Ecosystems and Land Use Policy Exchange Group (ELPEG) Bulletin

Issue 7, June 2018

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 May – November 2018. 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 November 2018. 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). 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. Manuscripts based on these results have been submitted to scientific journals, and 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** (**January 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. Research so far has shown that extant barley landraces selected over many generations on marginal soils have adapted to

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

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 (**October 2018**; 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. 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). Site visits have been undertaken to assess the species' ecological requirements, information has been used to choose appropriate reintroduction sites and plants have been planted into three new sites in the Cairngorms National Park. In 2018-2019 we will continue to monitor the survival of germinating plants resulting from cross-pollinations, and monitor the survival of reintroduced plants (**October 2018**). We will develop further studies targeted on a wider range of priority species (**December 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 have been 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. 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 (**March 2019**; 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 have included workshops with farmers and their advisors to assess their attitudes to biodiversity management (e.g. peatland restoration, deer and livestock grazing controls, moorland management etc.) and woodland management and creation on farms. This includes interviews with stakeholders to collect data on ES benefits, disbenefits and their linkages, which will enable the development of example maps of ecosystem services (and their uncertainties) for discussion with stakeholders. Work in 2018-2019 will involve a workshop with local experts to elicit their views on land use change scenarios and the likely impact on ecosystem service delivery (**September 2018**). It will also involve draft example maps of ES and uncertainties at a farm/estate level being disseminated and discussed with a small group of wider science and policy audience to allow the co-construction inform the development of final draft versions (**August 2018**; 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). Most recently we have been working on development of a novel biodiversity indicator based on distributional records of mosses, a key component of Scotland's biodiversity; following planning discussions with SNH staff (**May 2018**) we will be taking this work forward with a fuller analysis of the indicator's trends and the aim of inclusion of this new indicator in the EHI suite (**March 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 initial discussion with key staff in SNH to

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

determine research priorities for the year (**May 2018**; intended audience: agencies, SG, SRP researchers; Rob.Brooker@hutton.ac.uk).

- An important element of ecosystem health is **habitat connectivity** (1.4.2cii). The results of a habitat connectivity analysis have been mapped and a report is available. Findings will be discussed with key stakeholders (**October 2018**; intended audience: SG and agencies; Alessandro.Gimona@hutton.ac.uk). Future plans for 2018-19 include integrating this analysis with one grounded on individual-based movements, and then consulting stakeholders (particularly SNH in relation to the National Ecological Network) in order to apply the approach to further habitat types (**November 2018**; intended audience: SG and agencies, scientists, land managers; Alison.hester@hutton.ac.uk).
- 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 (**March 2019**; intended audience: SG and agencies, land managers; C.Ellis@rbge.ac.uk).
- **Animal diseases play a regulatory role in and can threaten** Scotland's natural environments. Work within the SRP (1.3.3, O3.2b) examines the role of squirrelpox virus (SQPV) in the replacement of native red squirrels by invasive grey squirrels. SRP 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 was provided direct to appropriate stakeholders and a similar plan of work will be adopted in 2018-2019 (**March 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 (**March 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. Application to **non-native trees and woody shrubs** informed a meta-analysis designed to address questions such as which groups of introduced species are more invasive and which habitats are at higher risk of invasion. This work has now been written up as a draft paper (1.3.3, O3.1a). Current work involves identifying and prioritising potential areas for improvement in our analytical approaches for handling INNS spread data (**August 2018**), as well as consideration of the extension of modelling techniques to the spread of plant pests/pathogens (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 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. The workshop report[4] identified knowledge gaps,

