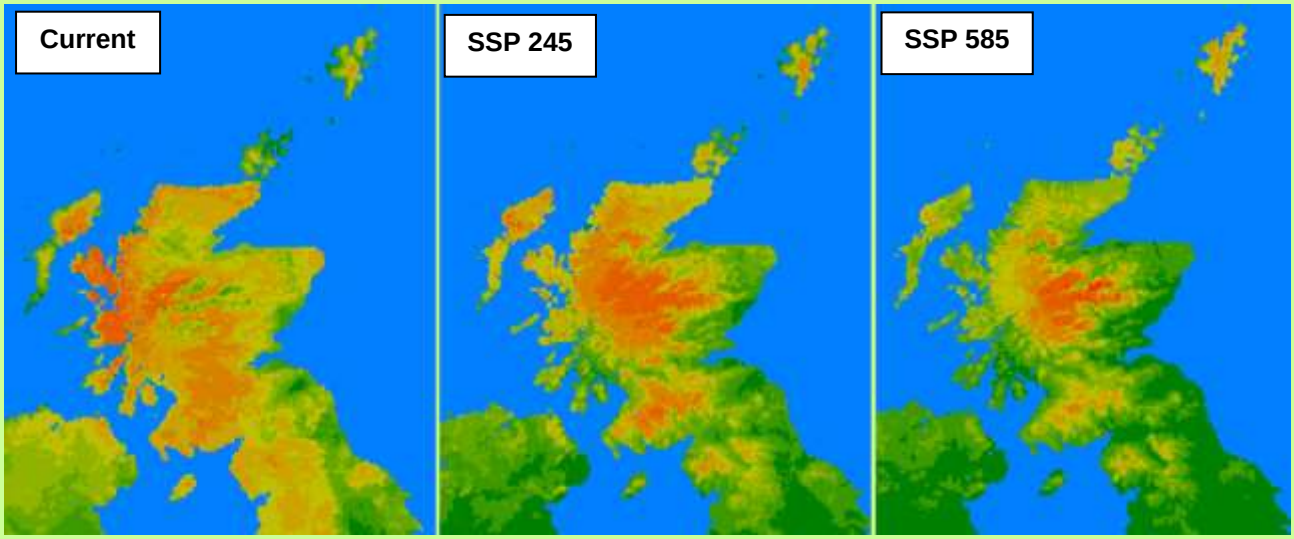


Distribution maps for *Salix herbacea* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80

Under the current climate, most areas of Scotland represent the ideal climate for *S. herbacea*. The areas that remain unfavourable are found along the East Coast, South of Aberdeenshire. The most favourable conditions with a score of 0.7-1 are found in areas of the North Highlands and Aberdeenshire, the Outer Hebrides as well as the Orkney Islands and the Shetland Islands.
By 2061-80 under SSP 245 the climate is primarily within the score bracket of 0.1-0.4. The areas presenting the most suitable climate are confined to the east and north of the Highlands, mainly in the Cairngorms and areas of western Aberdeenshire as well as the Orkney Islands and the Shetland Islands.

By 2061-80 under SSP 585 the climate in Scotland is primarily restricted to a score of between 0-0.3. In comparing the current climate to the SSP 585 model, the difference is certainly worrying for the future of *S. herbacea* populations in Scotland. The only areas that remain somewhat suitable with a score of 0.4-0.5 are fragmented areas in the Shetland Islands and small areas of the Cairngorms.

Sorbus rupicola



**Distribution maps for *Sorbus rupicola* in Scotland.
From left to right: current climate, SSP 245 and SSP 585 for the period 2061-80**

The variables that most contributed to the climate model, were 7 (Temperature Annual Range (BIO5-BIO6)), 2 (Mean Diurnal Range (Mean of monthly (max temp – min temp))) and 8 (Mean Temperature of Wettest Quarter).

Under the current climate, Scotland is largely favourable for *S. rupicola*. There are clear hot spots along the West Coast, especially in the Highlands, Argyle and Bute, Stirling and Perth and Kinross. Areas in Aberdeenshire, the Shetland islands and the Orkney islands present as an appropriate climate also. To the west, the Outer Hebrides represent a largely favourable climate, especially to the north in Harris.

By 2061-80 under SSP 245 the climate remains largely favourable for *S. rupicola*. There is a visible slight shift away from the west coast with parts of Argyle and Bute becoming less ideal, and parts of the Shetland and Orkney islands becoming increasingly favourable. The same hot spots persist across the Highlands, Perth and Kinross and parts of west Aberdeenshire.

By 2061-80 under SSP 585 the climate the favourable climate again shifts eastward, away from the west coast. The areas in the Outer Hebrides that were favourable under the current climate parameters are now largely unfavourable, with a few areas remaining in the North because the North of the Island is where the highest and most extensive mountain ranges of the Outer Hebrides are found.

Discussion & Conclusion

All seven species mapped lost appropriate climate under each of the climate scenarios when compared with the current climate, which is consistent with the findings of Berry *et al*. (2002) in their mapping of Arctic–Alpine montane heath communities. When observing the maps of each prediction, an interesting pattern emerges: through each of the species maps the area of the Cairngorms mountain range National Park remains the most suitable area. This is likely due to the high altitudes in this mountain range, where 36% of the total area of the Cairngorms National Park is over 800m. This highlights the importance of conservation management in this area of the North East of Scotland.

Limited to altitudes above 600m in UK (Newsholme, 1992), *Salix reticulata*, an already scarce species is forecast under both SSP 245 and SSP 585 climate scenarios to lose the already limited habitats in which it currently occurs. Under both SSP 245 and SSP 585 J*uniperus communis* subsp*. nana, Salix herbacea, Salix lapponum* are going to become further limited, with the remaining areas representing an appropriate climate for these species found within the area of the Cairngorms National Park, highlighting it as an area of great conservation importance. Areas around the Shetland Islands will also remain appropriate for *S. herbacea* under both climate scenarios. Montane species have a comparatively narrower ecological niche than lowland plants, which can be expected to be further limited by grazing pressures.

The changes occurring to the climate in Scotland under SSP 585 by 2061-80 would threaten wild populations of *Salix myrsinites, S. lanata* and *S. herbacea* perhaps as far as to extinction in the wild, thus underlying the need for robust *in situ* and *ex situ* conservation practices. This is consistent with the findings of Garavito (2014). Observation of their current habitat is needed to provide the ideal conditions that will allow them to thrive outside of their natural distribution, such as in botanic garden collections. If these species were to become absent from Scottish landscapes, the already fragile habitat of montane scrub woodland would become further compromised.

The MaxEnt outputs, in the case of *Salix myrsinites* and *Sorbus rupicola*, highlighted areas where the species are not currently recorded (BSBI, 2020), but that represent an appropriate climate. This data could be a useful tool for conservationists in identifying appropriate areas for expansion and regeneration. The reasons for the species not currently being present at these sights could be due to competition (Berry *et al*., 2002) and likely grazing pressures by herbivores narrowing the

fundamental niche of the species, and thus exclusion of herbivory would be appropriate prior to introduction (Adair, 2018; Cairngorms Connect, n.d; Tipping *et al*., 2008; Watts, 2020). Conversely, more rigorous legislation surrounding the control of deer populations being introduced would likely aid in the regeneration of these vulnerable species (Keegan *et al*., 2013).

According to the MaxEnt output, *Sorbus rupicola* will be the least affected by climate change out of the species studied, even with some loss of appropriate climate in which it would grow the populations are not under threat of extinction under either climate scenario. What lies beyond 2080, however, is not currently known and so further mapping would be appropriate.

Climate envelope mapping is a significant tool for conservationists in order to gain a greater picture of how montane woodland habitat will be affected by a changing climate more species should be mapped, ideally over time periods further into the future such as 2080-2100. It would be interesting to see how using a UK climate model would affect the results given by MaxEnt, for example the HadCM3 model. Further species should be mapped in order to gain better insight into how the habitat as a whole will be affected by a changing climate as the results obtained by this thesis give strong insight into the outcome of individual species however the time frame did not allow for more species to be included.

