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Evaluating the potential to record habitat information for Earth observation through volunteer recording initiatives

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UK Centre for Ecology & Hydrology

BTO
British Trust for Ornithology

Summary

Biological recording in the UK spans many decades and a wide taxonomic range. The wealth of volunteer-collected biological data is an invaluable resource in monitoring national biodiversity and furthering conservation aims. Citizen science recording schemes traditionally focus on specific taxa, with some initiatives recording habitat information to varying degrees of detail. With the growth in Earth observation (EO) applications in recent years, the possibility of collecting habitat information more explicitly through citizen science has been explored.

Building on previous projects, such as the 2020/21 Terrestrial Surveillance Development and Analysis (TSDA) programme report by the British Trust for Ornithology (BTO) and the 2018 UK Terrestrial Evidence Partnership of Partnerships (UKTEPoP) EO workshop, this report investigates the potential to collect additional habitat information through volunteer recording that could contribute to EO initiatives, as part of the TSDA project. The report outlines:

- Benefits of improved habitat information, from national habitat monitoring to informing local site management decisions (Section 2.2).
- EO applications of habitat data, including detailed case studies of applications that would benefit from citizen science habitat data (Appendix 1).
- Habitat information currently recorded through citizen science schemes, as well as information on volunteer attitudes to recording habitat data and the training resources currently offered to volunteers (Section 2.1).
- The potential for collecting habitat data for EO through citizen science, discussing possible routes of collecting further habitat information and the applicability of existing habitat recording apps, which present an opportunity to tailor data collection to meet EO requirements (Section 6). The proposed data collection options were discussed at the 2021 UKTEPoP Habitat Recording Workshop and stakeholder views and suggestions are summarised in Section 5. Detailed descriptions of each proposed data collection method are presented in Appendix 2.
- Potential volunteer feedback mechanisms (Section 7), as discussed in detail at the UKTEPoP Habitat Recording Workshop, together with volunteer training and support options (Section 8), aiming to encourage volunteer engagement with habitat recording initiatives. In order to engage volunteers with habitat recording initiatives, careful consideration of the volunteer experience is required. Providing interesting and encouraging feedback to volunteers and establishing clear and accessible training resources is essential in incentivising habitat collection and ensuring volunteers are supported.

This report demonstrates the significant potential to collect further habitat information through volunteer recording initiatives. Improved habitat information could improve EO-derived habitat maps in terms of their content and quality, facilitate more complex analyses of habitat condition, measure the impact of management strategies, and interpret trends in species populations, including identifying possible drivers of change. Extending habitat data coverage across the UK could significantly improve the quality and scope of EO products and analytics, meaning policymaking decisions are based on up-to-date, robust, accurate information.

To further develop this project, it is essential to gather volunteer attitudes towards habitat recording to understand any barriers and capture views on attractive feedback mechanisms and useful training resources. Recommendations for next steps are presented in Section 10.3, following valuable input from the 2021 UKTEPoP Habitat Recording Workshop (details in Appendix 3).

Contents

Abbreviations

ADS:	Avian Demographic Scheme
AI:	Artificial Intelligence
BBS:	BTO/JNCC/RSPB Breeding Bird Survey
BTO:	British Trust for Ornithology
CNCB:	country nature conservation body
CSM:	Common Standards Monitoring
EES:	England Ecosystem Survey
EO:	Earth observation
FIT counts:	Flower-Insect Timed counts
NBMP:	National Bat Monitoring Programme
NE:	Natural England
NIEA:	Northern Ireland Environment Agency
NPMS:	National Plant Monitoring Scheme
TSDA:	Terrestrial Surveillance Development and Analysis
UI:	User Interface
UKBAP:	UK Biodiversity Action Plan
UKBMS:	UK Butterfly Monitoring Scheme
UKCEH:	UK Centre for Ecology and Hydrology
UKPoMS:	UK Pollinator Monitoring Scheme
UKTEPoP:	UK Terrestrial Evidence Partnership of Partnerships
WBBS:	Waterways Breeding Bird Survey
WCBS:	Wider Countryside Butterfly Survey
WeBS:	Wetland Bird Survey

1 Introduction

1.1 Background

Biodiversity is declining at an unprecedented rate, with more than 25% of species assessed by the International Union for Conservation of Nature (IUCN) Red List threatened with extinction, and rapid rates of habitat loss across the globe (The Sustainable Development Goals Report 2021). Halting and reversing biodiversity loss is a crucial priority for international and UK policy. Globally, the Sustainable Development Goals aim to "halt and reverse land degradation and halt biodiversity loss", while the UK Government's 25 Year Environment Plan establishes national targets to conserve biodiversity. Monitoring progress towards targets is essential in achieving these goals. Tracking changes in species populations over time is important in monitoring the impact of species protection strategies, and it is equally important to assess changes in habitat extent and condition to better understand drivers of change, and help to achieve wider environmental targets, such as the UK's commitment to achieve net zero emissions.

Monitoring habitat extent and condition over time requires regularly updated habitat data across the UK, including details such as habitat type, an assessment of condition, information on specific habitat features and evidence of the impacts of management practices. Traditionally, these data are collected as part of bespoke surveys to monitor specific aspects of habitats. However, monitoring habitats at a national scale poses a significant challenge, and with resources constrained such a complex survey requires novel techniques. The extensive spatial and temporal coverage of Earth observation (EO) missions pose an opportunity to monitor habitats at a national scale. EO capabilities have expanded to include techniques and sensors that have proved invaluable in monitoring landscapes (Kuenzer *et al.* 2014; Lausch *et al.* 2016; Medcalf *et al.* 2014), realising the potential of monitoring habitat condition, composition, and structure, as well as habitat extent (Coops *et al.* 2020). As the EO field expands, it is crucial to incorporate robust, representative in-situ data to train and validate models.

The key role of volunteer recording schemes in collecting in-situ species data is well documented (Chandler *et al.* 2017; Pescott *et al.* 2015; Pocock *et al.* 2018; Roy *et al.* 2012) but habitat information gathered through citizen science varies considerably. There is an existing network of knowledgeable, dedicated volunteers that already regularly visit sites across the UK to participate in species recording schemes. Hence there may be significant potential for volunteer recorders to collect further habitat information for EO applications, aligning EO and citizen science aims in establishing national biodiversity monitoring systems. Evaluating the potential to collect habitat information tailored for use by EO applications through volunteer recording initiatives is an area of ongoing research. Recent projects include Living Wales, which provides an example of how citizen science data can be used to train and validate national land cover and habitat maps, a pilot study scoping the incorporation of volunteer collected data into the Norfolk Living Map (Newson *et al.* 2016), and the National Plant Monitoring Scheme (NPMS) review (Pescott *et al.* 2019), which includes a section exploring the applicability of NPMS data for EO ground-truthing. In addition, the British Trust for Ornithology (BTO) have evaluated the potential for volunteers to collect additional biodiversity information, including habitat assessments (report in draft) as part of the Terrestrial Surveillance Development and Analysis (TSDA) programme. The UK Environmental Observation Framework (UKEOF) has recently established an Earth Observation Calibration and Validation Working Group aiming to realise the potential of EO for monitoring by improving integration of EO practitioners with existing in-situ surveying communities. The group aims to support mutual benefits to EO and volunteer recording communities of increasing the use of field data for calibration and validation of EO products.

UKCEH and JNCC are involved in this group and have established links between this project and wider activities in this area to ensure alignment.

1.2 Objectives

This TSDA report aims to evaluate the potential for volunteers to record further habitat information that will benefit habitat monitoring applications at both local and national scales. The report will outline data collection routes, explore possibilities for integrating habitat data collection into current recording schemes, and consider the support and feedback mechanisms to engage and encourage volunteers. This report will largely focus on habitat recording for EO but acknowledges that in-situ habitat data benefits a much wider range of applications. The review will consider how to integrate additional habitat recording into UKTEPoP surveillance schemes as a subset of UK citizen science activity.

The project objectives are:

- Scope potential for collecting habitat information as part of existing UKTEPoP recording schemes
- Explore short-term options to expand habitat data collection, and outline longer-term aspirations
- Outline possible volunteer feedback and training mechanisms
- Consult UKTEPoP partners on the proposed data collection pathways, feedback mechanisms and volunteer support, and plan potential next steps

1.3 Why collect habitat data for EO?

In recent years there have been significant developments in EO capabilities worldwide, and in the UK these developments have been applied to improve our understanding of environmental dynamics. EO plays an important role in monitoring progress towards targets established by environmental policies, such as Welsh Government's Sustainable Management of Natural Resources framework and UK Government's 25-Year Environment Plan, including Nature Recovery Networks and Biodiversity Net Gain. One key element of EO-based monitoring is generating accurate and up-to-date habitat extent maps. All four UK countries are in the process of developing methods to regularly update habitat maps using EO data, including through Living Wales, the development of the landcover map of Scotland, which was produced in 2021 by Space Intelligence for NatureScot, the Northern Ireland Habitat Map and Living England produced by Natural England (Kilcoyne *et al.* 2021).

Accurate habitat information improves the UK's ability to protect, manage and restore sites, at both local and national scales. For example, the Canals and Rivers Trust supplement targeted field surveys with existing Wildfowl and Wetlands Trust (WWT) habitat data to inform river restoration efforts at a local scale. Continuously monitoring habitat extent and condition through the regular generation of national habitat maps can identify areas of change, helping to evaluate the success of management strategies and facilitate adaptive management protocols. Updated national habitat maps can also contribute to an improved understanding of species habitat associations, with potential to feed into predictive species modelling, thereby helping to progress towards species protection goals by providing updated estimates of area of available habitat. Discussions at the UKTEPoP 2018 workshop suggested improved habitat data could help to validate species records, particularly those collected by citizen scientists, and contribute to recording scheme survey design. For example, EO-based habitat maps could help to develop stratified site selection or target high-risk areas such as those flagged as changed, in both structured and unstructured recording schemes. The ability to direct volunteers accurately to the correct habitats for specific species would avoid volunteers needing to search for appropriate sites. A range of

species related applications of habitat data were identified by workshop attendees, including evaluating drivers of changes and associated pressures (causes of impacts), informing stratification of surveys, studying links between species, habitats and features, and measuring species responses to different landscape configurations.

As EO-based applications expand, field data becomes increasingly important for validation and interpretation of modelled observations. Improvements in resolution, coverage, and frequency of remote sensing data, and the addition of new sensors, enhance the capabilities of EO to extend beyond mapping habitat extent. EO missions are now able to monitor more complex environmental parameters, such as habitat condition, sward height, dead material presence, invasive species distribution, and spread of disease. Detailed descriptions of EO habitat data applications are available in Appendix 1.

Discussions at the UKTEPoP 2018 workshop acknowledged that the required spatial scale of data varied according to the research question. Both broad landscape-scale information and fine-scale site-specific information on habitat features are valuable. The required spatial scale of habitat information, the important features of a habitat, and the concept of “good” condition are specific to the species or ecosystem of interest. When studying specific taxa, information on specific habitat features are as important as habitat classification. Features of interest might include types of management, elevation, evidence of pond drying, barriers to species movement, sward height, dung heaps, and tree cover along waterways. Habitat connectivity, and the presence of individual trees are important for species related research. Collecting habitat classification is just one facet of habitat information that could potentially be recorded by volunteers. However, it is unrealistic to expect volunteers to record a comprehensive suite of habitat characteristics at regular intervals, and therefore consideration as to which data to prioritise is required, taking into account likely volunteer uptake and potential improvement to EO products.

1.4 Existing habitat data

In-situ habitat data are currently collected through both professional and volunteer surveys across the UK. Professional surveys collect detailed information, often tailored towards a specific data application. For example, country nature conservation bodies (CNCBs) periodically collect information on key habitat features on designated sites to inform management strategies. These surveys are part of Common Standards Monitoring (CSM) and are designed to gather information regarding the condition of habitat features. For example, CSM surveys assessing lowland grassland habitats may include measuring the grass:herb ratio to ascertain the sward composition (JNCC, 2004). Each CNCB has its own method of collecting and managing these data. CSM data are not currently collected in a format that can readily be used in EO applications, as often only the condition assessment of designated features is reported, while the raw data are not openly available to internal CNCB staff or wider users. CSM protocols are currently under review. For example, NatureScot are trialling the use of the ArcGIS Survey123 recording app to collect habitat data as part of Site Condition Monitoring surveys, which presents an opportunity to collect information tailored towards EO training and validation.

For specific EO applications, CNCBs tend to commission professional surveys to collect the required training and validation data. Natural England (NE) contracted custom surveys to gather training and validation data to generate the initial version of the Living England habitat map, and also utilised existing volunteer collected data, such as the National Plant Monitoring Scheme (NPMS) data. NE are continuing to collect habitat data through bespoke surveys to produce regular updates to the Living England habitat maps. The Living England team are keen to explore the possibility of validating the continuously updated maps using volunteer-collected habitat records. NatureScot commissioned surveys to collect habitat data across Scotland to generate the Space Intelligence habitat map. Northern Ireland

Environment Agency (NIEA) used Areas of Special Scientific Interest (ASSI) survey information to provide training and validation data for a national habitat map. In generating the Living Wales habitat map, which was based on land cover classifications according to the Food and Agriculture Organisation (FAO) Land Cover Classification System, volunteer-collected habitat data, gathered using Aberystwyth University's "EarthTrack" mobile application were used with some reference made to CNCB data. Future iterations of the Living Wales habitat map will be validated using EarthTrack but will also integrate information collected from other surveys. CNCBs are keen to incorporate all available data into ongoing EO projects to improve the accuracy of derived products and are particularly interested in the possibility of collecting further habitat information through citizen science initiatives.

