Ecosystems and Land Use Policy Exchange Group (ELPEG) Bulletin

For the period Sept 2018-Jan 2019

Issue 8, October 2018

Contents

What is this document?

The ELPEG Bulletin provides updates for policy stakeholders on research activities being undertaken in the Scottish Government Strategic Research Programme, in particular in the areas of Biodiversity and Ecosystems, and Integrated Natural Assets. 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 the work where there will be policy-related outputs and stakeholder engagement during the period September 2018 to January 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 January 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.

Scottish Biodiversity Strategy

This work is aimed at supporting delivery of the Scottish Biodiversity Strategy (SBS). 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.

Regulation of ecosystem function

- 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 are following these up with field trials using controlled manipulations of weed diversity in crop systems. We are also analysing data from our 2017 study of the links between genetic diversity and **resilience of ecosystem functions** (**Jan 2019;** intended audience: SG, academics, land managers; Alison.Karley@hutton.ac.uk).
- Detailed studies are examining 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. Work in 2018-2019 will continue to focus on multi-site trials established in 2017, and will go on to assess the performance of crosses between Bere barley and commercial cultivars in marginal soils (**Oct 2018)** and with

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

alternative fertilizers (**Feb 2019)**; intended audience: SG, academics, land managers; Tim.George@hutton.ac.uk).

- 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-pollinations, and monitor the survival of reintroduced plants (**Oct 2018**) (1.3.1, O1.2a). We will develop further studies targeted on a wider range of priority species including *Woodsia ilvensis* (**Oct 2018**) and *Saxifraga hirculus* (**Dec 2018**; intended 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) is 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 2018-2019 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**; intended audience: SG, SNH, academics; Robin.Pakeman@hutton.ac.uk).

Developing and refining ecosystem health indicators

- 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, a key component of Scotland's biodiversity, has been done with the aim of inclusion of this new indicator in the EHI suite (**Feb 2019**; intended audience: agencies, SG). 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[2] on data gaps and the handling of cultural services within the NCAI. Work in 2018-2019 on the NCAI will continue this collaborative approach through development of a research publication – requested by and co-authored with SNH staff – setting out the NCAI approach (**March 2019**; intended audience: agencies, SG, SRP researchers; Rob.Brooker@hutton.ac.uk).

Scaling and connectivity

- At a more detailed scale, **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 in 2018 and beyond will continue to identify specific sites for practical habitat restoration efforts (**Mar 2019**; intended audience: SG and agencies, land managers; C.Ellis@rbge.ac.uk).

Understanding and rebuilding ecosystem service supply

- 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 will be translated into draft guidance for land managers and advisors on how to conduct ES accounting at a farm scale. This guidance will include practical management of *Cryptosporidiosus* in farm livestock (**Mar 2019**; intended audience: agencies, SG; Davy.McCracken@sruc.ac.uk).
- A novel approach to the collection of biodiversity and other ecosystem services (O1.4.2ciiD9) is progressing. 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

[2] http://www.hutton.ac.uk/sites/default/files/files/NCAI_gaps%20analysis%20and%20cultural%20services%20report_final.pdf

data display. The Open data kit server (an open-source set of tools) has been created and ODK collect sample-forms for capturing sample data been uploaded and tested with the design of an initial form for forest data collection underway (**Mar 2019**; intended audience: agencies; cheng.wang@hutton.ac.uk).

Resilience of ecosystems/biodiversity

- **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**; intended audience: SG, NGOs, agencies; Colin.Mcinnes@moredun.ac.uk). Field studies (1.3.3; 1.4.3) will also investigate the risk of liver fluke disease to livestock associated with animals grazing as part of agri-environment schemes aimed at promoting biodiversity, specifically around newly-established wader scrapes and on designated natterjack toad habitat[3]. We will keep relevant stakeholders – e.g. RSPB, SNH, Soil Association, ARC-Trust – regularly informed on progress and will communicate best practice advice to farmers and land managers in a timely manner. Work in 2018-2019 will involve, in particular, monitoring of livestock use of toad habitat and associated liver fluke infection risk (**Mar 2019**; intended audience: SG, agencies, NGOs, land managers, farmers; Philip.Skuce@moredun.ac.uk).
- We developed a novel statistical modelling approach to characterise **invasive non-native species (INNS)** in terms of habit preferences and dispersal using species atlas data (1.3.3, O3.1a). We will apply this to approximately 50 INN species of trees and woody shrubs for which suitable data exists (**Jan 2019**; intended audience: SG, agencies; Stephen.Catterall@Bioss.ac.uk).
- **System – including ecosystem – resilience** (1.3.3, O1) is an emerging focus for research and policy. Our current activities build on foundation work undertaken in 2016-18 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[4]). 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 (**December 2018**; intended audience: SG, agencies, NGOs, land managers; Glenn.Iason@hutton.ac.uk/ Rob.Brooker@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. Work on developing a participatory GIS (PGIS) for Capercaillie "CaperMap" has now been completed and was handed to stakeholders. After consultation with stakeholders, mountain hares have been chosen as the second policy-relevant case study. Building on CaperMap we will develop a GIS tools "HareMap" to assess the effects of woodland expansion on the availability of mountain hare habitat and resilience. Work in 2018-2019 will focus on gathering the data needed (**Dec 2018**, intended 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 2018-2019 will focus on the