While MaxEnt can highlight areas that could be considered appropriate for the fundamental niche of a given species, the realised niche should be expected to narrow with the addition of grazing pressures and therefore care should be taken to consider biotic influences. MaxEnt does not consider the presence of microclimates, and so the results of this thesis will not be a perfect picture of the situation on the ground. Future studies should consider utilising climate envelope modelling coupled with onsite surveying in order to critically analyse the results given by MaxEnt.
Unless serious action is taken to combat climate change, our planet's precious resources are at risk of dropping out of existence. Plants underpin life as we have come to know it and are therefore worthy of meticulous stewardship in an increasingly altered environment. Without air-tight legislation, I'm afraid we are likely destined to a SSP2 scenario of slow-off-the-mark development of sustainable goals. Mercifully, there is incredible work being done by action groups and organisations to preserve the fragile and ancient montane scrub woodland habitat. Whether or not these efforts will have been enough in the scope of 2061-80's climate remains uncertain.

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Microsite conditions determine differences in regeneration density of Scots pine and birch at Mar Lodge │ Annabel Everard

Introduction

It is vital we address the climate emergency and biodiversity collapse. In Scotland, this may be helped by facilitating natural regeneration, as an alternative to tree planting, when enhancing woodland cover and restoring native woodlands. Managing deer impacts is crucial to promote regeneration, especially in Scotland, where deer populations have been elevated through past and present land management.

In 2009, Mar Lodge Estate, in Scotland's Eastern Cairngorms, adopted a zero-tolerance (< 3.5 red deer per km^2) approach to deer to promote regeneration of native Caledonian pinewoods and upland birchwoods within a designated forest restoration zone.
Regeneration is now occurring apace, but its density and distribution is patchy and seemingly unpredictable.

Destructive overgrazing by deer on a birch sapling

This research aimed to determine whether microsite conditions influenced regeneration density, and thus site-suitability, of *Pinus sylvestris* (Scots pine) and *Betula pendula* and/or *Betula pubescens* (silver birch and downy birch) - characteristic tree species within Scotland's native Caledonian pinewoods and upland birchwoods.

Glen Quoich upland birchwood (left), and Caledonian pinewoods (right) at Mar Lodge Estate

Field methodology

In May/June, 2019, 48 plots (5m^2 plots with centrally placed 2m^2 quadrat) were surveyed within areas identified as having Scots pine and/or birch regeneration in 2016 (Rao, 2016). The data recorded is outlined in table 1. To minimise the ecosystem engineering effects of these tree species, where maturing trees alter local soil pH and fertility over time, and help ensure sapling detection, we defined saplings as being ≥15cm and ≤100cm tall. Ellenberg Indicator Values (EIVs) were calculated based on the vascular plant composition of each quadrat to assess plot light, soil moisture and nutrient availability, and soil acidity.

An example 2m^2 quadrat within a survey plot overlooking Mar Lodge Estate (left), and vegetation survey in progress in Glen Derry (right).

Unit	Variable(s)
5m^2 plot	Average sapling height (cm) Average basal diameter
	Average sapling browsing damage (low/moderate/high)
	Sapling density (per m-2)
2m^2 quadrat	Ground cover (% all plant species, bare ground etc.)
	Mean heather depth (cm)
	Mean moss/litter depth (mm)
	Mean heather damage (Recorded as (1) ≤ *c.*33%; (2) *c.*33–66% or (3) ≥ *c.*66% of long shoots browsed)
Plot centre	Aspect (categorised as either northeast or southwest facing to determine effect of prevailing wind)
	Altitude (m.a.s.l.)
	Peat depth (cm)
	Canopy openness (recorded using a spherical densitometer)
60m radius	Seed trees presence or absence i.e. mature Pinus and/or Betula, established using aerial photography (GetMapping, 2019)

Table 1: Data collected in the field

Linear modelling was used to investigate the most important microsite conditions for determining species-specific regeneration densities. Detrended correspondence analysis (DCA) was used to visually assess relationships between environmental variables, ground flora composition and the regeneration density of both species.

Key findings

As expected, proximity to mature trees enhanced regeneration, however we also found microsite conditions influenced site-suitability for regeneration. Greater regeneration of Scots pine and birch was associated with northeast facing slopes. Enhanced winter heather dieback on these more exposed slopes may promote regeneration via niche creation (Hancock, 2008). However, it's questionable whether such conditions are favourable for growth.

DCA results suggested niche separation, since favourable microsite conditions seemingly varied between tree species. Greater Scots pine regeneration was associated with microsites with less competitive vegetation (shallow moss/litter layers and shorter heather) and/or negligible vegetation cover (bare ground, *Cladonia* spp., and *Cytisus scoparius*). In contrast, competitive vegetation seemingly did not limit birch regeneration. Instead, greater birch regeneration was associated with less acidic and more fertile sites (EIV's Moisture and Nitrogen), and particularly with wetland flushes and grassland habitats (*Ajuga reptans, Plantago lanceolata* and *Geum rivale*). Correlations between birch height, regeneration density, soil fertility and acidity suggest birch may be engineering more favourable microsite conditions (Mitchell *et al*., 2007). However, with increases in competitive vegetation, there is uncertainty if such conditions are suitable for future site colonisation despite being favourable for growth of established saplings.

This is a summary of research that has been published by *Scottish Forestry*: Everard *et al*., 2021. Microsite conditions determine differences in regeneration density of Scots pine and birch following the reduction in deer grazing pressure, Scottish Forestry, 75(3), pp. 26-33.

Whilst regeneration was enhanced by proximity to seed trees, tall heather was found to hinder Scots pine regeneration through competitive exclusion at Mar Lodge.

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Beginning the "genetic rescue" of the Mar Lodge Estate montane willow populations │ Shaila Rao & Andrew Painting

Back in the Autumn 2020 edition of Scrubbers' Bulletin (issue 14) (Rao 2020) we outlined the preliminary survey and monitoring work carried out at Mar Lodge Estate (MLE) which identified the small, fragmented and precarious nature of the few existing *Salix lapponum* and *Salix myrsinites* populations. (Photos 1 & 2). This far-from-ideal situation is common to many estates around Scotland. Subsequent genetic analysis of willow leaf samples collected from MLE, Glen Feshie and Abernethy (Finger 2020, Finger *et al* 2022) evidenced the need to reinforce these populations and introduce suitable new genetic material. This will facilitate a "genetic rescue" of these tiny populations and hopefully bring them into a position where they can cross pollinate easily and thus regenerate and expand.

Photo 1 (left): *Salix lapponum* in upper Glen Quoich; Photo 2 (right): *S. lapponum* in Coire Etchachan

Montane willow restoration is by no means a new road travelled and NTS were one of the pioneers with their fantastic work at Ben Lawers. However, the Cairngorms are just getting going with montane willow restoration and the planting in spring 2021 was the first montane willow planting to be carried out at MLE. We have subsequently followed this up with further planting in 2022. Our aspirations are firstly to boost existing populations such that they have the capacity to regenerate and hopefully expand in the future. Secondly, we want to improve connectivity between populations and increase the probability of cross-pollination through establishing new stepping-stone populations between the existing ones. Finally, for *Salix myrsinites* where we have only two known populations, we want to establish further robust populations of this species to reduce its susceptibility to stochastic events (Photo 3).

In 2021 we chose to focus our initial planting work in the north of the estate in the Upper Glen Derry and Coire Etchachan area (Photo 4). This part of the estate supports four separate *Salix lapponum* populations ranging in size from two plants to approximately 35 plants. There are no *Salix myrsinites* in the area. In addition to the presence of *Salix lapponum*, this area was selected for the low deer use over much of the area and a higher level of human disturbance due to the popular footpaths and the bothy located in Coire Etchachan. These factors were important as we were planting the willows unprotected from herbivores.

Photo 3 (left): *Salix myrsinites* in Garbh Coire
Photo 4 (right): Looking up the Etchachan burn into Coire Etchachan. Two of the planting areas.

In 2022 we focused our efforts on planting *Salix lapponum* into two exclosures, part-funded by Cairngorms National Park Authority, that were erected in 2021 around very small and isolated *Salix lapponum* populations in the southern part of the estate. Deer numbers here are higher and will not allow unprotected tree planting. We also added a further *Salix lapponum* and *Salix myrsinites* into the Coire Etchachan area where planting had occurred in 2021.

