ECOSYSTEMS AND LAND USE POLICY EXCHANGE GROUP (ELPEG) BULLETIN

Issue 9, May 2019 (covering Oct 2018 – Oct 2019)

CONTENTS

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. 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 October 2018 - October 2019. 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 up until October 2019. The researchers involved would welcome any queries, input and discussions concerning their work, and can be contacted directly via the e-mail addresses provided. Given the post 'Brexit' context, we would particularly welcome any insights and suggestions from you regarding how and when work may need to be adjusted to take account of changes in policy objectives and/or policy delivery mechanisms, including funding availability.

Please do get in touch with the person named for the area to find out more information.

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

SUMMARY OF POLICY-RELEVANT OUTPUTS

(Expected delivery dates are included)

Topic	Contact	Activities	Outputs
Scottish Biodiversity Strategy			
Diversity effects on ecosystem function & resilience (1.3.1, O1.1a)	alison.karley@hutton.ac.uk	Explore in more detail the effects of diversity in service delivery **(Mar 2019).**	Research summary **(Mar 2019),** research paper **(Mar 2019).**
Agronomy and nutrition of bere barley (1.3.1, O1.2b)	tim.george@hutton.ac.uk	Results on performance of crosses between bere barley and elite lines **(Oct 2018).**	Research paper (**Jan 2019**), research summary for SEFARI Gateway **(Jan 2019)**.
Monitor grazing pressure for *Cicerbita alping at reintroduction sites* (1.3.1, O1.2a)	a.finger@rbge.ac.uk	Monitor survival at reintroduction sites, use cameras to detect grazing activities (**Aug 2019**).	Report (Dec 2019).
Impact of management regimes on biodiversity, ecosystem function and ecosystem service delivery (1.3.1, O1.3a)	robin.pakeman@hutton.ac.uk	Linkages between plant digestibility/palatability, invertebrate species composition and bird foraging (**Mar 2019**).	
Impacts of management regime on ecosystem service supply in upland ecosystems (1.3.1, O1.3a)	Davy.McCracken@sruc.ac.uk	Development of guidance on ecosystem service accounting (**Mar 2019**).	Guidance documents (**Mar 2019**).
Ecosystem Health Indicators (1.3.1, O2.1) & Natural Capital Asset Index (1.4.1, biii)	rob.brooker@hutton.ac.uk	Publication of bryophyte indicator – (**Dec 2019**); Development of plans for NCAI research (**May 2019**).	Information notes, research summaries, journal paper (**Mar 2020**).
Visualisation tool for integrated open data kit and google earth ((1.4.2 cii D9)	chen.wang@hutton.ac.uk	Developing new method for forest data collection using mobile devises.	Sampling visualisation tool (**Mar 2019**); Invited talk at Tree Health Citizen Science Network, Environment Centre Wales **(Feb 2019**); Oral presentation at ELSEG Workshop, Victoria Quay, Edinburgh (**Jan 2019**)
Connectivity metrics for temperate rainforest systems (1.3.3, O3.3)	C.Ellis@rbge.ac.uk	Identify specific sites for practical habitat restoration efforts (**Mar 2020**).	Invited talk on climate change and habitat conservation for the inauguration of the Atlantic Woodland Alliance (**May 2019**).
Animal diseases – squirrel pox virus (1.3.3, O3.2b)	Colin.Mcinnes@moredun.ac.uk	Tracking progression of SQPV **(Mar 2019).**	Data and advice on SQPV provided direct to appropriate stakeholders (**Mar 2019**).
Animal diseases – liver fluke (1.3.3, O3.2b)	Philip.Skuce@moredun.ac.uk	Agri-environment schemes and liver fluke risk to livestock (**Mar 2019**).	Interim report (**Mar 2019**).
Develop enhanced analysis methods for data on the spread of INNS and plant pest/pathogens (1.3.3, O3.1a)	Stephen.Catterall@Bioss.ac.uk	Apply methods to data on the spread of the Great Spruce Bark Beetle in Scotland (**Jan 2019**).	Scientific paper (**Jan 2019**).
System – including ecosystem – resilience: identifying gaps in knowledge for Scotland's biodiversity and ecosystems (1.3.3, O1.1 and O3)	Ruth.Mitchell@hutton.ac.uk	Joint work with SNH to implement resilience assessments (**Jan 2020**).	
Consequences of environmental and climate change for ecosystem resilience (1.3.3, O2.2b)	Scott.Newey@hutton.ac.uk	Develop a species distribution model for mountain hares in Scotland (**Mar 2020**).	A GIS based species distribution model of mountain hares in Scotland (**Mar 2020**).
Frost tolerance of Scots pine provenances (1.3.3, O2.1)	Alison.Hester@hutton.ac.uk	Results from experimental work communicated to stakeholders (**Feb 2020**).	
Biodiversity management mechanisms: (1.3.4, O1.2)	Paula.Novo@sruc.ac.uk	Data collection to investigate influence of social values, place and identify (**Jan 2019**).	
Assessment of habitat/species distributions and impacts of habitat loss and gain (1.3.4, O3)	Alistair.Mcvittie@sruc.ac.uk	Communication of work on economic value of biodiversity and ES (**Mar 2019**).	Conference paper (**Nov 18**), scientific paper (**Mar 19**).
Test cases to examine feasibility of offsetting for woodlands (1.3.4, O3)	C.Ellis@rbge.ac.uk	Exploration of time for biodiversity restoration (**Nov 2019**).	

