Traps, Apps and Maps: to what extent do they provide decision-grade data on biodiversity?

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Abstract

Ecosystem services arising from the restoration of natural capital are now increasingly recognised as environmental opportunities and monetised, with international climate negotiations focussing on the need for investment into natural capital, and the finance sector pledging to invest. The finance sector has called for decision-grade, asset level data about nature projects in order to facilitate their reporting to investors. This paper offers a case study of novel digital data collection methods used to establish a baseline of faunal biodiversity in a Scottish nature-restoration project on the Bunloit estate which has secured private natural capital investment. Digital camera traps, acoustic sensors with eDNA samples and apps were used to create digital maps to ensure annual survey replication, and citizen scientist engagement. The results were classified by both professional ecologists and citizen scientists. We discuss how the digital data gathered through traps, apps and maps in the case study can be qualified as decision-grade data, according to the Taskforce for Nature-based Financial Disclosure's specification. We conclude that decision-grade biodiversity data may be produced by practitioners, with limited resources, and make recommendations for data collection and governance methods to ensure nature restoration projects generate decision-grade data for ecosystem services markets.

Keywords: natural capital; biodiversity net gain; asset level data; decision grade data.

Introduction

Nature provides critical societal benefits to individuals and communities around the world, including Greenhouse Gas removal and emissions avoidance, protection from soil erosion and flood risk, habitats for wildlife, pollination and spaces for recreation and wellbeing (Daily, 2003). The combination of soils, species, communities, habitats and landscapes which provide these ecosystems services are natural capital. However, the last few hundred years of human activity have created climate and other environmental changes that threaten the natural capital and ecosystem services upon which humans rely (Sarukhán et al., 2005). Damage to the natural environment and loss of biodiversity pose a comparable risk and ecological threat (Gitay et al., 2002; Pörtner et al., 2021). Natural resources are one of the most important inputs to the global economy (Costanza et al., 1997; 2014). Whether it is raw materials like wood from trees, water, or ecosystem services like flood protection, biodiversity or pollination, nature provides much of the capital businesses use for the production of goods and services. The World Economic Forum reported that more than half of the world's total gross domestic product involves activities that are moderately or highly dependent on nature (WEF, 2020). The degradation of natural capital, including the loss of biodiversity and depletion of renewable stocks, therefore poses a real risk for businesses, their earnings and investors, which the World Wildlife Fund recently calculated as a direct cost of $10tr globally between 2011 and 2050 (Roxburgh, et al, 2020).

Neoclassical economics suggests that when property rights are well-defined and transaction costs are not too high, markets should protect the natural capital and ecosystem services upon which they depend (Coase, 1960; Stigler, 1989; Engel et al., 2008). However, while this may work in the short-term for provisioning services like food and fibre, markets often fail to reward those who are ultimately responsible for the provision of services. This is especially pertinent when it is difficult to quantify their value in economic terms or when benefits accrue to a range of beneficiaries (including competitors) over long time-horizons, for example flood mitigation or pollination services (Braat and de Groot, 2008). As a result, many business decisions generate short-term private benefits to the company at the expense of longer-term public benefits, leading to negative externalities for society, such as pollution or flooding.

However, there is now growing interest from the private sector in paying natural resource managers to adopt more sustainable practices and carry out work that can deliver wider public benefits from nature. There are a number of reasons for this, including policy drivers (e.g. national regulation and incentives, or international policy signals, such as those arising from the UNFCCC process), or the need to mitigate risks to their business (e.g. climate risks to supply chains or infrastructure), reduce costs (e.g. by reducing water treatment costs), and contribute towards corporate sustainability goals (Vidal et al., 2010; Esteves et al., 2012). Broadly speaking, private investment in nature occurs via carbon markets (including international compliance and voluntary markets as well as domestic carbon markets), wider ecosystem markets (including regional ecosystem markets and national payment for ecosystem service schemes) and green finance mechanisms (including green bonds, insurance products and habitat banking) (Reed et al., 2022). Nature has become an investable asset, as part of a connected economic system and natural world (Dasgupta, 2021), and investment has the potential to ensure that natural capital is not driven below critical thresholds, and flows of ecosystem services can regenerate (Green Finance Institute, 2021).

