The opportunities for semi-structured and effort recording to enhance the value of biological recording by volunteers

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Summary

- Biological recording is essential for monitoring changes in the distribution and abundance of species supporting conservation and policy actions to benefit biodiversity. Volunteers are important contributors of these data, providing broad taxonomic and spatial coverage.
- Volunteers can participate through structured surveys (in which volunteers follow recording protocols at set sites, sometimes selected according to a formal survey design) and opportunistic recording (in which people submit records as and when they choose). However, structured surveys require substantial investment in recruitment and retention and have relatively limited uptake, whereas opportunistic data have greater coverage across sites and taxa but lack of information about the 'observation process' making the data challenging to analyse.
- Here we explore semi-structured and effort recording. These are ways of retaining much of the relative simplicity opportunistic recording, while including information about the observation process. This can be achieved through volunteers following a simple observation protocol (semi-structured recording) or recording information about the process of observation (effort recording).
- Semi-structured and effort recording can operate over several domains: spatio-temporal (either recording or fixing duration and/or distance), methodological (information about the sampling methods) and taxonomic (e.g. complete list or absence recording). Each of these has different benefits for volunteers and for improved analysis. The benefits will vary across taxa.

Technology has great potential in supporting semi-structured and effort recording through automating recording of effort or prompting users to record effort.

- It is vital to consider the feasibility of different semi-structured and effort recording approaches for volunteers: assessing whether effort be recorded accurately and with confidence. New statistical approaches can allow semi-structured and effort data to be analysed along with existing data, so adding further to their value.
- There are simple ways in which semi-structured and effort recording can be applied now, so we recommend that researchers and recording schemes and societies consider how to apply these approaches and begin to co-develop options for testing with volunteers. Existing focus on structured and opportunistic recording should continue, but semi-structured and effort recording provides an additional opportunity to add greater value to biological recording.

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1. Introduction

Biological recording is essential for monitoring changes in the distribution and abundance of species. To effectively use any collected information for monitoring purposes, there are five core principles of biological recording schemes: 1) representative sampling locations, 2) an adequate sample size, 3) sufficient detection of the target species, 4) recording a representative sample of species present (or all species), and 5) a long-term sampling strategy that enables valid inference of change (Buckland & Johnston 2017).

Citizen science is increasingly seen by researchers and policy-makers as a cost-effective method of gathering biological records, and can make substantial contributions to biological recording through the voluntary collection of species occurrence data for recording schemes. Voluntary engagement in environmental monitoring encompasses a spectrum from 'mass participation' to 'scientific sampling' (Pocock *et al*. 2017). Alternatively, this can be described as the variation between 'opportunistic' or 'unstructured' recording towards more 'structured' recording. Structured and unstructured recording each have advantages, but they also have disadvantages. In particular, structured recording typically requires high levels of commitment from volunteers and is therefore limited in how many locations and taxa can be included, whereas data from unstructured recording cover a much wider range of taxa and locations but can be challenging to analyse.

Here we explore the use of recording approaches that lie between these two extremes; we collectively term this range of approaches semi-structured and effort recording (see Glossary). We ask how these approaches are beneficial for biological recording, if they are feasible for volunteers and how they could be implemented by recording schemes or organisations in the UK.

Firstly, we explore the benefits of semi-structured and effort recording compared to structured and unstructured recording. Secondly, we explore the wide variety of ways in which semi-structured and effort recording can be used within recording schemes and other activities. Thirdly, we consider the role of technology in supporting semi-structured and effort recording. Fourthly, we consider the analytical benefits of using semi-structured and effort recording, and especially how it can be combined with unstructured datasets. Finally, we conclude with recommendations for organisations and recording schemes to explore.

Glossary

Effort recording: Volunteers record how, when and where they choose (as in unstructured recording), but they also record one or more measures of the observation process ('effort'), such as duration or area of search, or details of the recording method, which can be used to standardise across different recording visits.

Semi-structured recording: Volunteers record when and where they choose, but they follow a protocol (which can be more or less prescriptive) provided by scheme organisers. This term has been used more widely by others to include any recording that lies between unstructured and fully structured (Kelling *et al*. 2019).

Structured recording: Also called fully structured recording. Volunteers record following a protocol (which can be more or less prescriptive) provided by scheme organisers detailing how, when and where to record. Survey design is also important: in some activities the sites are pre-defined according to a survey design (e.g. UK Breeding Bird Survey, National Plant Monitoring Scheme), in others the sites are chosen by volunteers, but revisited across years (Wetland Bird Survey, UK Butterfly Monitoring Scheme).

Unstructured recording: Also called opportunistic, casual or ad hoc recording. Volunteers record how, when and where they choose, submitting the basic attributes of a biological record (what, when, where and who).

2. Different approaches for biological recording

Biological recording by volunteers covers a wide range of activities, all of which contribute data that can be valuable to inform about the state and trends of different aspects of nature (Pocock *et al.* 2015). In all of these activities, information about the observation process (the how, when and where of recording) needs to be included, in order for analyses to take any potential biases into account (Dobson *et al.* 2020). Here we explore how recording activities can be designed or adapted to increase their value through semi-structured and effort recording (Figure 1).

