ECOSYSTEMS AND LAND USE POLICY EXCHANGE GROUP (ELPEG) BULLETIN

Issue 14, Nov 2021 (covering June 21 – Mar 22)

CONTENTS

Calicium viride, an example of a species ('pin-head' lichen) associated with ancient woodland, and which are being examined as part of a strategy to understand factors affecting broad community structure and function, as well as individual threatened species (see page 20).

What is this document?

The ELPEG Bulletin provides updates for policy stakeholders on research activities being undertaken within the Biodiversity and Ecosystems, and Integrated Natural Assets work packages of the Strategic Research Programme. The focus is the policy areas of:

- Scottish Biodiversity Strategy; Land Use Strategy for Scotland; Climate Change Plan and Climate Change Adaptation Programme; Scottish Rural Development Plan and CAP greening; Scottish Forestry Strategy.

This edition of the ELPEG Bulletin focuses on work where there has been, or will be, policy-related outputs and stakeholder engagement during the period June 2021 – March 2022. In the Bulletin we outline the work which we believe will be of direct interest to policy makers working in these areas. We also have an ELPEG webpage[1] where you can find past copies of the Bulletin.

The text below includes information on what has happened to date and what is planned until the end of the current programme in March 2022. The researchers involved would welcome any queries, input and discussions concerning their work, and can be contacted directly via the e-mail addresses provided.

With the current Strategic Research Programme ending in March 2022, we would welcome feedback on continuing with the bulletin and/or ELPEG meetings from 2022 onwards. Please send any feedback to Holli.Hunter@hutton.ac.uk.

[1] http://www.hutton.ac.uk/research/srp2016-21/elpeg-ecosystems-and-land-use-policy-engagement-group

ACRONYMS

AECS	Agri-Environmental Climate Scheme
BTO	British Trust for Ornithology
CCAP	Climate Change Adaptation Programme
CCP	Climate Change Plan
CNPA	Cairngorms National Park Authority
CREW	Scotland's Centre of Expertise for Waters
ESCOM	Ecosystem Services Community Scotland
GIS	Geographical Information System
GWCT	Game & Wildlife Conservation Trust
H2020 MOVING	EU project on MOuntain Valorisation through INterconnectedness and Green growth
H2020 PROVIDE	EU project on public goods and bads from agriculture and forestry in Scotland
JNCC	Joint Nature Conservation Committee
LLTNPA	Loch Lomond and The Trossachs National Park Authority
NFU	National Farmers Union
NGO	Non-Government Organisation
RSPB	Royal Society for the Protection of Birds
SASA	Science and Advice for Scottish Agriculture
SBS	Scottish Biodiversity Strategy
SFS	Scottish Forestry Strategy
SG	Scottish Government
SLE	Scottish Land & Estates
SQPV	Squirrel pox virus
SRDP	Scottish Rural Development Programme
SRP	Strategic Research Programme
SWT	Scottish Wildlife Trust

SUMMARY OF POLICY-RELEVANT OUTPUTS

Expected delivery dates are included. As well as specific outputs mentioned, the research will also be discussed with the key policy contacts listed.

Topic	Contact	Policy contacts	Activities	Outputs
Scottish Biodiversity Strategy				
Diversity effects on ecosystem function & resilience (1.3.1, O1.1a).	Alison.Karley@hutton.ac.uk	Cecile Smith (NatureScot), Jacqueline Hughes and Fiona Highet (SASA), David Michie (NFU Scotland), Bruce Pearce (Soil Association Scotland).	Established a network of farm sites for testing diverse crop mixtures.	Innovative Farmers Intercropping Field Lab (**Nov 2020**). Video produced for the Arable Scotland 2021 virtual event. Podcast by James Hutton Limited and SEFARI researchers on the agronomic and environmental impacts of intercropping, relevant to Scottish Climate Change plan update (especially on agriculture and Nitrogen use), COP26 (resilient farming practices) and COP15 (enhancing agrobiodiversity).
Agronomy and nutrition of bere barley (1.3.1, O1.2b).	Tim.George@hutton.ac.uk	Denise A'Hara (SASA), Susie Turpie (SG).	Work to unravel the genetic control of Bere traits.	SEFARI Event and video podcast produced, available on the SEFARI website.

Impacts of genetic factors on reintroduction success of threatened plants (1.3.1, O1.2a).	A.Finger@rbge.ac.uk	Iain Macdonald, Mike Smedley (NatureScot), David Hetherington (CNPA).	Testing growth differences in *Woodsia ilvensis* populations at the nursery and conservation translocations of over 900 genetically mixed *Cicerbita alpina* plants.	Report (**Mar 2022**).
Impact of management regimes on biodiversity, ecosystem function and ecosystem service delivery (1.3.1, O1.3a).	Robin.Pakeman@hutton.ac.uk	Des Thompson (NatureScot), Hamish Thompson (Woodland Trust), Alan Bell (LLTNPA).	Linkages between plant digestibility/palatability, invertebrate species composition and bird foraging (**Mar 2022**).	SEFARI case study
Connectivity metrics for temperate rainforest systems (1.3.1, O3.3).	C.Ellis@rbge.ac.uk	Verity Brosnan (FR), Atlantic Woodland Alliance.	Filming for SEFARI climate change virtual tour linking between climate change and rainforest research (**Jul 2021**) and for training materials on improving habitat quality/connectivity for forestry practitioners (**Sep 2021**).	Contributing to release of virtual tour of climate change research in advance of COP 26) (**Jul 2021**).
Biodiversity and ecosystem service delivery in Scotland's uplands **(1.3.2).**	Davy.McCracken@sruc.ac.uk	Des Thompson (NatureScot), MSP members of Scottish Parliament Rural Affairs, Islands and Natural Environment (RAINE) Committee, National Sheep Association, Farm Advisory Service,	Input provided to a Scottish Biodiversity Programme Advisory Group paper on "*What biodiversity success looks like in 2030 and 2045*" (Aug 2021). Provision of evidence to the Rural Affairs, Islands & Natural Environment committee on Wednesday 22nd September 2021, in answer to the committee's request for suggestions of what they should	Recording of full RAINE Committee evidence session available here (Sept 2021). Recording of NSA webinar available here. FAS importance of peatlands video available here, future of farming in the uplands video available here, webinar on the