This private sector interest comes at a time when there is a significant gap between the public funding currently available and the funds that are needed to address climate change and biodiversity decline (Defra, 2011). Eftec (2021) suggested that a minimum of £44 - £97 billion of investment will be needed to deliver the UK's nature-related ambitions over the next 10 years and the cost of reaching net zero GHG emissions by 2050 has been estimated at between £50-70 billion (RSPB, 2018). There are significant challenges in delivering biodiversity targets and emission reductions in the land use sector, where it is estimated that it may cost £247 million to deliver net zero targets (Committee on Climate Change, 2019, 2020). This funding gap is likely to increase as Governments respond to the economic impacts of the COVID pandemic, and in the UK land use sector, the gap may be further widened by post-Brexit agricultural policies, which will lead to an overall reduction in public funding for the sector by 2027 (Reed et al., 2022).

To deliver private investment in nature at scale, high-integrity markets are needed that can provide assurances to investors, natural resource managers and the public that investment is delivering permanent and additional ecosystem services to society that would not have been possible without private investment (Financing UK Nature Recovery Coalition, 2021; Reed et al., 2022). Common additionality tests in carbon and ecosystem markets include

1. the requirement that funded projects and their practices: were not already legally required;
2. would not have been financially viable without funding for the provision of ecosystem services (often setting a minimum threshold for the contribution of private finance);
3. carbon finance enabled other barriers (e.g. social or environmental) to be overcome; and/or
4. practices were not already widely adopted in the region and so likely to have been adopted in the case of the project (Kendall et al., 2022).

To quantify additional benefits, projects typically measure changes in ecosystem services in relation to a baseline. This is usually established at year zero, but in many cases, multi-year (historic) baselines may be necessary to account for natural variability, and where variability can be predicted, variable baselines may be established. Baselines may be measured empirically or estimated using models, IPCC default values or peer-reviewed published datasets (Kendall et al., under review). Empirical baseline measurements may be carried out using direct measurements e.g. by a surveyor or ecologists, or via remote sensing of features (e.g. bare ground) or proxies (e.g. using the presence of indicator species to infer GHG emissions after damaged peatbogs have been restored) (Reed et al., 2017). However, collection of empirical data in the field is time-consuming and expensive, and reliable proxies have only been developed for a small number of ecosystem services.

This is a problem because to be operational, ecosystem markets need decision-grade data that is cost-effective enough to avoid over-inflating prices (Craig, 2020). The Taskforce for Nature-based Financial Disclosures, launched in 2021, to deliver a risk management and disclosure framework for organisations to report on evolving nature-related risks and opportunities. It was endorsed by the G7 Finance Ministers and G20 Sustainable Finance Roadmap (TNFD, 2021). The framework's Technical Specification (ITEG, 2021) suggests what the characteristics of decision-grade data should be, and its core assumption is that data is digital. Simultaneously, earth science, ecology and conservation literature have highlighted recent shifts to digital practices for environmental data collection, monitoring, and management practices (Bakker & Ritts, 2018; D'Urban Jackson et al., 2020). Digital tools are being increasingly studied and used in environmental management (Salam, 2020).

This study therefore set out to understand whether projects for ecosystem services markets can improve their acceptability and credibility with investors, by providing decision grade data via digital devices. If this is possible, it may eventually be possible to develop high-integrity markets that provide better prices for validated credits or certificates. To do this, we use a case study of Bunloit*,* an estate outside Drumnadrochit in Highland, Scotland. The estate was purchased in March 2020, and a team of rangers and environmental consultants proposed a range of nature-based solutions to climate change as part of the Bunloit Rewilding Project[i]. The baseline carbon and biodiversity evidence they collected (Bunloit, 2021) will inform the design of interventions to boost carbon sequestration and biodiversity, and feed into business plans that could attract investment for ecosystem services, such as biodiversity net gain. In this context, the aims of this paper are to consider whether the digital data collection devices and methods Bunloit used in its faunal biodiversity survey are likely to provide decision-grade data that can drive ecosystem services markets; and make recommendations for digital data collection and governance methods to ensure projects can generate decision-grade data in future.