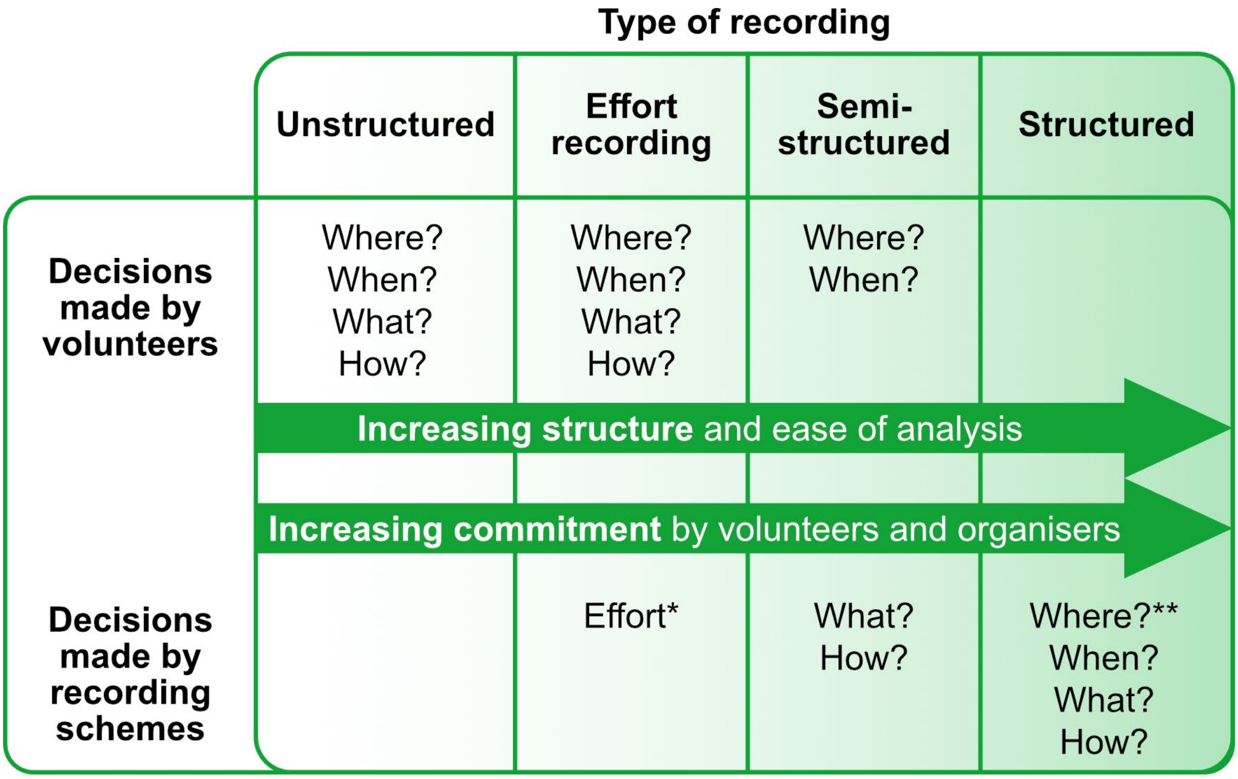


Figure 1. A simplified schematic of the continuum between unstructured and full structured recording, showing the position of effort and semi-structured recording with respect to the decisions made by the observer and the decisions made by a recording scheme organiser. The degree of effort and commitment required from the observer increases with increasing structure. For fully structured and semi-structured recording the ‘effort’ is dictated by the protocol, for effort recording it is submitted by the recorder, and for unstructured recording this information is not captured.

* In ‘effort recording’ the recording scheme organiser allows the recorder to enter details of the ‘effort’ as discussed in this report.

** Some structured recording projects follow a formal survey design where sites are pre-selected, whereas others require revisits to volunteer-selected sites.

Unstructured (opportunistic) recording

Unstructured, also called opportunistic or haphazard, recording is that in which volunteers make records when, where and how they choose (Figure 1). The record may involve just the species name, a location (at any scale), and the date of sighting, with or without other information, such as the number of individuals. Although each volunteer may have a plan or reason for when and where to collect records, this information is lost when the records are collated and so the dataset is 'unstructured'. Examples of unstructured records include casual observations, often of notable or distinctive species seen during a walk or other activity. Casual or opportunistic records can capture any type of species encountered, and this way of recording is accessible to the greatest range of participants because it has the least constraints of any type of recording.

- **Benefits of unstructured recording**
    - Simple data requirements.
    - Easy to participate, so potential to gather vast amounts of data covering many different species (including taxa for which no structured method is available) from many people.
    - Analytical approaches such as occupancy modelling (Altwegg & Nichols, 2019) or Frescalo (Hill, 2012) can be used to attempt to account for biases.
- **Challenges of unstructured recording**
    - No information on the 'observation process', so no distinction is made between a casual observation or a detailed search by a volunteer expert.
    - Often spatially and temporally uneven, with over-representation of certain types of site, e.g. nature reserves or near where people live.

The many recording schemes supported by the Biological Records Centre accept opportunistic records, and these observations can contribute the majority of information we have about the distribution, and changing distribution, of many taxa. Mobile technologies, such as the iRecord app, can facilitate the submission of these records. Opportunistic records can also supplement structured recording where the structured recording has poor detection of certain taxa. Examples of this are the unstructured 'roving records' collected by the British Trust for Ornithology's (BTO) bird atlas projects, alongside the highly structured timed transect surveys; roving records were an important source of information for nocturnal species, such as owls, that are unlikely to be encountered during daylight transect surveys, but could often be encountered opportunistically after dark.

Structured recording

In contrast to opportunistic records, structured recording involves following a set protocol at targeted locations, often revisiting the locations at fixed time periods (weekly to annually, depending on the project). Structured recording therefore controls most aspects of the observation process (Figure 1) and requires greater commitment and (for some taxa) identification skills than unstructured data collection. For analysts, an increase in structure brings a substantially greater ability to derive meaningful inferences from the data (Dobson *et al*. 2020). Some of the JNCC-supported schemes (e.g. Breeding Bird Survey and National Plant Monitoring Scheme) have a formal spatial survey design, whereas others focus on revisits to volunteer-selected sites (e.g. core sites in the UK Butterfly Monitoring Scheme, and Wetland Bird Survey). Where there is a spatial survey design it ensures that the visited sites are more representative of the region, or that this representativeness can be taken into account (Pescott *et al*. 2019).

- **Benefits of structured recording**
    - Designed to achieve specific purposes, that require collection of particular data attributes.
    - Site coverage is statistically more representative and less biased (where sites have been chosen according to a sampling design).
    - Records are comparable and easier to analyse because the observation process is controlled.
    - Increases the likelihood that abundance, in addition to presence, will be monitored over time and space.
- **Challenges of structured recording**
    - Requires a high commitment by the recorder to follow protocols and undertake recording in specific places at specific times in specific ways.
    - May require a lot of time to contribute, or require travel to specific sites.
    - Requires a high level of commitment by the organisers to design the monitoring in advance of roll out.
    - Requires a high level of commitment by the organisers to support and communicate with volunteers to maintain volunteer participation.