All *Salix lapponum* and *Salix myrsinites* planted out in both 2021 and 2022 were grown on from seed collected in preceding years from the existing MLE populations. Seed collection from the remote and high-altitude populations was challenging, time consuming, exhausting and at times frustrating. There were many fruitless visits either a bit early or a bit late but this activity could be extremely rewarding if timed to perfection (Photos 5 & 6). A number of the small populations produced catkins which fluffed up but contained no viable seed. A couple of the populations supported high numbers

of seed eating caterpillars which only emerged from the catkins when laid out to dry. (Photos 7 & 8). Over three years of seed collection, viable seed was collected from four of the nine *Salix lapponum* populations and from both *Salix myrsinites* populations. Getting the seed delivered to Trees for Life's tree nursery at Dundreggan quickly after collection to allow speedy sowing and germination of the willows was a somewhat stressful logistical challenge but was achieved successfully. The plants were grown on at Dundreggan and while fertiliser was used the quantities of this were intentionally reduced well before planting to try and decrease the palatability of the willows to herbivores (Photo 9).

Photo 5 (top left): *Salix myrsinites* catkins fluffed up on Beinn Bhrotain
Photo 6 (top right): Ripening catkins in Coire Etchachan
Photo 7 (below left): Caterpillar poo extracted from catkins from Coire Etchachan │credit: Trees for Life
Photo 8 (below centre): Willow seed extracted from catkins from one site │credit: Trees for Life
Photo 9 (below right): *Salix lapponum* ready for planting out

In Scotland, the majority of montane willow populations are at high altitude and clinging to crags or hanging to burn sides out of reach of herbivores. The temptation is to plant willows in similar situations because this is where they currently occur but also because we feel they have a higher chance of escaping browsing in such locations. However, having seen these species in other countries, it is apparent that both *Salix myrsinites* and *Salix lapponum* can occupy a variety of habitats and a range in altitudes (Photo 10). Hence our approach to planting at MLE was to try and

expand the type of locations these species can thrive in with the hope that we can establish populations away from the steep ground and rocky ledges. Data from deer counts and field signs suggested deer numbers within the Coire Etchachan and Upper Glen Derry area are generally low with the exception of one location where deer presence was noticeably higher (Glas Allt Mor). Although no physical protection was given to the planted willows, great care was taken in microsite selection for planting and to effectively hide them from deer and other herbivores.

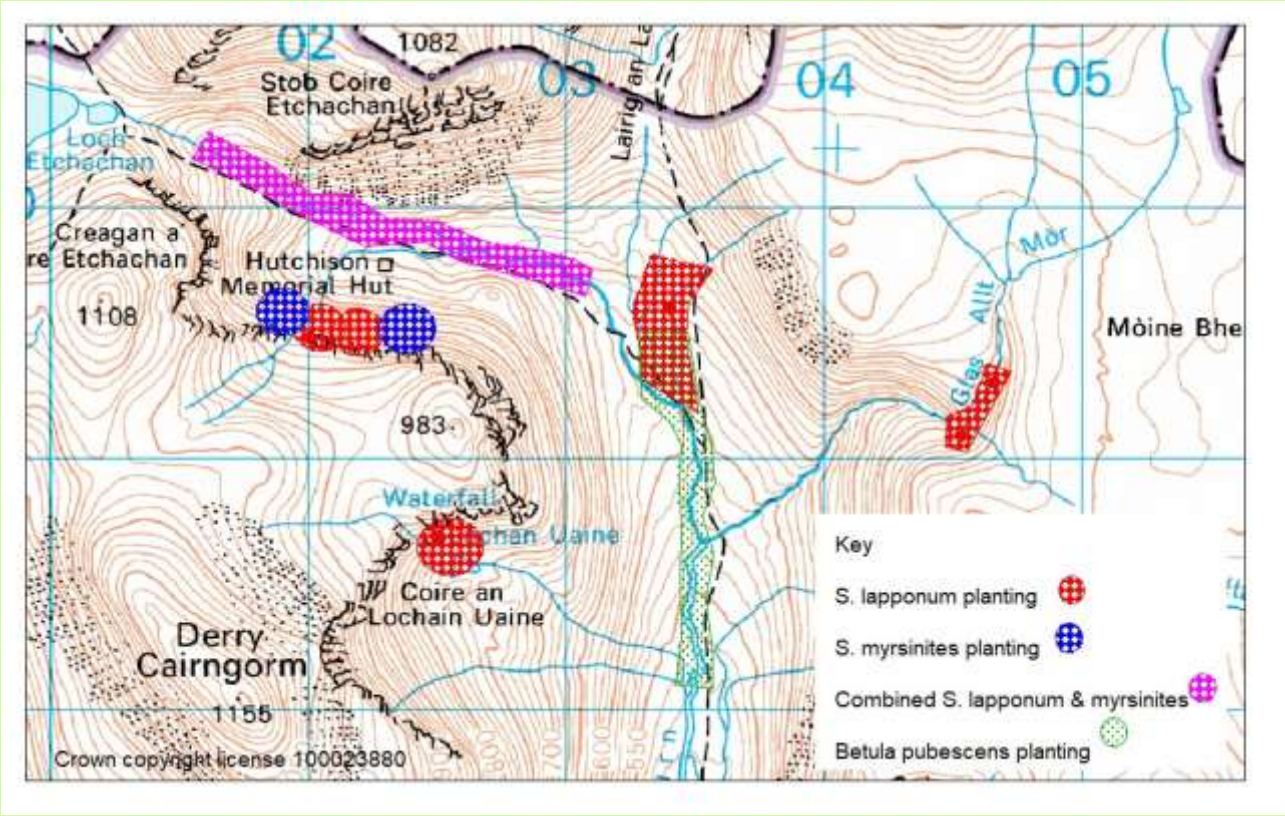
In May 2021, 2766 willows were planted in the Upper Derry and Coire Etchachan area into sites with ecologically suitable vegetation communities and ground conditions (Photo 11). This was supplemented by a further 500 *Salix lapponum* and 103 *Salix myrsinites* in 2022. Table 1 details the number of willows planted at each planting site and Map 1 indicates the general areas of planting. Three new *Salix myrsinites* populations were created, four *Salix lapponum* populations re-enforced and three new *Salix lapponum* populations created. The planting sites all fell within the Cairngorms SSSI and SAC and so SSSI consent for planting was required. In order to protect open ground priority habitats, consent was not given to plant willows in blanket bog, alpine heaths (except an agreed small area of H19 NVC community) or into calcareous grassland.

Photo 10 (left): Montane woodland habitat in Norway.
Photo 11 (right): Planting along the Etchachan burn │credit: Treesurv

The willows were planted in clusters of approximately 50 trees at each planting site. This strategy was employed in the hope that the trees will in the future gain mutual protection from one another, will grow together to form one large patch and this may help protect trees from future deer and hare browsing. Where willows were planted to reinforce an existing willow population the new trees were planted around the outer edge of the existing population and were not planted within the population. At the Derry burn, the lowest altitude of the *Salix lapponum* planting sites, 2064 downy birch (from MLE collected seed) were also planted partially overlapping the area where the willows planted. This planting was experimental to observe browsing levels when the willow were interspersed with another species.

Year	Species	Location	Altitude	Reinforcement or new population	No. trees planted
2021	*S. lapponum*	Coire Etchachan	820-892m	reinforcement	308
2021	*S. lapponum*	Coire Etchachan	820-892m	new	308
2021	*S. lapponum*	Etchachan burn	666-715m	new	320
2021	*S. lapponum*	Derry burn tributary	606-681m	reinforcement	320
2021	*S. lapponum*	Glas Allt Mor	750-786m	reinforcement	200
2021	*S. lapponum*	Coire Lochan Uaine	792-824m	reinforcement	200
				Total S.lapp	**1656**
2021	*S. myrsinites*	Coire Etchachan	834-892m	new	400
2021	*S. myrsinites*	Coire Etchachan	834-892m	new	400
2021	*S. myrsinites*	Upper Etchachan burn	778-838m	new	310
				Total S.myr	**1110**
2022	*S. lapponum*	Allt an Bhrathaich	650m	reinforcement	1738
2022	*S. lapponum*	Allt Christie Mor	650m	reinforcement	600
2022	*S. lapponum*	Coire Etchachan	820-892m	new	250
2022	*S. lapponum*	Etchachan burn	666-715m	new	250
				Total S.lapp	**2838**
2022	*S. myrsinites*	Upper Etchachan burn	778-838m	new	103
				Total S.myr	**103**

Table 1. Number of willows planted at each planting site



Map 1: Willow planting sites 2021 and some planting 2022

It is our intention to monitor the ongoing growth and survival of a 10% sample of the willows planted in 2021 in this area broadly following the monitoring protocol detailed in the Montane Scrub Action Group BPG 5 document. In spring 2021 a quick assessment of the sample trees was made directly after planting (see Table 2) and then in September 2021 and 2022 they were re-visited to determine survival, condition and browsing levels (Table 2). Autumn 2022 monitoring repeated that of 2021 but with some additional variables being recorded.