Methods

The Bunloit estate team established a baseline biodiversity count, including both floral and faunal diversity, across the varied habitats in the estate in 2021, see figure 1 below for a breakdown of the different basic characteristics of the mosaic of habitats from native woodland to peatland, pastures to plantations. The 513 hectare estate is overlooked by the mountain Meall Fuar-Mhonaidh and drops down to the shores of Loch Ness. A desktop Biodiversity Net Gain assessment was established, undertaken using the Natural England Biodiversity Metric v2.0 (Natural England, 2018), with drone footage capturing digital data of what was on the ground locally, that experts could interpret absent from site, supported with explanations from the onsite team via video conferencing calls about what the drone footage was showing. The flora count was developed using traditional manual methods, and is not discussed in this paper, but for the fauna count, the data collection was acquired through the use of digital camera trap devices, digital acoustic sensors, and environmental DNA (eDNA) surveys, and their related apps and digital maps. This section summarises the methods used for the digital data collection, and then the results are presented in the following section and how the digital data collection methods and their outputs measure-up as decision-grade data is then discussed.

From discussions with UK-wide specialists, academics and local ecologists, the Bunloit team worked with specialist biodiversity consultancies and local ecologists to collect digital data sets for the fauna count. Faunal data came from digital camera traps, ultrasonic acoustic sensors, and eDNA, and was presented digitally via apps and maps to provide a baseline picture of the state of biodiversity on the estate. Data fusion approaches, such as this one at Bunloit, appear in just under half of papers (46%) published in the last 2 years, as mapped by a literature review of technological applications for forest ecosystems (Nitoslawski, 2021).

Digital Camera Traps

Species surveys were undertaken by local ecologists using digital camera traps. Fifteen digital camera traps were provided by NatureSpy[ii] - a non-profit organisation that aims to research and protect wildlife whilst engaging local communities. They designed the camera trap survey method including the protocol for placing them, for annual surveys to track changes in wildlife over time. The Browning Recon Force Elite HP4 camera trap with high quality video (HD – 60fps, 1920x1080p) was deployed by Bunloit Estate's on-site ranger in May 2021. The NatureSpy team helped design the placement of the cameras across the estate, and attended site in May to help with their distribution to ensure coverage across various habitats, and camera setup for the large mammal data collection. Figure 1 below shows the location of the digital camera traps on the estate map, and where they were placed across a range of habitats. They were attached to trees close to trails, above the head hight of deer. With this map for the baseline measurement, ongoing measurement can now be replicated annually by matching camera trap locations to the map.

[f]Figure 1[/f]

The digital camera traps had infrared sensors that were movement triggered to record a 20-second video of the animal that triggered them. Standard digital camera traps recorded large mammals. For larger mammals, data was collected over a period of 90 days (1,350 camera trap days), on the basis of inventory studies from NatureSpy (private report to Bunloit, 2021) showing this period to be long enough to detect species within a study area. For smaller mammals, the traps were redeployed after being adapted with lenses for a shorter focal length and to reduce the flash intensity, and mounted in boxes that could be moved around the site. Moving picture sequences were obtained of sufficient quality for identifying species (using methods as described in Littlewood et al., 2021). 12

camera traps were installed across 12 habitats, these were checked, rebaited and relocated every 3 days, totalling 10 locations per habitat, resulting in 30 trap nights per habitat and 360 trap nights across the estate.

The collected sequences of images from the camera traps were then uploaded to a citizen science platform called MammalWeb[iii], where at least two citizen scientists classified each of the 2353 sequences uploaded according to standard species lists, having first become trained in spotting mammals and their classification via MammalWeb's online leaning guides. Using the MammalWeb online platform ensured that the citizen scientists classifying Bunloit's footage were trained in the basics of UK mammal classification,. The use of MammalWeb's existing online platform meant that the estate team did not have to deal with the citizen scientist recruitment or management, which is the most difficult and costly part of using citizen scientists for data classification (Lasky, et al, 2021). MammalWeb did all this for them, and 92% of the 1350 camera trap days' footage (1242 days' worth) was classified, for free, over a five month period.