[3] http://www.hutton.ac.uk/sites/default/files/files/Solway%20fluke%20%20NJTs_abridged_Skuce%20August%202017.pdf

[4] http://www.hutton.ac.uk/sites/default/files/files/Final_Resilience%20workshop%20notes.docx

susceptibility of native Scots pine provenances to pests (**Dec 2018**) and fungal pathogens (**Feb 2019**, intended audience: agencies; Glenn.Iason@hutton.ac.uk/ Jenni.Stockan@hutton.ac.uk).

Biodiversity management

- 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[5] and a workshop[6] with key stakeholders involved on biodiversity governance, including representatives from government agencies, land manager and environmental organisations. Further data will be gathered in 2018 to investigate the influence of social values, place and identity on biodiversity management. Findings from this work will be summarised as reports and also discussed directly with key stakeholders (**Jan 2019**; intended 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 are being used to prepare a research paper on biodiversity and ES impacts from proposed development. This considers 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. Work in 2018-2019 will focus on communicating the work to a range of stakeholder groups. A paper has been accepted for the Valuing Nature Programme Conference, Nov 13-14 2018, Cardiff. We will also hold joint workshop with SNH with invitees from bodies with interests in offsetting to identify future case studies, timing will reflect completion of the current review of the Defra offsetting metric (**Mar 2019**; intended 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 2018**; intended audience: SG and agencies, land managers; c.ellis@rbge.ac.uk).

[5] https://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/Governance%20for%20biodiversity%20interviews%20-%20report.pdf
[6] https://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/Biodiversity%20workshop%20report%20Edinburgh-final.pdf

ELPEG SPOTLIGHT: Cultural Ecosystem Services (CES) indicators and mapping

The National Asset Register (NAR) is to bring together information about the Ecosystem Services (ESS) for Scotland. The concept of ESS is introduced by the global Millennium Assessment, which defined CES as "*non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences"*. These benefits include cultural diversity, spiritual/religious values, recreation/tourism, social relations, educational values as well as aesthetic values, sense of place and cultural heritage.

The process of mapping and assessing ecosystem services is particularly challenging for CES as these are less tangible than other ecosystem services. However, ESS classification methods like the European Common International Classification of Ecosystem Services (CICES) have included CES and by dividing them broadly into CES that focus on physical and intellectual interactions and those that are less tangible: spiritual, symbolic and other sorts of interactions with environmental settings. The NAR has adopted the CICES classification.

Early CES mapping was developed based on expert knowledge and interpretation of the CES relationship with specific land covers. Another popular way to map CES is through visitor numbers i.e. the number of individuals who visit a specific environmental setting. However, while this approach may provide evidence of a 'market' for the habitat, it does not necessarily capture all aspects of cultural services. For example, it underestimates the value of remote habitats/landscape features with high conservation status, and important symbolic or emblematic value rather than a physical experiential value, e.g. Caledonian woodland or machairs. These aspects of CES have a place in the CICES classification, but new indicators and new interdisciplinary methodological approaches need to be developed to improve the quality of the CES data and to enable the mapping of less tangible aspects.

With the rich data sources of Historic Environment Scotland, the cultural heritage of Scotland has been assessed using new indicators which represent both the content and the frequency of cultural heritage in Scotland. The natural setting of cultural heritage is often not associated with single natural habitats but a mosaic of habitats. Therefore, mapping by landscape character areas rather than land cover or km2 are proposed for national mapping.