			focus their scrutiny on during this parliamentary session (Sept 2021). Participation in a National Sheep Association (NSA) webinar focussed on nature recovery on sheep farms (Sept 2021). Contribution to Farm Advisory Service (FAS) COP26 oriented videos on the future of farming in the Scottish uplands (Sept 2021) and the importance of peatlands (Sept 2021), to FAS webinar on a changing policy climate (Oct 2021) and to a FAS podcast on biodiversity, climate change and COP26 (Oct 2021). Plans being developed with Moredun and SRUC colleagues for an on-farm workshop focussed on assessing ecosystem services in the uplands to take place on 1st February 2022	changing policy climate available here and podcast on biodiversity, climate change and COP26 available here.
Animal diseases – squirrel pox virus (1.3.3, O3.2b).	Colin.Mcinnes@moredun.ac.uk	Scottish Squirrel Group, Scottish Wildlife Trust.	Tracking progression of SQPV (**Mar 2021).**	Data and advice on SQPV provided direct to stakeholders (**Mar 2021**).
Animal diseases – liver fluke (1.3.3, O3.2a).	Philip.Skuce@moredun.ac.uk	Suzanne McIntyre (NatureScot, Nia Ball (SG AH&W).	Liver fluke risk and conservation grazing.	SEFARI case study on liver fluke risk to livestock.

				'Fluke Risk and Conservation Grazing' for Moredun Foundation Newssheet (distributed to ~15000 MF members) (Nov 2021). In discussion with Kirsty Hutchison, NatureScot, regarding incorporation of SEFARI case study & MF newssheet into AECS Guidance (Mar 2021).
System – including ecosystem – resilience: identifying gaps in knowledge for Scotland's biodiversity and ecosystems (1.3.3, O1.1/3).	Ruth.Mitchell@hutton.ac.uk	Duncan Stone, Jeanette Hall (NatureScot).	Assess impact of multiple tree diseases on woodland biodiversity and whether a diversity of tree species provides resilience.	SEFARI case study: Ecological Resilience – woodlands and tree pests/pathogens.
Response of Scots pine provenances to climate-driven weather events (1.3.3, O2.1).	Jenni.Stockan@hutton.ac.uk	Colin Edwards, Bob Frost (Scottish Forestry), Mike Perks (Forest Research).	Results from experimental work communicated to stakeholders (**Feb 2022**).	SEFARI Case Study (Mar 2022).
Consequences of environmental and climate change for ecosystem resilience (1.3.3, O2.2b).	Scott.Newey@hutton.ac.uk	Rob Raynor (NatureScot), Adam Smith, Ross MacLeod (GWCT)	Assess the likely effects of woodland expansion on the distribution of mountain hare habitat (**Dec 2021**). We will use aerial imagery to complete mapping the distribution of muirburn across Scotland and use this to explore the	Complete the write-up of habitat-species distribution model of mountain hares in CNP and research summary (**Mar 2022**).

			distribution of upland herptiles in relation to this management activity (**Mar 2022**).	
Connecting young people with nature in greenspaces (O1.3/1.4-KE3).	Antonia.Eastwood@hutton.ac.uk	Alan Cameroon (NatureScot)	Paper and Blog and how participatory video can create nature connections and pro-environmental behaviour in young people (**Sep 2021**).	Paper and blog on nature connection and greenspace.
Test cases to examine feasibility of offsetting for woodlands (1.3.1, O3.3).	C.Ellis@rbge.ac.uk	David Genny, Jeanette Hall (NatureScot), Atlantic Woodland Alliance.	Data analysis completed, including a targeted focus on rare, niche specialist species (**Dec 2021**).	
Modelling the spread of invasive non-native pests **(1.3.3, O3.1a).**	stephen@bioss.ac.uk	Scottish Forestry	Use of modelling to understand the spread of non-native pests and the effects of control, applied to the pest *Dendroctonus micans* (**Feb 2022**).	Software for use in modelling the spread of invasive non-native pests subject to control. (**Feb 2022**)
Indicators of whole system resilience (1.3.3, O1.3b).	eleanor.watson@moredun.ac.uk	Caroline Carter (NatureScot), CREW.	Completed survey of antimicrobial resistance genes within Scottish grey seals, a marine sentinel species. Trialling novel sequencing technologies to monitor microbial contamination.	SEFARI case study (**Mar 2022**).
Land Use Strategy				
Assessment of habitat/species distributions and impacts	Alistair.Mcvittie@sruc.ac.uk	John Uttley and Mareike Moeller-	Further applications of biodiversity and ecosystem	Case study report on SSEN sub-station development (**Mar 2021**).