Ultrasonic acoustic surveys

Bats were recorded using ultrasonic acoustic surveys, via both transect walks and static detection methods (following The Bat Conservation Trust's methods for professional ecologists; Collins, 2016). Four transects were initially established, to cover a mix of habitats and differing geographic areas of the estate. These needed to be navigable at night and repeatable. Each transect was normally completed by a pair of surveyors and involved walking a set route to record bat echolocations as ‘bat passes’ (where a bat pass is defined as a sequence of greater than two echolocation calls made as a single bat flies past the microphone) and to note the bats’ behaviour. Transect surveys were completed along four different routes (2-4 km each, covering a mix of habitats on the estate); each transect was surveyed 30 minutes before sunset and 2 hours post sunset in calm dry weather, and surveyed at least twice between June and October 2021. The Echo Meter Touch 2 app (v2.8.3) and sensor by Wildlife Acoustics[iv] was used by rangers on transect routes to record bat echolocation pulses (the Echo Meter Touch sensor plugs into a tablet or mobile phone providing GPS location). It processes the sound using highly complex, proprietary algorithms called “classifiers”. The Echo Meter Touch app matches the audio file from the sensor to a country-specific database (for the UK, Kaleidoscope Pro v5.4.0 with ‘sensitive’ auto-id settings was used), revealing in real time the most likely species of bat, and logs recording locations on a digital map. Where required, further analysis of the recordings and confirmation of species identification was completed by an expert environmental consultant using Kaleidoscope Pro and/or AnalookW, against a known library of calls (Russ 2012). Static detectors (Anabat Express[v] and Anabat SD2[vi]) were deployed at 16 monitoring points covering all habitat types, recording for a minimum of five nights at each location.

Environmental DNA (eDNA)

Environmental DNA (eDNA) is nuclear or mitochondrial DNA released from an organism into the environment. Scientists have lately transformed biodiversity monitoring through using cutting-edge DNA technologies to detect this DNA in water and soil samples at very low concentrations (Ruppert, et al, 2019). Metabarcoding is a method of identifying multiple taxa in a single reaction by sequencing the DNA barcodes of a whole taxonomic group using High Throughput Sequencing. Metabarcoding can be applied to eDNA samples (e.g. water samples collected with kits), or from bulk samples of organisms (e.g. insects collected in a malaise trap). A total of 42 eDNA kits were sent by NatureMetrics[vii] to the Bunloit rangers, for them to take the soil samples and send back (NatureMetrics could not visit the site due to COVID restrictions at the time). Digital maps (such as Figure 1, above) showing topography and habitat type were shared with NatureMetrics so they could suggest the 42 data collection points across all habitats on the site from which the local team collected soil samples using the sampling kits – a 10ml core was gathered by a handheld small syringe and stored in a uniquely labelled plastic pot with screw top lid. At least one sample was collected for each of the representative habitats, and was sent back to NatureMetrics' lab for processing.

Results

Digital Camera Traps

Over a 90-day period, 859 video/moving image sequences were classified via MammalWeb. The MammalWeb portal enables spotters to identify the species and whether the images are of an adult or a juvenile (or unknown). The estate-wide picture is shown in Figure 2, below, with sika deer being by far the most numerous – accounting for 53% of all classifications during this time. Wild boar classifications came in third at 12% of overall classifications (and 62% of these were classified as juvenile).

[f]Figure 2[/f]

The other key large mammals detected on the site were roe and red deer, badgers, foxes and red squirrels. There was also a long tail of lower density bird, other small mammal species detected.

