Ecosystems and Land Use Policy Exchange Group (ELPEG) Bulletin

Issue 5, September 2017

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 Bulletin does not try to cover all of the research being undertaken in the Biodiversity and Ecosystems and the Integrated Natural Assets work packages. It focuses on the work where there will be policy-related outputs and stakeholder engagement during the period September 2017 to March 2018, and 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 March 2018; note this includes some work with end dates beyond March 2018 but where activity will be underway this year. 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. It involves studies examining the ecology of keystone species of conservation concern, both native and non-native (including pests and diseases), as well as the relationships between biodiversity, people and the delivery of ecosystem services. It also includes work helping support delivery processes for the SBS, including for example the development of Ecosystem Health Indicators, or development of a National Ecological Network for Scotland.

- The underlying **mechanisms linking biodiversity and ecosystem service delivery** are being explored through focussed experimental studies (1.3.1, O1.1a). We are undertaking further analysis of data from our 2016 experimental study of barley-weed interactions, assessing how barley diversity effects propagate across trophic levels and impact on ecosystem function (initial results from which are now available[2] here); we have also been exploring experimentally the effects of barley genetic diversity on **resilience of ecosystem functions** (**February 2018**; intended audience SG, academics, land managers; Alison.Karley@hutton.ac.uk). In addition, detailed studies are examining the **genetic resource available within traditional bere barley landraces**, including assessing the growth

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

[2] http://www.hutton.ac.uk/sites/default/files/files/projects/Brooker%20et%20al__Barley%20mixtures%20poster_BES%202016.pdf

of different landraces under a range of environmental conditions. Understanding the adaptation of bere's to stressful environments might help in breeding crop lines able to cope with reduced inputs and so deliver more sustainable cropping systems (**March 2018**; intended audience SG, academics, land managers; Tim.George@hutton.ac.uk). More general information on our crop diversity work can be found online[3] and in the ELPEG Spotlight (below).

- Understanding the **impacts of genetic factors on reintroduction success** is critical for the conservation of threatened plants and animals. Building on foundation fieldwork undertaken in 2016, we have completed - for the threatened alpine plant species *Cicerbita alpina* - controlled long-term cross-pollination experiments at a RBGE nursery (1.3.1, O1.2a). This has involved crosses between material already sampled from UK populations (**August 2017**) and we are monitoring the survival of germinating plants. Site visits have been undertaken to assess the species' ecological requirements, information has been used to choose appropriate reintroduction sites (**D1.2i, due March 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. Field survey data from 2017 will be integrated into a long-term dataset prior to final analysis. This will focus on the vegetation dynamics across the first fifteen years of a controlled grazing experiment at Glen Finglas, identifying the functional impacts of removing or intensifying grazing (**September 2017**; intended audience SG, SNH, academics; Robin.Pakeman@hutton.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; data gathering includes interviews with stakeholders to collect data on ES benefits, disbenefits and their linkages (**October 2017**, following discussions within 1.3.2 of common approach to take). This new data will be combined with that gathered during 16-17 for the development of maps of ecosystem services (including uncertainties) for use by stakeholders such as SNH, LLTNP, SG, and will facilitate their translation into guidance for land managers (intended audience SG, agencies, land managers; Davy.McCracken@sruc.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). In particular we have provided information notes on the possibility of developing new EHIs focussing on urban greenspace[4] and previously-unused species diversity data[5], and we are currently developing the species diversity indicator (**March 2018**; intended audience agencies, SG). Likewise we are undertaking further work on refinements of the **Natural Capital Asset Index** (NCAI) (1.4.1, biii). Following an assessment of new NCAI datasets (available here) we are currently exploring how developments with the Natural Asset Register to plug gaps in the NCAI (**March 2018;** intended audience agencies, SG, SRP researchers; Rob.Brooker@hutton.ac.uk).
- One central element of ecosystem health is **habitat connectivity** (1.3.1 O3.2). Building on a connectivity scoping workshop held in March 2017 (Report available on request: Alison.Hester@hutton.ac.uk) and work presented at ELPEG[6] in May 2017, where a number of connectivity measures were applied to some of the main Scottish habitats, the results of this analysis will be mapped (1.4.2cii) and a report detailing results will be produced and discussed with key stakeholders (**January 2018)**, intended audience: SG and agencies;

[3] http://www.hutton.ac.uk/research/srp2016-21/wp131-biodiversity-and-ecosystem-function/crop-diversity
[4] http://www.hutton.ac.uk/sites/default/files/files/Information%20Note%20EHI%20Green%20Space.pdf
[5] http://www.hutton.ac.uk/sites/default/files/files/Information%20Note%20EHI%20Complex%20diversity%20indicators.pdf
[6] http://www.hutton.ac.uk/research/srp2016-21/elpeg-ecosystems-and-land-use-policy-engagement-group

Alessandro.Gimona@hutton.ac.uk). At a more detailed scale, and again building on work undertaken in 16-17, **connectivity metrics for temperate rainforest systems** (1.3.1, O3.3) are being used to identify areas that make a disproportionately high contribution to spatial connectivity for key (or a wide range of) species in that they (a) already harbour many species with large-scale isolation problems and function as spatial "bridges", or (b) the restoration of their natural vegetation would result in large overall connectivity gains (**January 2018**, intended audience: SG and agencies, land managers; C.Ellis@rbge.ac.uk).