Natural Asset Register: Data Portal (1.4.1a)	David.Donnelly@hutton.ac.uk	Expand data sets as they become available (**Mar 2020**); Continue to improve the guidance to users and the usability of the site (**Dec 2019**); Evaluate an improved map section (**Oct 2019**).	Metadata tool implementation (**Mar 2019**); Natural Asset Register website: http://nar.hutton.ac.uk (**Continuing to Mar 2021**).
The importance of spatial habitat configuration in affecting resilience to drivers of change (1.4.2cii)	alison.hester@hutton.ac.uk	Presentation on our research findings at National Ecological Network event lead-organised by SELink (**Jun 2019**)	
Human-environment interactions in the supply of ecosystem services (1.3.2, O1.1-O1.9)	antonia.eastwood@hutton.ac.uk	Workshops to assess changes in ecosystem services in response to land management (**Dec 2019**); Participatory and citizen science approaches to monitor and evaluate woodland interventions (social and ecological) (**Dec 2019**). Analysis of data on the role of humans in the production of ecosystem services in remote locations (**Jul 2019**)	Workshop report Glas Drum National Nature Reserve: Exploring the perceived impacts of different management interventions on woodland benefits (**Jun 2019**). Participatory videos and associated reports on monitoring and evaluation tools for greenspace interventions (**Oct 2019**). Research paper on citizen social science methodology (**Aug 2019**).
Land Use Strategy			
Cultural Ecosystem Services indicators and mapping (1.4.1bvi)	inge.aalders@hutton.ac.uk	CES indicator development (**Dec 2018**); Two community workshops in collaboration with the Galloway and South Ayrshire Biosphere (**Mar 2019**).	Methods for intangible CES (**Dec 2018**); Indicators from 2^{o} data (**Jan 2019**); Scientific paper (in press).
Modelling multiple ESS (1.4.2ci and cii)	alessandro.gimona@hutton.ac.uk	Model development and application (**Mar 2019**).	Methods for AE targeting (**Nov 2018**); Model about biodiversity offsetting (**Mar 2019**).
Using social innovation to deliver multiple benefits in forestry (1.4.2biii)	maria.nijnik@hutton.ac.uk	Organise conference session and paper preparation (**Dec 2018**)	Conference sessions at the IUFRO Congress, the Forum Carpaticum and a workshop with cross-sector stakeholders in Scotland (**Oct 2018**).
Assessing economic impacts of changes in Ecosystem Services (1.4.2ciii)	Alistair.McVittie@sruc.ac.uk	Extending GCE model to account for farmer behaviour and apply to case-study (**Dec 2018**).	Framework and database for case-study (**Dec 2018**).
Opportunities to increase multiple benefits through policy and industry delivery mechanisms (1.4.2bi)	kirsty.blackstock@hutton.ac.uk	Empirical data collection on catchment partnerships that combine public policy and private sector mechanisms to deliver multiple benefits (in conjunction with WP 1.2.4) (**Dec 2019**).	Outputs already published (e.g. Briefings) can be found on our website[2]; Outputs from this phase will be available in Mar 2020 (interim report for discussion with case stakeholders).
Using Monitoring and Evaluation to deliver multiple benefits (1.4.2bii)	kerry.waylen@hutton.ac.uk	Preparation of briefing and slideshow, submission of academic paper (**Jun 2019**).	Short recommendations briefing Slideshow explaining research, Open access academic paper (**Jan 2019**); Presentation at the ALTERNET-EKLIPSE conference (**Jun 2019**).
Landscape level collaborative arrangements for the management of natural assets for multiple benefits (1.4.3a).	kit.macleod@hutton.ac.uk	Preparation of research briefing which will provide an introduction to a series of case-studies (**Mar 2019**).	Research Briefing (**Mar 2019**).
Adaptive co-management in the Scottish Uplands	antonia.eastwood@hutton.ac.uk	Completion of research brief and paper on adaptive management in the Scottish Uplands (**Sept 2019**).	Research briefing (**May 2019**), Research paper (**Sept 2019**); Conference presentation (**Aug 2019**).
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	Producing model algorithms to allow future predictions of range shifts in ticks and Lyme disease over Europe (**Mar 2019**).	Data sets of tick and Lyme distribution. (**Dec 2018**); Algorithm to allow range shift predictions (**Mar 2019**); Invited talks at: NHS Lyme disease conference, COSLA, Edinburgh (**Feb 2019**); Institute for Biodiversity Animal Health and

[2] https://www.hutton.ac.uk/research/projects/analysing-how-policy-instruments-shape-soil-water-and-biodiversity