Filtering the dataset by broad habitat types showed that woodlands had the largest abundance and diversity of species, followed by scrubland and grassland. The most abundant species - sika deer - was present in all habitat types. The second most abundant species, wild boar, were only found in woodland areas. These findings are in line with the known habitat preferences of these species (Howells and Edward-Jones, 1997; Swanson and Putman, 2003). The most common species encountered were rodent species, namely wood mice and voles (bank and field). These were recorded across most habitats, with wood mice recorded in all habitats surveyed. Shrews and weasel were less common.

Ultrasonic acoustic sensors

At least six species of bat (of the 10 known to Scotland) were recorded across the estate, in all areas sampled based on NBN Atlas records[viii]. Figure 3, below, summarises bat species recorded by ultrasonic surveys in different habitats. Common pipistrelle (*Pipistrellus pipistrellus*) and soprano pipistrelle (*P. pygmaeus*) were recorded in all twelve habitats sampled and are by far the most numerous and widely distributed bat species on the estate Nyctalus noctula and N. leisleri are amongst the rarest bat species in Scotland[ix], but were recorded in select habitats - as shown in the table below. Brown long-eared (*Plecotus auritus*) along with Nyctalus sp. (possible Leisler's, not verified by an expert yet) were the least recorded and the Leisler's record still needs verifying by an expert.

[f]Figure 3[/f]

eDNA

Figure 4 shows a taxonomic heat tree visually representing the number of operational taxonomic units (OTUs) across all samples for fungal communities, with Nature Metrics' summary report summarising a total of 1,168 fungal OTUs and 352 faunal OTUs detected across the samples. Consensus taxonomic assignments were made for each Operational Taxonomic Unit (OTU) using sequence similarity searches against two reference databases, NCBI nt (GenBank) and either the UNITE database (v8.0) or SILVA 18S database (v132) for fungal and faunal datasets, respectively. The GBIF taxonomic backbone was used for consistency between databases. Results from both searches were combined and assignments made to the lowest possible taxonomic level where there was consistency in the matches. Conflicts were flagged and resolved manually. Minimum similarity thresholds of 98%, 97%, and 95% were used for species-, genus-and higher-level assignments respectively. Samples collected from the bog and modified grassland habitats had distinct fungal and faunal community compositions, fungal taxa richness was lowest in the semi natural coniferous woodland habitat and faunal taxa richness was highest in the bog. (Nature Metrics, 2021).

[f]Figure 4[/f]

[f]Figure 5[/f]

An example of fungi diversity across the estate is shown in Figure 6. The eDNA analysis corroborated that non-native coniferous plantations had the lowest species richness and diversity within both fauna and fungal soil samples. The peatlands and grasslands had the highest and most distinct species richness and diversity in the soil samples. The clear-felled plantation in Borlum Wood, seen on the far right of Figure 5 showed a high level of fungal species richness and diversity. This can be attributed to the fact that the clear-felling had caused a lot of disturbance, which may have created opportunities for increased biodiversity. Cross-referencing against the ICUN red list of the datasets identified the presence several rare and threatened species. These included fungi *Russula lilacea* and *Clavicorona taxophila* on the grasslands.

[f]Figure 6[/f]

A desktop Biodiversity Net Gain assessment was undertaken using the Natural England Biodiversity Metric v2.0 (Natural England, 2018), as a similar model is yet to be developed in Scotland. No site visits were made due to COVID-related travel restrictions, and the initial assessment of the habitats was based on drone imagery, the eDNA data, and conversations with the site team. Figure 7 shows the summary of this analysis. This considered most habitat types as moderate or poor condition. The metric uses an assessment of habitat distinctiveness, area, condition and strategic significance to calculate a habitat unit for each parcel, and a suggests management action. This led to a site baseline of 4,429 habitat units, as shown in the last totals column in Figure 8. This high-level work identified the wetland peatbogs and heathland and shrub habitats as highly distinctive – and therefore worth more in terms of biodiversity units.