of habitat loss and gain (O1.4.2diii).		Holtkamp (NatureScot).	service net gain metrics (**Mar 2021**).	
Natural Asset Register: Data Portal (1.4.1, Oa).	David.Donnelly@hutton.ac.uk	CREW, NatureScot.	Continue to improve the guidance to users and the usability of the site (**Dec 2020**); Expand data sets as they become available (**Mar 2021**).	Natural Asset Register website (**Mar 2021**). Report on creating the data portal (**Mar 2021**).
Cultural Ecosystem Services (1.4.1, WP4).	Katherine.Irvine@hutton.ac.uk	Pete Rawcliffe (NatureScot)	Developing integrative methods for mapping cultural ecosystem services.	SEFARI Case Study on principles for making green infrastructure socially inclusive. Digital stories on Sense of Place values and cultural ecosystem services (see A Story Tour of Glentrool (arcgis.com)). Paper on green infrastructure and social inclusivity. Report to stakeholders in Galloway and Southern Ayrshire Biosphere Reserve on 'favourite places' (available upon request).
Delivering Multiple benefits from our land (1.4.2 & 1.2.4).	Alison.Hester@hutton.ac.uk	Relevant to Land Use Policy Team in Scottish Government	Keynote Presentation: Delivering Multiple Benefits: informing land use decision making" at the Challenging	Conference programme available from here.

			Upland Futures Conference, 5-6 **Oct 2021**.	
Learning from application of natural capital accounting to land-based businesses (1.4.2, Obi).	Kirsty.Blackstock@hutton.ac.uk	Scottish Forum on Natural Capital (Rory McLeod) NatureScot (Mary Christie), Scottish Government (Ross Johnston), SLE (Stephen Young).	Workshop on resilience and vulnerability of Scottish mountain natural assets (with H2020 MOVING) (**Nov 2021**).	Invited presentation to Challenging Upland Futures (**Oct 2021**). Report on Vulnerability assessment across EU mountains (**Mar 2022**). Published outputs on accounting frameworks can be found here.
Opportunities to increase multiple benefits through public-private partnerships (1.4.2, Obi).	Kirsty.Blackstock@hutton.ac.uk	SEPA (Nicola Melville) Scottish Government (Alice Hunter) Rory McLeod (SFNC)	Analysis of partnerships to deliver multiple benefits (in conjunction with 1.2.4 and 2.4.2) being used to support Pilot Regional Land Use Partnerships and other relevant initiatives. Activities include Joint work with H2020 MOVING on upland value chains (**Dec 2021**); RLUP coordination network facilitated discussion(s) with UKRI fellow (Leo Peskett) (**Jun 2021**) and further engagement being planned; SFNC ESCom webinar planned (**Jan 2022**).	Published outputs can be found on our website; partnership report and briefing available now Internal confidential report for RLUPs finalised (**Sep 2021**). Digital Story on Mountain Value Chains (**Dec 2021**). ESCOM webinar planned (**Jan 2022**).

Individual-based connectivity analysis tool (1.4.2, Ocii – new14).	Marie.Castellazzi@hutton.ac.uk	Debbie Basset; Brian Eardley (NatureScot).	Assess connectivity over large areas.	Movement simulator to answer questions about connectivity between habitat patches (**Mar 2022**).
Low emissions land use change scenarios for woodland expansion for multiple benefits using SLM-OT tool (1.4.2, Ocii - new14).	Alessandro.Gimona@hutton.ac.uk; Marie.Castellazzi@hutton.ac.uk	Mary Christie (NatureScot); Peter Phillips (Scot Gov)	Create and assess land use scenarios in Scotland.	Highlight areas where land use change (including woodland expansion) would be beneficial to reduce potential emissions from land (**Mar 2022**).
Climate Change Plan and Climate Change Adaptation Programme				
Response of key pest species to climate change (1.3.3, O2.2a).	Lucy.Gilbert@glasgow.ac.uk	Roger Evans (NHS), Dominic Mellor (RESAS), Nia Ball (CNPA), Nia Ball (SG), Adam Smith (GWCT), Ian Francis (RSPB).	Major synthesis on the impact of climate change on different ticks and tick-borne diseases globally.	Major publication: Gilbert, L (2021) The impacts of climate change on ticks and tick-borne disease risk. *Annual Review of Entomology* 66, 373-388. https://doi.org/10.1146/annurev-ento-052720-094533. Publication submitted for Book in CABI Climate Change Series (**Dec 2021**).
Peatland restoration (1.3.3, O2.2c).	Rebekka.Artz@hutton.ac.uk	Johan Schulten, Claire Campbell (SEPA), Andrew McBride and Andrew Coupar (NatureScot), Russell Anderson, Mike Perks (Forest Research),	Contribution to a major synthesis on water table depth as the major variable affecting peatland greenhouse gas emissions. Study showing the potential for remote sensing of the plant	Major publication: Evans et al (2021) Overriding water table control on managed peatland greenhouse gas emissions. *Nature* 593, 528-522. https://www.nature.com/art

		Neil Cowie, Mark Hancock, Jeremy Wilson (RSPB), Zoe Frogbrook (Scottish Water).	photosynthetic uptake of carbon in peatlands through remote sensing completed (not shown in outputs) and the potential to directly monitor hydrological resilience of peatlands using synthetic aperture radar. Contributed to a major synthesis of the research gaps on the understanding of the contribution of microbiota to peatland resilience. Further synthesis work on hydrological resilience is ongoing, but preliminary data can be made available on request. We also provided both written and oral evidence to the House of Lords Inquiry on Nature-based solutions for climate change: UK peatlands and marine environments (https://committees.parliament.uk/event/5263/formal-meeting-oral-evidence-session/).	icles/s41586-021-03523-1 (**April 2021)**. Lees et al (2021) Using remote sensing to assess peatland resilience by estimating soil surface moisture and drought recovery. *Science of the Total Environment* 761, 143312. https://www.sciencedirect.com/science/article/abs/pii/S0048969720368431 (April 2021) Ritson et al (2021) Towards a microbial process-based understanding of the resilience of peatland ecosystem service provisioning – A research agenda. *Science of the Total Environment* 759, 143467. https://www.sciencedirect.com/science/article/abs/pii/S0048969720369989