Commonly the insight about intangible CES is gathered through the traditional qualitative social science methods of interviews and focus groups. These methods allow an in-depth analysis and understanding of the CES afforded by particular (usually local) landscapes. They are, however, time-consuming and resource intensive thus often only feasible for use with a relative small proportion of a population. A challenge for mapping CES is what methods could be used to generate reliable national scale data that retains this localised experiential insight. Preliminary studies with Public Participation GIS (PPGIS) using a touch table with closed-ended questions and a photo-word matching task have proven encouraging in their ability to capture people's experience and interactions with different environmental settings.

The mapping of the spiritual, symbolic and other intangible interactions of CES remains challenging but it is a scientific area that is rapidly developing (reflected by the modifications to the CICES classification). This work is contributing to the discourse through its exploration of new technologies and interdisciplinary methods.

For further information contact Inga.Aalders@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.

Natural asset inventory and natural capital accounts

- The **Natural Asset Register** (NAR) (1.4.1a) which may be viewed here[7], continues to develop and had been updated with the addition of further data including soil risk maps (RD1.1.4), additional biodiversity metrics for AECS targeting, and a series of datasets relating to water quality and quantity. A first working version of a metadata creation tool has been produced to improve the efficiency with which data can be uploaded to the NAR by scientists with testing and refinement of the tool ongoing with the objective of rolling out to SEFARI members by March 2019. Finally, a review of software applications and platforms that provide access to environmental information on mobile devices will report in October 2018 (O1.4.1aD6), informing the development of NAR apps due to take place later this year (**Mar 2019;** intended audience: SG and 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[7]. The results are informing the development for 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. (Intended audience: agencies, local authorities; Inge.Aalders@hutton.ac.uk).
- Initial case studies of **Natural Capital Accounting** (1.4.1c) have focused on agriculture and 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 short summary[8] 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 2018, whilst a third case-study (peri-urban green space) will be started.

Multiple benefits and trade-offs

- 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 and predict the response to climate and land use change with the resulting maps made available to stakeholders in SG and agencies. These approaches will be refined and applied further in the areas of spatial targeting of incentives (**Nov 2018**) and the biodiversity off-setting (**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) 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

[7] http://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/RESAS_141_D4-Soc_Sci_StudyReport_FINAL.pdf
[8] http://www.hutton.ac.uk/research/srp2016-21/wp141-natural-asset-inventory-and-accounts

people and assist in specifying, selecting and evaluating policy options. The findings from this work have been communicated and discussed with SG agencies at a workshop on Social Innovation in rural areas of Scotland (**May 2018**) and will be disseminated within the scientific community via a conference session on social innovation at the 125 IUFRO Congress in Freiburg and several journal articles which are in preparation (**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 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 looked at the interactions between 10 policy instruments to deliver multiple benefits. The findings see here[9] are being disseminated (RGS-IBG conference Cardiff August, 2018, Scotland's Biennial Land Use and the Environment Conference XII, Edinburgh 28-29th November 2018 and via a blog). A review of the range of 'new' instruments in international practice that may potentially be relevant to managing Scotland's natural assets is in progress, resulting in a research brief. (**Oct 2018**). The review will be consulted on in order to select a case study to consider in more detail (**Mar 2019**; intended 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) with preliminary findings reported here[10]. A paper has been submitted to the journal 'Science of the Total Environment'. The key findings and recommendations will be shared with other audiences including SG and SG agencies in the next two months (**Nov 2018**; intended audience: SG and agencies; kerry.waylen@hutton.ac.uk)
- Research briefing for policy and management audience summarising our adaptive management case studies, and initial considerations of the issues and themes that have arisen across them (1.4.3a). Comparative assessment of landscape scale collaborative arrangements for the management of multiple benefits, cases include agri-environment (1.4.3b); woodland expansion (1.4.3c) and catchment (1.4.3d) case studies. Contributing to **Practical interventions to realise multiple benefits and manage trade-offs** (1.4.3) (**Mar 2019**; intended 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.