Variable	**Details**
Year 1. Spring 2021 monitoring	
Canopy volume (of each sample tree)	height x max crown diameter x perpendicular diameter (cm)
Dominant plant species within 1m radius of each sample tree	
Percentage cover of broad species groups	in 1m x 1m quadrat at centre of sample group
NVC community for sample group area	in 1m x 1m quadrat at centre of sample group
Aspect	degrees
Slope	gradient
Altitude	metres above sea level
Year 1. Autumn 2021 monitoring	
Sample tree condition	healthy, surviving, poor condition and dead.
Sample tree browsed	yes/No
Leading shoot browsed of sample tree	yes/No
Mean percentage of the canopy browsed.	percentage
Browser	deer/hare/invertebrate/unidentified
Year 2. Autumn 202 monitoring additional variables recorded.	
Evidence of catkins being produced	yes/no
Invertebrate damage (Y/N)	yes/no
Hare and deer pellets (in a 2m radius plot around the sample tree)	Number of pellets (hare)or pellet groups (deer)
Plant length	base to tip of longest shoot (cm)
Shoots	number of them
Leaves	Number of then

Table 2: variables measured for Year 1 & Year 2 monitoring

Two hundred and ninety-five of the 300 sample trees were re-found and monitored in September 2022, 16 months after planting. Of these 295, all were alive and there was no tree mortality recorded. 88.7% (±5.7 SE) of trees were recorded as healthy, 8.4% (±3.0 SE) as surviving and 2.9% ((±2.9 SE) in poor condition (Figure 1).

The mean percentage of sample trees browsed since planting in spring 2021 was 28.2% (±12.8 SE). However, this mean was influenced significantly by one site – Glas Allt Mor where heavy browsing was recorded (95% of sample trees). Glas Allt Mor is an area which is highly attractive to deer as it offers winter shelter and good quality forage. We were aware of the higher deer pressure at this site and deliberately only planted a small number of willows here due to the browsing risk.

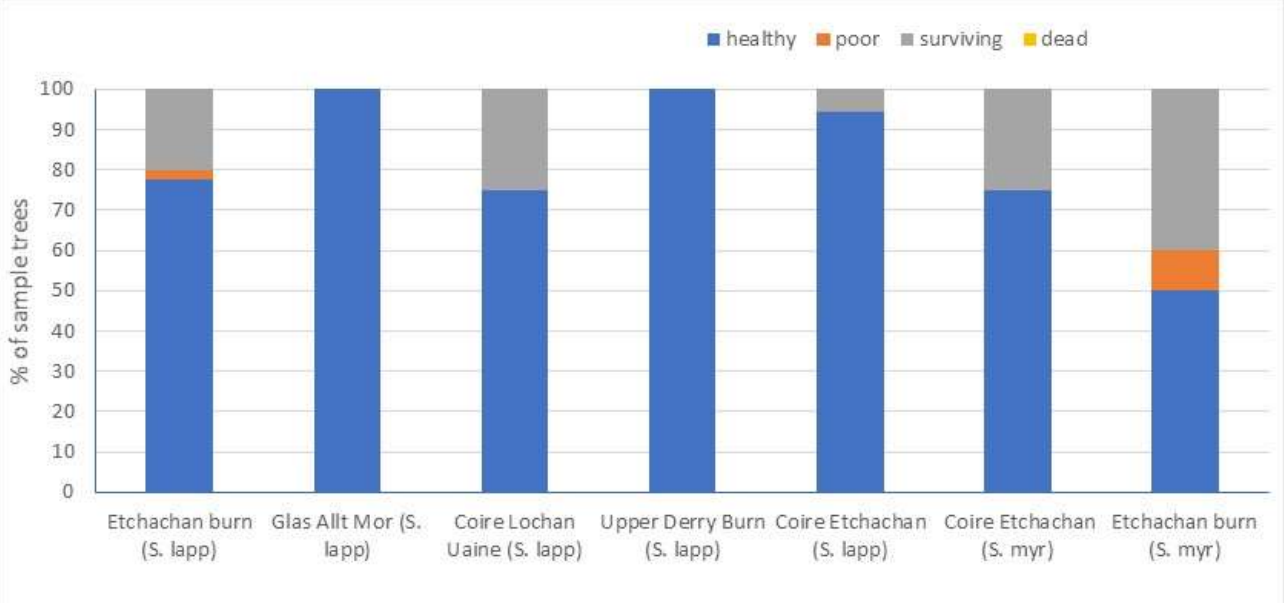


Figure 1: condition of the sample trees recorded in September 2022

If this site is omitted then the mean percentage of trees browsed across the other six planting sites drops to 17.1% (±6.1 SE). In general browsing was higher at the lower altitude more accessible sites (see Figure 2). Deer were the primary browser at the lower altitude sites and mountain hares at the higher altitude sites.

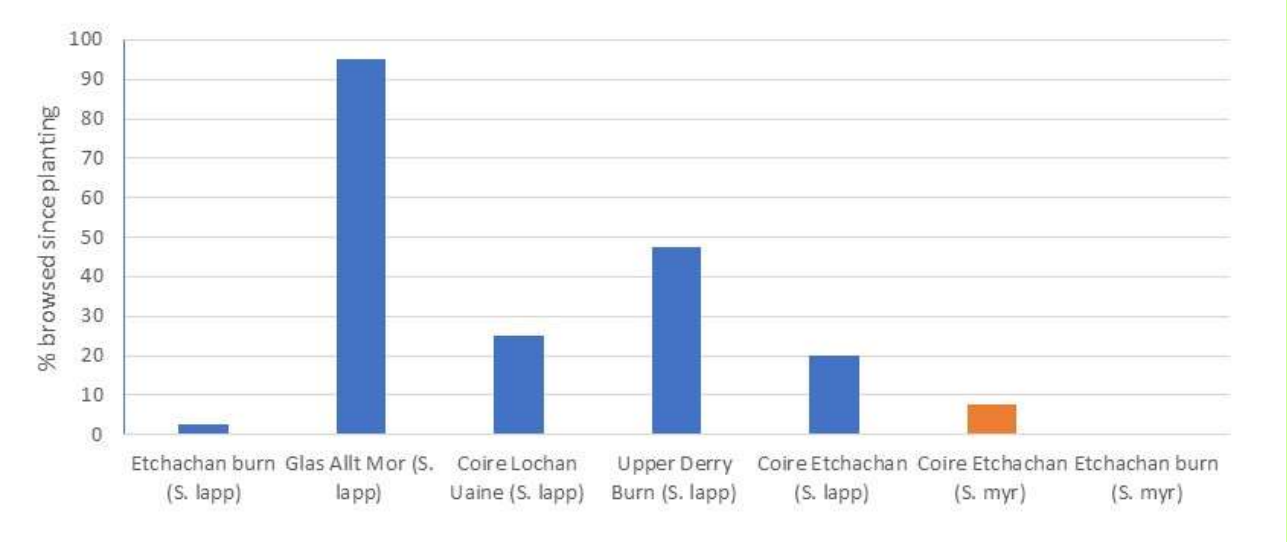
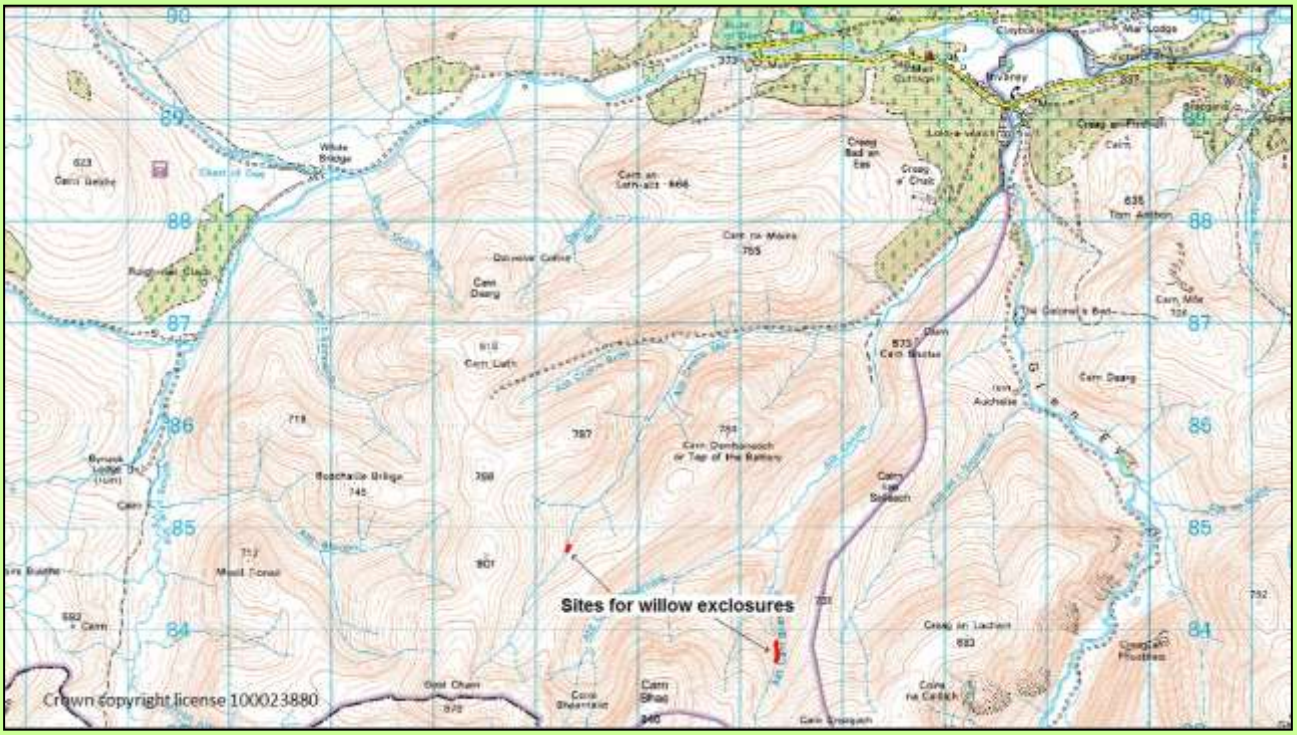