- **Animal diseases** are a threat to Scotland's natural environments. Work within the SRP (1.3.3, O3.2b) examines in particular the role of squirrelpox virus (SQPV) in the replacement of native red squirrels by invasive grey squirrels. SRP researchers will provide blood testing as required by SWT and other landowners to track the progression of squirrelpox virus and 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 direct to appropriate stakeholders (**March 2018**; 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[7]. 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 (**March 2018**; intended audience SG, agencies, NGOs, land managers, farmers; Philip.Skuce@moredun.ac.uk).
- The spread of **invasive non-native species (INNS)** is also of major current concern. Within current INNS, **non-native trees and woody shrubs** are one group causing particular anxiety. The invasive behaviour of this group will be assessed using meta-analytical techniques (1.3.3, O3.1a; **March 2018**; 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. To enable the development and targeting of management actions to enhance resilience we will build on foundation work undertaken in 16-17. We will undertake a consultation with a key stakeholder - SNH - to identify main gaps in knowledge of ecological resilience in Scotland's biodiversity and ecosystems (**October 2017**) and will produce a report summarising these identified knowledge gaps (**January 2018**; intended audience SG, agencies, NGOs, land managers; Glenn.Iason@hutton.ac.uk).
- Understanding the **relationships between biodiversity and cultural ecosystem services** is a key current research priority. We are in the process of publishing our rapid evidence assessment literature review on the effects of biodiversity enhancement on the delivery of cultural ES (1.3.2, O1.1), focussing on "does the ecology of a place matter in terms of cultural ecosystem services being delivered". A research note will be produced summarising the findings from the rapid evidence assessment (**March 2018**; intended audience SG, SNH, researchers; Katherine.Irvine@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 during 16-17 on developing a participatory GIS (PGIS) will be continued to assess the impact of human disturbance and mitigation measures on resilience of Capercaillie within a study area in the Cairngorms National Park (**December 2017**). Secondly the PGIS will be extended to a second policy-relevant case study system, which will be chosen through consultation with stakeholders (**February 2018;** intended audience National Park Authorities, NGOs, agencies Scott.Newey@hutton.ac.uk).

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

- The extent to which **biodiversity of insects 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. Initial assessments have been made in July 2017. Results from the work will be the focus of a scientific publication and will also be communicated directly to key stakeholders (**March 2018**; intended audience: agencies; Glenn.Iason@hutton.ac.uk).
- The review of **biodiversity management 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) for biodiversity management in Scotland (1.3.4, O1.2). Using different qualitative research methods, this research will assess Scottish stakeholders' attitudes to and support for different types of mechanisms, and their design, implementation, and metrics for measuring the 'value' of biodiversity and ecosystem services. Findings from qualitative work will be summarised as reports and also discussed directly with key policy stakeholders (Scottish Government, SNH, SEPA, etc.). We aim to do this through ELPEG or ELSEG (**March 2018**; intended audience: SG and agencies, land managers; Anja.Byg@hutton.ac.uk). Additionally, work developed during year 1 (review of biodiversity governance mechanisms) was discussed at a joint 1.4.2 – 1.3.4 ESCom event on 23rd May (report forthcoming on ESCom website[8]).
- Modelling approaches will explore the **consequences of habitat loss**. A metapopulation model (1.4.2cii) is being developed to investigate the theoretical consequences of loss and gain of habitat in a spatially explicit and dynamic manner (beta version completed and being tested). The results will be discussed with stakeholders in **March 2018**, (intended audience: SG and agencies, land managers; Alessandro.Gimona@hutton.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 16-17, and refined through stakeholder consultation, are being used to prepare a research paper on biodiversity and ES impacts from proposed development. This considers both habitats at risk from different types of development (identified at local and national levels) 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 (**March 2018;** 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 birch woodland, and whether recently regenerated wood can be substituted for more ancient woodland. The initial phase of this work is the identification of chronosequence sites enabling contrasts between stands of different age (**March 2018;** intended audience: SG and agencies, land managers; c.ellis@rbge.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.