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

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

- 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. This includes the development of statistical models that build on previous work to generate high resolution soil data and integrate expert opinion and process models. Work is focussing on soil moisture and will in turn be used to model time series of productivity and soil moisture from earth observation data. (**Mar 2019**; intended audience: agencies; alessandro.gimona@hutton.ac.uk).
- Work to understand the **range shifts and resilience of key pest species to climate change** will focus on analysing data collated from existing databases and the literature during 2016-17 (1.3.3, O2.2a). Specifically a database on altitudinal and latitudinal limits of ticks are being combined with climate data to build models to predict current altitudinal and latitudinal tick distribution over the UK and Europe. In 2018-2019 this work will be extended to model tick range shifts due to climate at both a Scottish and European scale (intended audience: SG, scientists and stakeholders with an interest in tick distributions such as Scottish Countryside Rangers, Foresters (**Mar 2019**; Lucy.Gilbert@hutton.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. Work has begun to develop a local high resolution model of peatland restoration success for the area surrounding RSPB Forsinard (**Jan 2019**; intended 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 (earth worms and Tipulidae) for breeding and over wintering waders. Over 2018-19 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 2019**; intended 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**; intended 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**; intended audience: land managers and advisors graham.begg@hutton.ac.uk).
- The delivery of **multiple benefits from innovative and collective approaches to water management**[11] (1.4.3d) involves work on the Dee, Lunan and Leven catchments. Spatial data and associated maps of natural capital and ecosystem services are being 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 has provided insight into the management of the Lunan catchment for multiple benefits and its governance. A report describing the implementation, technical monitoring and lessons learnt is in preparation **(Jan 2019)**. In addition, a presentation of the results to be 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, and a manuscript submitted to the journal Aquatic Conservation **(Sep 2018)**. Engagement with the management of the Lunan and Leven catchments is ongoing including involvement in catchment management groups and planned discussions with policy makers to share outcome of stakeholder meetings at Lunan and Leven **(Feb 2019;** intended 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[12] presenting the findings has been published at the SRUC website and a scientific article[13] 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. The model will be applied for other agricultural supply chains, and a stakeholder workshop will be organised to identify relevant topics for new supply chain case studies **(Sep 2018)**. A framework and database description for new supply chain case study will be based on the outcome of the workshop (**Mar 2019**) and developed as manuscript exploring trade-offs between environment and food security objectives **(Mar 2019**; intended audience: SG, NGOs, industry; Ilkka.Leinonen@sruc.ac.uk).

[11] http://www.hutton.ac.uk/research/projects/payments-ecosystem-services-lessons
[12] https://www.sruc.ac.uk/downloads/download/1299/distillery_by-product_use_and_greenhouse_gas_emissions_from_scottish_malt_whisky_production
[13] http://www.mdpi.com/2071-1050/10/5/1473

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 will continue to be the focus of work considering how management interventions (e.g. restoration), and their effect on the relationship between people and the environment, can alter the **supply of ecosystem services**. Work in 2018-2019 will include further fieldwork and 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). The first of the panel workshops in Glen Creran woods (FC site) was held in April 2018, and the results summarised in a report. In addition, further qualitative data will be collected on the role of humans in, and their perceptions of, ES production throughout 2018. Assessing the potential of participatory video as a monitoring and evaluation tool to assess management interventions in Cumbernauld's greenspace has commenced in two case-studies: Pupils of St Maurice's High School and Neighbourhood Network Cumbernauld. This work is in close collaboration with The Conservation Volunteers and Scottish Wildlife Trust. The preliminary findings on citizen social science approaches to monitoring impacts of management interventions will be completed shortly (**Mar 2019**; intended audience: agencies, NGOs; Antonia.Eastwood@hutton.ac.uk).
- **Drivers of change in woodland diversity:** SEFARI scientists have contributed to the design of actions for enhancing habitat connectivity and resilience reported in a recent paper in Journal of Applied Ecology. This has drawn on research (1.4.2cii) that highlights habitat connectivity as a key issue affecting resilience of different species. Scotland's native woodlands have undergone significant species change in the last 30-50 years and the findings highlight the possibility of significant plant species losses under predicted climate change. The significance of these outputs to Scotland's plans for a National Ecological Network have been highlighted to SNH. Connectivity analyses developed for woodlands in years 1-2 are being applied to other habitats in years 3-5 with moorland identified as the next priority habitat. A short summary table of data availability for different habitats is being prepared to share and discuss with our stakeholder team (**Oct 2018**) and work is under way for the submission of a paper on our moorland and woodland research findings **(Mar 2019**; intended audience: agencies and NGOs; Alison.Hester@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). Work in 2018-2019 will experimentally test the suitability of alternative tree species to replace those threatened by new emerging plant pests and pathogens. We have developed a database of over 2000 species that are found on oak trees and included an assessment of if they will or will not use any of 30 other alternative tree species. Six sites across the UK are being visited where the similarities and differences in the lichens supported, bark characteristics and soil properties under eight different tree species are being assessed (**Mar 2019**; intended audience: SG and agencies, land managers; Ruth.Mitchell@hutton.ac.uk).
- **Detailed studies of key pathogens** are also 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 assessed techniques for detecting the presence of the pathogenic *Phytophthora* species in landscapes via water sampling. In 2018-2019 this work will be continued and analysed to understand the drivers of *Phytophthora* distribution and dispersal (**Dec 2018**; intended audience: SG and agencies, land managers; David.Cooke@hutton.ac.uk).