Volunteer recording schemes often include an element of habitat recording but the method, habitat classification scheme, collection frequency and level of detail collected varies considerably. The majority of UKTEPoP recording schemes record habitat information to some degree of detail (see Table 1). The NPMS collects the most detailed habitat data at ground level, including an assessment of the habitat type according to a bespoke classification system, and collection of information on habitat-specific plant indicator species. Other schemes, such as BBS and UKPoMS record a broad habitat category as part of the surveys, while WeBS and UKBMS only collect broad habitat information when establishing a study plot. Outside UKTEPoP, many organisations lead volunteer recording initiatives that may collect relevant habitat information as part of specific surveys, for example the Freshwater Habitats Trust, Catchment Monitoring Cooperatives, People's Trust for Endangered Species, and The Wildlife Trusts. Many citizen science efforts gather information on specific habitat features or management information that could also be useful for EO applications. For example, volunteers participating in the UKCEH project Bloomin' Algae report the presence of algal blooms through a recording app. While these initiatives may hold important potential to contribute to further habitat data collection, this review focuses on the UKTEPoP schemes to scope how additional habitat information might be incorporated.

Citizen science initiatives have the potential to gather further habitat information of significant value in support of EO applications. The coverage and frequency of volunteer records would extend the present CNCB survey capacity considerably, which could be a cost-effective way to monitor habitat extent and condition at local and national scales.

2 Collecting habitat data through citizen science

The UK is fortunate in possessing enormous volumes of biological records covering an extensive range of taxa with broad geographical coverage over a long period of time. Biological recording in the UK provides invaluable data for monitoring trends and informing land management decisions at a local and national scale (Pescott *et al.* 2015; Pocock *et al.* 2015; Roy *et al.* 2012 for details). Currently, recording schemes are largely focused on collecting data on specific taxa, but it is recognised that the wide network of highly skilled and dedicated volunteers holds the potential to record additional habitat information to validate and improve EO products.

2.1 Current citizen science habitat recording

UKTEPoP schemes are a subset of UK citizen science activity covering a wide range of taxonomic groups. To gain insight into the current picture of citizen science habitat recording in the UK, as part of the 2020/21 TSDA work programme, BTO issued questionnaires to UKTEPoP recording scheme managers and the responses are summarised here. Responses were collected from the following schemes:

- UK Butterfly Monitoring Scheme (UKBMS)
- UK Pollinator Monitoring Scheme (UKPoMS)
- National Plant Monitoring Scheme (NPMS)
- National Bat Monitoring Programme (NBMP)
- Avian Demographic Scheme (ADS) including Constant Effort Sites (CES), Retrapping Adults for Survival (RAS) and Nest Record Scheme (NRS)
- BTO/JNCC/RSPB Breeding Bird Survey (BBS)
- Waterways Breeding Bird Survey (WBBS)
- Wetland Bird Survey (WeBS)

2.1.1 Habitat information collected

At present, some degree of habitat information is gathered by UKPoMS, NPMS, ADS, BBS, and WBBS, while volunteers with UKBMS have the option to record habitat information. NBMP do not currently collect habitat information and have instead used Land Cover Map (LCM) since 2001 but are willing to consider collecting habitat data. WeBS volunteer organisers provide the broad habitat type when establishing a plot, but habitat data are not collected through the scheme. Table 1 summarises the habitat data currently submitted as part of UKTEPoP schemes. Scheme organisers currently have no evidence that the proportion of volunteers recording habitat has changed.

Table 1: Summary of habitat information currently submitted as part of UKTEPoP recording schemes, including the habitat classification scheme employed, collection frequency and the proportion of volunteers providing habitat information.

Scheme	Data submitted	Classification	Proportion volunteers	Frequency
UK PoMS 1km	Habitat types 1-40 EUNIS pan-European classification	EUNIS	All	Every record
UK PoMS FIT counts	Broad habitat category (e.g. garden, hedgerow edge, woodland)	Bespoke	Most (50-95%)	Every record
NPMS	Broad and fine level habitat Additional information including management and grazing evidence, sward height, species present and percentage cover (see guidance)	Bespoke – NPMS Outlines equivalents to other systems (to EUNIS, to NVC, to Land Cover Map among others)	All	Every record
UKBMS	Primary and secondary habitat types Management information (e.g. grazing, felling)	EUNIS	Some (5-50%)	Once (setting up site) and if observed habitat change
NBMP	None			
BTO ADS (CES, RAS, NRS)	Crick habitat class	Crick (1992)	Most (50-95%)	Every record
WeBS	Habitat recorded when site established (e.g. river, estuarine, reservoir)	Bespoke	None – volunteer coordinator records once	Once by volunteer coordinator

Scheme	Data submitted	Classification	Proportion volunteers	Frequency
BBS	Compulsory broad habitat (farmland, woodland, etc.) plus 3 further levels optional (see form and guidance)	Crick (1992)	All In 2019, 4005 (100%) squares had level 1 broad habitat, 3969 level 2, 3774 level 3a, 3215 level 3b, 3611 level 4a, 2973 level 4b.	Annually
WBBS	Compulsory "waterway" class plus 3 further levels optional (see form)	Crick (1992)	All	Annually

2.1.2 Reason for recording habitat

Scheme managers identified several reasons behind collecting habitat information. Habitat data are fundamental to NPMS, as the scheme surveys the abundance and diversity of plants to better understand the health of different habitats. Most schemes use habitat information in analyses to assess the association of species with habitats and explain changes in species abundance/presence. Habitat information is also currently collected to enable potential analysis in future. NPMS, BBS and WeBS record habitat for another use by the partnership organisation. For example, WeBS use habitat information to control online data collection fields, with relevant fields only appearing in certain habitats. NPMS and UKBMS record habitat information for use by a different organisation, for example to assist in categorising sites for UK Government indicators.

2.1.3 Volunteer attitudes

Most schemes do not offer much explanation as to why habitat data are required, suggesting improvements could be made in communicating their use to volunteers. A notable exception is the NPMS, as scheme coordinators provide extensive information and explanation to volunteers, largely because collecting habitat information forms the entire basis of the scheme. BBS and WBBS scheme managers stated that information provided to volunteers clearly explains why habitat data are important to collect.

All scheme managers felt they know volunteer motivations for contributing to the scheme in general. All schemes gather this information through informal feedback from volunteers, while UKPoMS, NPMS, NBMP, ADS and WeBS also collate volunteer comments through formal feedback questionnaires. UKPoMS collect views via formal feedback focus groups and both UKPoMS and UKBMS collate exit feedback from volunteers leaving the schemes. NPMS also collect volunteer feedback from mentors and social media, particularly the scheme Facebook channel.

However, few schemes gather specific evidence about volunteer attitudes towards collecting habitat information specifically. Only the NPMS have evidence that volunteers are generally

motivated to record habitat but note that this is because collection of habitat information is mandatory, therefore continued volunteer participation indicates motivation to collect habitat data. NPMS coordinators have found that volunteers are particularly interested in how land management strategies affect habitats. By contrast, BBS and WBBS organisers have received negative feedback via email from volunteers complaining about the fact that habitat recording is now compulsory.

Discussions at the UKTEPoP 2018 workshop uncovered valuable insight into volunteer attitudes to recording habitat information. It was suggested that volunteers do not enjoy recording habitat data, as they have limited confidence in classifying habitats consistently. BBS scheme managers found that volunteers are often reluctant to identify the main habitat when there are many different habitat type present. Some UKTEPoP schemes found that when volunteers covered smaller sites, they seemed to enjoy habitat recording, but uptake reduced across larger, more complex sites. It was recognised that volunteers may be more comfortable recording basic habitat features, but less confident in recording more detailed information, meaning a trade-off between volunteer participation and the detail obtained could be necessary. Current recording scheme volunteers may also be more comfortable, and more interested in, recording habitat features of importance to the taxa of interest, meaning volunteer participation in recording finer details may vary across schemes. The fact that habitat classification schemes are complex and vary across the UK was raised as a barrier to habitat recording, and many feel that the interpretation of habitat classes required for EO does not align with habitat requirements relevant to species groups. Clear guidance would be required to assist in the interpretation of habitat classification schemes.

It was also suggested that volunteers do not find habitat recording a rewarding experience and are not always aware of the impact of their data collection. Clear, transparent communication of the impact of volunteer collected data would help to encourage volunteer engagement, for example the power of BBS habitat information was demonstrated in Martay *et al.* (2018). Applying collected habitat data to multiple applications, particularly in a species context, and disseminating the outputs, may help to showcase the value of these data.

2.1.4 Training currently provided

Table 2 provides details of the types of training in collecting habitat information currently offered to volunteer recorders.

Table 2: Details of training resources currently offered to volunteers undertaking habitat recording as part of UKTEPoP schemes.

Scheme	Training provided	Type	Improved amount data collected/ attitudes?
UKPoMS 1km square	✓	One day training/introduction on their survey square	No evidence
UKPoMS FIT count	×		
NPMS	✓	Field crib sheets Online/printed guides Email support for questions Training courses	Overall scheme growth
NBMP	×		
UKBMS	✓	Online/printed guides List of habitat types, with EUNIS equivalents	No evidence
BTO ADS (CES, RAS, NRS)	×		

Scheme	Training provided	Type	Improved amount data collected/ attitudes?
WeBS	×		
BBS	✓	Field crib sheets Online/printed guides Email support for questions	No evidence
WBBS	✓	Field crib sheets Email support for questions	No evidence

2.2 Benefits

Collecting habitat data through volunteer recording initiatives could significantly expand the volume and coverage (both spatially and temporally) of current data collection, which is often restricted to protected areas when field surveys are conducted by CNCB staff. This could improve the accuracy of analytical and mapping applications, including the production of national habitat maps. Utilising volunteer networks would raise awareness of current policy work across the UK and provide an opportunity to engage the wider naturalist community in current habitat focused projects and applications nationally. Improving understanding of management activities, and impacts on habitats and species, could help to engage people with current conservation and restoration efforts. Showcasing the impact of a particular management strategy, or implementing a protected area, could raise awareness of UK-Government policies and promote broader environmental protection aims. Involving citizen scientists in the workflow of EO applications could help to promote transparent communication of long-term goals across the UK and provides an opportunity to upskill people in analytical techniques.

As with other citizen science schemes, there are mental wellbeing benefits offered by taking part in a recording scheme. Volunteer motivations for participating in existing schemes include making new connections, sharing and gaining skills, and social interactions with other recorders. Recording habitat information would help to forge a connection with nature at an ecosystem or landscape level, while visiting sites at different times of the year promotes an understanding of annual changes in vegetation.

2.3 Challenges

Collecting additional habitat information through existing recording schemes poses some challenges. In previous attempts to understand volunteer attitudes towards collecting records, it has been suggested the volunteers do not enjoy, or are not motivated to collect habitat data. However, there is limited evidence to support this theory and it is recognised that gathering volunteer perceptions of habitat recording would be essential to gauge interest or uptake. Volunteers participating in existing recording schemes are predominantly interested in recording taxa of interest and collecting habitat information would be an additional constraint on their time, possibly detracting from the enjoyment of recording species information. Every effort would need to be made to ensure habitat recording did not become an off-putting addition to recording schemes, as, in a worst-case scenario, schemes could lose volunteers if habitat recording was seen as a major inconvenience. Equally, because habitat information would not be a priority for recorders, volunteers may be unlikely to spend time ensuring the accuracy of habitat data. A disconnect between volunteers collecting field data and EO specialists using the data could lead to a reluctance in volunteers to record habitat information and foster general unrest among the recording community. To avoid this, it is imperative to establish clear objectives to communicate the reasons behind collecting in-situ habitat data, what these data are being used for (demonstrating the links between the data collected and the EO product), and applications of

these data within a species context, to engage volunteer recorder and ensure recorders feel involved in entire workflow of a particular EO application.

While volunteer recorders are highly skilled in recording their taxa of interest, concepts related to habitat recording, including percentage cover and vegetation metrics, are often less familiar to recorders. This emphasises the need for thorough and accessible training to build confidence across the recording community.

Collecting habitat data through citizen science has significant data management implications. Habitat data would need to be validated, either centrally by the data managers, or users could undertake project-specific validation. There are Artificial Intelligence (AI) or machine learning opportunities that may help to validate automatically some aspects of habitat records, for example automatically identifying submitted images of poor quality. Many of these techniques are still experimental, and the models would need to be trained and validated using substantial amounts of data. Collating, hosting and sharing the dataset would incur costs. The data collection pathway may introduce complications regarding which organisation is ultimately responsible for habitat data management. For example, if existing recording schemes were expanded to collect further habitat information, data would be held within existing recording scheme frameworks, which could lead to difficulties when collating habitat data across multiple data management systems.

Ideally, EO requires a standardised habitat classification scheme, but in practice this may not be possible. Existing habitat information collected as part of recording schemes differs from classification schemes commonly used in EO applications, but even within EO applications different schemes are employed depending on the purpose and UK country involved.