- A draft prototype **Natural Asset Register** (NAR) (1.4.1a) for use in helping assess where agri-environmental action could be targeted has been developed. Design choices with regard to content, structure and interfaces will be discussed with key stakeholders very shortly

[8] http://escom.scot/news

resulting in a consultation report due **September 2017** (intended audience: SG, agencies, NGOs and academics involved in developing and using web-based databases). Following iterations and improvements based on the consultation, the NAR will be put online for testing in **November 2017,** with work continuing towards the launch of the NAR as a publicly accessible and spatially explicit collection of data on natural assets **in late spring 2018.** (David.Donnelly@hutton.ac.uk).

- **Cultural Ecosystem Services (CES) indicators and mapping** (1.4.1bvi) is evaluating participatory research methods for their ability to fill in the data gaps identified during year 1. Data generated by these methods are combined with existing data to generate draft maps for CES (particularly landscape, spiritual and experiential services) in Scotland to be discussed with stakeholders in **October 2017** and finalised in **November 2017**, supplemented by a research briefing on methodological insights due **January 2018**. The original 'gap analysis' deliverable will be updated in **March 2018** (Inge.Aalders@hutton.ac.uk).
- Following on from draft maps presented at ELPEG in May 2017 showing **current status and associated with delivery of ecosystem services** (1.4.2a), future work is focussing on trade-offs between provisioning, regulating and cultural ecosystem services; and the historical pathways that resulted in these trade-offs, providing further maps and research brief (**November 2017,** Alessandro.gimona@hutton.ac.uk**).**
- **Policy option appraisal for delivery of multiple benefits** (1.4.2ci) aims to take the trade-off analysis further to extend it beyond ecosystem services by combining bio-physical data with farm data (farm type, farm payments etc.) and/or socio-demographic data to generate maps illustrating ES delivery from policy scenarios (**January 2018**, audience: SG and agency staff working on agri-environment measures including woodland expansion). Based on results from these maps, and premised on availability and engagement of these policy stakeholders, we plan to develop a policy briefing on impacts of land use change on ES by **March 2018** (Alessandro.gimona@hutton.ac.uk).
- Knowledge of **social innovation**, including its definition in the context of rural development, is being improved (Maria.Nijnik@hutton.ac.uk). We are now drafting a systematic framework for categorising and understanding social innovation (1.4.2 biii linked to 1.4.3), and to test the conceptualization and promote operationalization of social innovation in rural areas of Scotland, a science-policy-practice workshop is planned (by **March 2018**) - (Intended audience: SG and EU policy makers, land-use planners and managers in Scotland).
- Initial case studies of **Natural Capital Accounting** (1.4.1c) will be agriculture and forests and woodland. To support these, primary valuation studies are underway on forest recreation (pan European, with Scottish element funded by the SRP) and water quality and biodiversity impacts of agriculture (funded by H2020 PROVIDE). Early insights were shared at a natural capital valuation seminar[9] (**June 2017).** Data collection has been completed and analysis is underway. A short summary of survey rationale, methods, preliminary results and planned future analysis will be available by end of **September 2017** and further results sharing seminar in **March 2018,** intended audience OCEA, (Alistair.McVittie@sruc.ac.uk).
- Research **assessing economic impacts of changes in Ecosystem Services** (1.4.2ciii) will be presented to a meeting of OCEA economists (Office of the Chief Economic Adviser – SG) in **September 2017** (Dominic.Moran@sruc.ac.uk). Using the methodology agreed December 2016 and published in two briefing papers by Fraser of Allander Institute available on request, the results from a case study will be presented in a technical report in **September 2017**. The stakeholders will then be consulted on the next case study for development in **November 2017** (the case study results will be shared in year 3).

[9] http://escom.scot/blog/natural-capital-national-performance-and-economy

ELPEG SPOTLIGHT

Diversity and ecosystem function: advancing knowledge using crop mixtures (RD 1.3.1, O1.1 & RDs 2.1.8 and 2.3.8)

Several studies within the 2016-2021 Strategic Research Programme (SRP) aim to understand the role of biodiversity in regulating the functioning of crop production systems. Species-rich systems often show higher productivity than monocultures, with fewer pest and disease outbreaks, improved resource capture and greater resilience to environmental fluctuations and stress. Arable crops offer a simplified production system that could capitalise on these benefits through increased species and within-species (i.e. genetic) diversity. Here, we describe our current work to investigate diversity-function relations, which builds on studies from the previous SRP and other projects in a number of thematic areas.

Biodiversity-function relationships - A critical research challenge is to understand the mechanisms underpinning relationships between biodiversity and ecosystem function. We use a range of approaches to explore this, all focussing on crop production systems. Greenhouse studies using constructed barley and arable weed communities have indicated that increased plant productivity is associated with both weed species diversity and barley genotype diversity. Weed species diversity effects were largest, probably because the relationship between diversity and function is strongly regulated by plant traits and, in our studies, traits varied more between weed species than between barley genotypes. However, positive effect of barley genotype diversity on productivity were due to genuine complementarity between the genotypes in their traits and associated functions, demonstrating the positive effects of crop genetic diversity on ecosystem functions. We have extended this work with large-scale field trials. Initial analyses indicate a positive relationship between weed diversity and barley production, and we are exploring this in more detail to identify the underlying mechanisms.