An example of structured recording is the UK Butterfly Monitoring Scheme, which uses a highly structured recording method of fixed transect counts with multiple repeated visits within and between years, conducted in specific seasons and weather conditions. A relatively high degree of skill is required to identify all of the butterflies that are encountered. As such, a greater amount of ability and, importantly, commitment is necessary for people to contribute to this recording scheme than to take part in opportunistic recording. However, the greater standardisation of structured recording allows more information to be derived from the records, such as abundance trends. Nevertheless, the trade-off of increasing the structural constraints is likely to be reduced participation compared to the number of volunteers undertaking unstructured recording. Organisers will also face substantial costs to establish the protocols, run the scheme and undertake all the communication with volunteers (estimated at £150-250k per year for some of the larger schemes in the UK; Roy *et al*. 2012).

Semi-structured and effort recording

Semi-structured and effort recording is a range of approaches that lie on the continuum between unstructured (opportunistic) and fully structured sampling (Figure 1). The aim of semi-structured and effort recording is to retain much of the relative simplicity and mass participation of opportunistic recording, but to increase the value of the record by including information about the observation process. Taking account of the observation process (‘effort’), in the analysis overcomes some of the challenges of analysing unstructured data, but does not have the burden and cost of undertaking fully structured recording. By knowing the type and degree of effort involved in collecting records, analysts can gain a more accurate picture of species occurrence or abundance, a better understanding of recorder behaviour, and the requirements needed to improve the consistency of recording.

Semi-structured and effort recording can allow more information to be included in various ways, for example:

- by following a **protocol** (e.g. observing a patch of flowers for 10 minutes during sunny weather) and so having consistent effort across records – this is what we term semi-structured recording;
- by **capturing information about the observation process** (e.g. the length of observation time, weather conditions, sampling method used) – this is what we term effort recording; or
- by including **additional information about the species** (number of individuals seen of each species, or confirming that a complete list of species has been submitted).

Semi-structured and effort recording benefits the volunteer recorder because the recorder still has a degree of freedom about what, when and where to record, but they are asked to follow a simple protocol or to document details of the observation process (e.g. by guiding choices through menus and checklists). Both of these approaches make potential biases easier to account for in analyses compared to opportunistic recording (Kelling *et al*. 2019). Studies of volunteers in biodiversity recording show that knowing their observations are of high value is a strong motivation (Domroese & Johnson 2016; Kragh 2016; West *et al*. 2021). This suggests there will be a willingness, at least for some recorders, to invest in semi-structured or effort recording, rather than purely opportunistic recording, if (1) it is made easy to do so, and (2) the benefits are clearly explained. Benefits can be explained, for example, by providing prompt feedback and sufficient information on how the data will be used (Kragh 2016).

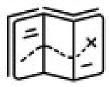
Enhancing the recording experience through semi-structured recording could also support greater retention and activity of recorders. Indeed making the ‘ask’ clear in this way could also support recruitment. The citizen science projects with highest participation in the UK are semi-structured recording in which people follow simple protocols, e.g. about 1 million people count birds for one hour in the RSPB Big Garden Birdwatch, and over 100,000 people submit 15 minute counts in Butterfly Conservation’s Big Butterfly Count.

Semi-structured and effort recording benefits the organisers and data users because the data have added value for analysis and interpretation; the observation becomes increasingly useful for the purpose of biodiversity monitoring. For example, by simply collecting and confirming a complete list of all species observed during a survey visit, rather than casual sightings, this enables more accurate and certain mapping of a species’ presence or absence. Complete lists could be all the bird species seen during a birdwatching trip, all the moths caught in a moth trap, all the plants found in a vegetation quadrat, or the species detected on camera traps or audio recorders during deployment. In addition, complete lists allow calculation of species richness for a site, and detection of phenological change, such as the arrival or departure of migratory birds or the timing of butterfly flight periods. Without confirming a complete list, an analyst cannot know if a species was not detected or simply not recorded on a particular visit, leading to many kinds of recording bias that make it more difficult to detect trends and changes (Isaac & Pocock 2015). Effort recording could also involve other simple pieces of information, such as the start and end time of the survey or recording period, the length of a transect or recording route, number of live-traps used, or the protocol used, such as the use of playback or other lures. Knowing how data were collected can be used to reduce or account for biases between datasets, to make records more comparable in analyses.

3. Review of approaches for semi-structured and effort recording

A wide range of approaches currently exist for semi-structured and effort recording, and these can be categorised into major domains in which effort can be recorded or constrained (Table 1). Not all actions or parameters will be appropriate or beneficial for all schemes, or all parts of an individual scheme, and much depends on the species groups involved.

Table 1. Summary of the domains over which semi-structured and effort recording can operate. These are explored further in Tables 2a & b. (Icons from the Noun Project, created by Álvaro Bueno, Ben Davis, Graphixs_Art, yejinland, Jan Wagner and inipagi studio.)

Domain		Examples
Spatial		Fixed area recording Measured distance
Spatio-temporal		Fixed time & area protocols Repeat observations (within/between years)
Temporal		Fixed time recording Measured time
Methodological		Recording sampling method
Methodological-taxonomic		Automated passive recording eDNA analysis
Taxonomic		Complete list recording Recording absence

Broadly, these approaches can be divided into:

- **Effort recording** in which the recorder has freedom to choose how to record, but they are invited to submit details of the observation process (e.g. the length of time recording, or the method used for sampling) along with the species records.
- **Semi-structured recording** in which the recorder is invited to undertake recording with a pre-defined level of effort by following instructions (e.g. counting birds for 1 hour, or recording insects visiting a 50 x 50 cm patch of flowers).

- Some types of recording, e.g. complete list recording, have aspects of both semi-structured and effort recording; the key point is that additional information on the observation process is submitted with the record.

Here, we consider the breadth of examples of different effort and semi-structured recording approaches, including their strengths, challenges and opportunities (Table 2a) and the analytical benefits of the different approaches (Table 2b).