SRDP and CAP greening				
New management options for agri-environment schemes (1.3.1, O4).	Robin.Pakeman@hutton.ac.uk	Maria de la Torre (NatureScot), Hugh Dignon (SG)	Survey of new experimental investigation delayed from 2020 (**Mar 2022**).	
Impact of liming (1.3.1, O1.3b).	Scott.Newey@hutton.ac.uk	Jessica Findlay, Alastair MacGugan (NatureScot), Adam Smith (GWCT), Chris Wernham (BTO), Duncan Orr-Ewing (RSPB).	Analyse and write up study of the effects of lime addition (**Mar 2021**).	Research summary on affects of liming on biodiversity and ecosystem function. SEFARI case study Does lime application to pastures offer win-win benefits for food production and biodiversity?
Scottish Forestry Strategy				
Human-environment interactions in the supply of ecosystem services (1.3.2, O1.3).	Antonia.Eastwood@hutton.ac.uk	Louise Sing, Duncan Ray, Bob Frost, Sasha Laing (Scottish Forestry), Dougie Peedle (SWT), Louise Bond, Nicola Melville (SEPA), Jessica Maxwell (Woodland Trust)	Two **online workshops/'local expert panels'** held for Loch Arkaig sites (Woodland Trust and Community Forest) (**Aug 2021**) completing the data collection over 6 sites, and 3 case-studies across Scotland.	Final workshop reports from Loch Arkaig (**Nov 2021**). Research brief and manuscript on perceived impact of woodland interventions across all three case-studies (Glen Creran, Cumbernauld and Loch Arkaig) and six sites (**Feb 2022**).
Woodland management and digital storytelling **(1.4.3, Oc)**.	Katrina.Brown@hutton.ac.uk Antonia.Eastwood@hutton.ac.uk	Arthur Keller and Ivan Clarke at NatureScot. Will Boyd-Wallis, Andy Ford (CNPA).	Comparative analysis of adaptive management in urban and rural woodlands.	Research brief on adaptive management in rural and urban woodlands.

			Creation and testing of video storymap of woodland expansion in the Cairngorms National Park.	New video stories collected and embedded in storymap (**Nov 21**) ready for testing in stakeholder workshops (**Jan 22**).
Impacts of tree pests and diseases - risk assessment for service provision (1.3.3, O3.1a).	Ruth.Mitchell@hutton.ac.uk	Duncan Stone, Jeanette Hall (NatureScot)	Two SEFARI case studies and two peer review papers published.	SEFARI case study: Ecosystem resilience – woodland establishment on heather moorland and carbon budgets. SEFARI case study: Ecological Resilience – woodlands and tree pests/pathogens. Mitchell et al (2021) Identifying substitute host tree species for epiphytes: The relative importance of tree size and species, bark and site characteristics. Applied vegetation science, DOI: 10.1111/avsc.12569 Mitchell et al (2021) Functional and ecosystem service differences between tree species: implications for tree species replacement. Trees Structure and Function, 35, 307-317. DOI

				10.1007/s00468-020-02035-1
Using social innovation to deliver multiple benefits in forestry (1.4.2, Obiii).	Maria.Nijnik@hutton.ac.uk	Bianca Ambrose-Oji (Forest Research), Richard Murray, Heather McCabe (SG), Matt Smith (JNCC) Andy Ford (CNPA), Marc Metzger (ESCOM).	Developed a framework to identify the role of social innovation for sustainability transformation. Explored Reconstructive Social Innovation Cycles in Women-Led Initiatives in Rural Areas.	Talks given at the Earth System Governance (**Sep 2021**) at the IUFRO Conferences (**Oct 2021**). UN IMPRO lecture delivered **(Jul 2021).**

SCOTTISH BIODIVERSITY STRATEGY

This work is aimed at supporting delivery of the Scottish Biodiversity Strategy. It involves studies examining the ecology of keystone species of conservation concern, both native and non-native (including pests and diseases), as well as the relationships between biodiversity, people and the delivery of ecosystem services. It also includes work helping support delivery processes for the SBS, including for example the development of Ecosystem Health Indicators, or development of a National Ecological Network for Scotland.

The underlying **mechanisms linking biodiversity and ecosystem service delivery** are being explored through focussed experimental studies (1.3.1, O1.1a).

We have published a research paper based on our 2017 experimental studies. These show that the benefits of increasing cultivar diversity in terms of weed and disease suppression are maintained under drought conditions. However, the response of aphids to the combination of diversity and drought was much more complex, demonstrating that the benefits of biodiversity are not constant. In addition we published a review paper exploring the role of beneficial plant-plant interactions in driving biodiversity-ecosystem function effects in crop systems, discussing in

Building on our network of farm sites established in 2020 for testing diverse crop mixtures in commercial settings, we have monitored and sampled from 19 on-farm mixture trials. These datasets are being used to develop and pilot an open science data platform for stakeholders in farming and education, and to support key messages in dissemination activities about efficient resource use, agrobiodiversity enhancement and environmental resilience (**Dec 2021;** audience: SG, academics, land managers, policy; Alison.Karley@hutton.ac.uk).

Photo: Diverse forage crop mixtures.