[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

and a UK-level forum run by JNCC has emerged. In 2018-2019 we will continue to work closely with SNH on these issues, with an initial planning meeting (**May 2018**) in particular helping to develop a resilience assessment framework and to "road-test" this framework at a number of sites (**December 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. A research summary has been developed from the 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". Distribution is currently underway (**June 2018**) and we are in the process of publishing the review in a peer-reviewed journal (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 2016-17 on developing a participatory GIS (PGIS) for Capercaillie "CaperMap" has now been completed and was handed to stakeholders at a recent workshop. In 2018-19 we intend to work with stakeholders to use CaperMap in a case study within a study area in the Cairngorms National Park (**September 2018**). After consultation with stakeholders mountain hares have been chosen as the second policy-relevant case study. Building on CaperMap we will develop a PGIS "HareMap" to enable stakeholders 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 (**December 2018**, intended audience: SNH, National Park Authorities, NGOs, agencies; Scott.Newey@hutton.ac.uk).
- 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 and results from the work will be the focus of a scientific publication and will also be communicated directly to key stakeholders (**September 2018**). Work in 2018-2019 will focus on the susceptibility of native Scots pine provenances to pests and fungal pathogens (**February 2019**, intended audience: agencies; Glenn.Iason@hutton.ac.uk).
- The review of **biodiversity governance mechanisms** developed in 2016/17 is being used as the basis to explore with stakeholders the potential for using different governance mechanisms (including market, non-market and hybrid mechanisms) and the role of values and perceptions for biodiversity governance in Scotland (1.3.4, O1.2). Interviews and a workshop with key stakeholders, including government, land managers and environmental organisations exploring these issues have been conducted and results summarised in two reports. Findings suggest that attempts to promote biodiversity conservation inevitably have embedded in them particular perceptions of biodiversity and people as well as the relationship between them. Values play a role in determining what to conserve and where, what to regard as acceptable ways of using and managing land and biodiversity, and how to frame and negotiate trade-offs. The interviews highlighted the need for a variety of governance approaches that can promote human connections with nature and can reconcile different values, uses and needs. Similarly, workshop results indicate that different values can appeal to different people and therefore there is a need to work across a range of mechanisms. Participants highlighted the role of partnerships, partly as a response to resource limitations but also as they're seen to constitute 'good' governance. This research will be followed up by another stakeholder workshop in **June 2018** and further fieldwork focusing on the role of values for biodiversity governance. Findings from this work will be summarised as reports and also discussed directly with key stakeholders (**March 2019**;

intended audience: SG and agencies, land managers, environmental organisations; Paula.Novo@sruc.ac.uk).

- 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 have been discussed with stakeholders (**March 2019**; intended audience: SG and agencies, land managers; Alessandro.Gimona@hutton.ac.uk). The focus in 2018-19 will be to develop the results for a scientific publication.
- 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, 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. Work in 2018-2019 will focus on communicating the work to a range of stakeholder groups (**March 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 (**November 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 **Natural Asset Register** (NAR) (1.4.1a) has been developed and is publicly available here[5] and the consultation report is available here[6] Future work includes updating the NAR with data as it becomes available; developing a user group and a tool to help data providers ensure the data are in a suitable format for sharing with end-users. (**June 2018**; (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. Data generated by these methods have been combined with existing data to generate draft maps for CES (particularly landscape, spiritual and experiential services) in Scotland as the basis for discussions with stakeholders leading to prototype CES maps. These have been finalised and supplemented by a research note[7] on methodological insights from a social science perspective Future work will concentrate on disseminating the findings from the first two years as well as continuing to advance the methods and indicators (**September 2018;** Inge.Aalders@hutton.ac.uk).

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

ELPEG SPOTLIGHT: Conserving a rare plant *Cicerbita alpina*

The alpine-blue sow thistle (*Cicerbita alpina*; Asteraceae) is one of the largest and rarest arctic-alpine plant species in the UK. Only four populations remain, all of which lie within the Cairngorms National Park. The species is very palatable and is only found on small and inaccessible cliff ledges where it is protected from grazing. Being at the brink of extinction in the UK and with a direct threat of grazing, *Cicerbita alpina* has become a flagship for species recovery through changed land management.

To date no reproduction or viable seeds have been observed for the UK's *Cicerbita alpina* and landslides are further endangering its tiny populations. The species is therefore designated as Vulnerable in the Vascular Plant Red Data List of Great Britain (2005) and protected under Schedule 8. It is included in the Cairngorms Nature Action Plan, mentioned as one of the priority species in the Scottish Biodiversity Route map to 2020 and is part of the RESAS strategic research programme.

While *Cicerbita alpina* is close to extinction in the UK it is widespread and locally abundant in other European mountain ranges (e.g. submontane birch and pine forest in Scandinavia, Pyrenees, northern Apennines, Balkan Peninsula). It is still not clear what is causing its lack of regeneration in the UK and research is being done to explore possible effects. Apart from grazing which impacts plants directly, other reasons that are known to negatively affect plant populations include: (i) genetic problems (inbreeding depression); (ii) reduced pollen quality and quantity; (iii) habitat loss; (iv) climate change. Our work on *Cicerbita alpina* is exploring these potential issues in more detail.