Most recording is **active**, involving the volunteer travelling to a location or along a route and directly observing and noting the species, and sometimes it includes estimation of abundance. However, **passive** recording is increasingly enabled by advancing technology, innovation and affordability. Passive recording can allow the detection and counting of species at a location without the presence of a volunteer, and may involve audio, video or still images. Data may then be retrieved from storage media (e.g. memory cards) or sent to a device via communications networks (wifi, mobile networks), such as images or video from a monitoring camera that are automatically emailed to the volunteer or streamed online. Passive recording can lower the bar to participation; it may reduce people's engagement with nature because they do not see the organism, but it may also be very appealing because previously hidden biodiversity can be detected. Some recording activities may lie somewhere **in between active and passive**. This includes live-traps and lures, such as those used for small mammals, moth-trapping or pheromone lures and traps.

Table 2a. Examples and strengths and weaknesses of different approaches to semi-structured and effort recording. (Benefits are shown in Table 2b.)

Type of semi-structured or effort recording	Domain	Suitable groups	Example	Ease of engagement	Strengths	Challenges	Opportunities
1 Complete list recording	Taxonomic	Birds, Mammals, Flowering plants, Some of the taxa of large insects	BirdTrack[1] eBird[2] iRecord[3] forms for some groups	High	Simple concept. Compliments other sampling. List increases with effort. Suits commonly observed groups.	Suits groups with fewer & easily identifiable species; assumes recorders can identify all species and all can be identified in the field (or an unbiased sampling protocol is used). Unsuitable for groups sampled by multiple methods. Inappropriate for casual recording.	Can be applied to more groups than at present. Effort is inferred from list length. Rewards effort by organising / comparing records.
2 Recording absence	Taxonomic	Birds, Mammals, Flowering plants, Some insects	National Willow Tit Survey[4]	Medium	Simple concept. Easily reported. Suits single-species surveys, especially those with pre-selected sites.	Not handled well by most recording systems or schemes. Unsuited to casual recording. Cannot confirm an absence, so very difficult to interpret without information on effort (e.g. exact area surveyed, experience of recorder). Data likely to be unbalanced: there is likely to be lower motivation to record absences than presences.	Absence can be estimated from non-detection on complete lists where conditions met (e.g. sufficient expertise & search effort).
3 Recording abundance	Taxonomic	Most taxa that can be identified in the field	BirdTrack[1]	Medium	Simple concept. Complements presence recording.	More difficult for mobile or abundant taxa. Data are often ‘noisy’. Counts can be affected strongly by activity patterns, which can be dramatically affected by local conditions (e.g. weather).	Can infer changes in abundance, relative abundance or detection likelihood.

Table 2a continued. Examples and strengths and weaknesses of different approaches to semi-structured and effort recording. (Benefits are shown in Table 2b.)

Type of semi-structured or effort recording	Domain	Suitable groups	Example	Ease of engagement	Strengths	Challenges	Opportunities
4 Recording order of sightings, or time to first observations	Taxonomic	Birds, Mammals, Flowering plants, Some insects	Could be incorporated into any sequential recording.	Medium	Simple if using smartphone app and ticking species off a list as they are encountered.	Recorders unlikely to follow 'random encounter sampling'; affected by expertise & habitat (more accessible species, e.g. found in car parks, likely to be recorded first). But, once detectability is taken into account, species later on lists are likely to be scarcer.	Potential to appeal to recorders at bioblitzes with emphasis on up-to-date species listing, or those who are motivated by 'listing' or gamified approaches. Good statistical models already exist for such data. Simple to implement.
5 Automated passive recording (e.g. acoustic recording, camera traps, or eDNA)	Methodological, Taxonomic	Bats, Some Birds, Mammals & Insects	BTO Acoustic Pipeline[5]	Low	Algorithms or experts can identify species from audio /video / stills, with consistency	Specialist equipment. Good internet for audio. Automated identification still developing but important for big datasets. Automated identification may differ from human expertise.	Could be applied to more groups as technology develops. Affordibility, usability and comprehensiveness will increase.
6 Fixed recording: area and / or time and/ or method	Spatial, Temporal, Spatio-temporal, Methodological	Most taxa	RSPB Big Garden Birdwatch[6], PoMS FIT count[7], National Plant Monitoring Scheme[8]	Medium-High	Simple concept. Easily repeatable	Volunteer skill varies. Effort can be biased to good habitat / sites, important to choose appropriate duration. May need app or map skills.	Can be facilitated by apps, e.g. a countdown timer can be combined with a recording app.

Table 2a continued. Examples and strengths and weaknesses of different approaches to semi-structured and effort recording. (Benefits are shown in Table 2b.)

Type of semi-structured or effort recording	Domain	Suitable groups	Example	Ease of engagement	Strengths	Challenges	Opportunities
7 Recording search time / distance	Spatial, Temporal	Most taxa	Butterfly Timed Count[9], Mammal Mapper[10]	High	Simple concept. Easily repeatable	Volunteer skill varies. Requires pre-planning & app or map-reading skills if not recorded via GPS in smartphone app.	Can be facilitated by apps. Could indicate recording intensity, although many other aspects could influence search efficiency.
8 Repeat observation / fixed point revisits (area / site)	Temporal, Spatio-temporal	Most taxa	Natures Calendar[11]	High	Simple recording of e.g. phenology. Fixed location (garden / window) or route (local walk). Multiple taxa / seasons	Some parameters, e.g. phenology, are sensitive to missed visits. Biased to common or easy species to observe.	Can be extended to many taxa. Can be derived from complete lists. Repeat visits to 1 km squares are valuable for estimating detectability from opportunistic recording.
9 Repeat observation	Temporal	Nesting birds	BTO Nest Record Scheme[12]	High	Simple recording of observation series. Semi-automation via cameras, loggers	Disturbance risk. Biased to common or easily observed species.	Technology can increase data quality & coverage, e.g. cameras, loggers, PIT tag, drone.
10 Recording sampling methods	Methodological	Any sampling or survey of any taxa	iRecord[3], eBird[2]	Medium - High	Simple way of standardising recording technique, e.g. net sweeps, number of traps, etc.	Difficult to capture all possibilities in simple menus. Open responses unlikely to be useful. Unsuited to casual recording.	Can identify efficient, effective & popular methods. Can help design or refine better methods / surveys. A more accurate way of accounting for effort than simply search time or list length.