3 Short-term options

In order to collect in-situ habitat data suitable for EO applications, it is important to understand the minimum amount of information required and consider options for volunteers that allow relevant data to be gathered with minimal additional effort. EO specialists suggest that, as a minimum, records must include the location, date and habitat class to be useful for EO applications. The collection of metadata, including information on data collection protocols, quality-control procedures, any restrictions on data use, appropriate acknowledgements, and a data custodian contact, is also essential. As discussed, there are many other habitat features relevant to wider EO applications and species-related research. However, it is widely acknowledged that a compromise may need to be reached in order to allow volunteers to collect information they are confident in recording, and to avoid over-burdening volunteers. Adding a field to allow volunteers to estimate their level of confidence in the estimated habitat class might help to encourage volunteers to submit habitat information and flag points to be validated, possibly using submitted comments or photographs of a location. In future, there may be potential to expand data collection to include information on habitat features, but this will depend on volunteer uptake.

To maximise in-situ data availability for EO applications, the following options could be implemented:

a) All habitat data collected across recording schemes could be translated into a standard classification system after submission. This would avoid changing existing scheme protocols but introduces uncertainty through the process of matching classes and limits the potential for establishing cross-scheme training resources.
b) A standardised habitat classification system is adopted with a habitat recording element added to existing citizen science schemes to ask volunteers to take a GPS location and classify the dominant habitat at that location. These data could most

easily be recorded using a mobile phone app. This process would avoid more complex concepts of habitat condition and would be relatively simple to implement in recording schemes already using mobile phone apps to record data. However, volunteers would require training on habitat classification methods, for example detailed instructions and examples could be provided through an app interface.

c) Asking volunteers to collect information on the different components of landscapes as far as their knowledge allows. This approach is adopted in Living Wales and the EarthTrack mobile application where continuous and categorical information on different environmental descriptors is collected, which can then be combined subsequently to generate land cover classifications according to the Food and Agricultural Organisations Land Cover Classification System (FAO LCCS) and support their translations to habitat classes. The approach replicates that used to generate national land cover and habitat maps from EO data.

d) To ask volunteers to submit photographs or videos alongside existing records, including GPS coordinates. Some schemes, such as NPMS, already encourage volunteers to do this. Comprehensive guidance of what to include, required lighting conditions, distance and angle, among other details would need to be provided. These photographs could be used to classify habitat at that location centrally, or analysis could be undertaken by volunteers, which potentially provides an opportunity to engage with a wider range of volunteers, including those who are unable or not interested in completing field surveys. However, this process incurs heavy data management, processing and analysis costs to convert the photographs to usable data. As technology advances, there may be the possibility of implementing automated image analysis, but this process would also incur substantial costs. Submitted photographs would need to meet strict criteria to be suitable for analysis. Obtaining habitat information using image analysis, whether automated or visual, would introduce additional uncertainty. This process removes volunteers from the habitat information collection process, which may result in a lack of interest and engagement across the recording community. The ultimate use of the data would need to be decided prior to data collection, as without an established process of data collection, classification, and analysis in place, it would be difficult to justify gathering data to volunteers.

4 Long-term potential

While habitat classification at a particular location is the minimum requirement for mapping habitat extent, there are many additional EO applications that would benefit from in-situ data collected by citizen scientists. Additional species-focused applications could also be facilitated by collecting further information on habitat features. Asking volunteers to record more detailed measurements would need to be optional and would be dependent on volunteer uptake and feedback.

Monitoring habitat condition is an increasingly important area of research across the UK, as changes in condition indicate possible changes in ecosystem function and have implications for ecosystem services. Monitoring habitat condition using EO would require in-situ data such as presence/absence of bare peat, presence of burn scars, species composition, presence/absence of indicator species, graminoid:forb ratio, and evidence of pollution or illegal activities. These field measurements introduce another level of complexity and would require more specialist training for volunteers. It may be possible to train volunteers to recognise broad categories of condition for habitats of interest, for example poor/medium/good condition, and collect geolocated data points estimating the habitat condition alongside the classification. Measurements such as indicator species presence/absence may be of more interest to volunteers and could be tailored to match the taxa of interest of existing recording schemes. Reporting changes in condition may be more

engaging to volunteers, especially if changes are related to a local protected area or trends in a species of interest. Change in condition could also be linked to evaluating the effectiveness of management strategies. However, there are possible safety concerns in some cases, for example it would not be advisable to record bare peat locations in a severely eroded peatland area, and volunteer safety must be prioritised.

More detailed information on vegetation characteristics would facilitate further analysis of EO data. For example, canopy height, canopy cover, leaf type, woody biomass, structural diversity and vegetation moisture would help to build understanding around habitat productivity and diversity, provision of services such as carbon sequestration, and measure suitability for different management strategies. Collecting evidence of different management activities could help to interpret observed changes in habitat condition or extent, explain trends in species populations, and assess the effectiveness of management strategies. Volunteers would require additional training to gather these data, but these more detailed measurements could be more inherently interesting to volunteers and are more applicable to species related analysis.

Another option is to collect information on land cover and change at the same time. For example, in EarthTrack, information on the environmental descriptors that can be used to construct land cover classes also conveys information on vegetation condition. The app also contains a change module that describes change according to unique combinations impacts and pressures using the notation “impacts (pressures)” with examples being “vegetation dieback (bushfire)” or “water extent (gain) (flooding)”. Hence, recording of these implies and gives evidence for a condition change.

As EO capabilities continue to expand, novel sensors require an extended range of training data. For example, thermal or spectral data collected by specialist equipment may be useful in training land surface temperature models, such as climate change scenario modelling. Abiotic measurements, such as soil moisture content or soil pH, can help to inform models of soil moisture content and other research areas (Greifeneder *et al.* 2021). As these field data collection methods are more complex and often require specialist equipment, gathering this information through volunteer recording schemes may not be possible or advisable.

In future, it may be possible to expand in-situ data collection methods to improve coverage. Collecting field data through citizen science presents an opportunity to extend significantly the coverage of professional surveys, which are currently focused on protected sites. At present, citizen science data collection can be biased towards “honeypot” sites or more accessible areas. However, NPMS, WCBS and BBS employ a stratified random sampling strategy, aiming to remove spatial bias, though in reality not all survey locations are visited with equal effort across the sampling strategy. For EO applications, collecting data over as much of the UK as possible, avoiding spatial bias as far as possible, would provide representative data for accurate habitat maps. As this ideal scenario is likely to be unattainable, it may instead be possible to direct volunteer recorders to areas that require investigation, such as areas showing outliers in spectral values, or land parcels with low classification accuracy. The Delivering Enhanced Biodiversity Information with Adaptive Citizen science and Intelligent Digital Engagements (DECIDE) project, led by UKCEH, follows this approach and has developed an online tool for recorders to identify high priority locations to target field surveys. The Targeting Revisits Maps produced by the Biological Records Centre at UKCEH are another example of how recorders can be directed towards particular areas. It may also be beneficial to engage with wider groups, for example mountaineers could collect upland data points, or landowners could submit data on private, inaccessible land. Data collection methods could also be updated to include new technologies. For instance, some volunteers have their own drones and may be interested in supporting recording schemes. These data could prove valuable in collecting in-situ data

over a large area, but there are significant safety and licence implications, as well as the potential reputational risk if any problems arose.

5 Habitat data collection methods

Potential pathways for collecting additional habitat information are summarised in Table 3 and presented in more detail in Appendix 2. Each option was discussed at the 2021 UKTEPoP Habitat Recording Workshop (details in Appendix 3) and attendees' views are summarised for each in Appendix 2. The findings from the workshop are summarised here.

Discussions highlighted the fact that there is no "one-size-fits-all" solution to collecting additional habitat information. Attendees reiterated that the preferred collection route for additional habitat data would depend heavily on what information was collected and the target audience. Each collection route discussed had advantages and disadvantages, and no clear consensus was reached as to a single "best" collection method. However, attendees expressed most support for both a fully integrated approach and establishing an entirely separate habitat recording initiative.

Attendees saw substantial benefits to integrating additional habitat recording into existing UKTEPoP recording schemes. Some advocated an entirely integrated approach, where volunteers record detailed habitat information, while others favoured a minimal approach, where volunteers submit only a GPS location and habitat type. A possible method could include an optional simple data entry (such as GPS and habitat type) with an integrated extension to allow volunteers to collect more detailed habitat information. Examples include evidence of management, vegetation metrics, condition estimates, and details of specific habitat features of interest. This would enable volunteers to record as much or as little habitat information as they wish, with the option to focus on aspects of most interest. It was suggested that some core entries, for example GPS location and habitat type, could be made mandatory with the more detailed entries optional. Additional habitat data would need to be collected in standardised formats for the data to be transferable across schemes and it was suggested that data could be collated into a central data hub. It was also noted that free text entries should be avoided where possible to standardise data. The importance of designing additional data collection protocols with schemes and clearly communicating to volunteers the reasons behind recording habitat information, including what the data are being used for, was emphasised throughout discussions.

Despite concerns around establishing a separate habitat recording initiative scheme, particularly possible competition for volunteer time and duplicating land access requests, many felt a specific scheme may be necessary to avoid discouraging or irritating existing volunteers who are not interested in habitat recording. Attendees highlighted the fact that establishing a new scheme or recording app provides opportunities to engage with the wider volunteer community and connect people interested in monitoring habitat dynamics. It was suggested that EarthTrack or similar initiatives might be used to gauge the appetite for habitat recording before establishing a bespoke scheme.

Table 3 summarises the data collection pathway options, the minimum data collected through each pathway, and pros and cons of each.

Table 3: Summary of different data collection approaches

Approach	What is involved	Minimum information	Long-term aims	Pros	Cons
"Is this still the case" approach	Adapt current apps/forms to include a field with predicted habitat class and a field to state if this is correct and possibly suggest alternative	Validating predicted habitat	Option to submit correction Option to submit images Updated as habitat assessments are updated to facilitate continuous validation and measurement of any changes	Relatively simple for volunteers Little additional time required Provides validation data for habitat maps Potentially easier to say if something is wrong than make new assessment	Volunteers may be unlikely to take much time on this assessment, limiting certainty in answer Would still require training resources volunteers were expected to understand more complex habitats (e.g. Dry acid grassland) or to suggest alternatives
Volunteers submit additional photographs	Clear guidance is provided to standardise photographs. Volunteers submit photographs alongside scheme data for centralised analysis.	Photographs including ground cover, overhead view, view from each cardinal point.	Habitat classification from photographs automated through machine learning or AI	Little extra volunteer effort required Engage with wider volunteer community to classify photographs Standardises classification process	Specific guidance required to standardise photographs Photograph quality issues Time-consuming and resource-intensive to manually classify habitat centrally
Each scheme adapted to use another scheme's habitat recording classification	Altering existing habitat recording protocols to match a single scheme's classification, adding a habitat recording element in cases where none currently exist	Habitat assessment for established plot/point along transect according to selected habitat classification scheme		Some volunteers already familiar with protocol Existing method may have less resistance Standardised classifications	Not able to tailor habitat collection to suit needs Schemes may want to keep existing protocols in place

Approach	What is involved	Minimum information	Long-term aims	Pros	Cons
Each current scheme data collection process would be adapted to record habitat data more explicitly	Add in field to take GPS location and record habitat category at locations across survey square or transect. In apps, this would require additional data fields plus guidance in the app itself In survey forms, there would be a field to record the GPS location (by a handheld GPS or phone) and habitat type (again guidance required)	GPS location and habitat class at that location (classification scheme to be decided based on EO requirements)	Option to add images Add additional information on management, condition, details of habitat features of interest or vegetation structure for example	Volunteers asked to record an additional field only, rather than being asked to go to another site/app Habitat data recorded tailored to meet EO needs	Involves significant development of recording apps and forms, which requires time and financial support for recording schemes. Each app/form needs to be individually adapted, increasing the costs
Scheme volunteers would be directed to additional app at end of recording – autofilled with current app information	If possible, habitat app would auto-fill fields based on previous records (e.g. indicator species recorded suggests habitat class – this would be particularly relevant for NPMS)	GPS location, habitat class, metadata plus any additional information including species records from previous scheme submission	Option to submit images Add additional information on management, condition, habitat features of interest or vegetation structure for example	Autofill would reduce the number of additional data entries Using a separate app makes it easier to provide guidance and feedback via this platform centrally to all volunteers	Additional app for volunteers to download Autofill complications If only at the end of survey, transect surveys only provide habitat at end of transect Consideration required to ensure autofill is possible in offline mode
Scheme volunteers would be directed to additional app at end of recording	Each app/ form would direct you to an app to submit habitat information (this could be mandatory in order to submit record, or optional)	GPS location, habitat class, metadata	Option to submit images Add additional information on management, condition, habitat features of interest or vegetation structure for example	Using a separate app makes it easier to provide guidance and feedback via this platform centrally to all volunteers	Volunteers need to fill in information again, leading to possible frustration

Approach	What is involved	Minimum information	Long-term aims	Pros	Cons
Establish new habitat recording system and publicise through existing and new channels, but not integrate with current schemes	Selecting the most effective habitat classification scheme, generating or adapting recording app, and publicising with existing volunteers and new citizen scientists	GPS location, habitat class, metadata	Option to submit images Add additional information on management, condition, vegetation structure for example Possible to add modules similar to EarthTrack, for example ask volunteers to record burn scars, turbidity etc. Links with monitoring wider environmental issues	Reduced pressure on existing recorders Possibility of engaging wider audience while utilising current networks and enthusing volunteers about this initiative in its own right Removes complexities /costs of joining up with existing apps More scope for integrating techniques to maximise data collection and distribution	Takes time to establish volunteer base Possible conflict with existing schemes

6 Habitat recording apps

Mobile phone apps are increasingly employed in citizen science recording schemes, as they provide an efficient method of standardising data collection and enable volunteers to directly submit records while in the field. As technology advances to allow offline data entry, live location maps, and efficient data management, apps are becoming ubiquitous across the volunteer recording community. In recent years, there has been an explosion of different citizen science recording apps worldwide (see examples) and in the UK (see examples). In UKTEPoP, NPMS have recently developed a recording app for volunteers to submit records alongside support photographs. In species recording, iRecord, iNaturalist are very widely used, and taxa-specific recording apps include BirdTrack, Mammal Mapper, WhaleTrack and Lichen App among many others. More specific field data are collected through tailored apps, such as Bloomin' Algae, which gathers records of blue-green algal blooms, mySoil, which collects soil characteristic data, Long Forest, which surveys hedgerows across Wales, and Dynamic Dunescapes, which monitors dune ecosystem health.