Current conservation efforts include repeated monitoring of all four populations by counting the number of flowering stems. *Cicerbita alpina* has a lot of rhizome growth and plants grow in tight clumps. It was therefore not clear how many individuals occur in its remaining populations, how diverse these individuals are and whether inbreeding (mating between close relatives) is likely. Genetic analyses have been conducted and have shown that only few (< 10) different and closely related individuals are present in each population. Inbreeding is therefore very likely.

Increasing the genetic diversity of populations and introducing new genes into inbred populations by mixing them (also known as genetic rescue) has been shown to increase plant fitness. Our work has therefore focused on testing whether cross-pollination between populations can increase seed viability in *Cicerbita alpina*. In the nursery at RBGE we have manually crossed pollen between all UK populations and resulting seeds have been sown. In 2017 we've also used 240 plants grown and bulked up at RBGE and originating from two different populations to increase genetic diversity within new translocated populations. These were planted out into three carefully chosen locations in the Cairngorms National Park. These genetically mixed populations will serve as a trial translocation to inform the importance of genetic diversity, habitat requirements and grazing for the conservation of this iconic plant.

Conservation efforts around *Cicerbita alpina* are a prime example of how different stakeholders work together to reverse a negative ecological trend. All work has been done in close collaboration with landowners, SNH, Cairngorms National Park Authority and other research institutes (Norwegian Institute for Nature Research, Norway). The latest biosecurity measures and standards (using molecular testing of plant material) have been applied to ensure a safe working environment for translocations. All work is in progress and ongoing throughout the Strategic Research Programme, and we hope to begin transferring our learning to other critically endangered plants including *Woodsia ilvensis*.

For further information contact AFinger@rbge.org.uk

- **Policy option appraisal for delivery of multiple benefits** (1.4.2ci and cii) aims to assess multiple land use options and to look at options for payments in relation to ecosystem services by combining bio-physical data with farm data (farm type, farm payments etc.) to generate maps that illustrate ES delivery from policy scenarios, with an initial focus on woodland expansion (audience: SG and agency staff working on agri-environment measures including woodland expansion). A presentation that illustrates the approach and the scenarios explored so far at the national scale is available (Alessandro.gimona@hutton.ac.uk). Further work on ecosystem services dynamics at the national scale in 2018-19 will include soil functions and pollination. A presentation of the main trade-off results is planned for spring 2019 (**March 2019**; alessandro.gimona@hutton.ac.uk). Feedback on the maps and briefing will be used to guide further analysis and outputs in 2018-19.
- National-scale multi-criteria analyses have been produced for some limited scenarios and will be expanded. Mapped results are available on request as are policy briefings summarising opportunity mapping results (Alessandro.Gimona@hutton.ac.uk).
- Knowledge of **social innovation**, including its definition in the context of rural development, is being advanced (Maria.Nijnik@hutton.ac.uk). A special issue of Forest Policy and Economics journal is a key follow-up to previous high-profile presentations on the role of social innovation in addressing current challenges and will be completed by **September 2018**. Also, following the presentation of the concept at the ELPEG meeting of January 2018 and to test the conceptualization of social innovation and eventually to promote its operationalization in rural areas of Scotland, a science-policy-practice workshop is planned for **May 2018**. A number of other KE and stakeholder engagement events are planned and case study work has started (specifically relating to social innovations were forestry and renewable energy are the focus).
- Initial case studies of **Natural Capital Accounting** (1.4.1c) have focused on 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). A short summary[8] of survey rationale, methods, preliminary results and planned future analysis is available (intended audience OCEA, (**December 2018**; 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.
- Research **assessing economic impacts of changes in Ecosystem Services** (1.4.2ciii) was presented to a meeting of OCEA economists (Office of the Chief Economic Adviser – SG) in September 2017 (Alistair.McVittie@sruc.ac.uk). Using the methodology agreed December 2016 published in two briefing papers by Fraser of Allander Institute available on request, the results from a case study were presented in March 2018 to an audience including RESAS and OCEA economists. An internal proposal paper was produced on the incorporation of agricultural biomass into the CGE model which will be followed by selection of a further case study (the case study results will be shared in 2018/19). Planned year 3 work will consider how micro level farmer behaviours can have macro level impacts (based on SRUC farmer intentions surveys) and to incorporate changes to production systems that allow natural capital regeneration (e.g. rotations/ley periods based SRUC long-term experiments).
- **Opportunities to increase multiple benefits through policy and industry delivery mechanisms** (1.4.2bi) has analysed 10 policy instruments. Overall it was found that there is already much alignment but there are gaps and areas for improvement, particularly to tackle soil health, air quality, terrestrial biodiversity and climate change. The report and summary