1. https://www.bto.org/our-science/projects/birdtrack
2. https://ebird.org/home
3. https://irecord.org.uk/
4. https://national-willow-tit-survey-rspb.hub.arcgis.com/
5. https://www.bto.org/our-science/projects/bto-acoustic-pipeline
6. https://www.rspb.org.uk/get-involved/activities/birdwatch/
7. https://www.npms.org.uk/
8. https://ukpoms.org.uk/fit-counts
9. https://ukbms.org/sites/default/files/downloads/UKBMS%20Ng1%20-%20Timed%20count%20guidance%20notes.pdf
10. https://www.mammal.org.uk/volunteering/mammal-mapper/
11. https://naturescalendar.woodlandtrust.org.uk/
12. https://www.bto.org/our-science/projects/nrs

Table 2b. Key potential benefits of different approaches to semi-structured and effort recording.

Type of semi-structured or effort recording	Potential benefits for a recording scheme & analysts
1 Complete list recording	Species presence/absence is known with confidence if a 'complete list' is submitted, supporting more rigorous use of 'occupancy analysis' and species distribution modelling. This also provides more comprehensive data (for common, as well as notable species) for understanding species composition/co-occurrence.
2 Recording absence	Absence data are valuable for species distribution modelling and occupancy analysis. Recording absence is best suited for designed surveys with protocols and targeted sites, e.g. single-species surveys and is incompatible with opportunistic recording strategies. The motivation to record absences differs from recording presences so requires clear justification and the record quality depends on recorder skill (which might require an additional attribute field or verification).
3 Recording abundance	When combined with recording 'effort' (fixed or measured time or space), abundance data can provide valuable information for assessing species trends.
4 Recording order of sightings, or time to first observations	Variation in detectability can be accounted for in analysis. Once this is done, the order in which species are recorded in a habitat can indicate their abundance, based on 'random encounter sampling'. Even if recording is not strictly a 'random encounter' search, the data may still be informative.
5 Automated passive recording (e.g. acoustic recording, camera traps, or eDNA)	Valuable for under-recorded taxa, habitats or periods (e.g. nocturnal). Digital observations can be retained permanently, for future (re)analysis. Provides comprehensive and consistent sampling over time, allowing for rigorous statistical analysis, but detection is limited by the technology used. This could be transformative in the amount of data that can be gathered, spatial extents, geographic and temporal resolution and, possibly, taxonomic coverage.
6 Fixed recording: area, time, or area & time	Fixed time surveys can aid participation because there is a specific request from participants. The analysis is relatively straightforward because this aspect of effort has been controlled through the semi-structured survey design, and there is no need to account for people observing over different periods or areas.
7 Search time/distance for recording	If the time spent recording (searching or observing) is known, then this can be used as a measure of 'effort' and taken into account in analyses. The more time spent, the fewer species are likely to be missed, but this depends on the field skills and identification abilities of the recorder and the focus on surveying on a particular day. It will vary a lot between taxa. The relationship of effort to species richness will saturate to a maximum. Greater distances increase the chance of recording in multiple habitats.

Table 2b continued. Key potential benefits of different approaches to semi-structured and effort recording.

Type of semi-structured or effort recording	Potential benefits for a recording scheme & analysts
8 Repeat observation (area/site)	Repeat observations can have high statistical value, especially if by the same observer (consistent recording). Participation can vary, however, as recorders may lack the desire or opportunity to revisit a location to collect a sequence of data records or observers may change or leave the area. Repeat visits to a site within a season are valuable to estimate detectability, required for occupancy modelling.
9 Repeat observation (individuals)	As with repeat observation of a site/area, a time series of data for individuals, such as a bird nest or leafing tree, can have high statistical value for survival analyses and phenology.
10 Recording sampling methods & implementation	Different sampling techniques will have different abilities to detect species, e.g. light traps vs. searching for leaf mines will result in different types of moth being recorded. Recording the sampling method can be used as a factor in the analysis, or to filter datasets, to allow better interpretation of non-detections.

4. How can technology support effort and semi-structured recording?

Apps to automatically record effort

Apps on mobile devices (typically smartphones with built-in geolocation via GPS) are increasingly well-used tools that can automate the capture of data on effort. Apps have the benefit of recording activity in real time, with data being entered as the person is progressing along their route. This allows for the app to influence recording behaviour by querying records as they are submitted, alerting the volunteer to time limits (e.g. for fixed time recording) or spatial boundaries (for fixed area or transect recording). The integration of apps with identification software will ensure their future expansion in recording.

Recording tools that prompt users to record effort

Apps and web-based recording forms can require or invite recorders to add effort data to their biological record. For example, apps for BirdTrack, eBird and Mammal Mapper all prompt for complete lists (optional or imposed) and the start and end time of a recording visit, as well as using a device's GPS location to automatically plot a location or route. Effort can also be submitted via open questions, but is more useful for analysis if answers are structured according to predefined categories. For example, moth records can be submitted via the iRecord moth species group form and the sampling method is selected from a drop-down list of options.

Tools for automated recording and standardising methodology

Automated passive recording has significant potential for structuring effort (Table 3), especially for less well-recorded taxa, or recording in under-represented locations or time periods, such as at night. It is becoming increasingly easy to use tools to capture high quality audio, video and images. There can be significant barriers to mass participation of some of these innovative technologies through cost, access or usability of the technology. However, low-cost devices such as the Raspberry Pi can act as dedicated audio, image and video recording systems capable of long-term monitoring effort (Jolles 2021), and trail cameras and acoustic recorders are increasingly widely used (e.g. MammalWeb and BBats projects, respectively) and their affordability, usability and comprehensiveness will increase over time (Wägele *et al*. 2022). Technology can also allow professional or automated analysis of samples, for example the BTO's Acoustic Pipeline allows analysis of sound files, or physical samples can be analysed for eDNA.

Table 3. Technological innovations that are currently, or have significant further potential, to assist effort recording.

Type of recording	Examples	Potential groups	Effort recording
Motion-activated cameras	Trail cameras, Mammal boxes, Feeder cameras	Mammals, birds, reptiles	Deployment period, number of cameras
Time-lapse cameras	Trail cameras	Mammals, birds, plant phenology	Deployment period, Fixed duration (e.g. an image once per day/hour)
Streamed video	Nestbox cameras	Birds, mammals	Deployment period
Passive acoustic recording	SongMeter, AudioMoth, Nocmigging	Birds, bats, small mammals, stridulating insects	Deployment period, Fixed duration sampling (e.g. 1 minute each 10 minutes)
eDNA	Habitat sampling	All taxa	Sample volume (e.g. water)

Effort recording with these fixed devices is often straightforward or collected automatically (e.g. time stamps, GPS coordinates, audio/video clip duration). eDNA can also simplify effort recording by standardising sample collection, and large scale surveying is already possible (Lawson Handley 2015). However, specialist support partnerships are still required for analysis of eDNA samples. It is important to establish data reporting systems that allow recording effort to be reported alongside the species records.