Detailed studies continue to **examine the genetic resource available within traditional bere barley landraces**, including assessing the growth of different landraces under a range of environmental conditions and producing crosses between Bere barley and commercial cultivars to unravel the genetic control of useful traits (1.3.1,

O1.2b). Research so far has shown that extant barley landraces selected over many generations on marginal soils have adapted to tolerate limited micronutrient availability and harbour some pathogen resistance. Field trials in 2018 demonstrated that there is significant variation in manganese efficiency in the progeny of a cross between Bere barley and an elite cultivar Irina and this was confirmed in an advanced cross population in 2020 and 2021. In addition, a field trial in 2019 assessed the performance of Bere barley lines in comparison to the industry recommended list for spring barley. These findings form the basis of letter to Nature Plants, which explains the value of utilising the diversity in landraces.. In 2020/21 we continued to unravel the genetic control of the unique Bere traits as work began on the genomics of the physiological mechanisms involved when an EU Marie Curie Fellowship building on the RESAS work, started in August 2020. In 2021 the work also extended our understanding of response of the Bere landraces to acidic marginal soils on mainland Scotland and as a source of plasticity trait for drought tolerance. The latter findings are being used as preliminary data in a proposal to BBSRC for funding. The culmination of the current programme of work will include the production of promotional videos and a stakeholder event to be held in Orkney in June 2022. (**Nov 2021**; intended audience: SG, academics, land managers; Tim.George@hutton.ac.uk).

Photo: *Cicerbita alpina* translocation site at Mar Lodge with each plant protected by a vole cage.

Understanding the **impacts of genetic factors on reintroduction success** is critical for the conservation of threatened plants and animals (1.3.1, O1.2a). Over 900 genetically mixed *Cicerbita alpina* plants have been bulked up, grown from seed and monitored in the nursery over the past years. These plants have now been planted out into five new sites, two at high altitude (~800m asl) at Glenfeshie, two at low altitude (~400m asl) at Mar Lodge and one site out with the species natural range in Scotland at Glenlochay (~400m asl). These conservation translocations will serve as safe sites where the species can grow and hopefully expand and will also help to understand whether genetic rescue is possible for *Cicerbita alpina*. Growth differences have been recorded for different *Woodsia ilvensis*

provenances in the nursery and data analysis will explore whether differences can linked to genetics or provenance (**Mar 2022**; audience: SG, NatureScot, academics; A.Finger@rbge.ac.uk).

The **impact of management regimes on biodiversity, ecosystem function and ecosystem service delivery** (1.3.1, O1.3a) are being examined in upland ecosystems. A manuscript has been published that shows that the mosaic of vegetation communities at Glen Finglas has been remarkably stable in terms of their functional characteristics despite the large shifts in management (including tripling numbers or complete removal of sheep) . However, a further publication has shown that removing grazing had the highest impact on species replacement, whilst increased grazing was closest to maintaining the original species complement. However, the increased offtake associated with increased grazing led to a degree of homogenisation as grazing tolerant species associated with preferred communities increased in the unpreferred ones. The work of the whole long-term project has been summarised in a SEFARI case study. The focus of the work to investigate how management affects the linkages between plant digestibility/palatability, invertebrate species composition and bird foraging has moved on to characterising the quality of plants and invertebrates as food (**Mar 2022**; audience: SG, NatureScot, academics; Robin.Pakeman@hutton.ac.uk).

Connectivity metrics for temperate rainforest systems (1.3.1, O3.3) have been presented as a key climate change adaptation option for biodiversity, in a SEFARI-funded film that formed part of a virtual tour in advance of COP26. Filming is also partly complete for the provision of additional training materials for forest operational staff, explaining how non-sensitive woodland sites might be managed to improve biodiversity outcomes and offer increased connectivity across the landscape. A first site visit focussed on high biodiversity value sites in western Scotland, and a second visit scheduled for November will examine biodiversity interventions for production forest in the Scottish borders. (**Jan 2021**; audience: land managers; C.Ellis@rbge.ac.uk).

Animal diseases play a regulatory role in, and can threaten, Scotland's natural environments. Work within the SRP (1.3.3, O3.2b) examines the role of squirrelpox virus (SQPV) in the replacement of native red squirrels by invasive grey squirrels. Researchers provide blood testing as required by SWT and other landowners to track the prevalence of squirrelpox virus in grey squirrels and therefore the potential threat to red squirrels. Data and advice on the general problem of SQPV and recommendations for animal and disease management will be provided to appropriate stakeholders (**Mar 2022**; audience: SG, NGOs, agencies; Colin.Mcinnes@moredun.ac.uk).

We continue to work with the local NatureScot Project team and the Wildfowl & Wetlands Trust, monitoring livestock grazing on selected saltmarsh (merse) habitat on the Solway Firth, home to Scotland's only breeding population of natterjack toads (1.3.3; 1.4.3). Conservation grazing is required to maintain the optimal habitat for toad feeding and breeding but brings with it a potential risk to the livestock from infection with liver fluke, which can cause significant health and production impacts in both sheep and cattle. There was a legacy of the hot dry summer of 2018, in that potential fluke intermediate host snails proved hard to find this season, but the New Zealand Mud Snail dominated. This species has been shown to harbour liver fluke stages, but those collected and analysed proved to be negative for fluke by DNA-based testing. We also progressed some lab-based pilot studies, which demonstrate that liver fluke and eggs did not hatch well in high salinity Solway water, suggesting the risk of snails becoming infected on the merse (saltmarsh), from fluke eggs deposited by infected livestock, is actually quite low. This work has been summarised in a SEFARI case study (**Mar 2021**; audience: SG, agencies, NGOs, land managers, farmers; Philip.Skuce@moredun.ac.uk).