[8] http://www.hutton.ac.uk/research/srp2016-21/wp141-natural-asset-inventory-and-accounts

briefing is available here[9]. (Kirsty.Blackstock@hutton.ac.uk). This work will help to frame the research on **Using Monitoring and Evaluation to deliver multiple benefits** (1.4.2bii). We have analysed monitoring associated with Water Framework Directive, Natura 2000 directives and Agri-environment schemes in Scotland and 9 other member states and preliminary findings can be found here[10] (Kirsty.blackstock@hutton.ac.uk). These state that there are opportunities to make monitoring more participatory and transparent; and to improve how data are used in managing systems for multiple benefits. During the next year, we will be discussing these findings with the policy leads and stakeholders, including potentially holding a workshop with work on biodiversity governance (1.3.4) and the Horizon 2020 project PROVIDE focused on public goods from agriculture and forestry (**August 2018**).

- 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 (1.4.3d) case studies. Contributing to **Practical interventions to realise multiple benefits and manage trade-offs (O1.4.3)** a description of the catchments using a common adaptive management framework is underway to provide a short summary of the 'adaptive management' cases e.g. where located and what is being studied. This will aid sharing of information across the case-studies and with other stakeholders. This is a key step in producing a research briefing in **March 2019**.

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.

- 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 whether new satellite sensors are able to produce improved habitat maps based on the EUNIS classification. These habitat maps have been consulted on (intended audience: SG and agencies with an interest in modelling ES delivery) and a report on the potential of the methodology was prepared in March 2018, (Alessandro.gimona@hutton.ac.uk). This complements **analysis of Earth Observation (EO) data in biodiversity modelling** (1.4.1bi) that generated experimental results at a finer resolution (Alessandro.Gimona@hutton.ac.uk), and has been shared with selected stakeholders for evaluation (intended audience: SG and agencies, particularly SNH).
- 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 (**March 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

[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

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 (internal review concluded March 2018, intended journal submission **May 2018**). Work in 2018-2019 will involve further improvements to this national-scale model, as well as developing a local high resolution model of peatland restoration success for the area surrounding RSPB Forsinard (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). Work within year 2 of the Programme will establish the experiment 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 2018-2019 (**March 2019**; 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. In 2017-18 we established field level lime addition experiment and collected baseline data. 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 (**March 2019**). Data on sward diversity, invertebrate data, and soil characteristics (pH, water regime, and carbon) will be combined to assess the effects of liming on farmland waders (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 (intended audience: SG and agencies involved in AECs implementation post 2021, Robin.Pakeman@hutton.ac.uk), leading to recommendations on a potential new scoring system outlined in a paper (**October 2018**).
- Based on the spatial pattern of co-occurrence and trade-offs between ecosystem services opportunity maps improvement of land use, (relevant for targeting potential payments linked to ESS) will be produced at the national scale (**December 2018**) alessandro.gimona@hutton.ac.uk
- The delivery of **multiple benefits from innovative and collective approaches to water management**[11] 1.4.3d. This work has reported on options for water quality and water

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

quantity management (see report online; intended audience: policy, agencies, land managers), and changes in monitored parameters. Monitoring report on Lunan Water multiple benefits due spring 2019 (**March 2019**; Andy.Vinten@hutton.ac.uk).

- Work on **improving the environmental performance of beef supply chains** (1.4.2biv) has analysed the environmental burdens and benefits (in terms of GHG emissions) of using distillery by-products in both livestock production and renewable energy production. A research briefing presenting the findings has been published at the SRUC website[12] and a scientific article has been accepted for publication in the journal *Sustainability*[13]. 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 (Ilkka.Leinonen@sruc.ac.uk), 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 **(August 2018).**