			Comparative Medicine, University of Glasgow (**Dec 2018**); One Health Research into Bacterial Infectious Diseases, University of Glasgow. (**Dec 2018**).
Peatland restoration (1.3.3, O2.2c).	rebekka.artz@hutton.ac.uk	Local high-resolution model of peatland restoration success (**Mar 2019**).	Scientific papers of the potential to remotely sense general peatland ecological condition and Sphagnum moss drought response (**Apr 2019**); Invited Conference presentation (WETSCAPES, **Sep 2019**); Interim research note, to be circulated to key stakeholders (**Apr 2019**).
Ecosystem service flows and our inventory of natural assets (1.4.1bii)	alessandro.gimona@hutton.ac.uk		Statistical model of soil moisture (**Mar 2019**).
Scottish Rural Development Plan & CAP Greening			
New management options for agri-environment schemes (1.3.4, O1.1 & O1.2)	robin.pakeman@hutton.ac.uk	Establishment of new experimental investigation(s) (**Mar 2019**).	
Impact of liming (1.3.1, O1.3b)	scott.newey@hutton.ac.uk	Continue ongoing monitoring and data collection of established field level lime trials (**Mar 2020**).	
Targeting SRDP payments for biodiversity (1.4.1bv)	robin.pakeman@hutton.ac.uk	Developing new methods maps (**Oct 2018**).	Maps added to NAR and paper describing methodology (**Oct 2018**).
Innovative and collective approaches to water management (1.4.3d)	andy.vinten@hutton.ac.uk	NC and ESS mapping of Dee catchment (**Nov 2018**). Reporting on implementation and monitoring of management for multiple benefits at Luna (**Jan 2019**).	NC/ESS maps for Dee (**Nov 2018**); Lunan management report (**Jan 2019**).
Improving the environmental performance of beef supply chains (1.4.2biv)	Ilkka.Leinonen@sruc.ac.uk	Application of model to supply chain case studies.	Framework and database description for new supply chain case study (**Mar 2019**).
Scottish Forestry Strategy			
Impacts of tree pests and diseases - risk assessment for service provision (1.3.3, O3.1a).	ruth.mitchell@hutton.ac.uk	Assessment of the suitability of alternative tree species to replace trees under threat from pests/pathogens (**Dec 2018**).	Article for Woodland Trust Magazine Woodwise (Summer 2019); Scientific paper published (**Apr 2019**); Forest Research Note (**Dec 2019**).
Detailed studies of key pathogens – *Phytopthora* monitoring programme (1.3.3, O3.1c).	K.Hayden@rbge.ac.uk	Best practice management guidelines for managing disease transmission risk during conservation translocations (**Mar 2019**).	Best practice management guidelines communicated directly to stakeholders through oral presentations at meetings (**Jan 2019**), website on disease risks in the natural environment (**May 2019**) and written report (**Jun 2019**).
Detailed studies of key pathogens – *Phytopthora* detection and diversity (1.3.3, O3.1c).	david.cooke@hutton.ac.uk	Drivers of *Phytophthora* distribution and dispersal (**Dec 2018**).	
Approaches that reconcile woodland expansion with other land use priorities (1.4.3c)	antonia.eastwood@hutton.ac.uk	Capturing a range of digital stories with communities of interest in the Cairngorms National Park has been completed, as have the qualitative interviews with land managers on adapting management to change. (**May 2019**).	Research brief (**May 2019**) and paper on the roles of stakeholders and relationships in adaptive co-management (**July2019**).

SPOTLIGHT: BERE BARLEY – TIM GEORGE

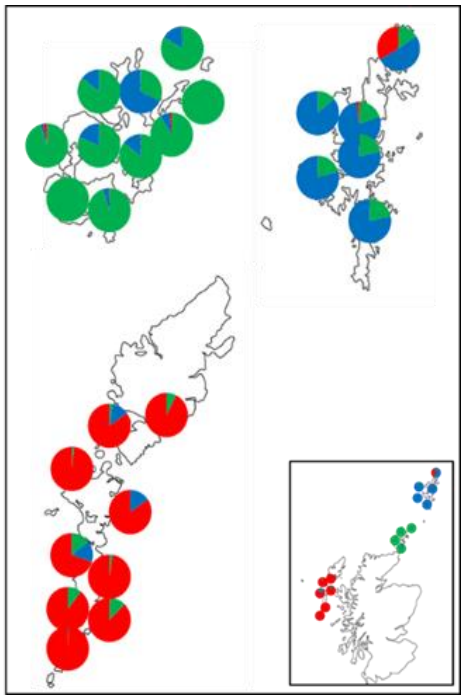

Fig 1. Biogeographical map – genotypic variation of barley with distribution across geographical zones in the western and northern isles of Scotland highlighting the divergence of populations which have genetically adapted in-situ in different environments.

In recent research, an unprecedented variation in the ability of Scottish barley landraces, known as Bere barley, to tolerate manganese (Mn) deficiency has been observed. Bere is the oldest continuously grown barley in the UK and has been grown, predominantly on marginal land, for at least the last half millennium and is currently grown in isolated populations on the mainland and western and northern islands of Scotland. The soil conditions in the regions where Bere grows vary widely with many areas supporting crops on highly alkaline soils. This genetic resource from such diverse environments offers promising diversity for breeding micronutrient efficient barley for all environments but especially marginal ones (Fig. 1).

Recently we demonstrated the unique ability of Bere landraces to overcome limitations caused by high pH soils and to generate robust grain yields under severe Mn deficient conditions, while modern elite varieties completely failed to set seeds (Fig. 2D). In Fig. 2 we show a range of Bere and elite varieties growing in marginal soil. It is clear from this that the elite varieties both show visual symptoms of severe Mn deficiency and reduced PSII efficiency (as measured by chlorophyll fluorescence Fv/Fm), while most of the Bere lines do not show deficiency symptoms (A,B). It was particularly striking that the subgroup of Bere landraces demonstrating superior tolerance to Mn deficiency were those that have become adapted to alkaline, sandy and high organic matter soils, which have inherently reduced plant Mn availabilities. Whereas, the Bere landrace which showed no superior Mn-efficiency compared to the elite genotypes were selected on acidic soils where Mn deficiency is not likely to be critical.

Under such strong and geographically varied selection pressure it is likely that the adaptation to Mn deficiency has developed independently since the different island genotypes became distinct and that the genotypic differences related to this trait are more subtle than represented by the biogeographically distinct groups. The physiological mechanisms underlying this Mn efficiency is not fully understood. Unique traits in the landraces may involve mechanisms yet to be elucidated or polymorphisms in single genes controlling processes that are already known.