Recording apps provide unique and exciting opportunities to provide tailored guidance, training and support, such as video demonstrations of how to use the app in the field. Apps replace the need for volunteers to use survey forms and GPS equipment, making data collection and submission more streamlined and portable. Using apps may help to engage younger generations in citizen science recording, as the data collection process can be adapted to ensure it is easy, fun and rewarding. However, apps are not accessible to all, as they depend on volunteers having a compatible smartphone and assume that volunteers are comfortable using the interface.

A range of different habitat recording apps are currently in use across the UK. A subset of relevant apps are explored here and their applications, merits and shortcomings are discussed below.

6.1 EarthTrack

Development and application: EarthTrack was developed by Aberystwyth University to facilitate the collection of land cover and change. The collection of land cover information follows the hierarchical and modular structure of the FAO LCCS, allowing detailed descriptions of agricultural and urban environments, semi-natural vegetation, natural bare surfaces and water. Additional information on species can also be provided, with over 25,000 listed for expert use. However, options are available for citizens to submit what they know, even if these appear quite simple (for example, "is it a tree?"). EarthTrack also allows for the collection of information on change based on the notation of "impacts (pressures)", with over 200 categories listed. While the app has been developed for global application, country specific options are also included such as recording of Phase 1 Habitat categories (primarily for use in Wales). Throughout, capacity to record habitats is provided through the recording of different environmental descriptors. The sequence of steps in the app mirrors that undertaken for generating land cover and evidence-based change maps across local, national, or even continental scales, for example through the Living Wales initiative. EarthTrack is also being used in Australia to collect land cover points and also supports the validation of Global Mangrove Watch mangrove extent and change maps.

Habitat classification system: Food and Agriculture Organisation (FAO) Land Cover Classification System (LCCS V2).

Platform details: EarthTrack has been developed as a professional version by Natural Apptitude and will be released in the spring of 2022 for use on both Android and IOS systems and smartphones.

Data management: All data are collated to produce a continuously updated global dataset. All anonymised data points are available to download via an online portal under a Creative Commons licence.

Advantages: EarthTrack was specifically designed to collect habitat data through citizen science, using open-source software and both the app and data are not limited by licence restrictions. The app can collect data offline and the forms can be tailored to meet specific needs. EarthTrack is already widely used by volunteers and is currently undergoing redevelopment to further enhance the interface.

Disadvantages: EarthTrack is currently only compatible with Android mobile phones, but this will not be the case with the redeveloped app.

Future development: Aberystwyth University are working with Natural Apptitude to create a new, user-friendly interface for the EarthTrack app, set to be completed in 2022. The format will be similar to the Long Forest app and the project team are eager to incorporate suggestions from JNCC and the UKTEPoP recording schemes, which offers an exciting opportunity to generate an app that existing volunteers would find attractive and engaging.

Suitability for citizen science: EarthTrack has been specifically designed to enable volunteers to collect habitat information, and as a result is tailored to meet citizen science needs. The app itself and generated data are all openly available for use and there are no licencing constraints at present. With Natural Apptitude currently generating a new UI, EarthTrack holds real potential for wider use across the UK.

6.2 E-Surveyor

Development and application: UKCEH have created E-Surveyor as part of the Achieving Sustainable Agricultural Systems (ASSIST) project which aims to develop innovative farming solutions to increase the efficiency and resilience of food production systems. Flumens have developed the app interface. E-Surveyor allows farmers and landowners to monitor plant species composition on their land. The app has three modes: i) use AI to identify plants and compare the observed species to those listed within seed mixes, ii) allow users to survey locations by submitting photographs of plant species, and iii) enable users to conduct structured transect surveys for agri-environment or Common Standards Monitoring or create a custom survey. Additional functionality for surveying trees is in development.

Habitat classification system: When completing structured surveys, habitat types are aligned with Common Standards Monitoring guidance.

Platform details: The app is currently in development, but an early access system is available for both Android and iOS systems.

Data management: Data collated for use in ASSIST project.

Advantages: The use of AI to identify plants makes the app accessible to non-specialists. The app supports different types of surveys, allowing landowners to choose their preferred method.

Disadvantages: The remit of the app if very specific to the ASSIST project, and the main focus is gathering data to assess how landowners and farmers are managing their land, specifically seed mix success. Habitat data are not explicitly recorded, as the app is more focused on plant species and associated pollinators.

Future development: UKCEH and Flumens have developed the initial release of the app but are constantly developing updated iterations based on user feedback.

Suitability for citizen science: E-Surveyor meets the requirements of the ASSIST project but does not currently allow collecting habitat information required by EO. It may be difficult to adapt the app to incorporate more explicit habitat classification within the current app, but the app infrastructure could potentially be repurposed to create a more specific habitat recording app.

6.3 ArcGIS Collector/Field Maps

Development and application: ArcGIS Field Maps (the updated version of ArcGIS Collector) allows users to collect and edit data in the field using a live map. NE are currently using ArcGIS Collector to conduct field surveys gathering training and validation data for generating Living England maps. ArcGIS Field Maps is also used in citizen science, for example the Amphibian and Reptile Conservation (ARC) Trust use a Community User account to share the app with volunteers.

Habitat classification system: Depends on user requirements as data collection forms are bespoke. NE have created a bespoke habitat classification system based on UK Biodiversity Action Plan (UKBAP) broad habitat types to generate Living England habitat maps.

Platform details: The Field Maps software can be used with both Android and iOS devices.

Data management: Depends on the user. NE collate data internally and aim to share the derived data (national habitat maps) under an Open Government Licence.

Advantages: The app interface enables users to track their location, and users can drag the location point to an inaccessible area, such as private land, to record the habitat at that location. The interface shows current maps and allows users to edit maps directly.

Disadvantages: The ESRI licence fee is significant, and the licence restricts the use of the app to licence holders only, which limits its suitability for citizen science.

Future development: NE are scoping possibilities to extend their current licence to include non-staff members, but it is not yet clear if this is feasible.

Suitability for citizen science: The ARC Trust issue each volunteer with an ArcGIS Online Community User account, which enables them to use the ArcGIS Field Maps app to collect data in the field and view interactive maps of their survey sites and previous records through an online portal. For some organisations the licence fees associated with the use of this app by volunteer networks may be prohibitive. However, if a licence were jointly funded by organisations, using Field Maps would be a viable option. The data collection forms are customised to collect required information, however the interface itself is static, meaning training resources and volunteer feedback mechanisms could not currently be implemented through the app interface.

6.4 ArcGIS Survey123

Development and application: ArcGIS Survey123 has been developed by ESRI to facilitate in-situ data collection, allowing users to create a form-based interface, share and analyse data. Natural England have tested the app as an alternative means of collecting field data to train the Living England mapping models. The ARC Trust also use ArcGIS Survey123 mobile and desktop apps to collect data for semi-structured surveys. Volunteers

can simply click on their survey site and open the correct survey form in the app, with some fields such as location prefilled.

Habitat classification system: Depends on user requirements as the forms are bespoke. NE have created a classification system based on UKBAP in the Living England project.

Platform details: The system requirements state that the app can be implemented on a range of operating systems, including Android and iOS, but also on Windows, Ubuntu and macOS devices.

Data management: Depends on the user.

Advantages: Survey123 can be used by citizen scientists under existing ESRI licence agreements held by a central organisation and the app is compatible with a range of devices. The data collected can be easily integrated with other ESRI software for data management and analysis.

Disadvantages: Since the app is form-based it does not include a map interface, which NE have identified as important in collecting field data for Living England. While licence restrictions are more lenient than with other ESRI products, the app does require the project manager to hold a specific licence, either as a Creator or Field Worker user type.

Future development: Ongoing support for Survey123 has been discontinued for certain devices, as ESRI will no longer test updates or support the legacy versions of the app from January 2021. While NE recognise it was a useful process to test Survey123 it is unlikely they will continue to use the app as part of the Living England project.

Suitability for citizen science: While the ARC Trust use of Survey123 highlight its current applicability in citizen science schemes, the app may not be suitable in future due to discontinued software support.

6.5 Input

Development and application: Input is a free and open-source app developed by Lutra Consulting. It enables users to collect field data, view data and live location on a map, submit geotagged photographs and synchronise data between devices using Mergin, facilitating collaborative data collection. Input is based on QGIS software, and an additional tool Mappin can be used to generate QGIS maps through a simplified UI. Survey points, lines or areas can be captured, and the data collection forms can be customised to include a range of information.

Habitat classification system: Depends on user requirements as data collection forms are bespoke.

Platform details: Available on Android and iOS devices.

Data management: A project manager would establish a project and customise data collection forms. Data collected on mobile devices is synchronised with a desktop via Mergin, with data from multiple collectors submitted as part of a QGIS project.

Advantages: Free and open-source, avoiding licencing fees and restrictions on data. The app is integrated with QGIS, which is also free and open-source. The data management process is already optimised using Mergin and Mappin tools.

Disadvantages: Unclear how to provide public read and write capabilities to facilitate citizen science contributions to a project.

Future development: N/A

Suitability for citizen science: While the tool is free and open-source, making it an ideal platform for volunteer recorders, further research into how to provide public write access to a project would be required. At present, it seems that publicly accessible projects are only readable, with users prohibited from submitting records unless the project managers grant access to individual users, which would be time-consuming. Further research would be required to optimise this process. Were this obstacle overcome, the ability to merge and collate all submitted data could make it a powerful tool to collect habitat information. The data collection forms can be customised by the project manager to collect required information, but the interface itself cannot be altered, meaning training resources and volunteer feedback mechanisms could not currently be implemented through the app.

6.6 Sweet

Development and application: Sweet is the latest ESRI field app, designed to collect and edit data with built-in quality checks. Several organisations are using Sweet to collect field data, including Natural England and UKCEH. Natural England have developed a Sweet app to collect data as part of the England Ecosystem Survey (EES) and are currently testing its capabilities. Development is ongoing to create a bespoke tool to collect many nested elements of the EES.

Habitat classification system: Sweet can be adapted to use any classification system, depending on the user requirements. For EES, NE are using a classification scheme based on UKBAP broad and priority habitats plus additional “detailed habitats” to fill any gaps.

Platform details: Sweet is compatible with Android, iOS and Windows systems.

Data management: Data collected through the app are compatible with ArcGIS and other ESRI applications. The data flow depends on the user.

Advantages: Sweet can be adapted to incorporate different elements of habitat recording, enabling users to focus on specific features and facilitating data collection for complex surveys, such as the EES.

Disadvantages: ESRI licence fees are applicable to Sweet, which could restrict wider use across citizen science initiatives.

Future development: ESRI are continuing to develop Sweet for various applications. Development of Natural England’s Sweet-based app to collect EES data is ongoing.

Suitability for citizen science: While access to Sweet can be shared across many licences, enabling volunteer engagement, the app is potentially overly complex for citizen science data collection. Natural England have found that Sweet requires a tablet as the interface is too complicated for smartphone use, which restricts its suitability for volunteer data collection.

6.7 Summary

At present, EarthTrack is the most relevant app for expanding the collection of in-situ habitat information across the UK. EarthTrack has been specifically designed for this purpose, and the fortuitous timing of the update to the UI presents an invaluable opportunity to tailor the

app interface to meet volunteer requirements, including an interface that is easy to navigate, simple data collection protocols, and provision of volunteer support resources. Input is also a promising option, as it uses free, open-source software, but there is limited scope to adapt the app itself to provide training and feedback directly to volunteers. The ESRI licence fees limit wider use of both Field Maps, Survey123, and Sweet, and E-Surveyor is tailored to meet the different requirements of the ASSIST project.