Crop – rare plant interactions - As well as looking at interactions between biodiversity and common arable weeds, we have explored the relationship between crops and survival of rare plants which were once common weeds of arable systems. Our greenhouse studies showed that the diversity of common weeds has negative impacts on the establishment of new plant species, in particular rare arable plants, indicating that these rare species might be inferior competitors. In field trials the rare plant, *Valerianella rimosa*, germinated better in the presence of spring barley, suggesting that crops provide the conditions which these rare plants need to establish. We followed this with further field trials to examine the response of a wider range of rare arable plants to diversity in crop systems.

Breeding for better mixtures - Work from the Strategic Research Programme underpinned development of the new H2020-funded DIVERSify project, aiming to optimise the performance of crop species mixtures ('plant teams') to improve yield stability, reduce pest and disease damage, and enhance stress resilience in agricultural systems. A particular focus is the synergies between cereal and legume species, which are being studied in RESAS Research Deliverable 2.1.8 "Novel Crops" to develop winter crop species combinations for use in silage for feed or biomass for anaerobic digestion, and in RD2.3.8 "Alternative approaches to sustainable land management" to examine their contribution to ecosystem services of pollination and biocontrol.

In our presentation for the ELPEG meeting on 4th September 2017 we will show results from our experimental trials and discuss in more detail the link between this fundamental research and new studies exploring plant breeding for mixtures.

For further information contact Alison.Karley@hutton.ac.uk or Rob.Brooker@hutton.ac.uk

More information on our crop mixtures work can also be found here: http://www.hutton.ac.uk/research/srp2016-21/wp131-biodiversity-and-ecosystem-function/crop-diversity; More information on DIVERSify can be found here: https://www.plant-teams.eu/

- **Opportunities to increase multiple benefits through policy and industry delivery mechanisms** (1.4.2bi) will continue to focus on the alignment of existing policy mechanisms governing soil, water and biodiversity. We obtained stakeholder feedback on draft results in May 2017 (in a joint ESCom workshop with 1.3.4 on biodiversity governance, report forthcoming[10]). Based on criteria identified in year 1, we will continue to analyse 10 policy instruments with final summary reporting due **March 2018**. (Kirsty.Blackstock@hutton.ac.uk). This work will also help to frame the research on **Using Monitoring and Evaluation to deliver multiple benefits** (1.4.2bii). We have started to analyse monitoring associated with Water Framework Directive, Natura 2000 directives and Agri-environment schemes in Scotland and 9 other member states. The draft findings were discussed at an international workshop[11] in **June 2017**, leading a good practice summary report in **March 2018** (Kirsty.blackstock@hutton.ac.uk).
- The **adaptive management approach to facilitate the evaluation and coordination of measures to deliver multiple benefits (**kit.macleod@hutton.ac.uk) (1.4.3a) will be applied to evaluate our agri-environment (O1.4.3b); woodland expansion (O1.4.3c) and catchment (O1.4.3d) case studies and initial insights presented at an SNH Sharing Good Practice Event in **June 2018** (intended audience: SG and agency staff, SE-LINK, ESCom members).

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.

- Research **assessing multiple land use options** (1.4.2cii) is focussing on climate adaptation and mitigation impacts when trading off agriculture against woodland expansion, including a contribution to a CxC review paper[12] (**July, 2017**):. National-scale multi-criteria models of trade-offs based on the exploration of intensification and extensification scenarios (for 2050) will lead to maps of potential trade-offs (**November 2017**). Further scenarios will be run to look at national-scale multi-criteria models of potential future trade-offs based on the exploration of scenarios of afforestation and peatland restoration. Mapped results will be available by **January 2018** generating, if requested, policy briefings summarising opportunity mapping results by **March 2018** (Alessandro.Gimona@hutton.ac.uk).
- Further research on new methods to improve our understanding of **ecosystem service flows and our inventory of natural assets** (1.4.1bii) is focussing on improved habitat maps based in the EUNIS classification (initial results focussed on peatlands **September 2017**). These habitat maps will be consulted on (intended audience: SG and agencies with an interest in modelling ES delivery) and a report on the potential of the methodology will be published **March 2018**, (Alessandro.gimona@hutton.ac.uk). This complements **analysis of Earth Observation (EO) data in biodiversity modelling** (1.4.1bi) that will help generate results at a finer resolution (Alessandro.Gimona@hutton.ac.uk), leading to a collated data set (**January 2018**) and draft maps to be shared with stakeholders (**March 2018**). Intended audience: SG and agencies, particularly SNH.