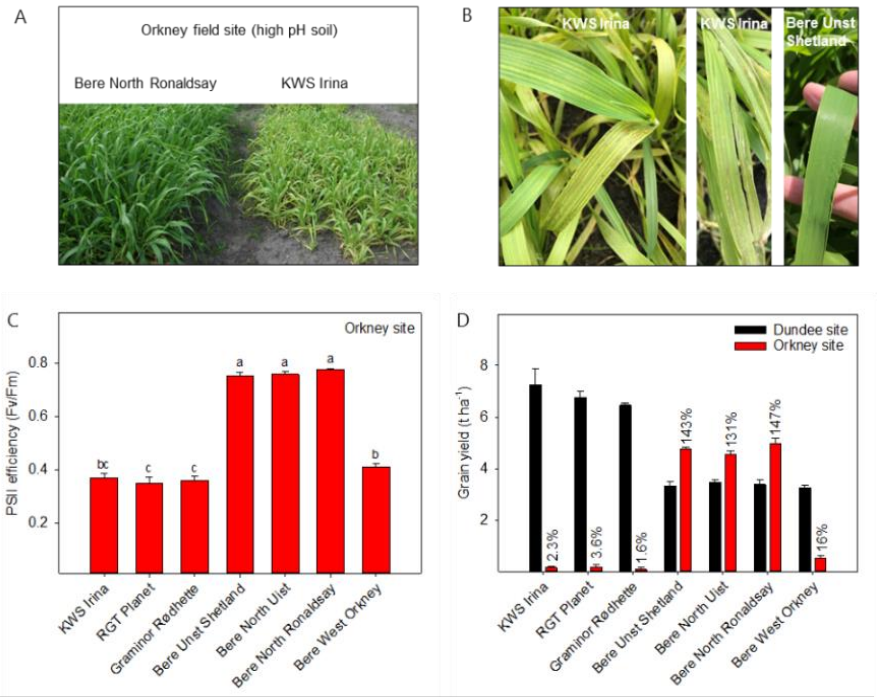

Fig. 2. Superior tolerance of Bere landraces to Mn deficiency when grown in marginal calcareous soils in Orkney.

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). Results from our 2016 experimental study showed changes in functional richness of the weed community related to crop genetic diversity, and a positive relationship between weed diversity and barley productivity. We followed this up with a field trial in 2018 using controlled manipulations of weed diversity in crop systems. Analysis of data from our 2017 study of the links between genetic diversity and **resilience of ecosystem functions** showed that while increased cultivar diversity did not mitigate the negative effects of drought on productivity, other positive biodiversity effects (e.g. weed and disease suppression) were maintained under drought (**Mar 2019;** audience: SG, academics, land managers; alison.karley@hutton.ac.uk).

Also relevant to Climate Change Adaptation

Photo: Seedlings of *Cicerbita alpina*

Photo: Planting *Cicerbita alpina* at Sharroch

Understanding the **impacts of genetic factors on reintroduction success** is critical for the conservation of threatened plants and animals. We will continue to monitor the survival of germinating plants resulting from cross-pollination and monitor the survival of reintroduced plants (**Oct 2019**) (1.3.1, O1.2a). Furthermore, we will install cameras to determine main grazers of *Cicerbita alping* at reintroduction sites (**Aug 2019**). Translocations across the four Botanic Gardens (Edinburgh, Dawyck, Benmore, Logan) will test the resilience of *Cicerbita alpina* to varying climates **(Oct 2019)**. A publication is currently being prepared looking at the amount of clonal reproduction in Scottish *Saxifraga hirculus populations* (**Dec 2019**; audience: SG, SNH, 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 submitted focussing on the vegetation dynamics across the first fifteen years of a controlled grazing experiment at Glen Finglas, identifying the impacts of removing or intensifying grazing. In 2019-2020 we will be extending the work to investigate how management affects the linkages between plant digestibility/ palatability, invertebrate species composition and bird foraging (**Mar 2019**; audience: SG, SNH, academics; robin.pakeman@hutton.ac.uk).

The development of **Ecosystem Health Indicators** (EHI) (1.3.1, O2.1) continues to be supported through work in the Strategic Research Programme (SRP), and collaboration between SRP researchers and key stakeholders (e.g. SNH staff). The analysis to prepare a bryophyte indicator is complete, and we are now working on incorporating this into the online indicator suite and publishing the results of this work – jointly with SNH staff – in a peer-reviewed journal (**Dec 2019**; intended audience: agencies, SG, researchers). Likewise, we are undertaking further work on refinements of the **Natural Capital Asset Index** (NCAI) (1.4.1, biii). We have recently produced a report on influential indicators within the NCAI which was passed to the SNH Science Advisory Board. Work in 2019-2020 on the NCAI will continue this collaborative approach through an initial planning meeting to develop research targets for the year (**May 2019**; audience: agencies, SG, SRP researchers; rob.brooker@hutton.ac.uk).

Connectivity metrics for temperate rainforest systems (1.3.1, O3.3) have been used to identify spatial strategies for woodland regeneration that allow for the persistence of extant populations and gains in terms of the colonisation/establishment of new populations. These results have been contributed as a management report to SNH focussed on their Glasdrum NNR. Future work continues to identify specific sites for practical habitat restoration efforts and informs the activities of members in the Atlantic Woodland Alliance. (**Mar 2020**; audience: SG, agencies, land managers; C.Ellis@rbge.ac.uk).

Larger-scale studies in upland management systems (1.3.2, O2.2) are exploring how **changes in management regime alter ecosystem service** supply. Through discussion with stakeholders, example maps of Ecosystem Services and uncertainties have been translated into draft guidance for land managers and advisors on how to conduct ES accounting at a farm scale. This guidance includes practical management of *Cryptosporidiosus* in farm livestock (**Mar 2019**; audience: agencies, SG; Davy.McCracken@sruc.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 2019**; audience: SG, NGOs, agencies; Colin.Mcinnes@moredun.ac.uk).

Field studies (1.3.3; 1.4.3) are ongoing to investigate the **risk of liver fluke disease** to livestock associated with conservation grazing as part of agri-

environment schemes aimed at promoting biodiversity, specifically around newly-established wader scrapes and on designated natterjack toad habitat. We have kept relevant stakeholders – e.g. RSPB, SNH, Soil Association, ARC-Trust – regularly informed of progress at on-farm events and have discussed best practice advice to farmers and land managers at a well-attended meeting with natterjack toad Species Champion, Emma Harper, MSP, on March 8th. Work going forward will involve monitoring of livestock infection status, access to toad habitat and associated liver fluke infection risk (**Mar 2019**; audience: SG, agencies, NGOs, land managers, farmers; Philip.Skuce@moredun.ac.uk).