Figure 2: percentage of trees browsed since planting in spring 2021 at each planting site. (*S.myrsinites* in orange)

We felt optimistic after the autumn 2022 monitoring results for these unprotected willows as worst-case scenario we had expected the willows to have had poor survival or be heavily browsed. It is hoped that the levels of browsing experienced can be tolerated and will still allow for growth and survival of the planted willows.

We followed a similar style of planting, in clusters of 50 trees, for 2338 *Salix lapponum* planted into two exclosures in 2022 (Map 2, Table 1 & Photo 14). These enclosures are not within the SAC or

SSSI. The willow planting was also supplemented with downy birch (600 in total) grown on from seed collected at Mar Lodge. These plants are protected from browsers so in theory the chances of success are higher. However, we have also initiated monitoring of a 10% sample of these willows as we are interested in their survival but also to see how their growth contrasts with that of unprotected willows planted at similar altitude.



Map 2: sites of willow enclosures planted 2022

Our initial monitoring in September 2022, four months after planting, showed very positively that all the 200 sample trees were alive and the majority were healthy (Fig 3).

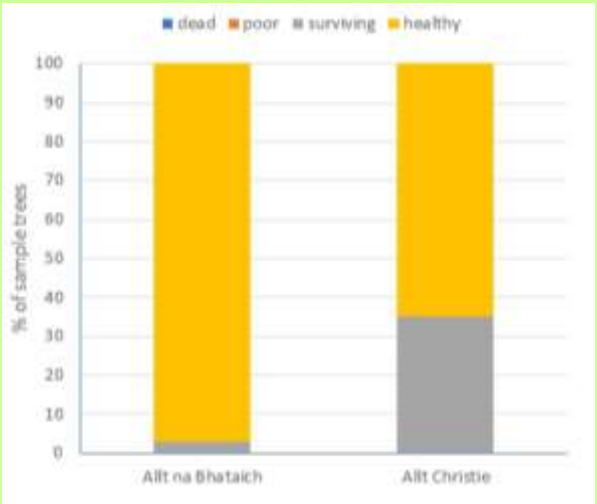


Figure 3: the percentage condition of sample trees within the two fenced enclosures.
Photo 14: willow enclosure for planting spring 2022

Points of interest from our work so far

It was great to see some of the planted willows with catkins in 2021. A few of these were collected and we have recently found out that they are producing viable seed. So the possibility of regeneration from these planted willows is already alive.

Many of the catkins we've collected have been inundated with sawfly caterpillars and generally when this is the case it seems to impact on the viable seed collected from such catkins. In 2022 we turned up the rare sawfly *Euura amentorum.* This record is one of only a tiny handful of records of the species from the UK. Whilst the caterpillars are a positive indication of the invertebrate diversity the willows can support, we are wondering whether the actions of these caterpillars may be compromising the regeneration potential of some willows

What lies ahead…..

The montane willow restoration work will continue over the next few years as we continue to reinforce our existing populations and create new populations in suitable sites across the estate.

For the future we will not have to rely on seed collection for our seed from which to grow on willow plants. In 2019 we gathered cuttings from the majority of *Salix lapponum* and *myrsinites* on the estate. Along with additional cuttings kindly given to us from RSPB Abernethy, Trees for Life has established a seed orchard with 50 clones for *Salix lapponum* and one for *Salix myrsinites* is underway. This should provide us with a good seed supply of suitable genetic diversity to continue our montane willow restoration work at MLE.

It is exciting times for montane woodlands in the Cairngorms. A number of estates have reduced their grazing pressure significantly and also begun similar work on montane willow restoration. Hopefully we can look forward to healthier, better connected montane woodlands in the future and a more natural woodland transition on our previously bare hillsides (Photo 15).

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Photo 15: Pine regeneration creeping up the slopes on Carn Crom at MLE

Shaila Rao, PhD, has worked for 20 years as the NTS Ecologist for Mar Lodge Estate overseeing the ecological monitoring and conservation work. She is particularly interested in woodland expansion and herbivore interactions with woodlands.

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Andrew Painting has been working at Mar Lodge since 2016. An ecologist, writer and avid hillwalker, his book *Regeneration* tells stories of the remarkable work underway to protect and restore Mar Lodge estate for the benefit of people and wildlife alike.

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MWAG visit to Mar Lodge on Tuesday 7th June 2022 – Chair's note

On a day of astoundingly good weather, the group met at the Mar Lodge NTS ranger base before piling into pickups and driving up the estate track through Glen Lui to Derry Lodge. On the way we passed an impressive array of mature Scots Pine forest and pine regeneration marching up towards the summit of Sgor Dubh at 741m.

Setting off on foot up Glen Derry the route took us through exceptional Caledonian pinewood habitat spreading up the hillside (Photo 1a). This area of Mar Lodge is subject to a zero tolerance of deer and the effect on pine regeneration has been remarkable, taking off particularly well in recent years. Walking higher up the majestic Glen, the continuous forest cover made way to more scattered fragments within a mosaic of heather and acid grassland. The large remnant pines are clearly providing a good seed source for a huge influx from the next generation freed from overgrazing pressures. Excellent visibility gave the group a superb view of birch, rowan and juniper emerging on the steeper scree slopes above. Shaila and Andrew pointed out key features up on the surrounding hillsides (Photo 1b), including good sites for tea-leaved willow (*Salix phylicifolia*), and an important area by the Glas Allt Mor burn for high-altitude birchwood, downy willow (*S. lapponum*), small cow-wheat (*Melampyrum sylvaticum*) and twinflower (*Linnaea borealis*).