- **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 Glen Creran are at an advanced stage and will now be developed for Cumbernauld (Forest Wood) (**Mar 2019**; intended audience: land managers, industry; scott.herrett@hutton.ac.uk).
- **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 will be analysed to provide a research brief **(Dec 2018**) and a journal paper on stakeholder roles and relationships in AM for realising multiple land use benefits **(Mar 2019**; intended audience: NGOs; Antonia.Eastwood@hutton.ac.uk).

Outputs

Please check the following webpages for more information and links to publicly available outputs. New outputs since the last Bulletin are also listed below.

- RD1.3.1: Biodiversity and ecosystem function[14]
  - Evolution of facilitation requires diverse communities (1.3.1, O1.1a)
- RD1.3.2: Ecosystem services supply[15]
  - Does woodland ecosystem health matter for cultural benefits (1.3.1, O1.1)
  - Does ecosystem quality matter for cultural ecosystem services? (1.3.1, O1.1)
  - Glen Creran Woods - Exploring the perceived impacts of different management interventions on woodland benefits (1.3.1, O1.3)
- RD1.3.3: Resilience of ecosystems and biodiversity[16]
- RD1.3.4: Biodiversity management[17]
  - Governance for biodiversity – the role of values and perceptions (1.3.4, O1.2)
  - Biodiversity governance characteristics and values (1.3.4, O1.2)
- RD1.4.1: Natural asset inventory and accounts[18]
- RD 1.4.2: Multiple Benefits and trade-offs[19]
- RD1.4.3: Practical Interventions[20] immeasurable

Please contact the named researcher if you would like more information or an output not posted on the website (as there may be some that are not appropriate for dissemination via a webpage).

[14] http://www.hutton.ac.uk/research/srp2016-21/wp131-biodiversity-and-ecosystem-function
[15] http://www.hutton.ac.uk/research/srp2016-21/wp132-ecosystem-services-supply
[16] http://www.hutton.ac.uk/research/srp2016-21/wp133-resilience-ecosystems-and-biodiversity
[17] http://www.hutton.ac.uk/research/srp2016-21/wp134-biodiversity-management
[18] http://www.hutton.ac.uk/research/srp2016-21/wp141-natural-asset-inventory-and-accounts
[19] http://www.hutton.ac.uk/research/srp2016-21/wp142-identifying-and-understanding-multiple-benefits-and-trade-offs
[20] http://www.hutton.ac.uk/research/srp2016-21/wp143-practical-interventions-realise-multiple-benefits-and-manage-trade-offs

Summary of activities

Topic	Contact	Activities	Outputs
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 (**Jan 2019)**	Research summary (**March 2019**), research paper (**Jan 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**)
Impacts of genetic factors on reintroduction success of *Saxifraga hirculus* (1.3.1, O1.2a)	a.finger@rbge.ac.uk	Visits to reintroduction sites (**Oct 2018)**	Research paper and report (**Dec 2018**)
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	Development of bryophyte indicator – (**Mar 2019**); Development of publication outlining NCAI approach - **March 2019.**	Information notes, research summaries, journal paper (**Mar 2019**)
Visualisation tool for integrated open data kit and google earth	Cheng.Wang@hutton.ac.uk	Developing new method for data collection using mobile devises.	Sampling visualisation tool (**Mar 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 2019**)	Scientific paper "An inter-specific study of dispersal in lichen epiphytes" submitted
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	Field studies of liver fluke risk to livestock (**Mar 2019**)	