Photo: Stakeholder events on best practice to reduce liver fluke disease

We developed a novel statistical modelling approach to characterise the spread of **invasive non-native species (INNS)** in terms of habit preferences and dispersal using species atlas data (1.3.3, O3.1a). We then extended the model and applied it to data on the spread of the economically damaging pest, the Great Spruce Bark Beetle. This work was driven by the need for data-driven risk assessments to inform Forestry Commission Scotland's annual surveillance and control programme. (**Jan 19**; audience: SG, agencies; Stephen.Catterall@Bioss.ac.uk).

System – including ecosystem – resilience (1.3.3, O1 and O3) is an emerging focus for research and policy. Our current activities build on foundation work undertaken in 2016-19 including a focussed workshop run jointly with SNH to identify main gaps in knowledge of ecological resilience in Scotland's biodiversity and ecosystems (see workshop report[3]). We are now working with Duncan Stone and Chrissie Valluri (SNH), contributing directly to SNH's Site Level Resilience Planning project, where we can feed our conceptual work on resilience planning into a project aiming to deliver this on the ground for key woodland habitats (**Jan 2020**; audience: SG, agencies, NGOs, land managers; Ruth.Mitchell@hutton.ac.uk

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 remain a high priority species in Scotland. In collaboration with the GWCT we will continue developing a species distribution model for mountain hares in Scotland. As well as informing our understanding of the factors that determine the distribution of mountain hares, we will use this model to explore how land use change, wood land expansion for example, may affect the distribution of mountain hares. (**Mar 2020**; audience: SNH, National Park Authorities, NGOs, agencies; scott.newey@hutton.ac.uk).

The **biodiversity** associated with **ecosystem foundation tree species** depends upon the provenance of the tree and the effect of climate change (1.3.3, O2.1) is being investigated using native Scots pine trees in a long-term experiment. Work in 2019-20 will focus on adapting to extreme weather, e.g. frost tolerance of pine seedlings and the combined effects of drought and herbivory (**Feb 2020**, audience: agencies; jenni.stockan@hutton.ac.uk/ alison.hester@hutton.ac.uk).

The **conservation genetics** of a keystone pinewood specialist, the rare Narrow-headed ant *Formica exsecta*, are being investigated (1.3.3, O2.1). The results will provide information on social structure, genetic variability and inbreeding which will be used to inform forest management and conservation that will, not only benefit this ant, but also other early successional species (**Feb 2020;** audience: agencies, NGOs, land managers; jenni.stockan@hutton.ac.uk).

The review of **biodiversity governance mechanisms** developed in 2016/17 is being used as the basis to explore with stakeholders the potential for using different governance mechanisms (including market, non-market and hybrid mechanisms) and the role of values and perceptions for biodiversity governance in Scotland (1.3.4, O1.2). We have conducted interviews and a workshop with key stakeholders involved on biodiversity governance, including representatives from government agencies, land manager and environmental organisations. Further data was gathered in 2018 to investigate the influence of social values, place and identity on biodiversity management. Findings from this work have been summarised as reports and discussed directly with key stakeholders (**Jan 2019**; audience: SG and agencies, land managers, environmental organisations; Paula.Novo@sruc.ac.uk).

Assessments of habitat/species distributions and impacts of habitat loss and gain in the context of planning are being developed (1.3.4, O3). ES maps developed during 2016-17 have been used to prepare a research paper on biodiversity and ES impacts from proposed development. This considered both habitats at risk from development (identified at local level) and where habitats might be created (e.g. green infrastructure investments such as in the Central Scotland Green Network). This will inform the integration of valuation data (from RD1.4.1) for the development of offsetting assessment tools in years 3 to 5. A paper was accepted for the Valuing Nature Programme Conference, Cardiff (**Nov 2018**). We have also held a joint workshop with SNH with invitees from bodies with interests in offsetting to identify future case studies; the timing will reflect completion of the current review of the Defra offsetting metric (**Mar 2019**; audience: SG and agencies, land managers; Alistair.Mcvittie@sruc.ac.uk).

As well as looking in a more general sense at the impacts of habitat losses and gains on biodiversity, research is developing specific **test cases to examine feasibility of offsetting for woodlands** (1.3.4, O3). The focus habitat is upland oak woodland, and whether recently regenerated wood can be substituted for more ancient woodland. The initial phase of this work has characterised the chronosequence of sites enabling contrasts between stands of different age. Work in 2018-2019 will continue to develop the woodland test cases, including an exploration of the time needed for biodiversity regeneration in restored woodland (**Nov 2019**; audience: SG and agencies, land managers; c.ellis@rbge.ac.uk).

In support of Scotland's National Ecological Network, we are examining the **role of patch size and connectivity in affecting the resilience of**

species and habitats to climate and other drivers of change (1.4.2cii). We have been testing the potential and limitations of different national land cover datasets in providing information at a scale that can be related to ground survey data (our paper can be downloaded from the Hutton website). This year we have focused on moorland as a test habitat - unlike woodlands, there is currently no national-level ground survey dataset for moorland. But the commitment made in the SBS to produce a comprehensive map of Scotland's main habitats (HabMoS – see SNH website) represents an important new development in this area. We have been invited to present a summary of our work in this area at a NEN workshop lead-organised by SELink (**Jun 2019**; main audience: government, agencies and NGOs; Alison.Hester@hutton.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.