There are aspects of similar projects that could be applied to habitat recording apps to maximise the benefits gained from data collection efforts. The DECIDE project, led by UKCEH, aims to collect new field data to improve biodiversity models, initially focusing on butterflies, moths and grasshoppers. The DECIDE project has developed a tool to identify locations where records are most needed, and direct volunteer recorders to these locations to gather required data. This approach could be applied to a habitat recording app to "nudge" volunteers towards locations that most require validation in a habitat map, for example, which would improve the distribution of data points for EO applications.

7 Volunteer feedback

7.1 Existing scheme feedback

It is widely acknowledged that volunteer recorders benefit from seeing how their data are used. In the past, UKTEPoP scheme volunteers have emphasised the importance of clear communication of the reasons behind data collection, how data are used, and celebrating the accomplishments made possible by collected data. It is crucial to showcase the value added by the submitted data and thank volunteers for their contributions. Providing feedback in habitat recording initiatives is especially important, as this is a new, and often poorly understood, area for volunteer recorders.

Current recording schemes provide feedback in the form of annual reports, regular newsletters, magazine-style articles focusing on a particular finding, email updates and social media posts. In existing schemes, newsletters explaining results and their significance in contributing to conservation, including clear infographics, are well received. Annual reports contain population trends and interpretation, statistics of volunteer participation and survey coverage for the year, as well as additional news items. See the BBS annual reports and NBMP annual reports for examples. NPMS volunteers also receive more focused newsletters (see the Winter 2020 example) throughout the year, providing information on scheme developments and flagging further volunteering and training opportunities. In many cases the collected data contribute to national official statistics, which are published every year and made available online, for example the UK Biodiversity Indicators. Scheme coordinators will also send email updates to volunteers sharing reminders about scheme events, and many schemes have active social media channels to raise awareness of exciting developments.

Collated data are made available online through scheme websites, the NBN Atlas and the Environmental Information Data Centre (EIDC). Volunteers in existing schemes seem to enjoy seeing data they have collected immediately incorporated into data portals. Many schemes also offer interpreted results online, such as customisable graphs of population trends or fact sheets for species of interest. For example, BTO provide detailed information on population trends, breeding performance and survival rates for different species, selected by the user, through BirdTrends and species characteristics and distribution, as well as identification tips, through BirdFacts.

Some schemes also provide individual feedback to volunteers. Blooms for Bees notify volunteers of the outcome of expert verification of submitted records, which has been well

received by volunteers. BBS provide online highlights of personal contributions, for example the number of years of involvement, which seems to be appreciated.

7.2 Feedback specific to habitat recording

To engage volunteers in recording additional habitat information, providing feedback to volunteers on how their data are used, and the value of the derived products in the landscape of ecological conservation is essential. Providing accessible outputs would help to clearly demonstrate the value of submitted data and raise awareness of EO projects. In order to appeal to existing recorders, habitat information could be presented in the context of species research, clearly demonstrating that improved habitat information can enhance our understanding of species population dynamics and the drivers of change. It may be beneficial to offer different feedback options for new and long-term volunteers, as new volunteers may be more interested in habitat facts, whereas people more familiar with the recording initiative may be more interested in interpreted statistics and graphs.

UKTEPoP Habitat Recording Workshop attendees discussed proposed feedback mechanisms and suggested ideas to engage volunteers in habitat recording. Attendees reiterated the important role feedback mechanisms have in ensuring volunteers understand how their data are used in research by clearly communicating how submitted data contribute to meeting policy targets, and the difference the data have made, such as improvements in map accuracy. Feedback provided could also highlight the relevance of habitat data in interpreting biological data results.

Workshop attendees felt volunteers may be interested in how their survey site compares to others, both within the context of a whole scheme survey and in a regional or national context. Information on how the habitat at their site has changed over time and proposed actions for a site in poor condition, for example links to policies or management plans, might help to engage volunteers at a local level. Other suggestions for habitat-related feedback included sharing a guide of what volunteers might expect to see in a particular habitat at this time of year, or throughout the year, and interesting facts about the habitat they have recorded. This would provide an opportunity to raise awareness of the value of a habitat, trends in condition, and pressures or drivers of change. Workshop attendees suggested that volunteers may enjoy the opportunity to convene with other volunteers as part of a community through large celebration events and social media groups, which would enable volunteers to discuss and validate records.

Workshop discussions highlighted the following general recommendations to engage volunteers in habitat recording:

- Essential to define audience, and possibly target different audiences with different feedback approaches providing information most of interest to each
- Aim to promote a sense of community across recorders
- Communicate results within a wider context, such as how a local site compares at a regional or national scale
- Demonstrate the local impacts of collected data
- Ensure feedback is as personal as possible, highlighting an individual’s contribution to wider conservation aims

Potential feedback options to encourage volunteers to record habitat information are outlined here alongside views gathered from the UKTEPoP Habitat Recording Workshop.

7.2.1 Communicating progress

Annual reports of progress towards EO product development, such as national habitat maps, could be used to summarise the impact of volunteer collected data. These reports could be publicised through volunteer networks to raise awareness of key projects across the UK. Newsletters provide a useful platform to delve into more detail on a particular topic of interest, such as a novel EO techniques utilising volunteer data, while emails to mailing lists and social media posts can be used to raise the profile of these developments. Progress updates, such as changes in the quality of habitat maps could be visualised to provide case studies highlighting the impact of submitted records. Similarly, statistics of ground covered, or area mapped by volunteers collectively can be publicised to celebrate volunteer contributions to EO projects. Data collection efforts to date could be visualised using a map, highlighting locations to target for future recording.

Some workshop attendees felt this would help to motivate volunteers and demonstrate the importance of collecting in-situ habitat data. However, it was suggested that volunteers are less interested in improvements to EO products themselves but would be more interested in how habitats are changing and the achievements made possible by our improved understanding of habitat dynamics. Headline improvements in EO products could be incorporated into scheme annual reports to give details of the wider context of scheme data.

7.2.2 Shared data outputs

Data collected as part of habitat recording initiatives could be made openly accessible through a continuously updated online mapping portal to enable volunteers to see their records appearing alongside other data. Creating a platform to see “live” data updates immediately illustrates where and how data are applied. When it is implemented, the JNCC regional landscape monitoring tool (see Appendix 1, JNCC landscape monitoring) will provide an online platform showing regularly updated field data points alongside EO data layers, helping to interpret change and flag habitat misclassifications. Allowing users to download the in-situ habitat dataset, as is currently offered by EarthTrack, could be explored, as volunteers may be interested in repurposing the data for many different applications.

Workshop attendees emphasised the fact that data collected should meet open data requirements if possible, and that volunteers should have access to their own data at least. Many suggested that access to raw data points was not likely to be a strong motivating factor for the majority of volunteers, as volunteers often do not currently make use of data access, but a subset of the recording community may be interested in using the data for academic research or similar.

EO outputs derived from volunteer collected data, alongside methods reports, could be made openly accessible to clearly illustrate how these data were used. Providing access to data portals, and publicising their capabilities, may help to engage volunteers with EO projects. For example, the NatureScot habitat map generated by Space Intelligence is available for download and online analysis via a webpage. Users can visualise land cover, land cover change, and opportunities for restoration without downloading the data, and there is also an option to show regional statistics for large national parks. The Living Wales geo-portal allows users to visualise the land cover map and different layers of interest, including canopy cover and leaf type.

In addition to providing the derived data products, publicising access to analysis-ready EO data, such as the CEDA archive or any licensed very-high resolution data available and providing training resources in how to use these data may be interesting to volunteers. This

would provide upskilling opportunities within EO and raise awareness of the vast range of data sources and analytical opportunities.

Workshop participants also felt that access to EO data and derived products may be useful for some people, such as academic researchers or Catchment Partnerships, but not for the majority of the recording community. Volunteers may be more interested in habitat products, particularly if linked to conservation or biodiversity data, rather than EO data, the sharing of which may incur licensing expenses. It was also suggested that volunteers may prefer an online portal to explore habitat data, instead of downloading raw data.

7.2.3 Interpreted outputs

While access to both the raw in-situ data and derived EO products is important, volunteers may appreciate further interpretation of outputs in the context of national policy, local land management and species conservation. Providing an easily understandable explanation of how outputs are being used in implementing policy could generate interest in national and local environmental conservation efforts. For example, a case study report focused on a particular habitat could provide information on the national health or conservation status of that ecosystem, any changes over time and possible drivers, as well as information on current strategies to protect or restore the habitat at a national scale. However, national trends in habitat condition or extent may be difficult to appreciate in a local context. Reporting on habitat extent, condition, and changes in habitat on a local scale may be of more interest to volunteers and could enable local action groups to carry out activities to further sustainable management at a site level. Focusing on local habitat information, for example communicating how concreted an area is compared to other areas in the UK, may help to generate interest in local recording communities.

To engage existing recording scheme volunteers, providing information on habitat status in the context of species associated with that particular habitat would be most important. Information could be tailored to each recording scheme according to the taxa of interest, providing updates on changes in habitat extent or condition and interpreting what this means for the specific taxa. Species recording schemes currently report population changes per habitat type as part of national official statistics reporting. Enhancing the underlying habitat data used in these reports, and providing further interpretation, including possible drivers of changes in species populations would be interesting to recorders.

Workshop discussions suggested that sharing local area reports would be of particular interest to volunteers, as it was recognised that a sense of place is a strong motivating factor. Presenting interpreted results at a local scale, in the context of a national picture, would help to build a sense of community and could support local recording groups. It was noted that people care deeply about their local area and more information about how volunteer efforts contribute to its protection would be well received. WeBS News was given as an example, as articles from volunteers about their local sites have been popular in past editions.

7.2.4 Gamification

Collecting habitat data through recording apps presents an opportunity to gamify the process, following the success of this concept in initiatives such as geocaching, parkrun and Duolingo among many others. Individual achievements could be reported immediately through the app interface, for example upon submitting a record volunteers could be presented with messages such as “Congratulations, you’re the first person to record this habitat in Lincolnshire”. A recorder’s personal achievements could also be reported to them at monthly, or annual intervals, including the area walked while recording, number of data points submitted, or area mapped using their submitted points. Some volunteers may be

motivated by improving their own performance, for example by comparing the area mapped or data points submitted during one month compared to the last.

Recorders could collect points, gems or coins as rewards for submitting data points through an app, with higher points awarded if a volunteer visits a location recorded by fewer people, or a priority location. Another possibility would be to incentivise volunteers using tangible rewards, such as identification guides, outdoor activity shop discount vouchers, or invitations to training courses. These could be awarded as a recorder reaches a certain threshold in collected points. Following the format of many apps, recorders could enter a leaderboard of reward points, or area covered for example, to compete against other recorders. While many people would be motivated by this competitive element to recording, other volunteers might find it irritating or in fact demotivating, and it would be important to allow recorders to "opt-out" of entering a leaderboard. However, this may result in a few volunteers consistently at the top of the leaderboard, and other volunteers may prefer to compete against people nearby, or at a similar recording level. For example, upon registration volunteers could assign realistic goals to themselves, such as visiting 10/50/100 locations in a year, which could be used to enter them in different leagues of recorders. This would ensure volunteers were competing against people at a similar level to themselves.

Gamification may appeal to a younger demographic, while at present the majority of the recording community are in older generations. Equally, there may be recorders of all ages that find the competitive element off-putting, and it may be advisable to include an "opt-out" option to avoid irritating volunteers. However, it could be an effective strategy to engage a wider range of volunteers in habitat recording initiatives. Measures to ensure that gamifying the data collection process does not impact the accuracy of records may be required. This could be achieved by asking volunteers to submit geo-tagged images for verification alongside habitat information to confirm that they have visited the location.

Workshop attendees felt gamification might be successful if designed carefully, as recorders are often competitive by nature, and many thought this approach may be well suited to younger recorders. Examples of successfully gamified initiatives include NASA's NeMO-Net, an iPad game where players help to classify coral reefs, providing training data for a deep learning model. Different features were suggested, such as assigning different levels of contributor, such as bronze, silver and gold, or a star award system for users to display on their app account. Another suggestion was to measure progress through sampling strategy as a percentage, so that volunteers see progress with every submission. However, many attendees raised concerns that this approach encouraged quantity over quality records, and could lead to unwanted outcomes, such as false records. Volunteers may be discouraged by some recorders "cheating the system" to attain more points. It was also raised that many scheme organisations do not have the resource to develop a complex gamified app, and volunteers sometimes have limited access to technology.

It was highlighted that volunteer attitudes towards gamification would heavily depend on their personality, and many felt that celebrating personal achievements would be preferred. This approach was very popular with workshop attendees, and it was acknowledged that recognising individual contributions has proved more successful than leaderboards in the past, for example BirdTrack removed leaderboards because the same recorders remained at the top. Celebrating participants more publicly in newsletters or similar communications was also suggested, but GDPR would need to be considered. Keeping a personal record of contributions to schemes may encourage volunteers to seek new challenges by recording other habitat features or taxonomic groups. Attendees mentioned this mechanism would need to be automated to avoid the time-consuming task of distributing feedback manually.

8 Volunteer training and support

As with all citizen science schemes, it is important to build volunteer confidence in recording habitat information, especially as this is a new area for many recorders. If volunteers perceive habitat classification as onerous and challenging, the uptake of a recording initiative would be limited. The data collection process itself needs to be as simple as possible to encourage participation. A dichotomous key approach could be employed to guide volunteers through the classification process, and “cheatsheets” of indicator species or features characteristic of a particular habitat could be used to simplify the habitat classification process. Establishing a standardised habitat classification scheme and method would help to improve volunteer confidence and would mean a universal training resource library could be generated.