Develop enhanced analysis methods for INNS distribution data (1.3.3, O3.1a)	Stephen.Catterall@Bioss.ac.uk	Extend methods to include 50 tree/woody shrub INNS (**Jan-19**)	Scientific paper (**Jan-19**)
System – including ecosystem – resilience: identifying gaps in knowledge for Scotland's biodiversity and ecosystems (1.3.3, O1.1)	Glenn.Iason@hutton.ac.uk/Rob.Brooker@hutton.ac.uk	Joint work with SNH to implement resilience assessments (**Dec 2018**)	
Consequences of environmental and climate change for ecosystem resilience (1.3.3, O2.2b)	Scott.Newey@hutton.ac.uk	Identify and compile data on mountain hare distribution and environmental drivers (**Dec 2018**)	Basic GIS model of hare distribution/abundance (**Dec 2018**)
Susceptibility of Scots pine provenances to pests and fungal pathogens (1.3.3, O2.1)	Glenn.Iason@hutton.ac.uk/Jenni.Stockan@hutton.ac.uk	Results from experimental work communicated to stakeholders (**Dec 2018**)	
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 2018**)	
Natural Asset Register (1.4.1a)	David.Donnelly@hutton.ac.uk	Expand data sets (**Jun 2019**) Develop metadata tool (**Nov 2018**) Develop mobile app (**Mar 2019**)	Metadata tool: design (**Nov 2018**); implementation (**Mar 2019**) Mobile app (**Mar 2019**)
Cultural Ecosystem Services indicators and mapping (1.4.1bvi)	Inge.aalders@hutton.ac.uk	CES indicator development (**Dec 2018)**	Methods for intangible CES (**Dec 2018**) Indicators from 2° data (**Jan 2019**)
Modelling multiple ESS (1.4.2ci and cii)	Alessandro.gimona@hutton.ac.uk	Model development and application – **March 2019**	Methods for AE targeting (**Nov 2018**)

			Methods for 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)**	
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	Dissemination of results via conference session, presentations and preparation of review briefing (**Oct 2018**) and stakeholder consultation (**Mar 2019**)	Briefing on potential new instruments (**Oct 2018**) Workshop or equivalent (**Mar 2019**)
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	Stakeholder engagement (format to be determined) (**Nov 2018**)
Adaptive management approach to facilitate the evaluation and coordination of measures to deliver multiple benefits (1.4.3a).	kit.macleod@hutton.ac.uk	Preparation of research briefing providing description of the catchments using a common adaptive management framework	Research Briefing (**Nov 2018)**
Response of key pest species to climate change (1.3.3, O2.2a)	Lucy.Gilbert@hutton.ac.uk	Scottish/European-scale models of tick range shifts due to climate (**Mar 2019**)	
Peatland restoration (1.3.3, O2.2c).	Rebekka.Artz@hutton.ac.uk	Local high resolution model of peatland restoration success (**Jan 2019**)	Scientific paper (**Jan 2019**)
Ecosystem service flows and our inventory of natural assets (1.4.1bii)	Alessandro.Gimona@hutton.ac.uk	Development of statistical models of soil properties and time series model of productivity and soil moisture from earth observation data. (Mar 2019)	Statistical model of soil moisture (**Mar 2019**)
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 2019**)	
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**)
Implementation of agri-environment schemes at a landscape scale to deliver multiple benefits and protect natural assets (1.4.3b)	Graham.Begg@huttonac.uk	Developing further studies of landscape scale agri-env management	
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.	Stakeholder workshop to identify new supply chain case studies (**Sep 2018).** Framework and database description for new supply chain case study (**Mar 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 (**Mar 2019**). Participatory and citizen science approaches to monitor and evaluate woodland interventions (social and ecological) (**Mar 2019**).	Workshop report Glen Creran Woods: Exploring the perceived impacts of different management interventions on woodland benefits (**Oct 2018**). A Participatory Video on the impact of the TCV Wild Ways Well programme produced by Neighbourhood Networks

			(Cumbernauld) (**Dec 2018**).
Drivers of change in woodland diversity (1.4.2cii)	Alison.Hester@hutton.ac.uk	Research paper and discussion of findings with key stakeholders (**Oct 2018**). Extension of connectivity analyses to moorland habitat (Mar 2019)	Research paper (**Sep 2018**)
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**)	Popular articles (**Mar 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 (**Mar 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 commenced, as has the qualitative interviews with land managers on adapting management and will continue until (**Mar 2019**)	Research brief and paper on the roles of stakeholders and relationships in adaptive management (**Mar 2019**)

Table of Acronyms

AECS	Agri-Environmental Climate Scheme
AM	Adaptive Management
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
ODK	Open Data Kit
PGIS	Participatory GIS
PPGIS	Public Participation GIS
RSPB	Royal Society for the Protection of Birds
SBS	Scottish Biodiversity Strategy
SEFARI	Scottish Environment, Food and Agriculture Research Institutes
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