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

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

[12] http://www.climatexchange.org.uk/files/8314/9847/9483/Natural_Resources_adaptation_research_priorities.pdf

- Work to understand the **response of key pest species to climate change** will focus on analysing data collected during 16-17 (1.3.3, O2.2a). Specifically a database on altitudinal and latitudinal limits of ticks will be combined with climate data to build models to predict current altitudinal and latitudinal tick distribution over the UK and Europe (**February 2018**; intended audience: SG and agencies with an interest in tick distributions, Lucy.Gilbert@hutton.ac.uk).
- Peatland systems are a key component of the natural environments contribution to climate change mitigation. We will produce a national model of **peatland condition** for Scotland based on MODIS satellite images (1.3.3, O2.2c). The results of this modelling exercise will be written up as a research paper along with associated targeted summary material (**March 2018**; intended audience: SG and agencies/NGOs with an interest in peatland systems, Rebekka.Artz@hutton.ac.uk). This will complement improvements in the way we model peat depth and condition (1.4.1biv) leading to maps and a report in **March 2018**; intended audience: SG and agencies/NGOs with an interest in peatland systems (Matt.Aitkenhead@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.

- Work to assess **new management options for agri-environment schemes** (1.3.4, O2) will bring together existing evidence, and information gathered from engagement with stakeholders, to propose new management measures for inclusion in agri-environment schemes in Scotland. Work within year 2 of the Programme will assess their suitability and cost-effectiveness for future inclusion in the SRDP (**March 2018**; intended audience: SG and agencies involved in Agri-Environmental Climate Scheme (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. We are monitoring the effects of lime on soil characteristics, earthworms and vegetation to investigate the effects of lime addition on soils processes and how these affect the availability of key invertebrate prey for upland waders, and habitat characteristics. Data on wader numbers will be combined with sward diversity data, invertebrate data, and soil characteristics (pH, bulk density and water regime) to assess the effects of liming on farmland waders. Liming trials are being established during the summer of 2017 (**March 2018**; 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 and how species respond to targeting will be carried out by **December 2017**; intended audience: SG and

agencies involved in AECs implementation post 2021, Robin.Pakeman@hutton.ac.uk), leading to a potential new scoring system outlined in a paper (**October 2018**).

- Research is **assessing the potential for Environmental Focus Areas (EFAs), Agri-Environmental Climate Schemes (AECS) and the Environmental Cooperation Action Fund (ECAF) to deliver multiple benefits at a landscape scale** (1.4.3b) within case study catchments based around i) the arable Balruddery Centre for Sustainable Cropping and ii) the three MRP grassland research farms (Glensaugh, Hartwood and Kirkton/Auchentyre) and the Game and Conservation Wildlife Trust farm at Auchnerran. Initial results from year one will be shared at an annual demonstration day at Glensaugh, looking a soil liming and woodland expansion issues (**September 2017**) (intended audience: local farmers, NFUS, Scottish Land & Estates). (Justin.Irvine@hutton.ac.uk). Initial analysis of cooperation data will be presented in a report (**December 2017**) and refined based on discussions in the catchments (Katrin.prager@hutton.ac.uk). Maps of catchment scale delivery of ecosystem services based on new high resolution data will be available **December 2017**, and these will be used as a baseline for scenarios illustrating gains in ecosystem service delivery given the landscape scale adoption of EFA or AECS measures, generating simulations by **March 2018**.
- **The** delivery of **multiple benefits from innovative and collective approaches to water management**[13] (Andy.Vinten@hutton.ac.uk). This work will report on options for water quality and water quantity management (draft report online; final reports due **September 2017**, intended audience: policy, agencies, land managers) and on the changes in monitored parameters by **March 2018**.
- 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 (**June 2017,** report available on request). A beef supply chain model is being developed and applied to the beef supply chain to identify geographical, sectoral and supply chain hotspots (in terms of GHG emissions resulting in a corresponding database of material flows of beef production at farm level **(March 2018)** (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 will continue to be the focus of work considering how management interventions, and their effect on the relationship between people and the environment, can alter the **supply of ecosystem services**. Using case studies of woodland management in the Cairngorms National Park, Glen Creran and the Central Scotland Green Network (Cumbernauld Living Landscape), initial activities included developing a conceptual framework for assessing the production of woodland ecosystem services and the outcomes of management interventions (e.g. ecosystem restoration). We are building on this work in year 2 of the SRP, collecting data on the human role in and perceptions of ES production, as well as assessments of service delivery at three points in time (past, present and future) and across study sites, in close interaction with stakeholders in these areas (1.3.2, O1.1-O1.9). Scenarios reflecting contrasting future woodland management priorities will be developed in collaboration with stakeholders (**September 2017**; intended audience: land managers;

[13] http://www.hutton.ac.uk/research/projects/payments-ecosystem-services-lessons

Antonia.Eastwood@hutton.ac.uk), and a first set of qualitative data on the role of humans in, and their perceptions of, ES production will be collected (**March 2018**; intended audience: land managers; Anke.Fischer@hutton.ac.uk).