[f]Figure 7[/f]

Discussion

As Scottish policymakers discuss post-Brexit policy options for transforming land management to reach net zero targets, a number of the options under discussion hinge on as granular an understanding of biodiversity inventory as possible for any tract of land under consideration. The WWF and World Bank as well as UNEP have called for high quality datasets and asset level data about nature, because as climate and environmental observational data is increasingly used in the financial sector to inform decision making, the quality of the data and how it is applied has increasing real world implications (World Bank and WWF, 2020). This data has to reference back to the decision that is being made, but there are likely to be common characteristics across all types of decision.

The Taskforce for Nature-related Financial Disclosures' Proposed Technical Scope has proposed a framework for a wide range of uses and users including financial institutions, non-financial companies, public bodies, and citizens. The framework has developed a set of characteristics which define decision-grade data as high-quality data, able to show relevance, resolution and scalability, temporality frequency of update, geographic coverage, accessibility, comparability, thematic coverage and authoritativeness including traceability (p.33. ITEG, 2021). The framework is proposed as a mechanism to help organisations understand, disclose and manage nature-related financial risks and opportunities, such as the potential financial benefits resulting from positive impacts on nature or the strengthening of nature. Table 1, below, reflects on how the Bunloit digital data collection methods and analysis results measure up to the characteristics the framework defines for decision-grade data with a red-amber-green (RAG rating) qualification of fit, offered for each characteristic.

[t]Table 1[/t]

With seven out of nine characteristics being qualified as green, two receiving amber categorisations, and none categorised as red, a simple RAG review suggests that Bunloit collected decision-grade data in its fauna biodiversity baseline count. Although the TNFD criteria were developed for a wide range of uses and users, they provided a good fit for the practical digital data collection methods Bunloit chose to apply as a replicable solution they can continue to undertake themselves. The linked sensors and their apps provided automatic high resolution data collection, with digital maps being created from sensor signals to easily enable lower-cost, repeat measurements. The species identification approaches used by Bunloit have been shown to produce high accuracy classification rates, e.g. of over 95% for image data classified by citizen scientists using MammalWeb (Hsing et al. 2018), 75% to 99% for ultrasonic data using auto ID (Wildlife Acoustics[x]; but note this was increased by manual verification of less common species) and OTU sequence similarity thresholds of 98% and 97% used for species- and genus-level assignments respectively (NatureMetrics private report to Bunloit). The digital data collected can be used as a baseline to track changes in species occurrence and/or activity levels (relative to the baseline) if comparable surveys are repeated in future. We recognise that more complex data analysis approaches (e.g. appropriate for spatio-temporally replicated data) would be needed for the calculation of precise estimators of species abundance and occupancy rates on the Estate. However, the work presented here is simply meant to be a demonstration of the data collection devices and methods that can be used to provide the digital evidence required for natural capital projects.

Data governance issues emerge in the case study. Does the data that Bunloit uploaded to apps belong to Bunloit or the app? In terms of data traceability, the finance sector wants to see the full journey of data use - from collection (sourced on the estate), to analysis (via app or lab), and presentation (in reports, maps and apps from other companies), then validation (peer review). Many of the opportunities identified by researchers working with digital technologies relate to automating resource-intensive data collection, management, and analysis practices. Few examples of mobile applications were found in ecosystem measuring papers (Nitoslawski, 2021). As smartphone usage expands globally, along with better broadband connectivity in rural areas and data storage capabilities, crowdsourced and citizen science-based ecological research may become more feasible (Silver, 2019). However, currently the data use journey is not transparent, and the validation of data, via citizen scientist review, would not necessarily be considered reliable enough the finance sector. The Bunloit team are currently considering how open access their datasets will be, but decision grade data characteristics will likely demand adherence to FAIR principles for scientific data management and stewardship (Wilkinson et al, 2016).

The continued adoption of digital measuring devices will create new research questions about ecosystems as dynamic social, ecological, and technological landscapes. Data fusion approaches, referring to combining multiple technologies and data inputs in tandem to produce more accurate and/or precise information, could present new opportunities for knowledge, policy and practice (Saah et al., 2019), with data collected using varied methods in different contexts.