The **Natural Asset Register: Data Portal** (NAR:DP) (1.4.1a) which may be viewed here, continues to develop and had been updated with the addition of further data including a soil water capacity map (RD1.1.4). A metadata creation tool is now in use and has been shared with RBGE. This is intended to improve the efficiency with which data can be uploaded to the NAR by scientists. A steering group with membership from SEFARI, Scottish Government, SEPA and SNH has been formed. The group has provided guidance on improving the usability of the NAR and will continue to guide, inform and support its development. Following a review and discussions with the Steering Group, the work for this year has been refocussed to improve the overall usability of the site rather than to develop a standalone app. The CKAN platform used by the site works equally well on mobile devices as on PCs, meaning that developing an app would not be a good use of resources (**Jun 2019**; audience: SG, agencies; david.donnelly@hutton.ac.uk).

Work on Cultural Ecosystem Services (CES) indicators and mapping (1.4.1bvi) has evaluated participatory research methods for their ability to fill in the data gaps identified during year 1. Methodological insights from a social science perspective have been reported in a research note[4]. The results informed the development of fieldwork (**Dec 2018**). Following results of mapping Cultural Heritage and modifications in CICES work on the creation of indicators based on other secondary data (**Jun 2019**) is in progress (audience: agencies, local authorities; inge.aalders@hutton.ac.uk).

Initial case studies of **Natural Capital Accounting** (1.4.1c) have focused on agriculture, forests and woodland. To support these, primary valuation studies have been completed 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 summary of survey rationale, methods, preliminary results and planned future analysis is available (intended audience OCEA, (**Dec 2018**; intended audience: SG and agencies Alistair.McVittie@sruc.ac.uk). Further research briefings and KE events will be held in 2019, whilst a third case-study (peri-urban green space) will be started.

Modelling approaches to provide combined estimates and map multiple ESS are being developed to contribute to the targeting of incentives, the appraisal of policy options for the delivery of multiple benefits, and to explore the consequences of land use change (1.4.2ci and cii). Meta-models, Bayesian Belief Networks and other modelling approaches have been used for the spatial estimation of multiple ESS. The resulting maps can be made available to stakeholders in SG and agencies. These approaches will be refined and applied further in the areas of spatial targeting of incentives (**Mar 2019**; intended audience: SG and agencies; alessandro.gimona@hutton.ac.uk).

Research into the use of **Social Innovation** (1.4.2biii) to deliver multiple benefits in rural areas (with a particular focus on mountains, forestry, forest-dependent communities and community energy) is continuing. Social and economic barriers and opportunities for woodland expansion have been investigated through stakeholder evaluation, including presentations on a deliberative support tool to outline opportunities to deliver multiple benefits from woodlands), define areas of consensus and conflict between people and assist in specifying, selecting and evaluating policy options. The findings from this work have been communicated and discussed with SG agencies and cross-sector stakeholders at a workshop on Social innovation in rural areas of Scotland (**May 2018**) and disseminated within the scientific community via organised conference sessions on social innovation at the 125 IUFRO Congress in Frieburg and the Forum Carpaticum and several impact factor journal articles produced (**Dec 2018**; intended audience: SG and agencies; maria.nijnik@hutton.ac.uk)

Assessing economic impacts of changes in Ecosystem Services (1.4.2ciii). Following the augmentation of the CGE model with the inclusion of ecosystem services, research is now considering how micro level farmer behaviours can have macro level impacts with consideration being given to the use of data/knowledge on i) farmer behaviour based on the 2013 Farmer Intentions Survey and ii) impacts of different rotations including use of legumes based on SRUC long-term experiment data. The work has been presented to Keith McWhinnie, Richard Haw and Helen Duncan (19th of June 18 titled "Strategic Research Programme June 2018"). Information on relevant micro disturbances in agriculture is currently accessed (through Keith McWhinnie) to further inform the CGE modelling. (**Dec 2018;** intended audience: SG and agencies; alastair.mcvittie@sruc.ac.uk).

Opportunities to increase multiple benefits through policy and industry delivery mechanisms (1.4.2bi) has reviewed 'new' instruments in international practice that may potentially be relevant to managing Scotland's natural assets , resulting in a research report[5]. (**Oct 2018**). Insights from work to date were also used to inform Scottish Parliaments inaugural Citizens' Jury on "How should funding and advice for land management be designed to help improve Scotland's natural environment?" in **March 2019**. We are now selecting case studies to consider how catchment partnerships combine public policy and private sector mechanisms to deliver multiple benefits (in conjunction with WP 1.2.4) with data collection completed by **Dec 2019** and an interim report due in **Mar 2020** (audience: SG, agencies and NGOs; kirsty.blackstock@hutton.ac.uk).

The findings from 1.4.2bi referred to in the preceding paragraph helped to frame the research on **Using Monitoring and Evaluation to deliver multiple benefits** (1.4.2bi)[6]. An open access paper summarising these findings has been published in the journal 'Science of the Total Environment'. This is complemented by a 4-page briefing focusing on recommendations and implications, and a pdf slideshow explaining the research. The key findings and recommendations will be presented to the ALTERNET-EKLIPSE conference discussing the EU Biodiversity

[5] https://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/1_4_2biD3final.pdf

[6] https://www.hutton.ac.uk/research/projects/monitoring-and-evaluation-ecosystem-management-meem-comparing-theory-and-practice

Strategy beyond 2020 (**Jun** 2019; audience: SG and agencies; kerry.waylen@hutton.ac.uk).

Photo: Activities for O1.4.2bi (above)

A research briefing summarising our adaptive management case studies and initial considerations of the issues and themes that have arisen across them (1.4.3a) has been produced. We have also carried out a comparative assessment of landscape-scale collaborative arrangements for the management of multiple benefits; cases include agri-environment (1.4.3b) and woodland expansion (1.4.3c). This will contribute to **practical interventions to realise multiple benefits and manage trade-offs** (1.4.3) (**Mar 2019**; audiences: agencies, NGOs; land managers; kit.macleod@hutton.ac.uk).

CLIMATE CHANGE PLAN & CLIMATE CHANGE 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.

