Biodiversity methodology learning package

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Table of Contents

Overview

The restoration of biodiversity is complex, with different taxa responding to change in different ways, at different spatial scales, and on different time scales. Consequently, there is no definitive protocol to evidence the impact of environmental improvements on biodiversity over time. Many factors need to be taken into account and prior to implementing a monitoring regime it is important to determine:

- Appropriate taxa to focus on.
    - Which suite of taxa provide good indicators of the expected environmental change.
    - What taxa can be surveyed robustly with the resources available.
        - Including financial, labour and expertise.

A robust and repeatable methodology to survey each taxa.

- What it the most appropriate methodology.
- How many surveys are required per location to provide reliable data.
- What is the most appropriate timeframe for each survey.

- The most appropriate metrics for each taxa to monitor change.
    - What aspect of the taxa will most robustly reflect change.
        - This could be abundance, total species richness, species richness weighted by rarity or vulnerability, or assemblage structure.
- An appropriate monitoring scheme for the site in question.
    - If the site has different habitats or if different restoration actions are to be conducted how should surveying account for these.
    - How many monitoring locations are required across the site.
    - How should monitoring locations be determined (e.g. randomly, systematically).
    - What actions are required to reduce bias.

Designing a Site Level Monitoring Scheme

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A robust monitoring scheme is underpinned by selecting appropriate taxa and associated metrics to reflect the expected change alongside sampling methodologies that generate robust and repeatable data. This section will provide guidance on how to implement such a scheme following the selection of taxa, metrics and sampling methods.

Consideration of different habitats and restoration actions

The impact of any restoration activity on biodiversity will depend on the activity in question, the habitat to be restored and its starting condition. For example, when restoring a blanket bog, different actions will be required depending on whether you are rewetting a formerly drained bog or converting a coniferous plantation back to a blanket bog. The difficulty and risks associated with achieving the desired end point (a functioning bog ecosystem) will differ as well as the time required to achieve this end point.

Step 1: Identify and map the location, size, and type of habitats to be restored, alongside details on the restoration actions to be undertaken.

How to account for different habitats and/or restoration actions

As highlighted above the impact of restoration will be dependent on the initial habitat and its condition and the proposed restoration action. The number of monitoring locations should therefore reflect the relative size of different habitats and their restorative actions. For example, if 75% of the site is degraded peatland to be rewetted then approximately 75% of the monitoring points should be in patches of this habitat which are to be rewetted. This is known as **stratified sampling.**

Step 2: Identify the proportion of monitoring points required in each habitat under a specific restorative action such that it reflects the proportion of that habitat/ restoration of the site as a whole.

How many monitoring points are required

There is no fixed rule to calculate the appropriate number of monitoring points when it comes to determining long-term change. The most appropriate number will vary between sites and taxa. Taxa that show considerable annual variation for example in response to weather conditions (e.g. pollinators) are likely to require a greater number of monitoring points to detect change.

At the site level, the number of monitoring points depends on the size of the site, the complexities of restoration actions and habitats present alongside available resources (e.g. manpower, budget, potential to store samples/data files). Determine the number of monitoring points required. This will be site specific. We recommend consulting an expert in biodiversity/ecology at this stage to ensure that

Step 3: Determine the number of monitoring points required.

Selecting of monitoring points

Once the appropriate number of points has been determined, alongside how they are to be partitioned across habitats and restoration activities there is a need to determine how to spatially arrange these points within the site. Having a surveyor simply visit the site and select points can introduce bias, for example surveyors selecting sites that are most likely to respond positively to restoration, sites that are easily accessed, or sites adjacent to existing patches of semi-natural habitat.

To avoid bias associated with surveyor selection, we recommend that monitoring points are selected randomly to ensure selected locations are representative of habitat under a specific restorative action. As highlighted above, the number of monitoring points per habitat/restoration action should reflect the proportion of that habitat/ restorative action (see Table 1 for some examples). This is known as **random stratified sampling**.

Table 1: Examples of how to stratify monitoring points across different habitats/ restorative actions.

Proposed action and habitats	
Degraded peatbog of which 50% has to be reprofiled and rewetted, and 50% has just to be rewetted.	50 % of the monitoring points would be placed in the area to be reprofiled and rewetted and 50% would be placed in the area just to be rewetted.
if 50% of a site is coniferous woodland to be felled and restored to blanket bog, and 25% is a degraded blanket bog to be reprofiled and rewetted, and 25% is a degraded blanket bog just to be rewetted.	50 % of the monitoring points would be placed in the coniferous woodland to be felled, 25% would be placed in the area to be reprofiled and rewetted, and 25% would be placed in the area to be just rewetted.

This can be achieved using tools in GIS, or more manually by placing a numbered grid over the habitat map and assigning each number of the grid to a specific habitat and restorative action. A random number generator in a spreadsheet or calculator can then be used to select the required number of grid squares. It is important to ensure monitoring points are sufficiently spaced to provide independent samples (additional guidance on the minimum distance between monitoring points is provided in survey methodologies). We recommend selecting a slightly higher number of monitoring points to allow for the exclusion of points found to be unsuitable during the pre-survey visit.