- Building on new connectivity data analysis undertaken in 16-17 and our connectivity scoping workshop with stakeholders from relevant initiatives across Scotland (see above under SBS), a paper on **drivers of change in woodland diversity** at different scales (local, regional, national), and the implications of these drivers for land management will be produced (1.4.2cii). Findings will be discussed directly with relevant SG policy and agency staff (**February 2018**; intended audience: SG and agencies, land managers; 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). A draft protocol to assess environmental risks from tree diseases will be discussed with stakeholders and summarised in a short research note (**February 2018**; 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 (**March 2018**; intended audience: land managers; K.Hayden@rbge.ac.uk) and (1.3.3, O3.1c) assessing techniques for detecting the presence of the pathogenic *Phytophthora* fungi in landscapes via water sampling, as well as the impact of environmental factors in regulating *Phytophthora* species diversity (**February 2018**; intended audience: SG and agencies, land managers; David.Cooke@hutton.ac.uk).
- Related work to develop **approaches that reconcile woodland expansion with other land use priorities** (1.4.3c) will address processes of adaptive management i) in Cumbernauld (Central Scotland Green Network) and ii) the Cairngorms National Park. Maps of woodland expansion options and consequences of these options for ecosystem services and biodiversity are being developed (alessandro.gimona@hutton.ac.uk). Work will begin on planning and executing the digital storymapping exercise with communities of interest in the Cairngorms National Park (katrina.brown@hutton.ac.uk). Participatory mapping workshops will be held **(September 2017)** to work with key stakeholders to identify and clarify the social and ecological criteria needed for the woodland expansion model to be useful aids to deliberating land-use change decisions. Using insights from this approach and further model iterations, the results of woodland expansion options will be published **December 2017**. (Proposed audience: SG agency staff; justin.irvine@hutton.ac.uk).

Please check the following webpages for more information and links to publicly available outputs:

- RD1.3.1: Biodiversity and ecosystem function[14]
- RD1.3.2: Ecosystem services supply[15]
- RD1.3.3: Resilience of ecosystems and biodiversity[16]
- RD1.3.4: Biodiversity management[17]
- RD1.4.1: Natural asset inventory and accounts[18]

[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

- RD 1.4.2: Multiple Benefits and trade-offs[19]
- RD1.4.3: Practical Interventions[20]

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).

Summary of activities

Topic	Contact	Activities and Due dates
Scottish Biodiversity Strategy		
Resilience of ecosystem functions (1.3.1, O1.1a)	Alison.Karley@hutton.ac.uk	Explore in more detail the effects of genetic diversity in service delivery - **February 2018**
Genetic resource available within traditional bere barley landraces (1.3.1, O1.2b)	tim.george@hutton.ac.uk	Results of nutrient deficiency tolerance studies – **March 2018**
Impacts of genetic factors on reintroduction success (1.3.1, O1.2a).	a.finger@rbge.ac.uk	Controlled pollination experiment (**August 2017**) and visits to field sites (**March 2018**).
Impact of management regimes on biodiversity, ecosystem function and ecosystem service delivery (1.3.1, O1.3a)	robin.pakeman@hutton.ac.uk	Identification of the functional impacts of removing or intensifying grazing – **September 2017**
Impacts of management regime on ecosystem service supply in upland ecosystems (1.3.1, O1.3a)	Davy.McCracken@sruc.ac.uk	Interviews with stakeholder – **October 2017**
Ecosystem Health Indicators (1.3.1, O2.1) **& Natural Capital Asset Index** (1.4.1, biii)	Rob.Brooker@hutton.ac.uk	Development of species diversity indicator – **March 2018;** Identifying data gaps and links to NAR - **March 2018**.
Habitat connectivity mapping (1.4.2cii)	Alessandro.Gimona@hutton.ac.uk	Habitat connectivity results discussed with key stakeholders - **January 2018**
Connectivity metrics for temperate rainforest systems (1.3.3, O3.3)	C.Ellis@rbge.ac.uk	Identify areas that make a disproportionately high contribution to spatial connectivity for key species - **January 2018**
Animal diseases – squirrel pox virus (1.3.3, O3.2b)	Colin.Mcinnes@moredun.ac.uk	Data and advice on the general problem of SQPV provided