Costs were reduced by the digital data collection techniques. Live trapping small mammals in any given habitat would have required a line of at least 10 ten traps, set over a minimum of 5 nights, and these would have been checked 2 times, morning and evening. Checking and processing a single trap line (x2) would take approximately 7-8hrs/day. So 40hrs per line, surveying 10 lines and then processing the data would have been up to 400hrs manual work. In contrast to this, the adapted camera traps used for small mammals could all be installed in one day (8hrs) across 12 habitats, these were checked, rebaited and relocated every 3 days, totalling 10 locations per habitat. So approximately 80-90 hours of field time was spent instead on the digital camera trapping solution. The other time and cost saving was in data processing. Much of the data is captured in the field with live trapping, whereas camera trapping videos/images were classified for free by citizen scientists via MammalWeb.

Conclusion

This paper has provided a case study in which biodiversity data was collected as part of a privately funded natural capital investment project, showing how decision-grade data may be produced by practitioners, with limited resources. Although the characteristics of decision-grade data are still being debated between practitioners, academics and the financial sector, this is the first time that criteria proposed by TNFD have been operationalised and tested in a UK natural capital project. Lessons from this research may have wider international relevance as these criteria are increasingly operationalised and refined in different contexts, and provide guidance for practitioners seeking cost-effective options for the generation of decision-grade natural capital data.

Further research is required to standardise processes for cheap digital devices and their data to clarify the quality and trustability of the more cost-effective non-lab calibrated or tested digital devices/instruments. These could prescribe how devices prove they are accurately scientifically measuring (calibrated), and are ‘who they say they are’ (authenticated). Standardised processes for digital devices used for measurement could eventually cover data gathering, managing and analysis and ongoing data governance through time, and could eventually cover quality of sampling, and data aggregation into app or lab tools via APIs. There is also a need to transparently govern data use journeys. The World Bank and WWF called for dataset governors to be public sector bodies, arms-length organisations and NGOs, rather than private sector financial market data providers (p. 50, World Bank and WWF, 2020). Data institutions, organisations that steward data on behalf of others with public value aims, and govern who has access to data, for what purposes and to whose benefit, could play an important role in the future (Keller, 2021).

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Declarations of interest:

BH, ME and CT work for Bunloit Rewilding Ltd., either as employees or contractors.

HR and MSR are Co-Directors of the Thriving Natural Capital Challenge Centre and are involved in the development of new domestic carbon markets and other ecosystem markets in the UK.

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Figure captions

1. Location of static digital camera traps for larger mammals on the estate map. Image created by NatureSpy for Bunloit.

2. The estate-wide picture of classified species spotted through static camera traps. Developed by the Bunloit Team for the Natural Capital Report.

3. Summary table of bat species detections: Presence (=1) / Absence (=0) data by habitat sampled. From private report by Wychwood Environmental for Bunloit.

4. Heat Tree visually showing number of units across all samples for fungal communities. From private report by NatureMetrics for Bunloit.

5. eDNA results for soil fungi as categorised by Shannon's Diversity Index. From private report by NatureMetrics for Bunloit.

6. Showing eDNA Fungal Richness and Shannon Diversity Index. From private report by NatureMetrics for Bunloit.

7. Showing desktop Natural England Biodiversity Metric 2.0 results. From private report by Ecosulis for Bunloit.

Endnotes

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[i] http://bunloit.com
[ii] https://naturespy.org/
[iii] https://www.mammalweb.org/en/
[iv] https://wildlifeacoustics.com
[v] https://www.titley-scientific.com/uk/downloads/dl/file/id/16/product/0/anabat_express_user_manual_v1_5.pdf
[vi] https://www.titley-scientific.com/uk/downloads/dl/file/id/17/product/0/anabat_sd2_user_manual_v1_8.pdf
[vii] NatureMetrics is a UK biotech company that provide commercial sampling kits to monitor soil and water biodiversity via DNA: https://www.naturemetrics.co.uk/
[viii] https://nbnatlas.org/
[ix] https://scotland-species.nbnatlas.org/species/NHMSYS0000080185
[x] https://www.wildlifeacoustics.com/uploads/downloads/classifier-performance-5.4.0.xlsx