Photo 1a (left): Glen Derry; Photo 1b (right): Shaila points out key features on Glen Derry slopes

At the top of Glen Derry the group stopped to visit a section along the Coire Etchachan burn where downy birch (*Betula pubescens*) and *S. lapponum* had been planted in 2021 (Photo 2a). It was evident to us that this work has been hugely successful so far – the seedlings were flourishing with no notable browsing damage and even some catkins already developing. The Mar Lodge ecologists will be monitoring growth and survival of tagged individuals on an annual basis, providing useful data to inform other montane scrub restoration projects planned for open hill locations outside of deer fencing. Elsewhere in the South of the estate small exclosures are also in place to protect relict and planted populations where grazing pressures are higher outside of the zero tolerance zone. This multifaceted approach by the NTS highlights that decisions on how to control overgrazing do not have to be binary and depend on location and historical land-use legacies.

Photo 2a (left): Planted downy willow seedling at Coire Etchachan Burn; Photo 2b (right): Natural downy willow at Coire Etchachan Burn

The Coire Etchachan burn site additionally hosts two large and easily accessible mature *S. lapponum* which is an uncommon occurrence in Scotland given that most are restricted to very rocky ground (Photo 2b). I was delighted to see plants in such a comfortable and reachable situation, having plans to revisit Mar Lodge later in the year to collect soil samples to determine fungi community composition within natural montane willow populations.

We broke for lunch at the Hutchison Memorial Hut as the stunning sunny weather continued to hold. There is so much of botanical interest to explore in this location but it was decided that the afternoon would be best spent visiting the relict downy willow population reinforced with planting in 2021 on the steep slopes to the South of the Hut; below Sgurr an Lochan Uaine. The scenery here makes an impressive backdrop composed of the striking cliffs of Creagan a' Choire Etchachan. Such rocky terrain is not for the faint-hearted, so it is testament to the agility and physical abilities of the group that everyone continued at a fast pace up the scree; though of course one could comment that this is because the MWAG are actually in their "natural habitat"! (Photos 3a & 3b).

Photo 3a (left): Downy willow regeneration above Hutcheson's Hut; Photo 3b (right): the MWAG group

On very high ground we were treated to a sizeable population of downy willow on broken outcrops with evidence of some natural regeneration occurring. Similar to lower down the Glen, the reinforced planting near to mature, relict individuals has established well in the last year (cover photo, this issue). All seedlings are from seed collected at Mar Lodge in preceding summers and intended to expand and improve connectivity of remnant populations. The surrounding vegetation also features other delightful upland plants such as goldenrod (*Solidago virgaurea*) and trailing azalea (*Kalmia procumbens*) (Photo 4a), with its stunningly minute pink flowers. Even here, on more fragile montane soils, there are still regenerating pines of some size scattered amongst the heather.

Having climbed the steep slopes we left the montane willow scrub behind and continued on a circular walk south back towards Derry Lodge along the stony ridge of Derry Cairngorm. A smaller sub-group decided to bag a Munro and took the route over the summit while the rest of us traversed around it. In glorious sunshine we experienced nesting ptarmigan, snow buntings, wheatear, and plenty more wind-clipped trailing azalea (*Kalmia procumbens*) (Photo 4a) putting on a stunning flowering display alongside vibrant patches of moss campion (*Silene acaulis*). The weather conditions could not have been more perfect, giving unbroken views towards surrounding Munros including Cairn Toul, Sgor an Lochain Uaine and the mighty Ben Macdui (home to a rather famous high-altitude rowan tree at 1093m!)

Photo 4a (left): trailing azalea (*Kalmia procumbens)*; Photo 4b (right): *Cicerbita alpina*

On the descent down the ridge to we passed NTS footpath contractors undertaking vital work to preserve walking routes and prevent erosion. The descent back down to Derry Lodge took us through another impressive collection of Scots pine and juniper regeneration with a flourishing understory of blaeberry (*Vaccinium myrtillus*) (Photo 5). On the drive back to Mar Lodge some of us stopped to visit one of the conservation planting sites for alpine blue-sow thistle (*Cicerbita alpina*) (Photo 4b) which is astonishingly rare in the Highlands and the subject of careful propagation work at the RBGE. Specially constructed cages are required to inhibit marauding black slugs from reaching the luscious young leaves; demonstrating the many challenges faced from different forms of grazing in conservation management. We also detoured through the mosaic of deciduous and pine woodland at Doire Bhraghad and past a patch of twinflower which had just begun to flower. Visiting such an iconic Caledonian pinewood species was a fitting end to an inspiring Mar Lodge experience for MWAG. We are hugely grateful to Shaila Rao and Andrew Painting for hosting the trip and giving up their time to show us the sights.

Photo 5: Regenerating pine and juniper

PhD research project: Improving outcomes in montane woodland restoration | Sarah H. Watts

Sarah H. Watts - Biological and Environmental Sciences, Faculty of Natural Sciences, University of Stirling.

Supervisors: Prof. Alistair Jump (University of Stirling), Prof. Kirsty Park (University of Stirling) and Dr Nadia Barsoum (Forest Research)

Project Summary

This PhD investigates the influence of abiotic and biotic environmental variables on the survival, growth rates and natural regeneration of montane woodland and scrub in Scotland. Focusing particularly on *Salix lapponum* (downy willow) and *Betula nana* (dwarf birch), the research will form part of ongoing efforts to facilitate the long-term resilience and expansion of the treeline ecotone. Industry outputs will include dissemination via the Mountain Woodland Action Group and recommendations to be incorporated into management plans and Best Practice guidelines for landowners undertaking habitat restoration in the uplands. Academic outputs will include scientific publications and conference presentations.

Background

The research proposal was devised by myself while working as an Ecologist for the National Trust for Scotland at Ben Lawers NNR. It was developed by drawing on my own environmental management experience at the site, but also through discussions with members of the Montane Scrub Action Group, academic researchers in forest ecology and other land managers working on upland habitat restoration. Funding for the research was obtained through a consortium of eight different project partners: University of Stirling, Woodland Trust, Corrour, Scottish Forestry Trust, Macaulay Development Trust, National Trust for Scotland, Forest Research and Future Woodlands Scotland. We have also welcomed discussion with staff from RSPB Scotland and the John Muir Trust. The PhD began in October 2019 and is based at the University of Stirling. It is part-time and therefore expected to be six years in duration; finishing in 2025.

Rationale

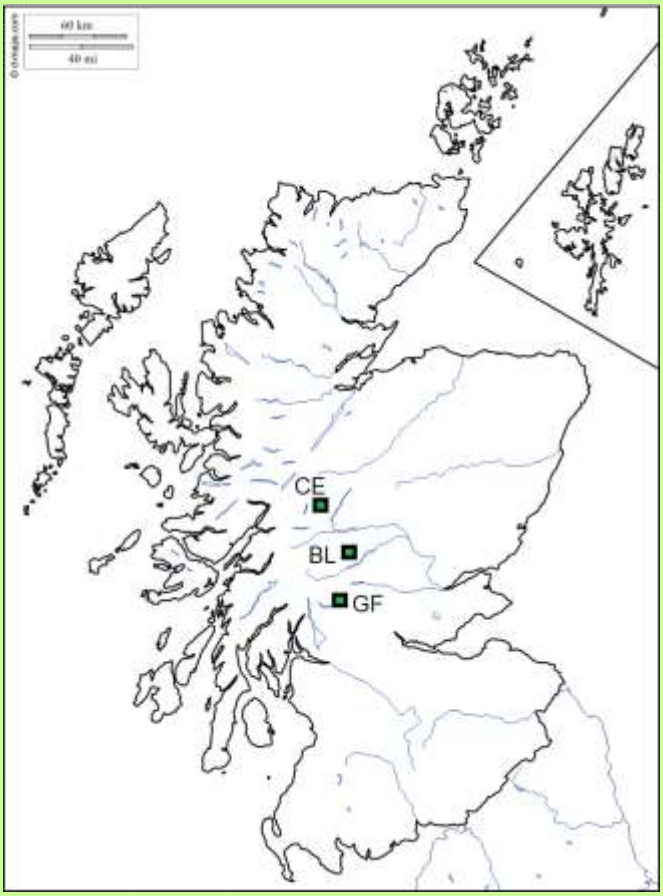
Pioneering montane woodland conservation initiatives have demonstrated restoration potential in Scotland. These have been documented in previous editions of the Scrubbers' Bulletin and include Coire Sharroch (Marriott, 2014), Creag Meagaidh (Scott, 2000), Carrifran (Ashmole & Ashmole, 2008; Adair, 2016; Savory, 2016), Dudreggan (Drury & Hodge, 2014), Kirkton (Holland *et al.*, 2009), and most significantly, Ben Lawers NNR (Mardon, 2003; Mardon, 2008; Watts, 2013; Warwick, 2016). Financial provision for treeline habitat creation is now available under Scotland's Forestry Grant Scheme, providing the prospect of more widespread restoration. The need to develop a contiguous ecotone is recognised, but this can only be achieved in the long term if populations of component species are healthy, resilient and self-sustaining.