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**. Following the co-development of scenarios (past, present and future) in case studies of woodland management in the Cairngorms National Park, Glen Creran and the Central Scotland Green Network (Cumbernauld Living Landscape), the first expert panel assessment in Glen Creran took place in April 2018. This included 3-D visualisation of the scenarios across a number of view-points in Glen Creran. The preliminary findings of the expert panel assessment will be fed back to the Forestry Commission as well as the stakeholders who participated in the panel. 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). In addition, further qualitative data will be collected on the role of humans in, and their perceptions of, ES production throughout 2018. Scoping studies and pilots of participatory and citizen social science approaches to monitor and evaluate the impacts of management interventions (ecological and social) were trialled in early 2018 in Cumbernauld. These will be further developed with Cumbernauld Living Landscape partners in 2018 (**March 2019**; Antonia.Eastwood@hutton.ac.uk)
- Building on data analysis undertaken in 2016-17 and our connectivity scoping workshop with stakeholders (a paper on **drivers of change in woodland diversity** at different scales (local, regional, national), and the implications of these drivers for land management planning will be produced (1.4.2cii). Findings will be discussed directly with relevant SG and agency staff

[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

(in particular, Pete Rawcliffe at SNH) to feed into their ongoing NEN work) (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). Currently a draft protocol to assess environmental risks from tree diseases is being discussed with stakeholders and summarised in a short research note. Work in 2018-2019 will experimentally test the suitability of alternative tree species to replace those threatened by new emerging plant pests and pathogens. Six sites across the UK are being visiting where the similarities and differences in the lichens supported, bark characteristics and soil properties under eight different tree species are being assessed (**April/May 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; 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 (**March 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. *Phytophthora*-positive eDNA samples from six locations within a catchment will be subject to barcode analysis in **May 2018** to determine the species present and examine the impact of environmental factors in regulating *Phytophthora* species diversity. In 2018-2019 this work will be continued and analysed to understand the drivers of *Phytophthora* distribution and dispersal (**December 2018**; intended audience: SG and agencies, land managers; David.Cooke@hutton.ac.uk).
- In developing **approaches that reconcile woodland expansion with other land use priorities** (1.4.3c) in the Cairngorms National Park, maps of woodland expansion options have been produced (February 2018). Methods to predict the consequences for ecosystem services are being developed with results to follow in 2018-2019 (alessandro.gimona@hutton.ac.uk).
- Work has also begun on the capturing of digital stories on woodland and woodland expansion with communities of interest in the Cairngorms National Park (scott.herrett@hutton.ac.uk) and undertaking qualitative interviews on adaptive management and woodland expansion with land managers (Antonia.Eastwood@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]
- RD 1.4.2: Multiple Benefits and trade-offs[19]

[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

- 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 diversity in service delivery – **January 2019**
Genetic resource available within traditional bere barley landraces (1.3.1, O1.2b)	tim.george@hutton.ac.uk	Results on performance of crosses between Bere barley and elite lines – **October 2018**
Impacts of genetic factors on reintroduction success (1.3.1, O1.2a).	a.finger@rbge.ac.uk	Visits to reintroduction sites - **October 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 – **March 2019**
Impacts of management regime on ecosystem service supply in upland ecosystems (1.3.1, O1.3a)	Davy.McCracken@sruc.ac.uk	Example maps of ecosystem service delivery – **August 2018**; Workshop on land use change scenarios – **September 2018**
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 2019**; Identifying further support needs for NCAI **- March 2019.**
Habitat connectivity mapping (1.4.2cii)	Alessandro.Gimona@hutton.ac.uk	Habitat connectivity **initial results. Report available.** Individual-based modelling of landscape connectivity/ fragmentation – **November 2018**
Connectivity metrics for temperate rainforest systems (1.3.3, O3.3)	C.Ellis@rbge.ac.uk	Identify specific sites for practical habitat restoration efforts – **March 2019**