[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

		direct to appropriate stakeholders - **March 2018**
Animal diseases – liver fluke (1.3.3, O3.2b)	Philip.Skuce@moredun.ac.uk	Field studies of liver fluke risk to livestock - **March 2018**
Meta-analysis of the invasive behaviour of non-native trees and woody shrubs. (1.3.3, O3.1a)	Stephen.Catterall@Bioss.ac.uk	Meta-analysis – **March 2018**
System – including ecosystem – resilience: identifying gaps in knowledge for Scotland's biodiversity and ecosystems (1.3.3, O1.1)	Glenn.Iason@hutton.ac.uk	Consultation with SNH – **October 2017**; Summarising identified knowledge gaps in short report – **January 2018**
Relationships between biodiversity and cultural ecosystem services (1.3.2, O1.1),	Katherine.Irvine@hutton.ac.uk	Rapid evidence assessment literature review on effects of biodiversity enhancement on cultural ES – **March 2018**
Consequences of environmental and climate change for ecosystem resilience (1.3.3, O2.2b)	Scott.Newey@hutton.ac.uk	Assess consequences of scenarios for target species (Capercaillie) – **December 2017** Stakeholder consultation on 2nd case study choice – **February 2018**
Biodiversity of insects associated with Ecosystem foundation tree species (1.3.3, O2.1)	Glenn.Iason@hutton.ac.uk	Results from experimental work communicated to stakeholders – **March 2018**
Biodiversity management mechanisms: (RD 1.3.4, O1.2)	Anja.Byg@hutton.ac.uk	Report on attitudes and perceptions of different ways of designing and implementing biodiversity management mechanisms in Scotland – **March 2018**
Consequences of habitat loss (1.4.2cii)	Alessandro.Gimona@hutton.ac.uk	Develop a meta-population model - **March 2018**
Assessment of habitat/species distributions and impacts of habitat loss and gain (1.3.4, O3)	Alistair.Mcvittie@sruc.ac.uk	Research paper on biodiversity and ES impacts from development - **March 2018**
Test cases to examine feasibility of offsetting for woodlands (1.3.4, O3)	C.Ellis@rbge.ac.uk	Chronosequence of sites identified and first phase of field sampling – **March 2018**
Land Use Strategy for Scotland		
Natural Asset Register (1.4.1a)	David.Donnelly@hutton.ac.uk	Consultation report - **September 2017** Testing online NAR – **November 2017**
Cultural Ecosystem Services indicators	Inge.aalders@hutton	KE meeting – **October 2017**

and mapping (1.4.1bvi)	.ac.uk	Draft maps for CES in Scotland - **November 2017** Research briefing - **January 2018**. Updated Gap Analysis Report – **March 2018**
Current status and associated with delivery of ecosystem services (1.4.2a)	Alessandro.gimona@hutton.ac.uk	Maps and research brief - **November 2017**
Policy option appraisal for delivery of multiple benefits (1.4.2ci)	Alessandro.gimona@hutton.ac.uk	Maps illustrating ESS delivery from policy scenarios – **January 2018** Policy brief – **March 2018**
Using social innovation to deliver multiple benefits in forestry (1.4.2biii)	Maria.Nijnik@hutton.ac.uk	Framework for categorising and understanding SI - **March 2018**
Natural Capital Accounting (1.4.1c)	Alistair.McVittie@sruc.ac.uk	Natural capital valuation seminar - **March 2018**
Assessing economic impacts of changes in Ecosystem Services (1.4.2ciii)	Dominic.Moran@sruc.ac.uk	Technical report - **September 2017**. Stakeholder consultation on the next case study - **November 2017**
Opportunities to increase multiple benefits through policy and industry delivery mechanisms (1.4.2bi)	Kirsty.blackstock@hutton.ac.uk	Stakeholder feedback summary **September 2017** Final summary reporting - **March 2018**.
Using Monitoring and Evaluation to deliver multiple benefits (1.4.2bii)	Kirsty.blackstock@hutton.ac.uk	Summary report - **March 2018**
Adaptive management approach to facilitate the evaluation and coordination of measures to deliver multiple benefits (1.4.3a).	kit.macleod@hutton.ac.uk	Case studies and initial insights presented at an SNH 'Sharing Good Practice Event' or equivalent – **June 2018**
Climate Change Plan & Climate Change Adaptation Programme		
Assessing multiple land use options (1.4.2cii)	Alessandro.Gimona@hutton.ac.uk	Maps of future trade-offs- **November 2017**. Maps of scenarios - **January 2018** Policy briefings (if requested) - **March 2018**
Ecosystem service flows and our inventory of natural assets (1.4.1bii)	Alessandro.Gimona@hutton.ac.uk	Improved habitat maps - **September 2017**. Published report on the