Such conservation action requires underpinning scientific research (Scottish Montane Willow Research Group, 2005), which can be promoted by adaptive management; the process of continually improving management by evaluating and learning from system responses to past and current interventions (Bunnefeld *et al.*, 2015). This approach is useful for delivering projects with greater cost efficiency that capitalise on the knowledge gained through previous experiences in woodland creation. New habitat restoration ventures which incorporate applied ecological research also offer the opportunity to explore novel planting techniques while closely monitoring the outcomes. For example, very little is currently known about the mycorrhizal associations of montane scrub species and whether there is a need to integrate symbiotic relationships into tree nursery or outplanting work (Mortimer *et al.*, 2000).

This research will utilise the excellent resource base provided by pioneering conservation work undertaken in Scotland over the last 30 years, but also take advantage of the next generation of projects at new sites to trial alternative restoration methods. This combined approach aims to develop our knowledge of the management actions required to improve the efficiency and outcomes of montane woodland restoration that is applicable to a diverse range of landowners and land-uses.

Field sites

The principal fieldwork locations are Ben Lawers NNR (National Trust for Scotland), Glen Finglas (Woodland Trust) and Corrour Estate (Figure 1).



All three are committed to landscape-scale ecological restoration of upland woodland and scrub habitats, but each is taking a slightly different approach in terms of tree planting, grazing management and the use of fencing.

At Ben Lawers the National Trust for Scotland has been excluding large herbivores from fenced areas for over 30 years and undertaken extensive planting of montane trees, including rarer species such as *Salix lapponum* (downy willow) and *Salix lanata* (woolly willow). The largest exclosure of 180 ha is at Creag an Lochain and features the best example of restored montane willow scrub and upland tall herb habitat in Britain (Watts *et al.*, 2019). Sheep grazing rights for parts of Ben Lawers are held by owners of farms below the head dyke (Mardon, 2003).

Figure 1: The locations of the key field sites for the research: Ben Lawers NNR (BL),Corrour Estate (CE) and Glen Finglas (GF).

The long-term plan for Glen Finglas is to create a dynamic ecosystem of wooded areas and open ground managed as a wood pasture system (Woodland Trust, 2017). Livestock have been reduced to 150 luing cattle and a small flock of approximately 200 adult sheep, while control of red deer maintains densities at 6 per km^2. Over one million trees have already been planted at Glen Finglas in lowland to sub-montane habitats, producing 404 ha of new woodland. A further 20 ha have naturally regenerated, mainly within deer fenced areas. Once tree cover has established it is hoped that this system will become self-sustaining and the enclosed areas can be opened up to grazing animals, blurring these boundaries over time (Woodland Trust, 2019).

Corrour is a privately owned estate in Lochaber covering 23,000 ha from the edge of Rannoch Moor to Glen Spean. A key land management objective is to maintain low grazing pressure by red deer at a level which improves ecosystem health, facilitates natural tree regeneration and allows expansion of native woodland (Swales, 2014; Edwards & Headley, 2018). The most recent helicopter count indicated an average deer density of 0.8 per km^2 across the Estate. Fencing is used only sparingly, and montane tree planting will focus on rare species which do not have large enough populations to regenerate without intervention. The environmental restoration work at Corrour is response driven and underpinned by long-term monitoring (Edwards *et al.*, 2020; Watts, 2020).

Research Questions

The first two sections of the research project will provide information to support conservation managers in decisions regarding the most appropriate habitats and microsites for planting montane *Salix* species and *Betula nana*. Section two will also advise on the use of large herbivore exclosures or alternative grazing managements. Further details on this work and progress so far is given in the expanded sections below on research questions 1 and 2. The third section will investigate the diversity of fungal associations in natural or restored montane willow scrub and explore potential for mycorrhizal inoculation. The fourth section is focused on the factors limiting natural regeneration and research is currently underway into seed dispersal patterns, seed germinability rates and seedling establishment at the planted population of *Salix lapponum* at Ben Lawers (see my other article on natural regeneration – this issue: p. 71).

RQ [1]: How do local abiotic and biotic variables relate to tree health and growth parameters in established, restored *Salix lapponum* montane scrub?

This research will inform future planting schemes by improving our understanding of the most suitable locations for establishing large, healthy and reproductive shrubs. The majority of project time in May-August 2021 was spent undertaking fieldwork at Creag an Lochain, Ben Lawers NNR, to address this section of the project. It had been scheduled for summer 2020 but was postponed due to COVID-19 restrictions. A range of growth measurements were taken from *Salix lapponum* (downy willow) planted at the restoration site during 2004-2006, including height, crown size, inter-annual growth, canopy density, leaf discoloration and foliar insect damage (Photo 1). The following abiotic and biotic variables were also sampled at the level of the individual shrub: altitude, slope angle, soil depth, sheltering feature, vegetation height, % cover of functional plant groups and % cover of the five most abundant vascular plant species within a 30cm perimeter of the shrub (Photo 2).

Photo 1 (top): Sampling restored *Salix lapponum* montane scrub at Creag an Lochain, Ben Lawers NNR | credit: Jane Watts

Photo 2a, 2b & 2c (below): Some of the 55,650 measurements undertaken at Creag an Lochain during summer 2021.

Photo 2a (below left): *Salix lapponum* height. Photo 2b (below centre): associated vegetation height. Photo 2c (below right): most abundant vascular plant species, such as *Geum rivale* (water avens).

This intensive fieldwork required two rounds of data collection because some variables could only be measured in late summer. 1050 individual bushes were sampled, giving a total of 55,650 data points. This achievement was undertaken solely by myself, creating a substantial high quality dataset that is completely free of inter-observer bias. Data analysis is now well underway, incorporating a range of approaches such as linear models, generalized linear models, mixed models, ordination and spatial autocorrelation. The vascular plant species data have been used to calculate cover-weighted Ellenberg indicator values, and several clear trends are already apparent. The initial results suggest that soil fertility has a strongly positive effect on *Salix lapponum* height, while soil wetness and the cover of sedges and rushes has a negative effect.

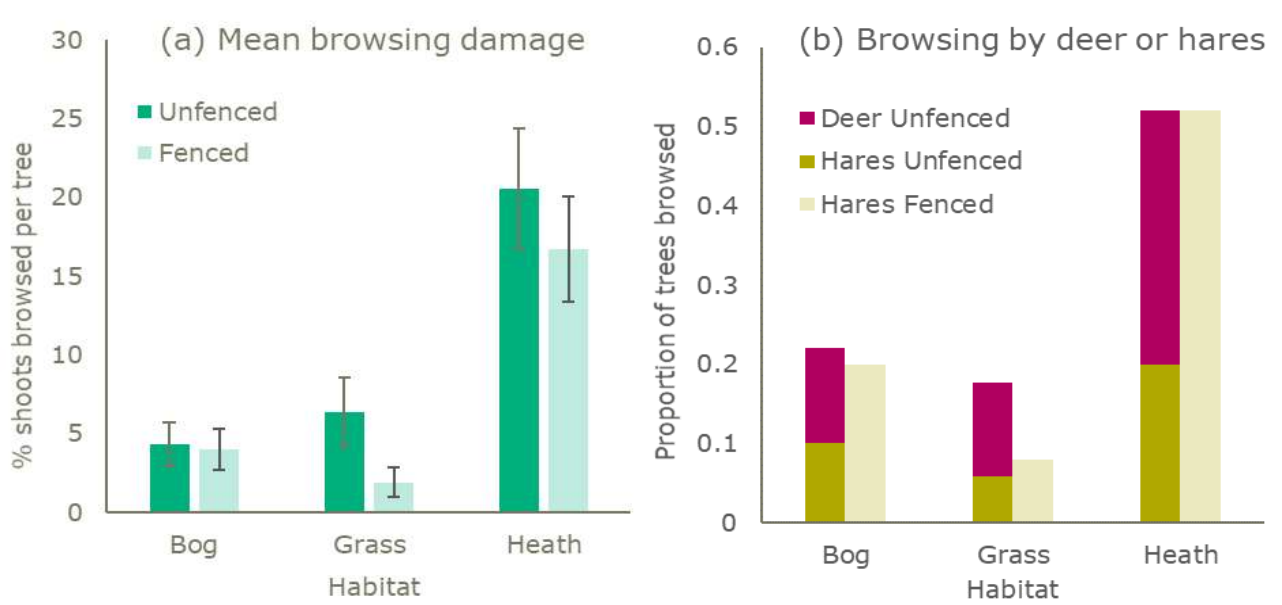
RQ [2]: Can montane woodland restoration projects utilise more planting habitats?