The data verification process needs to be clearly communicated to volunteers, to ensure recorders that their data are being validated, and feedback could be provided to volunteers after validation. For example, if a submitted habitat classification point has been verified as correctly identified, this will boost volunteer confidence. Equally, providing a detailed explanation of why an incorrect data point has been misclassified would expedite ongoing volunteer development. Data points could be verified using submitted photographs or videos of the location, though further consideration around how best to use these images would be required.

Table 2 summarises the training resources currently employed by UKTEPoP recording schemes. These training options and other potential volunteer support mechanisms are discussed below.

8.1 Structured training options

A library of training resources could be made available to all volunteers to ensure they have access to all the information they require. Training resources could include illustrated habitat identification guides and keys, which would ideally also be accessible directly via recording apps, both online and offline, and as hard copies. Video guides and webinars would help volunteers to visualise the method and provide detailed examples of how to classify habitats. Similarly, videos of how to use recording apps would clearly demonstrate how easy the platform is to use and can be revisited as often as required. As NPMS currently includes explicit habitat classification, it is important to understand how the training resources currently offered are being used by volunteers. NPMS volunteer coordinators have found that volunteers particularly enjoy videos of survey plot set-up and recording method, including how to classify habitat types and assess evidence of management practices, as well as more specific species identification tutorials, especially the grass identification series “Classes for Grasses”. These training videos are all embedded on the NPMS website for volunteers to re-watch as often as they like. Webinars have also been very popular across NPMS, and these sessions are recorded for volunteers to revisit. Hosting training videos and webinars via YouTube ensures these resources are easy to watch on all devices and also broadens the potential audience.

Interactive resources would help to hone volunteer classification skills and promote consistency across recorders. For example, online quizzes asking volunteers to classify a habitat, and provide any additional information on management or features of interest, using example photographs or videos would be a useful training process. The quiz interface could provide feedback on submitted answers and clearly explain how certain features could be used to classify the habitat type. Users could revisit these quizzes to build their habitat classification skills and feel more confident in their recording ability.

Another option would be to provide in-person training days, where volunteers could record mock plots to practice recording techniques and standardise habitat classification. In-person training events provide in-depth training and an opportunity for volunteers to ask questions, but NPMS volunteer coordinators have found that because these events are free, volunteers are likely to cancel their attendance, or not show up. Unfortunately, this means that field training events may be an expensive use of resource for little return.

8.2 Unstructured training options

Establishing a self-sustaining volunteer support network could facilitate continuous training opportunities as well as promoting the social aspect of biological recording. Habitat recording initiatives could offer mentors for newer volunteers to help to build confidence. NPMS coordinators have found that experienced volunteers are happy to offer support as a mentor but find that mentees rarely contact them for support or advice. To combat this reticence, NPMS coordinators are planning to provide more introductory details about each mentor via the website in a “Meet your Mentor” initiative. NPMS are also hoping to establish a “buddy” programme, whereby volunteers can share survey squares, or existing volunteers could act as a “buddy” to new participants, meeting them on site to demonstrate the survey method. This promotes the social element of participating in recording schemes and could facilitate more informal volunteer support networks. Connecting with local botany groups, such as Botanical Society of Britain and Ireland (BSBI) recorders, might also be an option to help to improve volunteer confidence in identifying indicator species or habitat classes.

Volunteer coordinators could offer more ad-hoc support through email. Support groups on Facebook and other social media platforms have been successful in existing schemes to promote social interactions and volunteer support networks. NPMS have also found social media platforms a useful tool to engage volunteers through quizzes and games. Other online forums could be used to promote community-based volunteer support, for example iSpot allows users to submit images to ask for help identifying species. This approach could be adopted with images of a particular habitat to gather volunteer input in classifying the type. This would promote consistency across recorders, and ultimately improve the quality of the data.

9 Further considerations

9.1 Spatial and temporal resolution

To maximise the benefit of in-situ data for EO applications, the field data need to be collected at a spatial resolution appropriate to the scale of EO data. The majority of recreational GPS devices are accurate to at least 10 m, and mobile phone GPS is typically accurate to 5 m. For Sentinel data, at 10 m spatial resolution, collecting field data using mobile phone or handheld GPS devices is suitable. However, when using very high-resolution (VHR) data, such as Planet or WorldView data, field data may need to be collected using professional GPS devices, some of which can be accurate at a centimetre level. When using VHR data, it may be advisable to conduct professional field surveys to ensure training and validation data are collected at an appropriate spatial resolution. Volunteer recorders can only be expected to use accessible GPS devices, most likely mobile phone GPS, which will meet the spatial resolution requirements for Sentinel and Landsat datasets, both of which are open-source and widely used. The accuracy of GPS devices is significantly impacted by geographic location, a user’s proximity to buildings or if the user cannot see clear sky overhead. Training and support could be offered to assist volunteers in taking an accurate GPS measurement.

It has been raised that for species recorders, 10 m spatial resolution may not be high enough to link habitat data to species trends. Producing regional or national habitat maps at 10 m resolution will facilitate broadscale species trend analysis, but more detailed information, such as the presence of habitat features important for a particular species, management information and estimates of habitat condition, could be more relevant for analysis of fine scale species population dynamics. As with EO applications using VHR data, the use of professional survey GPS devices may be required for specific species research at a land parcel scale.

Phenological changes throughout the year may introduce difficulties when assessing habitat types. For example, canopy cover will be difficult to assess in winter, while annual changes in water flows over seasonal wetlands may lead to misclassifications. The temporal aspect of habitat recording requires careful consideration in order to minimise confusion. Volunteer recorders could be advised to only collect habitat information in the summer months, which would align with most current UKTEPoP scheme recording, or to revisit a site twice a year, once in summer and once in winter, to validate their own habitat assessments. Field data verification could be targeted to validate habitat types that change seasonally.

9.2 Habitat classification schemes

Multiple habitat classification schemes are employed across the UK, with EO applications favouring national or international systems, and current volunteer recording schemes often using bespoke classifications. Classification schemes used in EO applications vary between UK countries: Natural England use UKBAP broad habitat classifications to generate Living England; NatureScot use EUNIS level 2; Natural Resources Wales use Phase 1 classifications; DAERA use broad classes derived from National Vegetation Classification (NVC) that are roughly equivalent to EUNIS level 3. For use in EO applications, citizen science habitat data would need to be collected at EUNIS level 2/3 or equivalent.

Volunteer recording schemes also use different classification systems (see Table 1) with many creating bespoke classifications. The wide range of classification systems applied across the UK make it difficult to select a universal scheme for future field data collection and could lead to confusion among recorders. It is possible to translate one classification scheme into another, for example Living England convert data from all classification schemes to match the UKBAP convention, and Living Wales converts LCCS data to Phase 1 classifications. JNCC produced a spreadsheet of correspondences to aid conversion between habitat classifications. To avoid confusion, and promote consistency across volunteer habitat assessments, a single classification system could be selected, and conversion tables to match other systems could be provided in order to standardise the process. Alternatively, habitat information could be collected without reference to a specific scheme, then related to a particular habitat classification system as required. For example, EarthTrack collects information on environmental descriptors that can later be combined to generate habitat classifications across multiple taxonomies. Further discussion around which classification scheme to use in volunteer habitat recording is required. Licence restrictions need to be considered, for example UKHab requires a licence, as well as applicability across environments, for example EUNIS may be more universally recognised, and would align with marine habitat classifications.

9.3 Data ownership and management

Data management of volunteer recorded habitat data would require further consideration. It is important that habitat data are discoverable, accessible, and interoperable to maximise the value added. Data ownership and management responsibilities will depend on the data collection pathway. Data ownership has implications for management of potentially large

volumes of data, as well as permissions and licence restrictions, and GDPR. It may be more efficient to manage volunteer recorded habitat information centrally, which may make it easier to share the dataset under an Open Government Licence or Creative Commons licence, ensuring these data are accessible. Data records may need to be anonymised to avoid GDPR complications, but volunteers may wish to include their name alongside submitted records, in which case they could opt-out of anonymisation.

Further consideration around data flows could help to ensure in-situ data are widely used. For example, submitted habitat information could be shared via a centrally managed online portal.

9.4 Data distribution

Obtaining a representative distribution of in-situ habitat points is crucial in generating accurate EO products. From an EO perspective, training and validation data need to be as widely distributed as possible and provide full coverage of the study area. Currently, CNCB habitat data collection is focused on protected sites, and data coverage needs to be expanded to include other areas. Volunteer recording schemes present an opportunity to extend data coverage significantly. Current recording scheme coverage reflects human density, with more data points collected in southern England and around “honeypot” tourist destinations, with sparse coverage in remote and upland areas. Some recording schemes, for example BBS, employ a stratified sampling technique across the UK, which presents an opportunity to collect valuable in-situ habitat data for EO. However, some schemes are restricted to particular habitats of importance to the taxa of interest. Mapping the existing recording scheme data distribution could help to ascertain whether the coverage needs to be expanded to meet EO requirements. Inaccessible, remote areas may present a risk to volunteers, and volunteer safety must be prioritised. The concept of developing local community biodiversity monitoring projects to effectively gather data required at a local scale links to ongoing work in England as part of Defra’s Natural Capital and Ecosystem Assessment programme.

A possible solution would be to direct volunteers towards areas of interest, similar to the NPMS weighting of survey squares to prioritise areas with larger coverage of rare habitats. This could follow the DECIDE approach to point volunteers towards areas of interest, low data coverage or areas displaying outliers in EO signals. This process could be automated to prioritise areas with low confidence levels generated by habitat classification algorithms. Once JNCC’s regional and national landscape monitoring system (see Appendix 1, JNCC landscape monitoring) is in place, areas that have deviated from a regional habitat mean value could be automatically flagged, and volunteers could be “nudged” towards these locations to provide validation data. This approach would be easier to implement if habitat information were recorded through an app and would require the development of additional infrastructure.

9.5 Monitoring success of citizen science habitat recording

In order to understand the impact of collecting habitat data through citizen science, it would be important to monitor changes in the accuracy and range of EO products made possible by the collection of additional field habitat data. Concerns have been raised about detecting misleading “change” in habitat condition or extent as habitat maps increase in accuracy as more data are added. Further validation of observed changes may be required to avoid misleading conclusions.

It will be equally important to monitor volunteer uptake of habitat recording, and any changes in UKTEPoP scheme participation to ensure the sustainability of habitat recording initiatives.

For example, surveys to capture volunteer perceptions towards habitat recording in general, as well as specific questions about any required further training or support, would provide an insight into the success of citizen science habitat recording and ensure this additional data collection does not have adverse effects on existing recording schemes.

10 Conclusions and recommendations

10.1 2021 UKTEPoP Habitat Recording Workshop summary

Discussions at the 2021 UKTEPoP Habitat Recording Workshop provided invaluable insight into potential approaches to engage volunteers in habitat recording and recommendations for next steps. Attendees emphasised the importance of establishing data requirements and clearly communicating the reasons for collecting habitat information to the recording community. Raising awareness of the value of habitat information will help to engage volunteers, for example by relating habitat data to taxonomic groups of interest, or by communicating the importance of habitat data for monitoring and protecting Natural Capital and Ecosystem Services. A tangible gain from collecting in-situ habitat data needs to be communicated to promote participation across the citizen science community.

Understanding volunteer motivations for or barriers to recording habitat data was raised as an essential next step, as only anecdotal evidence that suggests volunteers are not interested in recording habitat exists at present. Habitat recording potentially involves a separate audience than species recording schemes, and it was suggested that it may be interesting to gauge appetite across the general public. Many attendees highlighted the need to define the target audience to establish preferred data collection routes and feedback mechanisms.

It was reiterated by many attendees that additional data collection would need to be as simple as possible, for example using a dichotomous key approach to reach a habitat classification, and clear guidance and training would need to be provided to build volunteer confidence. This workshop served as an opportunity to gather initial reactions to possible data collection pathways. Attendees showed support for both adapting existing UKTEPoP schemes to collect additional information and for establishing a new habitat recording scheme. In general, attendees seemed to prefer an integrated approach, but recognised that it would be difficult to alter schemes, and therefore a separate recording initiative may be required. Attendees emphasised that the most effective collection route depends on the research question and the target audience, and that there would not be a “one-size-fits-all” approach. It was widely acknowledged that careful consideration was required to prevent competition with existing recording schemes, notably NPMS, and avoid duplicating requests to volunteers, land access requests, and recording apps.

10.2 Review conclusions

This review found that there is significant potential to collect further habitat information through citizen science recording networks. In-situ data are invaluable in providing training and validation information for EO applications, facilitating the production of accurate national habitat maps, as well as detailed analysis of habitat condition trends, assessing effectiveness of management strategies and interpreting species population trends. From an EO perspective, specialists are keen to use all in-situ data available and can translate between classification schemes to maximise the use of field data. The wide geographic coverage of citizen science recording schemes and the range of specialist skills the volunteering community possess present a real opportunity to expand the availability of in-situ data. Engaging the citizen science community could also raise awareness of the value of

habitats and associated ecosystem services to promote habitat protection and strengthen links between species and habitat conservation.