The development of new methods to improve our understanding of **ecosystem service flows and our inventory of natural assets** (1.4.1bii) has moved on to consider soil properties and their relationship with functional attributes and ecosystem functions. The has included the development of statistical models building on previous work to generate high resolution soil data and integrate expert opinion and process models. (**Mar 2019**; audience: agencies; alessandro.gimona@hutton.ac.uk).

Work to understand the **range shifts and resilience of key pest species to climate change** analysed data on tick altitudinal and latitudinal limits during 2016-17 (1.3.3, O2.2a). In 2018-2019 this work developed models to produce algorithms that allowed us to predict range shifts in ticks and Lyme disease (the most prevalent vector-borne disease in the northern hemisphere) due to climate and land use change at the European scale (**Mar 2019**; SG, agencies, SNH, NHS, land managers, public; Lucy.Gilbert@glasgow.ac.uk).

Peatland systems are a key component of the natural environment's contribution to climate change mitigation. We have produced a national model of **peatland condition** for Scotland based on MODIS satellite images (1.3.3, O2.2c), which has been written up as a research paper along with associated targeted summary material. We have also completed a publication on the potential for Earth Observations to determine changes due to drought in *Sphagnum* moss (**Mar 2019**). We have developed an initial local test model at high resolution of peatland restoration success for the area surrounding RSPB Forsinard using Sentinel-2 data (**Mar 2019**) A research note with our interim findings has been prepared (audience: SG and agencies/NGOs with an interest in peatland systems), 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.

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 2018-2021 (**Mar 2019**; intended audience: SG and agencies involved in AECS implementation; Robin.Pakeman@hutton.ac.uk).

One farmland management action that will be investigated in detail is the **impact of liming** (1.3.1, O1.3b). In collaboration with RD 1.1.2 and RD 1.1.4 field level studies will be used to assess the effects of lime application to extensively managed grassland on sward diversity and key invertebrates (earthworms and crane flies (Tipulidae)) for breeding and over wintering waders. Over 2019-20 we will continue to monitor the effects of lime addition on soil characteristics, earthworms and vegetation to add to the baseline data already collected (**Mar 2020**; audience: SG, agencies, land managers; scott.newey@hutton.ac.uk).

An associated activity is the development of methods for **targeting SRDP payments for biodiversity** (1.4.1bv). A consultation on how to refine SRDP AECs targeting has been carried out and a range of novel metrics has been studied. A paper is in development setting out the methods used and the resulting maps have been included within the Natural Asset Register (**Oct 2018**; audience: SG and agencies; robin.pakeman@hutton.ac.uk).

Research into the **implementation of agri-environment schemes at a landscape scale to deliver multiple benefits and protect natural assets** (1.4.3b) based on a lowland-intensive and upland-extensive agricultural catchment has progressed in the modelling of ecosystem services (biocontrol agents, potential soil loss, sediment and nutrient retention). Progress has also been made towards the understanding of collaborative management of such ecosystem services, through AECS and ECAF. A farm event was held at Glensaugh, inviting discussions from farmers and other stakeholders on cooperation for the delivery of ecosystem services. Several meetings were also held with farmers from the Balruddery catchment, securing their engagement in further research. Discussions have been held with SG and SNH to ensure the research meets the developing needs for future, evidence-based AECS (**Mar 2019**; audience: land managers and advisors graham.begg@hutton.ac.uk).

The delivery of **multiple benefits from innovative and collective approaches to water management** (1.4.3d) involves work on the Dee, Lunan and Leven catchments. Spatial data and associated maps of natural capital and ecosystem services have been drawn together to build an understanding of the multiple benefits associated with the agricultural and forestry land uses within the Dee catchment **(Nov 2018)**. Working with, and surveying the attitudes of local stakeholders and residents, has provided insights into the management of the Lunan catchment for multiple benefits and its governance. A paper on the challenges to implementation of payments for water services approach in the Lunan has been prepared. In addition, a presentation of the results was made at Scotland's Environment Land Use and Environment Conference XII: Rewarding the Delivery of Public Goods: How to Achieve this in Practice? 28-29 November 2018, Edinburgh. A manuscript has been revised for the Journal of Environmental Management. Engagement with the management of the Lunan catchment is ongoing including involvement in a catchment management group and discussions with Flood policy makers to share outcome of stakeholder meetings at Lunan. Reports describing the implementation of rural SUDS and lessons learnt and technical monitoring of water quality has been presented at the Lunan catchment group (March 2019). A report on current water level management arrangements for Loch Leven has been prepared by CEH (**Mar 2019**; audience: agencies, local authorities; andy.vinten@hutton.ac.uk).

Work on **improving the environmental performance of beef supply chains** (1.4.2biv) has analysed the environmental burdens and benefits (in terms of GHG emissions) of using distillery by-products in both livestock production and renewable energy production. A research briefing presenting the findings has been published at the SRUC website and a scientific article has been accepted for publication in the journal *Sustainability*. A herd level supply chain model was developed and applied to the beef supply chain to identify geographical, sectoral and supply chain hotspots (in terms of GHG emissions and nutrient balance) and links to other agricultural production systems. A corresponding interactive database of material flows of beef production was developed, allowing the researchers to investigate the effects of system changes on the spatial distribution of material flows. A framework and database description for new supply chain case study has been based on the outcome of the workshop (**Mar 2019**) and developed as manuscript exploring trade-offs between environment and food security objectives **(Mar 2019**; audience: SG, NGOs, industry; Ilkka.Leinonen@sruc.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, will 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 **supply of ecosystem services**. Work in 2019 will complete the local stakeholder panel workshops to assess changes in ecosystem services in response to changes in land management, as well as presentation of interim findings to stakeholder and policy audiences (intended audience: land managers) (1.3.2, O1.3-1.4). We plan to hold expert panel workshops in two other case-study areas, Cumbernauld and Mar Lodge in 2019. In addition, the qualitative data collected on the role of humans in, and their perceptions of, ES production in 2018 will be analysed and developed into a manuscript. We have completed our data collection on the potential of participatory video as a monitoring and evaluation tool to assess management interventions in Cumbernauld's greenspace. This will be written up as reports for the Creating Natural Connections project, with a scientific paper to follow. The participatory videos created (four in total) by pupils of St Maurice's High School and Neighbourhood Network Cumbernauld will be used as monitoring and evaluation baselines for the Creating Natural Connections project . The research on citizen social science approaches to monitoring impacts of management interventions has been completed and submitted for publication as scientific paper (audience: land managers; antonia.eastwood@hutton.ac.uk).