Identifying the most productive planting sites will encourage greater efficiency during restoration work, and this includes exploring the scope for incorporating a broader range of habitat types. Focusing on the plant communities that montane tree species currently associate with in Britain may appear to be the logical choice, but this approach could risk excluding additional opportunities for treeline creation more widely across the uplands. For example, *Betula nana* (dwarf birch) is typically found growing in blanket bog habitats in Britain, but its current range is more restricted than the area it is adapted to, according to ecological niche modelling (Wang *et al.*, 2014). Historical land management practices may be limiting factors for its distribution (Aston, 1984; Dickson, 1984; Scott, 1997), and populations could exist in blanket bog as a refuge from burning or overgrazing by sheep and red deer (de Groot *et al.*, 1997; Gilbert, 2011; Hesling & Taylor, 2015)

We have set up planting trials to investigate variation in survival and growth rates of *Betula nana* in three different upland habitats: acid grassland, dry heath and blanket bog (NVC U5, H10/18 and M19). There is also an additional fenced/unfenced treatment to determine the impacts of low-density deer grazing. Planting has been carried out at three contrasting restoration sites (Figure 1 & Photo 3): Ben Lawers NNR (fenced; planted in 2018), Corrour Estate (fenced vs very low red deer density; planted in 2020) and Glen Finglas (fenced vs medium-low red deer density; planted in 2021). A total of 750 individual *B. nana* saplings were used in the trial, with baseline growth measurements recorded immediately after planting. Survival, growth and grazing damage have been recorded annually and will continue for the duration of the research project.

***Betula nana* planting at:**
Photo 3a (top left): Ben Lawers; Photo 3b (top right): Carrour; & Photo 3c (below): Glen Finglas

A preliminary analysis has been performed for the 300 *B. nana* at Corrour during their first year of growth. In March 2021 71% of trees showed no signs of herbivory, although winter browsing rates were higher within the plots located in the heath habitat (Figure 2a). Damage was also assigned to either hares or deer based on visual appearance. Hares typically make a clean cut through the stem but deer browse gives a more ragged edge. As expected, only hare browse was recorded within the fenced areas, but damage by both animals was observed in the unfenced plots. Only the grassland habitat showed any clear initial difference in browsing levels between unfenced and fenced areas (Figu2b).



Figures 2a & 2b: Initial winter browse measurements from March 2021 recorded on *Betula nana* saplings planted at Corrour Estate in October 2020 in three contrasting habitat types. Error bars = ± 1 standard error.

By October 2021 97.33% of the planted *B. nana* had survived and summer browsing by deer and mountain hares was very low. Only eight trees had perished; all within the unfenced heath plots. New shoot growth was also shorter for the surviving individuals in the heath habitat compared to grassland or bog, but the trees grew equally well within fenced or unfenced planting sites (Figure 3). These results suggest that the *B. nana* planted in the heath plots at Corrour have not performed quite as well as those in the other two habitat types during their first year. However the monitoring will run for several fieldwork seasons and such initial indications may change over time.

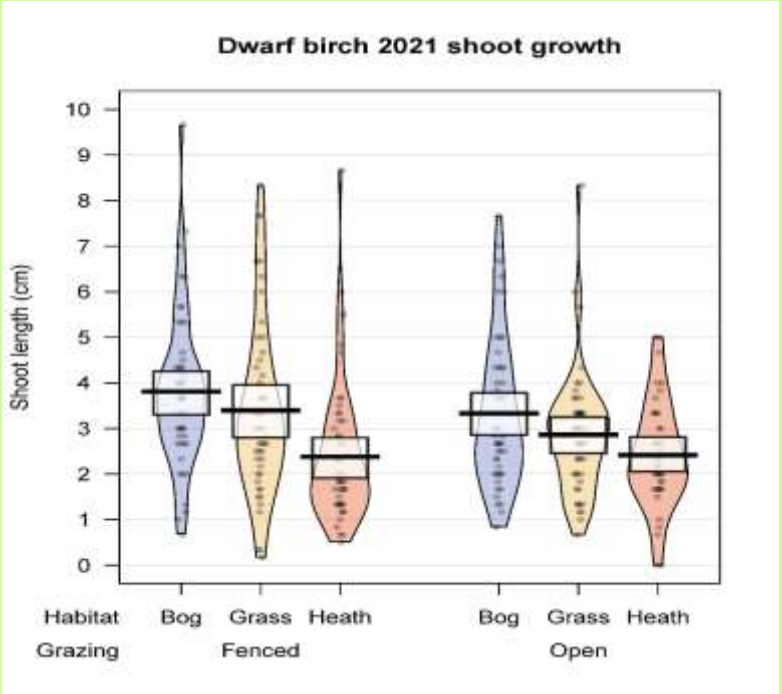


Figure 3: New shoot growth in the 2021 growing season for dwarf birch (*Betula nana*) planted at Corrour in three different habitat types and inside/outside fenced plots. Solid middle bars give the mean value across all trees measured.

Transparent boxes around these bars show the 95% Confidence Intervals. Raw data are given in jitter points, with the coloured "bean" representing their density across the whole range.

Publication

Watts, S.H. & Jump, A.S. (2022). The benefits of mountain woodland restoration. Restoration Ecology, 30(8), e13701. https://doi.org/10.1111/rec.13701

Acknowledgments

I am grateful to the funding provision from all my project partners (listed below), as well as the support and enthusiasm for my PhD project from colleagues at Corrour, including John Sutherland, James Ogilvie and Donald Rowantree. Volunteer assistance for *Betula nana* planting at Glen Finglas was kindly provided by the Woodland Trust and Loch Lomond and the Trossachs National Park.

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Mountain woodland snippets

Mountain birch project

Keep an eye out for birch trees growing above 650m. Reforesting Scotland have launched a citizen science project aiming to gather records of high-altitude birch, which can be submitted on this weblink:

https://reforestingscotland.org/portfolio/mountain-birch-project/

Montane willow genetics across Britain – volunteers wanted

We are looking for assistance with leaf collection from the rare montane willow species downy willow (*Salix lapponum*) and whortle-leaved willow (*Salix myrsinites*). The aim is to gather samples for genetic analysis from a range of sites across Britain, particularly remote and outlying locations. This work will follow on from a collaborative project focused on the Cairngorms with molecular analysis by the Royal Botanic Gardens Edinburgh (see Scrubbers' Bulletin no.14 pp. 36-43). If you would like to help out, please get in touch: s.h.watts@stir.ac.uk

The Benefits of Mountain Woodland Restoration

MWAG's Chair, Sarah Watts, has produced an important new Open Access publication in the Journal *Restoration Ecology* to promote mountain woodland restoration:

Watts, S.H. & Jump, A.S. (2022). The benefits of mountain woodland restoration. *Restoration Ecology* 30(8), e13701. https://doi.org/10.1111/rec.13701

It's a short review paper intended for a wide readership including land managers, conservation practitioners, researchers, the media and anyone interested in the upland environment. The paper emphasises that restoration is about more than just carbon sequestration and has many positive implications for people and wildlife, including nature-based solutions for mitigating the impacts of climate change.

Thanks for reading!

Phil Baarda is an ecologist who has been involved in land management in Scotland for the last couple of decades - the last 15 years of which with Scottish Natural Heritage (now NatureScot).

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