One of the major benefits to passive or automated recording is that it can remove decisions or bias by the volunteer on which species are recorded, as the identification and classification can be automated and standardised via image/audio analysis software or metabarcoding of eDNA samples. The biological records from these systems are therefore, by definition, a complete list of the species detected (of those it is possible to detect with the method used). However this is, of course, dependent on the quality of the tools and reference databases used. Methods and databases, e.g. acoustic analysis algorithms, image recognition tools, or molecular pipelines and DNA reference databases, are continually improving, so metadata are required for each dataset to ensure that these methods are repeatable and data are comparable over time.

Database standards

Technology supporting effort and semi-structured recording also offers an opportunity for improved data management (UKEOF 2020) including the use of data standards for recording effort, such as those in the ‘event’ class of DarwinCore (https://dwc.tdwg.org/) (Table 4). It is particularly valuable to use ‘controlled vocabularies’ for recording effort and data collection processes, e.g. via the implementation of tick boxes in online forms instead of free text boxes (Figure 2). This means that people use consistent terms to document their sampling effort. However, the possible methods listed should be sufficiently comprehensive and ideally co-created with recorders. When submitting records from semi-structured sampling (following a predefined protocol) the data for these DarwinCore properties can be pre-entered (and hidden from the recorder), or they can be included with the metadata for the overall dataset.

Table 4. DarwinCore standards relevant for recording effort as described in https://dwc.tdwg.org/terms/#event. DarwinCore is an accepted standard for biological recording that facilitates the sharing of information from biological recording

Property	**Definition**	**Example**
samplingProtocol	The names of, references to, or descriptions of the method or protocol used during an event	UV light trap | Audiomoth acoustic recorder | Sweep netting | Complete list of birds
sampleSizeValue	A numeric value for a measurement of the size (time duration, length, area, or volume) of a sample in a sampling event.	10 (e.g. with minute as sampleSizeUnit)
sampleSizeUnit	The unit of measurement of the size (time duration, length, area, or volume) of a sample in a sampling event.	Minute | Square metre
samplingEffort	The amount of effort expended during an event.	40 trap-nights | 10 observer-minutes | 30 sweeps of vegetation

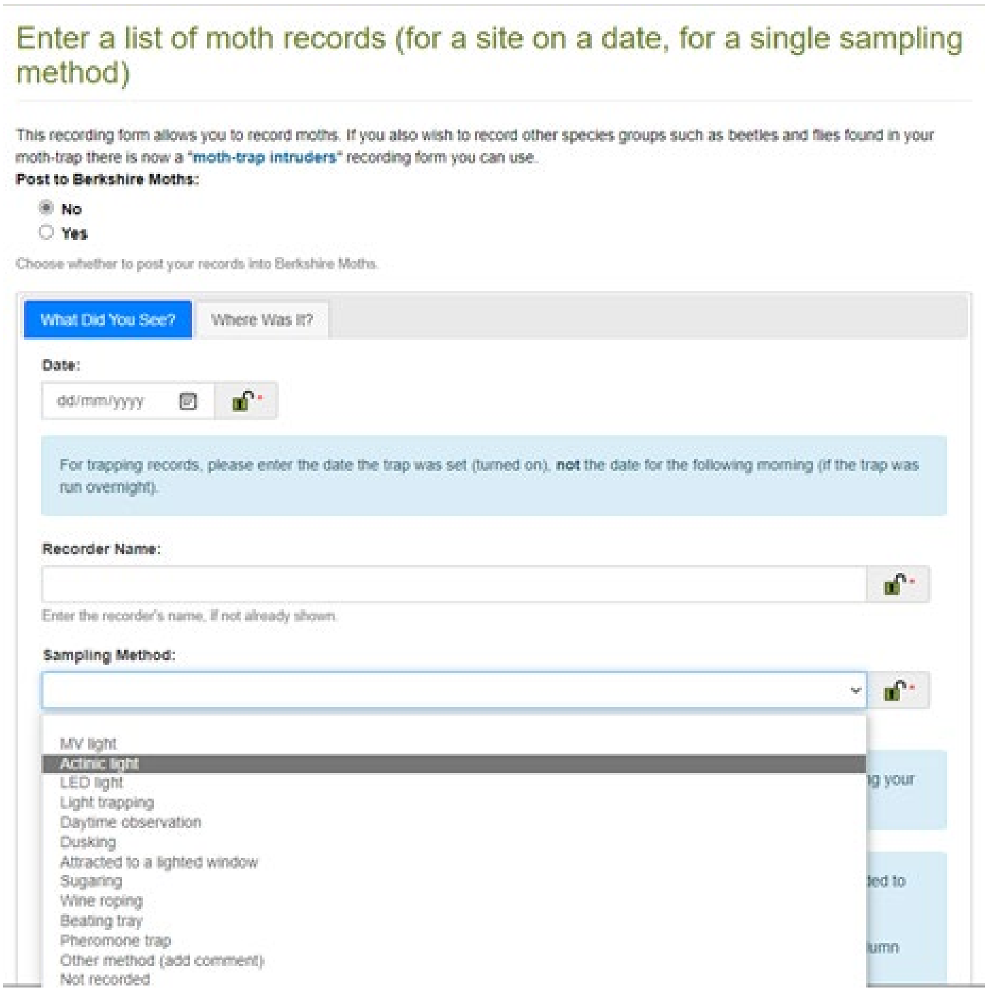


Figure 2. The iRecord submission page for moths, showing the use of a controlled vocabulary for Sampling Method. This means that the sampling method can easily be taken into account when undertaking analysis because (1) recorders are prompted to enter this information and (2) the sampling method is entered consistently.