		potential of the methodology - **March 2018**
Analysis of Earth Observatory (EO) data in biodiversity modelling (1.4.1bi)	Alessandro.Gimona@hutton.ac.uk	Collated data set (**January 2018**) Draft maps to be shared with stakeholders (**March 2018**).
Response of key pest species to climate change (1.3.3, O2.2a)	Lucy.Gilbert@hutton.ac.uk	Models to predict current altitudinal and latitudinal tick distribution over UK and Europe – **February 2018**
Model of peatland condition (1.3.3, O2.2c).	Rebekka.Artz@hutton.ac.uk	Research paper and associated targeted summary material - **March 2018**
Methodology to model peat depth and condition (1.4.1biv	Matt.Aitkenhead@hutton.ac.uk	Maps and a report - **March 2018**
SRDP and CAP greening		
New management options for agri-environment schemes (1.3.4, O1.1 & O1.2)	Robin.Pakeman@hutton.ac.uk	Stakeholder consultation on novel measures and associated policy brief – **March 2018** The establishment of new experimental investigation(s) - **March 2018**
Impact of liming (1.3.1, O1.3b)	Scott.Newey@hutton.ac.uk	Liming trials established – **March 2018**
Targeting SRDP payments for biodiversity (1.4.1bv)	Robin.Pakeman@hutton.ac.uk	Consultation – **December 2017** Potential new scoring system outlined in a paper – **October 2018**
Assessing the potential for Environmental Focus Areas (EFAs), Agri-Environmental Climate Schemes (AECS) and the Environmental Cooperation Action Fund (ECAF) to deliver multiple benefits at a landscape scale (1.4.3b)	Justin.Irvine@hutton.ac.uk	Demonstration Day – Glensaugh – **September 2017** Report on barriers to cooperation - **December 2017** Maps of catchment scale delivery of ES - **December 2017** Simulations of catchment scale delivery of ES -**March 2018.**
Innovative and collective approaches to water management (1.4.3d)	Andy.Vinten@hutton.ac.uk	Reports on innovative options for water management – **September 2017** Reports on changes in parameters – **March 2018**
Improving the environmental	Ilkka.Leinonen@sruc	Spatial database – **March 2018**

performance of beef supply chains (1.4.2biv)	.ac.uk	
Scottish Forestry Strategy		
Human-environment interactions in the supply of ecosystem services (1.3.2, O1.1-O1.9)	Antonia.Eastwood@hutton.ac.uk ; Anke.Fischer@hutton.ac.uk	Scenarios developed –**Sept 2017**; First set of qualitative data – **March 2018**
Drivers of change in woodland diversity (1.4.2cii)	Alison.Hester@hutton.ac.uk	Research paper and discussion of findings with stakeholders – **February 2018**).
Impacts of tree pests and diseases - risk assessment for service provision (1.3.3, O3.1a).	Ruth.Mitchell@hutton.ac.uk	Draft protocol discussed with stakeholders - **February 2018**
Detailed studies of key pathogens – *Phytopthora* monitoring programme (1.3.3, O3.1c).	K.Hayden@rbge.ac.uk	Detailed studies completed – **March 2018**
Detailed studies of key pathogens – *Phytopthora* detection and diversity (1.3.3, O3.1c).	David.Cooke@hutton.ac.uk	Detailed studies completed - **February 2018**
Approaches that reconcile woodland expansion with other land use priorities (1.4.3c)	Justin.Irvine@hutton.ac.uk	Produce digital storytelling methodology - **August 2017**. Participatory workshops completed **- September 2017** Woodland expansion options - **December 2017**.

Table of Acronyms

AECS	Agri-Environmental Climate Scheme
ARC-Trust	Amphibian and Reptile Conservation Trust
CAP	Common Agricultural Policy
CCAP	Climate Change Adaptation Programme
CCP	Climate Change Plan
CES	Cultural Ecosystem Services
ECAF	Environmental Cooperation Action Fund
EFA	Environmental Focus Area
EHI	Ecosystem Health Indicators
ELPEG	Ecosystems & Land Use Policy Exchange Group
ELSEG	Ecosystems and Land Use Stakeholders Engagement Group
ES	Ecosystem Services
ESCom	Ecosystem Service Community Scotland
EU	European Union
EUNIS	European Nature Information System
GBR	General Binding Rules
GHG	Greenhouse Gas
GIS	Geographical Information System
H2020 PROVIDE	EU project on public goods and bads from agriculture and forestry in Scotland.
INA	Integrated Natural Assets
INNS	Invasive Non-Native Species
LLTNP	Loch Lomond and The Trossachs National Park
MODIS	Moderate Resolution Imaging Spectroradiometer
NAR	Natural Asset Register
NCAI	Natural Capital Asset Index
NFM	Natural Flood Management
NFUS	National Farmers Union Scotland
NGO	Non-Government Organisation
NPA	National Park Authorities
OCEA	Office of the Chief Economic Advisor
PGIS	Participatory GIS
RBGE	Royal Botanic Gardens Edinburgh
RSPB	Royal Society for the Protection of Birds
SBS	Scottish Biodiversity Strategy
SEPA	Scottish Environment Protection Agency
SFS	Scottish Forestry Strategy
SG	Scottish Government
SI	Social Innovation
SLE	Scottish Land and Estates
SNH	Scottish Natural Heritage
SQPV	Squirrel pox virus
SRDP	Scottish Rural Development Programme
SRP	Strategic Research Programme
SWT	Scottish Wildlife Trust