A novel approach to the collection of biodiversity and other ecosystem services (**O1.4.2ciiD9**) has been implemented through a combination of ODK (Open Data Kit) and Google Earth. For use in mobile devices, the visualisation tool will enable data collected on the ground to be viewed in Google Maps with their locations by combining Questionnaire/Survey information, mobile data collection, data aggregation, and geospatial data display. We have tested the mobile application at Tyrebagger and Countesswells forests which contain different woodland types. Useful data related to tree species has been collected. Geo-reference ground photographs have been taken which are used to help validate land-cover and soil maps. Filled electronic forms have been sent to ODK server for analysis and aggregation. Geographic data has been presented on a custom map using Google MyMaps, visualized through bar graph and pie chart, annotating by Google Earth. This work has been presented at the ELSEG workshop. Useful feedback has been provided by engaging with stakeholders and this has identified this tool as being useful for local community groups, people reporting problems such as pathways, broken gates, fungal infections. *Vice versa*, land owners could communicate management plans for the forest, e.g. clear-fell. Other uses identified: estate agents (3D scanning of buildings), botanic gardens to spot plant health problems and to collect data over time (**Mar 2019**; audience: agencies; chen.wang@hutton.ac.uk).

Detailed studies of key pathogens are being undertaken. These include (1.3.3, O3.1b) establishing a monitoring programme for detecting and managing the spread of *Phytophthora ramorum* particularly in conservation nurseries and botanic gardens; these monitoring approaches will be continued in 2018-2019 and will be linked to the development of best practice management guidelines for managing disease transmission risk during conservation translocations (**Mar 2019**; intended audience: land managers; K.Hayden@rbge.ac.uk). Other studies (1.3.3, O3.1c) have validated environmental DNA (eDNA) based techniques for detecting the presence of pathogenic *Phytophthora* species in landscapes via water sampling. In 2019 data on the pathogen diversity will be presented at the Oomycete Molecular Genetics Network meeting in Oban (https://omgn.org/) and shared with other stakeholders (**July 2019**; audience: SG and agencies, land managers; David.Cooke@hutton.ac.uk).

Photo: Study site for Phytophthora showing dead and declining Alder trees

Woodland management and digital story-telling (1.4.3c)**:** Digital storytelling is being used to gain a deeper understanding of the social issues associated with natural asset management, including reconciling competing interests, strengthening collaboration between stakeholders, and reducing environmental conflict. Visualisation of potential future states are being developed using methods such as 3D visualisations, 360-degree videos and digital storytelling. Static visualisations of Forest Wood (Cumbernauld) are at an advanced stage and will be used in the expert panel workshop in Cumbernauld (**Jul 2019**; audience: land managers, industry; scott.herrett@hutton.ac.uk).

The **impacts of tree pests and diseases** are being considered, in particular the wider environmental risks from tree diseases. This work explores, in particular, methods to link assessment of service provision by woodland habitats to assessment of priority habitats likely to be affected by tree diseases (1.3.3, O3.1a). We have developed a database of over 2000 species that are found on oak trees and included an assessment of if they will use any of 30 other alternative tree species. The information is being used to develop 30 case studies across the UK to provide examples of how to manage oak woods to conserve oak-associated biodiversity in the face of a decline in the health of oak trees https://www.hutton.ac.uk/oak-decline. Data from six sites across the UK are being assessed to test the suitability of other tree species to replace oak in terms of biodiversity supported and ecosystem function (**Dec 2019**; audience: SG, agencies, land managers; ruth.mitchell@hutton.ac.uk).

Photo: Scottish Atlantic oak wood rich in biodiversity

Approaches that reconcile woodland expansion with other land use priorities (1.4.3c). Qualitative interviews and social maps have been conducted with land managers in the Cairngorms National Park on adaptive management and woodland expansion. These have been analysed to provide a research brief **(May 2019**) and a journal paper on stakeholder roles and relationships in AM for realising multiple land use benefits **(Jul 2019**; audience: NGOs; antonia.eastwood@hutton.ac.uk).

ACRONYMS

AECS	Agri-Environmental Climate Scheme
ARC-Trust	Amphibian and Reptile Conservation Trust
CCAP	Climate Change Adaptation Programme
CCP	Climate Change Plan
CES	Cultural Ecosystem Services
EHI	Ecosystem Health Indicators
ES	Ecosystem Services
GHG	Greenhouse Gas
GIS	Geographical Information System
H2020 PROVIDE	EU project on public goods and bads from agriculture and forestry in Scotland
INNS	Invasive Non-Native Species
MODIS	Moderate Resolution Imaging Spectroradiometer
NAR	Natural Asset Register
NCAI	Natural Capital Asset Index
NGO	Non-Government Organisation
OCEA	Office of the Chief Economic Advisor
PGIS	Participatory GIS
RSPB	Royal Society for the Protection of Birds
SBS	Scottish Biodiversity Strategy
SFS	Scottish Forestry Strategy
SG	Scottish Government
SI	Social Innovation
SNH	Scottish Natural Heritage
SQPV	Squirrel pox virus
SRDP	Scottish Rural Development Programme
SRP	Strategic Research Programme
SWT	Scottish Wildlife Trust