5. Is effort recording feasible for volunteers?

If we are interested in encouraging one of the approaches for effort recording for a particular taxonomic group, it is essential to consider the feasibility of effort recording for volunteers. If quantifying or reporting the effort is too complicated, time-consuming or for unclear reasons, then volunteers will be less inclined to engage. However, where the reasons for effort recording are clearly outlined and understood, where quantifying effort is straightforward, and when the reporting process is simple, then feasibility and engagement are likely to be higher.

Here we adapt the framework for considering feasibility of habitat reporting by volunteers (Barnes *et al.* in prep.) and apply it to the question of effort recording (Table 5).

Table 5. Assessing the feasibility of effort recording by volunteers

Question to assess feasibility for volunteers	**Higher feasibility**		**Lower feasibility**
Does it align with **timing** of existing recording?	Occurs during existing site visits	↔	Requires additional time or expertise
Is the **purpose clear** and easily communicated?	Reason for recording effort is clear and easily understood	↔	Reason for effort recording is unclear or vague
How **complex** are the effort attributes?	Simple protocol of recording a single variable (e.g. time or space)	↔	Complex protocol or spatial mapping
Can the effort be **recorded accurately**?	Effort can be recorded accurately (manual or apps)	↔	Relies on greater expertise (e.g. mapping) or planning
Can the effort be **recorded quantitatively**?	List length, duration, fixed area (e.g. quadrats)	↔	Complex spatial mapping of routes or sites
Can effort be **recorded with confidence**?	Confidence likely greater for simple variables time vs space	↔	Complex protocol or mapping of routes or sites

6. Is there analytical value in combining data from effort and semi-structured recording into existing datasets?

Typically, biodiversity data are analysed by only including data of a certain quality (e.g. from a single scheme using fixed protocols) or by bringing all data to a lowest common denominator (e.g. data merging: making all data presence-only records by dropping additional information). Therefore, is it worth considering starting semi-structured or effort recording approaches, if the data cannot be used? The answer is 'yes', because (1) these data will be increasingly valuable as the dataset increases (e.g. much of the current spatial and seasonal analysis of eBird data uses only records from 'complete lists' from the past decade), and (2) because model-based integration allows the inclusion of different data types in a single analysis.

Model-based data integration is a new statistical approach that, excitingly, can allow the richness of different datasets to be combined in a single analysis (Isaac *et al*. 2020). It is a statistical framework combining the analysis of data from multiple sources while retaining details of the observation process (e.g. fixed protocol, or duration of observation) associated with each datapoint. Model-based data integration has a number of analytical advantages to data merging (i.e. reducing both datasets to their lowest common denominator), including deriving more precise metrics and better correction of data biases. Consequently, with model-based data integration, a dataset with effort recording can be combined with an unstructured dataset without data on effort, benefitting the overall analysis. Although model-based data integration is a new technique that requires further investment, it will be beneficial for recording schemes to consider further supporting effort recording and semi-structured sampling now.

Model-based data integration is summarised in a separate guide published by JNCC.

7. Case study: eBird and BirdTrack

Birds are perhaps the most popular taxonomic group for public record submission, both in the UK and globally. Birds are generally easy to encounter and the number of species in a location is not overwhelming for birdwatchers. Additionally, some familiar species are identifiable by most people, and the majority of species are readily identifiable with moderate expertise.

eBird and BirdTrack are platforms for recording bird observations, as either casual observations or complete lists and counts. Functionality also exists for recording spatial area and duration of observation. Launched in 2002 by the Cornell Lab of Ornithology and collaborators, eBird primarily focuses on the Americas. Meanwhile, BirdTrack was launched in 2004 as a collaboration between the BTO, RSPB, BirdWatch Ireland, the Scottish Ornithologists' Club and the Welsh Ornithological Society, and primarily collates records from Britain and Ireland. Key features of both platforms are outlined in Table 6.

Both eBird and BirdTrack have expanded to accept records from anywhere in the world, via their websites or mobile apps. In 2020, eBird accepted 169 million records from 800,000 users, while BirdTrack had 8 million records from 4,500 users. The eBird and BirdTrack platforms collect data based on checklists of species, which enhance usability and accuracy by excluding very unlikely species (although additions can be made to the checklists offered). A checkbox allows the volunteer to explicitly confirm whether a complete list is being entered, removing any ambiguity for future analysis. Counts of each species (precise, approximate or minimum counts) can also be entered, adding further granularity to the complete list.

Both eBird and BirdTrack offer a sightings repository and summary information services as incentives for recording. These can include organising information by site, region, year and species, and calculating the number of species seen. Species totals can also be viewed as optional 'league tables' between volunteers, which can be valued by some people for context or recognition amongst their peers, and can also incentivise further data collection in order to enhance their 'ranking'.

By collecting extra parameters from observations, rather than just casual records, many more analyses can be reported from the data. Complete lists allow eBird and BirdTrack (and other data portals across Europe) to monitor the annual, seasonal and regional arrival and departure of migrating birds in remarkable detail. Such information has enabled analysis of the timing and abundance of birds through their full migratory cycle across two continents (Kelling *et al*. 2019), and also provided estimates of long-term population trends for certain common and widespread birds (Boersch-Supan *et al*. 2019).

Additionally, insights can be gained into the detectability of particular species throughout the year, including those whose presence may be obvious and easily recorded when singing in spring but then become elusive and under-recorded during breeding or moulting. Recording start and end times of a visit also allows interpretation of the detectability of nocturnal species that may have been overlooked, such as when a visit ends well before dark when species activity would be very low. Analysis of observer behaviour also becomes possible when extra parameters of effort are collected, such as estimating skill levels from the length of complete lists, which can be used for calibration in analyses. The time or place of recording can also reflect individual preferences or ability, which may also influence data collection.

These tools provide a great example of effort recording: they offer a simple concept with a high degree of functionality and connectivity, and provide valuable user services to aid accurate recording and facilitate enjoyment, which leads to a large volume of high quality data (Kelling *et al*. 2019).

Table 6. Features of the eBird and BirdTrack recording platforms, primarily for birds.