The **resilience of ecosystem foundation tree species to environmental and climate change** and how this is affected by provenance and genotype (1.3.3, O2.1) is being investigated using native Scots pine trees in a long-term experiment. We have demonstrated that associated insect and fungi with pine trees is linked to provenance. A pilot study on the effect of summer drought showed differential responses in growth and mortality according to provenance. A large-scale late frost tolerance experiment was conducted in Mar 2021 and monitoring is ongoing to assess who trees of different provenances respond. Data from across all six years of the SRP is being analysed to produce four research papers and a SEFARI Case Study on the effects of provenance and genetic variation on the growth and phenology of Scots pine (**Feb 2022**, audience: agencies; jenni.stockan@hutton.ac.uk).

Photo: Aberdeen University students visit the Glensaugh pine nursery.

Research will continue to explore **the consequences of environmental and climate change for ecosystem resilience** (1.3.3, O2.2b) by focussing on the possible redistribution of high impact and umbrella vertebrate species. Mountain hares are a species of high conservation concern in Scotland. In collaboration with the GWCT we will complete the species distribution

modelling to describe the distribution of mountain hares on mainland Scotland in relation to biophysical and land use characteristics, and explore how land use change, using wood land expansion as an example, may affect the distribution of mountain hares. (**Sep 2022**; audience: NatureScot, National Park Authorities, NGOs, agencies; Scott.Newey@hutton.ac.uk).

New research on grouse moor management is exploring the **extent, distribution and intensity of muirburn**. We will use the maped the distribution of muirburn from aerial imagery to explore the distribution of upland herptiles in relation to muirburn (**Mar 2022**; NatureScot, Scott.Newey@hutton.ac.uk).

Research is developing specific **test cases to examine feasibility of offsetting for woodlands** (1.3.1, O3.3). Analysis is complete to suggest that landscape context is important for woodland species composition and richness, as opposed to woodland age; however, additional analyses are now examining the specific case of rare and threatened species, to assess whether their response requires separate consideration. The study therefore explores a tension between broad aims focussed on habitat-scale conservation of community structure and function, and the more specific remedial conservation that might be required for individual threatened species (**Dec 2021**; audience: SG and agencies, land managers; C.Ellis@rbge.ac.uk).

Software has been developed for modelling the spatial spread of invasive non-native pests. The modelling can provide insights into the impact of control measures and the extent of the latent distribution of the pest, and is being applied to the forest pest *Dendroctonus micans* (**Feb 2022**; intended audience: academics, agencies; stephen@bioss.ac.uk).

Grey seals can act as an important indicator species of environmental contamination. We have monitored carriage of bacterial pathogens of potential anthropogenic origin and antimicrobial resistance genes by seals sampled in areas close to large human populations and more remote sites around Scotland (1.3.3, O1.3b). We are also currently assessing cutting-edge DNA sequencing technologies as a tool to monitor microbial contamination of this species. We aim to summarise the main findings of this research within a SEFARI case study (Mar 2022; audience, NatureScot, Marine Scotland, CREW; Eleanor.Watson@moredun.ac.uk).

LAND USE STRATEGY FOR SCOTLAND

This research is designed to support the delivery of the Land Use Strategy 2016-21, including the vision, objectives, principles and particularly the policies 1, 2, 4, 6, 7, 8 and 9; and the proposals 1, 3 and 5.

James Hutton Institute response to Scottish Government **consultation** on Scotland's Land Use Strategy. *Published on Scottish Government Consultation Hub.*

A comprehensive report on the activities required to produce the **Natural Asset Register: Data portal** (1.4.1a) has been produced. This report describes the decision processes and the various steps required to achieve successful implementation of the tool. The report also lists and includes links to the various outputs which were part of the project and reflects on what has been achieved and options for future funding (**Mar 2021**; intended audience: SG and agencies David.Donnelly@hutton.ac.uk).

Insights from several recent and ongoing parts of the SRP, including 1.4.2 & and 1.2.4, were drawn together in a presentation by Professor Alison Hester "Delivering Multiple Benefits: informing land use decision making" at the Challenging Upland Futures Conference, 5-6th October 2021. The talk integrated work from across Theme 1, CXC and PAWSA projects to present an overview of some of the latest research and tools to inform land use decision-making for multiple benefits, The slides are available in pdf from Alison.Hester@hutton.ac.uk.

As part of investigation of methods for **mapping cultural ecosystem services** (O1.4.1, WP4), interviews around sense of place were conducted with residents of the Galloway and Southern Ayrshire UNESCO Biosphere community of Glentrool. The interviews were filmed and edited to produce 2-7 minute digital stories. These stories were incorporated in an ArcGIS StoryMap capturing local knowledge about the history, landscape and special places in the area (see A Story Tour of Glentrool (arcgis.com)). A draft prototype map testing the applicability of methodology for ecological aspects of aesthetics as a cultural ecosystem service was published on the National Assets Register and a prototype spatially-explicit map of spiritual experiences is under development. Further work will compile insight on the novel methods utilised to map and understand the less tangible cultural ecosystem services (**Mar 2022**; intended audience: agencies and public; Katherine.Irvine@hutton.ac.uk).

Case studies of **Natural Capital Accounting** (1.4.1, Oc) initially focused on agriculture and forests have been completed. These utilised primary valuation studies on forest recreation (pan European, with Scottish element funded by the SRP) and water quality and biodiversity impacts of agriculture (funded by H2020 PROVIDE). A case-study on urban green space has been completed. This utilised both existing valuation data and a primary valuation study covering biodiversity and recreation. Further in-depth analysis of the primary valuation data (report available) and how capabilities impact on greenspace use (paper in preparation) have also been completed. Regionally disaggregated marine natural capital accounts were also completed during year 5 (**Mar 2021**; intended audience: SG

and agencies; Alistair.McVittie@sruc.ac.uk).