The recommended data collection pathway depends on the parameters collected and the target audience, but this review has uncovered support for both an integrated approach, by adapting existing schemes to include habitat parameters, and using a bespoke habitat recording app, which presents an opportunity to engage a wider portion of the recording community and could help to manage and share data efficiently. Designing and trialling data collection routes with UKTEPoP recording schemes as a next step will help to assess volunteer views to different approaches.

In order to encourage volunteer participation, it is important to raise awareness of the applications of in-situ data, clearly communicate the justification behind habitat recording, and demonstrate how submitted records are used. Producing personalised and interesting feedback, tailored to local areas or taxa of interest for existing recording schemes, will help to showcase the value added by submitted data records.

10.3 Next steps

This scoping review and the valuable input of Habitat Recording Workshop attendees have helped to shape the following recommended next steps:

1. Clearly define evidence requirements and develop meaningful case studies to aid volunteer engagement with habitat recording for EO.
2. Continue ongoing JNCC work to collate existing habitat data and assess the suitability of each dataset for EO applications.
3. Continue to engage with UKTEPoP and other initiatives already recording habitat information to learn from these schemes.
4. Volunteer perceptions towards habitat recording need to be captured to gain insight into motivations for, and better understand any reluctance to, collecting habitat data. Engaging with volunteers throughout the development of a habitat recording initiative will help to improve participation and ensure the necessary training and support mechanisms are in place to build volunteer confidence. Volunteer views could be gathered through a questionnaire distributed to UKTEPoP scheme participants.
5. Trial data collection pathways with volunteers to gather views on usability and suggested improvements.

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12 Appendix 1: Habitat data applications

12.1 Earth observation applications

As the capabilities of EO expands, the range of products generated diversifies. Outlined here are some of the main EO applications of in-situ habitat data.

12.1.1 Habitat extent maps

A major application of in-situ habitat information is training and validating machine learning approaches, such as convolutional neural networks, to create maps of habitat extent or feature extent, such as surface water, bare peat or felled woodland. Current efforts across the UK include Living Wales, a project generating national 10-25m land cover and change maps (Planque *et al.* 2020), Living England, employing the Living Maps Method (Kilcoyne *et al.* 2017), Landcover Scotland, generated by Space Intelligence for NatureScot, and the Northern Ireland Habitat Map. Benthic habitat maps can also be derived from satellite imagery using similar methodology, such as the high-resolution Caribbean Marine Maps produced by The Nature Conservancy. Habitat extent maps inform policy decisions across the UK, such as establishing Nature Recovery Networks, and contribute to local site management. Measures of habitat connectivity, productivity, and Natural Capital Asset Registers can be derived from habitat extent maps, and these products also feed into policy and land management decision-making.

12.1.2 Habitat change estimates

Continuous satellite image acquisition facilitates regular updates to habitat extent maps. Maps produced for multiple years can be used to assess changes in habitat extent over time. This approach has been adopted by Living Wales and the NatureScot Landcover Scotland maps. Continuous monitoring of habitat state to produce trends in habitat extent or condition is an important element of current EO work. JNCC is in the process of producing a regional landscape monitoring tool, flagging changes in habitat condition over time using Sentinel data. Field data can help to validate observed changes and provide interpretation around the drivers of change. For example, in-situ information on grazing intensity can explain changes in vegetation. Ongoing work in this area includes updates to the Crick Framework and Aberystwyth University's habitat-based taxonomy of change. Understanding changes in habitat extent and condition over time will help to inform management policies.

12.1.3 Condition assessments

Monitoring habitat condition is becoming more prevalent in current EO research as the range of sensors expands, spatial resolution and temporal frequency increases. Habitat condition measurements, including evidence of pest/pathogen damage, spread of invasive non-native species, nutrient enrichment, vegetation/soil moisture content, are made possible with EO developments. For example, monitoring peatland condition is an area of critical importance to progress towards UK net-zero goals as well as international convention targets (FAO, 2020). Over recent years, methods to map areas of degraded peat using satellite imagery have been developed (Trippier *et al.* 2020) and these methods require robust field data giving the location of bare peat to train machine learning models. Monitoring habitat condition in response to management efforts can help to assess the effectiveness of restoration or mitigation activities and track habitat recovery.

12.1.4 Monitoring management activities

EO analyses can contribute to planning management activities through opportunity mapping, to highlight areas suitable for restoration, habitat expansion, tree planting, and vulnerability mapping, flagging areas vulnerable to flooding that might benefit from defences for example. The impacts of management efforts can be monitored using EO, with robust training data from field surveys. For example, moorland burn regimes can be monitored using EO data (Blake *et al.* 2021) and agri-environment scheme success and compliance can be assessed using remote sensing data. Monitoring the impacts of management efforts using EO enables frequent assessments on a national scale, while observations feed into adaptive management plans.

12.1.5 Monitoring events

In-situ data are critical in interpreting EO timeseries data, as the timing of phenological events throughout the year have an impact on the spectral signal returned by EO sensors. For example, observations from Nature's Calendar can help to validate and explain observed changes in EO data. Similarly, field observations of discrete anthropogenic events, such as effluent plumes, pollution, or algal blooms can help to explain observed changes or outliers in EO signals.

12.1.6 Additional applications

Other, more complex field measurements include soil moisture, thermal data, soil type, geomorphological features and peat depth. These measurements often require specialist training and equipment, and can train EO models such as soil moisture models (Ali *et al.* 2015).

12.2 Case studies

The following case studies are examples of EO applications of in-situ habitat data that would benefit from the collection of further habitat information by volunteer recorders.

12.2.1 Living England

Aim

Natural England are using in-situ habitat data to train machine learning models to generate a satellite-derived national habitat map using methods developed by Kilcoyne *et al.* (2017).

Requirements

Field data points giving the habitat cover representative of at least 60% of the land parcel segment for input into the machine learning model. For this project NE has adapted UKBAP broad habitat classes to create a bespoke classification system, but the project team translate data from different classification systems, and at different levels of detail, into the required format to maximise data input. Ideally, a minimum of 50 points per habitat per biogeographic zone (there are 14 regions in England based on National Character Areas grouped to ensure each region is covered by a single Sentinel-2 orbit) are required to accurately train the model.

Current data collection

Natural England have commissioned project-specific surveys using ESRI Collector (now ArcGIS Field Maps) to standardise data collection. This recording app autofills fields for the

recorder and provides a live map of the Living England segmentation polygon, allowing recorders to drag-and-drop the location point to record a habitat classification. The ArcGIS Field Maps app is only available under licence, so is currently restricted to Natural England staff use (and contracted surveyors). The Living England team utilised field data from multiple sources, including citizen science schemes, to complete the initial phase of the project (Kilcoyne *et al.* 2017).

Future plans

The Living England team have made the national habitat map available under an Open Government Licence (OGL) through MAGIC and the Defra Data Sharing Platform (DSP). This allows users to download and interact with the habitat maps through an online interface. The Living England project team are investigating options to incorporate more citizen science data in future iterations of the habitat map, possibly through the purchase of a premium ESRI licence to share the ArcGIS Field Maps app outside Natural England.

Applicability of citizen science habitat data

Living England is heavily reliant on a continuous inflow of in-situ habitat data. To obtain the required data through citizen science, an established volunteer base would be required. The project team are keen to use in-situ habitat data from as many sources as possible to maximise data input and have a validation process in place to increase confidence in citizen science records. Existing tables translating habitat classification systems will help to incorporate field data from all sources.

12.2.2 Living Wales

Aim

The Living Wales initiative uses EO data, Airborne LiDAR, Open Street Map, and National Forest Inventory data among other sources to generate Environmental Descriptors that are combined to generate national land cover maps for Wales at 10 m spatial resolution (Planque *et al.* 2020). The project will assess changes in land cover, trends attributed to climate change, and identify pathways for conserving and restoring ecosystems.

Requirements

In-situ data are required to train the Earth Observation Data for Ecosystem Monitoring (EODESM) classification of land cover according to the Food and Agricultural Organisations Land Cover Classification System (FAO LCCS) (Lucas *et al.* 2015; Lucas *et al.* 2018). Field data support the validation of maps and ensure that changes in land cover are based on evidence.

Current data collection

Citizen science data are collected using EarthTrack, a free app that enables volunteer recorders to submit habitat information using a form-based system called ODK Collect. Data points are available for download under a Creative Commons licence.

Future plans

Aberystwyth University are in the process of rejuvenating the EarthTrack app, with Natural Apptitude developing the new interface. The Living Wales team are also establishing a Data Cube to facilitate efficient land use change detection and are currently researching reference and modified states of habitats within Wales to model transitions between states.

Applicability of citizen science habitat data

Living Wales is at the forefront of citizen science habitat data collection for EO applications, as EarthTrack has facilitated the collection of in-situ habitat data by volunteer recorders. The development of a new EarthTrack app presents opportunities to gather further information, for example recording features such as burn scars and pollution blooms to enable EO-based habitat condition modelling.

12.2.3 JNCC landscape monitoring

Aim

JNCC are building a web interface to enable users to monitor changes in habitat condition over time using the Sentinel data archive. This system will provide a national service for users to monitor landscape changes, assess the effectiveness of management actions and make informed decisions about future management of natural capital assets.

Requirements

This project is currently scoping the application of in-situ habitat data in validating observed changes in habitat condition and helping users to interpret changes. Field data from multiple sources can be processed to present point data alongside EO data.

Current data collection

Sentinel-1 and Sentinel-2 Analysis Ready Data (ARD) are processed to generate statistics for Living England land parcels for a range of EO indices. Land parcels are flagged as "changed" if they deviate from a geographically weighted mean index value for polygons of the same habitat type. For the prototype iteration of this system, NPMS data will be presented alongside EO data to allow users to validate and interpret observed changes.

Future plans

JNCC hope to incorporate field data from as many sources as possible, as this will maximise the opportunity to validate observed changes in habitat condition.

Applicability of citizen science habitat data

Citizen science habitat data will be invaluable in validating conclusions, interpreting change in habitat condition, and flagging misclassifications in habitat maps. Data from multiple sources will be visualised in the web app and will help to expand the capabilities of the system by providing information on possible drivers of change.

12.3 Other applications

Outside EO, in-situ habitat data contributes to a wide range of applications. Habitat information collected by volunteer recording schemes contributes to generating habitat-specific species trend indicators (Defra 2020). Regularly collecting detailed habitat information through recording schemes could help to ensure these indicators are accurate. Depending on the parameters collected, habitat information could also improve analysis of species data, which could interest and engage volunteer recorders. Gathering information on habitat features, such as presence of deadwood, habitat condition, disease presence, and vegetation metrics, such as sward height or composition, could help to explain species associations with habitats and enhance interpretation of population changes. Ultimately, collecting further habitat information across the UK can improve and expand our

understanding of species/habitat associations, species requirements, habitat-specific trends and the impact of management activities on certain species. Strengthening the link between habitat data and citizen science scheme species records can facilitate progress towards UK-wide and international biodiversity targets.

13 Appendix 2: Possible habitat data collection routes

There are several possible data collection pathways for recording habitat information through citizen science. Each option is integrated with current recording schemes to varying degrees. The options outlined here are presented in descending order in terms of how integrated the habitat data collection would be with existing recording schemes. These different approaches were discussed at the 2021 UKTEPoP Habitat Recording Workshop and participant views are summarised below.

“Is this still the case” approach

All volunteers will conduct data collection as part of scheme as normal. While in the field, recording apps will show pop-up window, saying “this site is classified as X, is this still the case?” and volunteers will be able to confirm/correct habitat classification at that location. This approach may be preferred by volunteers, especially if they are reluctant to identify the main habitat at a location, as it would limit the number of potential categories. Once a volunteer has confirmed or corrected a habitat class, there may then be potential to ask volunteers additional, but optional, questions related to that specific habitat, such as evidence of management, or an estimate of condition. However, incorporating additional questions would be dependent on volunteer feedback to the initial validation step. Recording apps could facilitate several requests for habitat confirmation/correction, including potential alerts while volunteers are travelling to/from/within their survey site, provided the app location permissions were accepted. The app would need to detect proximity to existing predicted habitat points, for example the centroid of habitat polygons, and provide pop-up requests for validation.

Without providing the context behind these confirmation requests the pop-up messages could become irritating to volunteers, and this may result in volunteers submitting erroneous results in an attempt to dismiss messages as quickly as possible. App users could limit the number of pop-ups per day to avoid frustrating interruptions that would detract from the enjoyment of field recording. Guidance of habitat features to confirm classification would need to be provided, for example a dichotomous key for habitat classes. For schemes without recording apps, this option would be more difficult to implement, but one possibility is adding a field to the survey form for recorders to enter the predicted habitat at a location and confirm/correct the estimate. An online tool could be employed to provide the predicted habitat class in the survey area (either a point within the survey square or start/middle/end of a transect) prior to a volunteer’s visit. The development of an automated tool showing predicted habitat classes at survey locations incurs an overhead cost and accessing this tool would be an additional request for volunteers.

Integration with schemes using apps:

The recording app would provide pop-up requests for habitat confirmation/correction while volunteers were travelling to/from/within survey location based on predicted habitat point data. Volunteers would confirm/correct habitat classes within the app, using provided guidance.