Description	**eBird**	**BirdTrack**
Main focal region	Americas, especially USA	Britain & Ireland
Global recording	Yes. Partner organisations in many other countries	Yes
Complete list	Yes. Potential species checklist provided, filtered by location & season	Yes. Likely species checklist provided for all Britain & Ireland.
Incomplete lists & casual records	Yes	Yes
Count data	Yes	Yes
Other taxa	No	Mammals, dragonflies, butterflies, reptiles, amphibians, orchids.
Spatial	Distance, entered manually or tracked via app	Sites recorded as point, polygon (area) or path (distance), entered manually.
Temporal	Start/End time. Entered manually or calculated on app	Start/End time. Entered manually or calculated on app.
Primary purpose confirmation	Yes. Select activity type	Yes. Select activity type.
Usability features	Menu & checklist driven. Pre-set protocols & filters. Online & app synchronizing	Menu & checklist driven. Pre-set protocols & filters. Online & app synchronizing. Remembered lists for visited sites. Approximate counts allowed. Pre-set additional data prompts for habitat, breeding status, grid reference, age/sex, confidential.
Free text comments	Yes. Captures further detail	Yes. Captures further detail.
Identification support	Full integration with identification app via audio, photo, description	Promotion of identification app and online resources.
Multilingual	Yes, up to 34 languages for app	App is translatable.

8. Recommendations for developing semi-structured and effort recording

Lessons from successful recording schemes suggest that, for most taxonomic groups, the components highlighted in Table 7 are the most useful for enhanced effort recording by volunteers. These components have wide applicability and few barriers to participation, being easily implemented and communicated, and have high value for analysis and interpretation. As noted above, it is valuable to develop a suitable app and/or website for implementing this, which can guide and constrain volunteer choice and behaviour through set checklists, tickboxes and menus.

Table 7. Recording scheme components that facilitate effort recording

Components	Implementation	Key advantages
Complete list	Tickbox confirmation, Species checklist	Simple to instruct & undertake. Very high value for analysis.
Start/end time	Menu prompt, App recording	Simple to instruct & undertake (especially for focused recording by individuals). Complements complete & partial lists.
Area extent or route length	Web map, App GPS location, Fixed area e.g. quadrat	Facilitated by apps. Complements complete & partial lists. Simple to use fixed areas (e.g. quadrats).

For taxonomic groups where accurate species identification is complicated or difficult, e.g. due to a very large number of potential species or the expertise required, parallel surveys can be used that involve different prescribed levels of effort, and which direct volunteers via rigid and distinct protocols. An example is the Pollinator Monitoring Scheme (PoMS) that combines a simple structured survey for mass participation (FIT counts) and a much more detailed sampling survey (1 km square survey) that requires significantly greater effort and professional support but generates more precise and more structured data (https://ukpoms.org.uk/). For schemes covering multiple taxonomic groups, where species detectability and volunteer engagement and expertise will vary enormously across species, enabling casual records or partial lists is essential. This limited effort can also be captured using confirmation tickboxes or inferred from list length and location.

Supporting schemes to develop suitable apps, web platforms, survey design and share best practice (via workshops and resources) are pathways for improving the recording of effort and improving the analytical value of records. Similar tools and platforms are likely to apply to a range of recording schemes, and so cooperation and collaboration between organisations is highly beneficial. Aligning basic protocols and tools between recording schemes will avoid duplication and enable greater integration and analysis potential of the resulting data. This is demonstrated by the success of iRecord, which integrates information from numerous recording schemes for data sharing, validation and warehousing (https://www.brc.ac.uk/irecord/).

What can we do now?

Firstly, it is important to consult with recording schemes and societies about the opportunities for semi-structured and effort recording.

To take advantage of these opportunities, below is a summary of actions that researchers and recording schemes or organisations could consider:

- **Researchers should engage with recording schemes** about opportunities for semi-structured and effort recording.
    - Co-develop opportunities that provide long-term, consistent solutions.
    - Develop consensus across similar schemes about the best forms of semi-structured and effort recording to support.
- **Researchers should develop effective, consistent ways of storing metadata associated with semi-structured and effort recording.**
    - Work with schemes to ensure that these data are recorded consistent and in a way that allows metadata to be shared efficiently.
- **Develop simple protocols** (e.g. fixed methods and fixed durations) to support semi-structured recording for your taxa.
    - Consider rolling out new approaches for sampling, or popularising existing approaches with appropriate standardisation.
    - Test new protocols with potential users.
    - Use this to recruit new recorders, because the ‘ask’ of recorders is clear.
- **Consider how recording effort can be meaningfully described** for your taxa. For example, duration, spatial extent or sampling approach could each be appropriate. It is unlikely that any single measure will perfectly describe effort, but there may be one or more simple measures that would easily contribute additional effort information.
    - Ensure that popular ways of recording (e.g. iRecord forms) enable these effort-based attributes to be recorded.
    - Consider whether apps can be developed to enable effort to be recorded automatically.
- **Consider how sampling methods can be defined** for your taxa.
    - Develop a simple list of these distinct ways of recording, such as protocols or equipment
    - Ensure that popular ways of recording (e.g. iRecord forms) enable these distinct attributes to be recorded, e.g. via a drop down list.
- **Consider whether ‘complete list recording’ is appropriate** for all or some of your taxa.
    - Develop a ‘complete list’ checkbox for popular modes for recording.
- **Plan ahead when developing and updating recording tools.**
    - Ensure that these opportunities are acted upon during key periods of development, e.g. new or updated recording platforms, and especially smartphone apps that automate the collection of key parameters.
- **Communicate across similar schemes.**
    - Align approaches across similar schemes, to facilitate data sharing and pooling of resources.
    - Where necessary, consider detailed conversations with analysts about the value of different effort recording or semi-structured monitoring.

- **Communicate with recorders.**
    - Ensure that recorders receive good feedback on the value of their records and the impact that the recording scheme has made, especially when introducing changes to popular recording tools. If recorders feel valued and satisfied, they are more likely to be retained by the scheme to contribute further high quality data.

Recording schemes and societies support volunteers in providing incredibly valuable data for biological recording, and this will continue to be the case. However, adopting semi-structured and effort recording could be a way to allow data to be used in even more informative ways for biodiversity monitoring and analysis. It remains an active area of development that will require the engagement of recording scheme organisers, researchers and volunteers to develop fruitful and effective innovations. This guide provides directions on areas for further exploration.

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