Learning from application of natural capital accounting to land-based businesses (O1.4.2bi). Further work has been completed on distribution of natural capital (working paper now available), Research on opportunities to invest in natural capital (with MDT fellowship) is ongoing a report is due in **autumn 2021**. A workshop on vulnerability of Speyside Whisky Value Chain to climate impacts on water will take place **Nov 2021**, with the report due **spring 2022**. Kirsty.Blackstock@hutton.ac.uk).

An Institutional Analysis and Reconfiguration Framework with identification of the role of social innovation for sustainability transformation was developed and tested (three journal articles published). Impacts of social innovation in the context of community forestry on the sustainable development of rural communities were assessed (three other journal articles published) (1.4.2biii). Findings were e.g., that community forestry in Scotland leads to positive impacts in the environmental, social, economic and institutional/ governance domains. Specific impacts were increased community cohesion, sense of place and well-being, local employment opportunities. A primer on social innovation in rural areas added value to H2020 AgriLINK). Reconstructive Social Innovation Cycles in Women-Led Initiatives in Rural Areas were explored (journal article published). The *marketplace stall on social innovation* in rural areas was organised, and Social innovation in marginalised rural areas *Video presented* at the EU Rural Vision Week, Imagining the Future of Europe's Rural Areas (**Mar 2021**). Invited talks were given at the Earth System Governance Community Conference **(Sep 2021**) linking this RESAS work to H2020 SIMRA and DESIRA, and at the IUFRO Conference (**Oct 2021)**). IMPRO UN lecture was delivered **(Jul 2021).** Maria.Nijnik@hutton.ac.uk.

Opportunities to increase multiple benefits through partnership working (1.4.2bi). The findings from selected four case studies in Scotland and England to consider how catchment partnerships combine public policy and private sector mechanisms to deliver multiple benefits (in conjunction with WP 1.2.4) have been developed into a journal paper (submitted). The insights were used to support peer learning between the five pilot regional land use partnerships in (**Jun 2021**); and a further webinar and briefing is planned (**Jan 2022**) run as part of the SFNC Ecosystem Service Community Working Group, linking to other initiatives such as Riverwoods. Finally, working with H2020 MOVING project and 2.4.2 (Rural Industries), we are producing a digital story about mountain value chains; and have convened a local community of practice to help us research the sustainability of the Speyside Whisky value chain (audience: SG, agencies and NGOs; Kirsty.Blackstock@hutton.ac.uk).

LEMMINGS, an Individual-based movement simulator, has been created to assess habitat connectivity and applied to assess some of the consequences of land use change scenarios for the whole of Scotland (O1.4.2cii-new14). Analysis will continue throughout 2021 including further low emissions and Shared Socioeconomic Pathways scenarios (**Mar 2022**; audience: NGOs, agencies; Marie.Castellazzi@hutton.ac.uk).

Recommendations for landscape-level adaptive management for ecological, economic, and social outcomes. We have made fourteen specific recommendations based on: understand the situation, direct stakeholders, and shared purpose; focus on the social relationships of landscape-level management; and assess ecological, economic, and social outcomes at every step of the adaptive management cycle. (**Oct 2020**; audience: SG and agencies; Kit.Macleod@hutton.ac.uk).

CLIMATE CHANGE PLAN & ADAPTATION PROGRAMME

This research addresses some of the major challenges arising from the CCP and CCAP, including understanding how climate-induced land-use change might alter the delivery of climate-relevant ecosystem services such as soil carbon storage and forestry. It will also look ahead to support development of the next Scottish Climate Change Bill.

A land use change scenario tool for multi-benefits (SLM-OT tool - Sustainable Land-use Management Options Tool) has been created to facilitate the creation of scenarios for multiple Ecosystem Services (O1.4.2cii-new14) (**Mar 2021**). The tool will be used to develop further low emissions scenarios, particularly regarding to woodland expansion. They will then be assessed for potential emissions savings (**Mar 2022**; audience: NGOs, agencies; Alessandro.Gimona@hutton.ac.uk, Marie.Castellazzi@hutton.ac.uk).

To understand the **range shifts and resilience of key pest species to climate change** we first developed models and risk maps to predict ticks and Lyme disease (the most prevalent vector-borne disease in the northern hemisphere) under climate and other environmental change scenarios (1.3.3, O2.2a) across Scotland and Europe (published in *Journal of the Royal Society Interface* and in *Environmental Health Perspectives*) (Figure 1). We also published a major synthesis for the journal *Annual Review of Entomology* (Impact Factor 11.8) on the response and resilience of ticks and tick-borne diseases to climate change globally. We are now synthesising Scotland-specific direct and indirect climate change impacts, (including green recovery schemes) on ticks and Lyme disease for publication in

a book published by CAB International, edited by Pat Nuttall (audience: NatureScot, NHS, land-managers; Lucy.Gilbert@glasgow.ac.uk.

Peatland systems are a key component of the natural environment's contribution to climate change mitigation.We contributed to major data synthesis work showing that the average annual water table explains more than half of the variation in annual net carbon dioxide and methane emission from peatlands (see outputs). We also developed a method to estimate soil surface moisture and water table depth in peatlands, using synthetic aperture radar (see outputs). These strands of research are still ongoing, with further major outputs in both areas expected by the end of the current SRP; **Mar 2022**), Rebekka.Artz@hutton.ac.uk).

Many projects listed under other headings include an aspect of climate change adaptation including: **understanding the role of biodiversity in delivering ecosystem resilience** (1.3.1, O1.1a)**; woodland supply of ecosystem services** (1.3.2a)**; adaptive management approach to facilitate the evaluation and coordination of measures to deliver multiple benefits** (1.4.3a); **assessing multiple land use options** (1.4.2cii)).