[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

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 direct to appropriate stakeholders - **March 2019**
Animal diseases – liver fluke (1.3.3, O3.2b)	Philip.Skuce@moredun.ac.uk	Field studies of liver fluke risk to livestock - **March 2019**
Develop enhanced analysis methods for INNS distribution data (1.3.3, O3.1a)	Stephen.Catterall@Bioss.ac.uk	Identify and prioritise potential areas for improvement – **August 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	Joint work with SNH to implement resilience assessments – **December 2018**
Relationships between biodiversity and cultural ecosystem services (1.3.2, O1.1),	Katherine.Irvine@hutton.ac.uk	Distribution of cultural ecosystem services research summary – **June 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 - **December 2019**
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 – **September 2018**
Biodiversity management mechanisms: (RD 1.3.4, O1.2)	Paula.Novo@sruc.ac.uk	Research guide for qualitative or quantitative methods – **June 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 2019**
Test cases to examine feasibility of offsetting for woodlands (1.3.4, O3)	C.Ellis@rbge.ac.uk	Exploration of time for biodiversity restoration – **November 2018**
Land Use Strategy for Scotland		
Natural Asset Register (1.4.1a)	David.Donnelly@hutton.ac.uk	Establish steering group – **June 2018**
Cultural Ecosystem Services indicators and mapping (1.4.1bvi)	Inge.aalders@hutton.ac.uk	CES Working paper published and maps made available to NAR – **September 2018**
Policy option appraisal for delivery of multiple benefits and assessing land use options (1.4.2ci and cii)	Alessandro.gimona@hutton.ac.uk	Policy briefing on updated results following stakeholder feedback – **March 2019**
Using social innovation to deliver multiple benefits in forestry (1.4.2biii)	Maria.Nijnik@hutton.ac.uk	Practice communities workshop – **May 2018**

Assessing economic impacts of changes in Ecosystem Services (1.4.2ciii)	Alistair.McVittie@sruc.ac.uk	Journal paper has been submitted to Fraser of Allander working paper series.
Opportunities to increase multiple benefits through policy and industry delivery mechanisms (1.4.2bi)	Kirsty.blackstock@hutton.ac.uk	Briefing on potential new instruments – **October 2018**
Using Monitoring and Evaluation to deliver multiple benefits (1.4.2bii)	Kirsty.blackstock@hutton.ac.uk	Report available now with potential workshop – **August 2018**
Adaptive management approach to facilitate the evaluation and coordination of measures to deliver multiple benefits (1.4.3a).	kit.macleod@hutton.ac.uk	Research Briefing – **November 2018**
Climate Change Plan & Climate Change Adaptation Programme		
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 – **March 2019**
Model of peatland condition (1.3.3, O2.2c).	Rebekka.Artz@hutton.ac.uk	Research paper and associated targeted summary material - intended journal submission **May 2018**
SRDP and CAP greening		
New management options for agri-environment schemes (1.3.4, O1.1 & O1.2)	Robin.Pakeman@hutton.ac.uk	Establishment of new experimental investigation(s) - **March 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 – **March 2019**
Targeting SRDP payments for biodiversity (1.4.1bv)	Robin.Pakeman@hutton.ac.uk	Potential new scoring system outlined in a paper – **October 2018**
Opportunity maps to improve ESS	Alessandro.gimona@hutton.ac.uk	Based on previous mapping results - **December 2018**
Innovative and collective approaches to water management (1.4.3d)	Andy.Vinten@hutton.ac.uk	Monitoring report on Lunan Water multiple benefits – **March 2019**
Improving the environmental performance of beef supply chains (1.4.2biv)	Ilkka.Leinonen@sruc.ac.uk	Report on spatial supply chain model – **June 2018;** Stakeholder workshop to identify new supply chain case studies – **August 2018**

Scottish Forestry Strategy		
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 – **March 2019**
Drivers of change in woodland diversity (1.4.2cii)	Alison.Hester@hutton.ac.uk	Research paper and discussion of findings with key stakeholders – **November 2018**).
Range shift of British native trees	Alessandro.gimona@hutton.ac.uk	Methods developed by **December 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 support the biodiversity support by oak site visits – **May 2018**
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 – **March 2019**
Detailed studies of key pathogens – *Phytopthora* detection and diversity (1.3.3, O3.1c).	David.Cooke@hutton.ac.uk	Barcode analysis of *Phytophthora* species diversity - **May 2018**; Drivers of *Phytophthora* distribution and dispersal – **December 2018.**
Approaches that reconcile woodland expansion with other land use priorities (1.4.3c)	Alessandro.Gimona@hutton.ac.uk 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 **March 2019**.

Table of Acronyms

AECS	Agri-Environmental Climate Scheme
ARC-Trust	Amphibian and Reptile Conservation Trust
CCAP	Climate Change Adaptation Programme
CCP	Climate Change Plan
CES	Cultural Ecosystem Services
EHI	Ecosystem Health Indicators
ELPEG	Ecosystems & Land Use Policy Exchange Group
ELSEG	Ecosystems and Land Use Stakeholders Engagement Group
ES	Ecosystem Services
EUNIS	European Nature Information System
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
NEN	National Ecological Network
NGO	Non-Government Organisation
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
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