Integration with schemes without apps:

Survey forms would be updated to include an additional field. Volunteers would be directed to an automated online tool prior to survey, where they can find the predicted habitat class at their survey location. Volunteers would enter the predicted habitat type on the survey form and confirm or correct this while in the field.

UKTEPoP Habitat Recording Workshop findings:

Workshop attendees felt this option would be easiest for volunteers, as a quick assessment could be made with little additional effort but would be more applicable for habitat type than habitat condition, as habitat condition would change more frequently. It was also recognised that this option would mean habitat class was only recorded when necessary, rather than every time recorders were in the field. Attendees noted that this approach could help to improve recorder confidence in assessing habitat type, as they could calibrate their understanding with previous assessments. However, this approach is heavily dependent on the quality of the first habitat classification. The main concern was around confirmation bias, and the fact that recorders would be influenced by the suggested habitat class instead of making an objective assessment. Some suggested including an "I don't know" option for volunteers unsure of the habitat type.

There were concerns around how this approach would work in areas of poor GPS accuracy, and many thought that this approach would provide only limited information. Some also felt that pop-up messages might be off-putting or annoying for volunteers, and it was suggested that recorders should be able to control the frequency of requests for habitat confirmation.

Volunteers submit additional photographs

Each scheme would adapt data submission processes to include an option for recorders to upload photographs of the habitat at a location. Photographs protocols would need to be standardised, with detailed instructions provided to ensure photographs included all required information and the influence of factors such as light conditions, photograph angle, distance from ground was minimised. Photographs would be collated into a database and analysed centrally to classify habitat type at that location. How these photographs were analysed would dictate the requirements. There are potential machine learning or Artificial Intelligence (AI) opportunities, but these methods are still experimental, and as a result photographs may be more suited for verifying habitat assessments made by volunteer recorders.

Integration with schemes using apps:

The app infrastructure would need to be adapted to include a photograph upload function and in-app guidance of how to take photographs that meet requirements. Recorders would take a GPS record and submit photographs at that location as instructed using their smartphone camera. Photographs would be collated into a central database for analysis.

Integration with schemes without apps:

Online survey forms would be extended to include a photograph upload function and recorders would be asked to submit photographs alongside a GPS location.

UKTEPoP Habitat Recording Workshop findings:

This collection route was viewed as an "easy win", particularly when using an app. Many participants felt this method was straight-forward, enabling less-experienced recorders to submit data, and would require little additional effort from volunteers. Many suggested that the habitat classification process could facilitate wider volunteer engagement, as some volunteers may be interested in identifying habitat type from photographs even if they are unable to participate in field surveys. A major benefit to this approach is that the photographs may have other applications, for example photographs in peatland habitats could be used to estimate the amount of bare peat in condition assessments. Photograph datasets could be shared across organisations for various applications. Plantlife Waxcap Watch was cited as a

successful example of this approach, as this survey asks users to upload a photograph through the Survey123 app.

Many attendees emphasised the need for clear guidance provision to standardise photographs, for example what to include in the field of view, at what distance or angle to take the photograph, and required lighting conditions. There were concerns around photograph quality limiting application, and associated staff resource for verification. Where schemes do not use an app, or do not already have an upload facility in place, this collection route would be unsuitable. Possible difficulties around data storage, ownership, licensing and access were recognised throughout discussions.

Each scheme adapted to standardise habitat classification

Each scheme would alter existing habitat collection processes to match a reference scheme method to standardise habitat classification schemes. Habitat would be recorded using the standardised scheme each time a volunteer visited a survey site to capture any changes in habitat. Employing this unified approach may help to build volunteer confidence, achieve consistency in habitat classification and would mean recording schemes could share training and feedback resources. However, switching to a new classification system may be frustrating for volunteers, and it would take time for them to familiarise themselves with the categories. Existing data analyses would need to be adapted to match the new habitat classifications, and the abrupt change in recording would restrict analysis of trends over time. Research would be required to identify which current habitat classification scheme would be most applicable to EO applications.

Integration with schemes using apps:

Volunteer recorders would submit habitat class estimates every time they visit a survey location using the standardised habitat classification scheme. This may require an additional field in the app, depending on how frequently habitat data are collected at present. For transect surveys, volunteers would submit habitat estimates at intervals along the transect, in line with the intervals used to collect current scheme data.

Integration with schemes without apps:

Survey forms would include a habitat classification field, and volunteer recorders would submit an estimate of habitat type each time they visit a survey location. For transect surveys, volunteers would submit habitat estimates at intervals along the transect, in line with the intervals used to collect current scheme data.

UKTEPoP Habitat Recording Workshop findings:

While workshop attendees recognised that this approach could improve the usability of in-situ habitat data for national projects, many raised concerns that this method would lose nuances useful for specific schemes as the standardised habitat classification may be too broad for specific research questions. Some suggested using a multi-grain approach to include a standardised broad habitat class but continue to collect more detailed information relevant for each recording scheme. Alternatively, the standardised classification could include sub-categories relevant to different taxa of interest. Standardising the classification system was acknowledged as very challenging and some suggested that generating an updated standardised mapping between classification systems might be more useful. This approach may require additional capacity from schemes to provide volunteer training and engagement. Some felt this method may also be less interesting to volunteers. Many mentioned that the applicability of this approach would depend on the existing survey frequency, as habitat type may not be required at each site visit.

Each scheme data adapted to record habitat data more explicitly

A new field would be added to exist recording apps or survey forms to record a GPS location and habitat category according to standardised habitat classification scheme, which would be selected to benefit EO applications. Habitat would be recorded with each visit to the existing survey sites, and multiple points could be submitted at different locations within a survey square or transect. Guidance would be provided either through the app, or online/paper forms.

Integration with schemes using apps:

An additional field would collect a GPS location, automatically populated using the mobile phone GPS, and a classification of habitat according to selected scheme.

Integration with schemes without apps:

An additional field would be added to the survey forms. Volunteers would record a GPS location, either using a mobile phone or handheld GPS device, and classify the habitat type at that location.

UKTEPoP Habitat Recording Workshop findings:

Workshop participants seemed to be in favour of an integrated approach where volunteers would submit habitat data alongside existing scheme records. Many noted that GPS readings are already automatically captured through existing apps, and many felt this option would require little additional effort from volunteers. However, some questioned what the incentive would be for volunteers to complete an additional entry if it was optional and emphasised the importance of clearly communicating the purpose of recording these data. How to apply this approach to each scheme would need to be considered in more detail, as each varies with relation to existing habitat recording, survey frequency and methodology.

Each scheme would be pointed at additional app at end of recording, which would be autofilled with scheme app information

At the end of scheme data collection, volunteers would be taken to a habitat recording app, which would autofill fields based on previous records. Volunteers would fill out the rest of the form and submit an additional record through this app. Even in offline mode, apps are able to write data directly to a location on a mobile device, and this information can be used to communicate with the habitat recording app. Further research into the most effective approach of communicating between apps would be required. The amount of information a volunteer would need to complete would depend on the level of habitat information already gathered as part of the scheme. Habitat information could be recorded using a dichotomous key style form and guidance will be provided within the app. Additional information, such as finer habitat classes, counts or % cover estimates of indicator species, evidence of management, and condition estimates could be completed within the recording app.

Integration with schemes using apps:

Volunteers would be taken to a habitat recording app upon submission of scheme app records. The habitat recording app would be autofilled with metadata (including GPS location) and habitat classification submitted through the scheme recording app. If the selected habitat scheme was different from NPMS, the species recorded through the NPMS submission could be used to suggest habitat classes using indicator species lists. Volunteers would then complete the rest of the form and submit this habitat record through the app.

Integration with schemes without apps:

Upon completing a survey form, volunteers would be encouraged to submit additional habitat records through an app, but autofilling data entries would not be possible.

UKTEPoP Habitat Recording Workshop findings:

Attendees felt that by autofilling entries where possible additional effort for volunteers would be limited, while collecting a range of habitat information. Changes to habitat classification systems could be implemented more easily across all schemes if one app was used to record habitat information. However, some attendees suggested that this approach carried the risk of app fatigue, possibly introducing a barrier for volunteers to be involved in habitat recording. Other concerns included the possibility of losing volunteers during the transfer between scheme recording apps and a habitat recording app, and the fact that volunteers may not read or check the autofilled information. Attendees reiterated the importance of creating a seamless link between apps to retain volunteer interest, but some expressed preferences for a more integrated approach instead of using a separate app.

Each scheme would be directed to additional app upon submission

Each scheme recording app or online/paper form would direct you to a habitat recording app or webpage for volunteers to provide habitat information. This could be mandatory in order to submit record, or optional depending on volunteer appetite. Making this additional submission mandatory could discourage volunteers from participating in recording schemes. Equally, optional habitat recording may not be completed at all, which reinforces the need to communicate the benefits of collecting these data and provide engaging feedback to encourage volunteer participation.

Integration with schemes using apps:

Volunteers would submit records as normal through their scheme app. Upon submission of records, volunteers would be redirected to habitat recording app to complete a new form providing a GPS location, habitat class, metadata, and any other information, such as management type. As with existing recording apps, the habitat recording app would need to allow offline data collection, and submit records when volunteers return home.

Integration with schemes without apps:

Volunteers would submit scheme records through online/paper survey forms. Volunteers would be encouraged to submit additional data through a habitat recording app while in the field, including GPS location, habitat class, metadata as a minimum.

UKTEPoP Habitat Recording Workshop findings:

Many attendees thought using a separate recording app specifically for habitat information would provide opportunities to engage with new volunteers from a wider community. It was also suggested that using a separate app might have greater potential for clearly communicating the purpose and justification for collecting habitat information to volunteers. However, again attendees suggested that using multiple apps might be off-putting to volunteers, though some acknowledged that this was an assumption rather than referring to evidence that volunteers were reluctant to use several apps. It was suggested that the additional effort of submitting separate records may mean that volunteers ignore this extra step. It was noted that the successful implementation of another app would depend on how similar the app is to current data collection systems.

Establish new habitat recording system and market it through existing and new channels, but not integrate with current schemes

Existing scheme volunteer networks would be utilised to advertise a new habitat recording scheme. Establishing new survey protocols would ensure data collected are suitable for EO applications using a standardised classification scheme. This approach would make it easier to develop universal training resources and volunteer feedback and support mechanisms. However, creating an additional recording scheme could cause conflict with existing schemes, and it would take time to establish a widespread volunteer base to gather large volumes of data.

Integration with schemes using apps:

No change to existing schemes. Volunteers would be invited to also participate in habitat recording scheme.

Integration with schemes without apps:

No change to existing schemes. Volunteers would be invited to also participate in habitat recording scheme.

UKTEPoP Habitat Recording Workshop findings:

Workshop attendees acknowledged that this approach would be an opportunity to engage different specialist volunteers and connect existing volunteers that are interested in recording habitat information, while maintaining the focus on habitats rather than species data. However, many questioned whether there was an appetite for a bespoke habitat scheme and emphasised the importance of understanding potential uptake before establishing a new scheme, potentially using EarthTrack uptake as an indication of public interest in habitat recording. A major concern around this approach was introducing competition for volunteer time, and possibly undermining NPMS, which of course must be avoided. It was also raised that this approach would not be making the most of existing recording efforts, and it was suggested that efforts to raise awareness of the importance of habitat data should be explored instead.

14 Appendix 3: UKTEPoP 2021 Habitat Recording Workshop

Details of the 2021 UKTEPoP Habitat Recording Workshop are summarised here. The presentations delivered in the workshop were recorded and are available via YouTube.

Representatives from the following organisations attended the workshop:

- Aberystwyth University
- Amphibian and Reptile Conservation Trust (ARC Trust)
- Bat Conservation Trust
- British Trust for Ornithology (BTO)
- Buglife
- Bumblebee Conservation Trust
- Chilterns Conservation Board
- Department of Agriculture, Environment and Rural Affairs (DAERA)
- Department for Environment, Food & Rural Affairs (Defra)
- Forestry Commission
- JNCC
- National Biodiversity Network (NBN)
- Natural Apptitude
- Natural England
- Natural Resources Wales (NRW)
- NatureScot
- People's Trust for Endangered Species (PTES)
- Plantlife
- UK Centre for Ecology and Hydrology (UKCEH)
- Royal Society for the Protection of Birds (RSPB)

The workshop was attended by 61 people across these organisations. Attendees were divided into breakout groups for the discussion sessions, ensuring representatives from a mix of organisations were present in each group. The discussion sessions were focused on:

The preferred data collection pathway for additional habitat recording

Seven potential data collection pathways were presented and the advantages/disadvantages of each were discussed. Attendees were also encouraged to raise other suggestions for data collection routes and to add general comments. The pathways and discussion comments are outlined in Appendix 2.

Volunteer feedback mechanisms

Attendees were asked to suggest feedback mechanisms that have worked well in current schemes and discuss the types of feedback the volunteers may find interesting when recording habitat information. Six proposed feedback approaches were presented and attendees gave their views on each method:

- Gamification (leaderboards, collecting points per data point submitted)
- Individual achievement reports (ground covered this month, points submitted this year)
- Access to raw habitat data points
- Access to habitat products and/or EO data
- Specific articles relating to species of interest/local area of interest
- Annual reports of progress of EO habitat products