SRDP AND CAP GREENING

This research is designed to support the implementation of the Scottish Rural Development Programme (2014-20) in particular, the implementation of the Agri-Environment Climate Scheme management and capital options and the Forestry Grant Scheme. However, research may also inform the implementation of Areas of Natural Constraint, beef efficiency scheme, and the advisory services plus we support and contribute to the Scottish Rural Network.

Photo: Surveying grassland sward diversification mixtures.

Using information from our assessment of gaps in the current agri-environment schemes we have developed an experimental study to assess a **new management option for agri-environment schemes** (1.3.4, O2). An experiment was established in spring 2018 to assess the long-term potential and cost-effectiveness of grassland

sward diversification to improve foraging resources for pollinators and increase the digestibility of forage for livestock. This work will continue through into summer 2021, as sampling wasn't possible in 2020, but initial analysis shows the medium-term persistence of some of the sown species (**Mar 2022**; intended audience: SG and agencies involved in AECS implementation; Robin.Pakeman @hutton.ac.uk).

The research project on solutions to provide **multiple benefits through innovative and collective approaches to water management** (1.4.3d) is now coming to an end a stakeholder workshop scheduled in the autumn to discuss the key findings of the project (**Dec 2021**) (audience: agencies, local authorities; Laure.Kuhfuss@hutton.ac.uk).

SCOTTISH FORESTRY STRATEGY

This research aims to support the implementation of the Scottish Forestry Strategy, including the vision, objectives, outcomes and themes, particularly climate change, biodiversity, environmental quality, community development and access and health. The research will also provide evidence, as requested for the SFS review (as highlighted in the Land Use Strategy and Programme for Government).

Woodland systems, including in urban areas, continue to be the focus of work considering how management interventions (e.g. restoration, public engagement), and their effect on the relationship between people and the environment, can alter the co-production **of ecosystem services** (1.3.2, O1.3).

We have now completed our data collection for all three woodland case-studies; Glen Creran, Loch Arkaig and Cumbernauld. Online workshops were held at the third of three case studies across Scotland in August 2021, with local participants in Lochaber (Loch Arkaig Pine Forest) using a scenario-based approach to discuss how woodlands can provide multiple benefits for nature, people and communities. Issues such as support for increasing public engagement opportunities while being sensitive to concerns about potential over-tourism were highlighted, as well as the value of woodlands for biodiversity and as a place for mental restoration and spirituality, and concern for creating opportunities for economic sustainability and community benefits. Workshop reports from Glen Creran and Cumbernauld are available, with the ones from Loch Arkaig due out very shortly (Nov 2021). A cross-site analysis of the impacts of different woodland interventions across the three case-studies and sites is currently underway with a research brief and manuscript planned for **Feb 2022** (1.3.2). The paper on citizen social science approaches to monitoring impacts of management interventions has now been published as

has the article on connecting young people with nature using participatory video (June **2021**); audience: land managers and policymakers; alice.hague@hutton.ac.uk and Antonia.Eastwood@hutton.ac.uk).

Changes in carbon storage following tree planting (1.1.2) have been assessed on experimental plots on heather moorland where birch and Scots pine were planted 12 years ago and where birch were planted 38 years ago. Compared to the heather control plots carbon was lost from the soil where the trees were planted and the gain in above ground carbon (tree biomass) was either less than or only equalled the below-ground losses. Thus, on decadal timescales, tree planting on these organic rich soils, did not contribute to the meeting net zero carbon emissions target. The results are available as paper here and a SEFARI case study here (**May 2021**; audience: SG, agencies, land managers; Ruth.Mitchell@hutton.ac.uk).

The **impacts of tree pests and diseases** are being considered. If a tree species declines due to disease, they are often replaced by different species. It is important to know how these replacement tree species will influence both ecosystem functioning and the biodiversity supported, i.e. how similar they are to the diseased tree species (1.3.3, O3.1a). Utilizing botanic gardens across the UK, each of which contained a range of tree species we assessed differences between tree species in their functioning and biodiversity supported. We found that tree species differed in their functioning (decomposition, nutrient cycling, soil properties) at the scale of an individual tree which will result in differences in ecosystem service provision. Replacement trees for diseased trees should take account of functional differences, paper available here. We also found that assessing similarities between tree species in their bark characteristics did not provide a good indication of the similarity in the lichen and bryophyte communities they supported, paper here. Thus, the epiphytes hosted by a wider range of tree species should be recorded to allow an assessment of their suitability as replacement trees and hence aid management decisions on replacement trees following tree loss (**May 2020**; audience: SG, agencies, land managers; Ruth.Mitchell@hutton.ac.uk).

Woodland management and digital storytelling (1.4.3, Oc). The prototype digital storymap featuring a multiplicity of video-based narratives and experiences relating to actual and potential woodland expansion in the Cairngorms National Park – enabling exploration of opportunities and barriers for meeting multiple land use objectives - has been prepared for testing through stakeholder workshops. A methodological approach for conducting the workshops has been drafted and meetings set up with key stakeholder representatives to receive feedback on both the storymap and the proposed approach for stakeholder engagement

(**Dec 2021**; audience: agencies; Katrina.Brown@hutton.ac. uk).

Approaches that reconcile **woodland expansion with other land use priorities** (O1.4.3c). We are now conducting a comparative analysis of adaptive management between urban and rural systems with a research brief planned for Feb 2022. We are also preparing a synthesis of our research on inclusive greenspace access and use. This will be in the form of an infographic and research brief (**Feb 2022**; audience: NGOs, stakeholders, policy makers). Antonia.Eastwood @hutton.ac.uk).