It is advised to draw on additional resources (websites, textbooks) for further guidance on random stratified sampling. The statistical robustness of the monitoring scheme should be validated by an independent expert (e.g. ecologist, biodiversity expert, GIS expert, statistician).

Step 4: Create a site specific random stratified sampling plan by selecting random monitoring locations stratified by habitat type and restorative action.

Frequency of monitoring

Ecosystems take time to respond to restoration and both the Peatland Code and Woodland Carbon Code require long-term monitoring with a minimum commitment of 30 years. It is important to undertake baseline monitoring prior to any restorative actions to allow future monitoring to be benchmarked against its initial state.

Monitoring not only allows us to detect the change in species assemblages over time, but also to determine if the ecosystem is responding positively to the actions undertaken. More frequent monitoring can therefore provide an early warning system, allowing management to be adapted help ensure the desired outcomes are realised. Additionally, populations of many taxa fluctuate annually (e.g. bees, ground beetles) in response to weather conditions, and more frequent monitoring can help untangle annual variation from the true impacts of restoration.

Monitoring biodiversity can be costly, with the identification of many taxa requiring taxonomic expertise or DNA methods. The frequency of monitoring should therefore be a balance between ensuring data is robustly collected at sufficient intervals to allow changes to be tracked and the viability of implementation on the ground. Monitoring should be conducted prior to any restoration to obtain a robust site baseline. Follow-up monitoring should then be repeated in line with the requirements of the code (e.g. every five years for a period of 30 years).

The timing and frequency of monitoring in any year differs between taxa and more detailed information is provided under the Survey protocols for each taxon.

Step 5: Produce a long-term monitoring plan. Monitoring should be conducted before any action is undertaken and at intervals as outlined in the relevant code.

Reference site

For some taxa, it may be difficult to predict how the assemblage will respond to restoration. For example, ground beetle species richness will not necessarily increase as we move from a productive grassland field to a native woodland. However, we do expect to see changes in the assemblage structure. Thus, to monitor progress, we need to compare the similarity of assemblages at the project site with those reflecting the desired end point. In some instances, this information could be obtained from existing databases, however, when such information is not available, the monitoring scheme may require also surveying a reference site. This reference site should be of similar soil type, geographical location, climate to the project site. It could either be in a near natural state or a previously restored site with a similar starting state and restoration actions to the project site.

Step 6: Determine if a reference site is required and if so identify a suitable site and implement surveying.

Pre-survey visit

It is important to visit the area prior to commencing the survey to determine the suitability of the proposed monitoring points. These should be accessible without danger to surveyors and in areas with low risk of disturbance (e.g. by people or animals). As monitoring will be long-term (i.e. 30 years), it is important to consider any factors that could impact suitability in the future (e.g. potential building works, infrastructure changes).

Each survey methodology will come with its own additional constraints, and these are outlined in the relevant methodology (e.g. open relatively unshaded locations for pan traps, or sufficient soil depth to install pitfall traps). A tolerance of 100 m around the proposed monitoring point is permitted. Any monitoring point deemed to be unsuitable should be altered to alternative locations predetermined through random stratified sampling. These final monitoring points will remain static for the duration of the monitoring period and consequently it is important to ensure that they are accurately mapped and given a unique code.

Step 7: Assess suitability of monitoring points and finalise sampling locations. Ensure each location is accurately mapped and given a unique code.

Validation

It is important that the monitoring scheme is fit for purpose from the outset as once established changes will impact on the robustness of the data collected. It is important that your monitoring scheme aligns with requirements of the relevant code (Peatland Code, Woodland Carbon Code) and relevant standards (e.g. BSI Flex 702 v1.0:2024-10).

Your monitoring scheme (including location of monitoring points, timing and frequency of surveys, target taxa and survey methodology) is validated by an independent biodiversity expert/ecologist. The expert should review the statistical robustness of the sampling strategy, and the suitability of the monitoring programme for the site in question.

Step 8: Ensure that your scheme adheres to requirements indicated in relevant codes/standards. Have an independent expert to review your monitoring scheme to ensure that it is fit for purpose.

Actions to improve validation

Accurate spatial map: All survey locations should be accurately mapped and each monitoring point a unique code.

Plan of monitoring activities: This should include methodology for each taxon, frequency of monitoring each taxon, timing of baseline monitoring and long-term monitoring plan with monitoring at least once every five years.

Data storage and handling plan: There should be a robust plan on who is responsible for data storage, how data will be collected and stored. All data should be stored digitally and be backed up on a remote server. This includes raw data, such as audio recordings, as well as derived data, such as results of metabarcoding analysis of eDNA.

Consistency: Ensure the same monitoring points, methods and metrics throughout the duration of the project. If a change is required it is important that action is taken to ensure comparability (e.g. if changing acoustic devices, run both devices simultaneously to detect any differences).

Statement of individuals who will conduct the monitoring and their level of experience. This should be a working document and updated if/when staff change.

Independent validation of the sampling strategy: A statement from an independent biodiversity expert reviewing the statistical robustness of the sampling strategy, the suitability of the monitoring programme for the specific site.

Georeferenced photography – to enable validation pan traps should be photographed with georeferenced photography. Four-point georeferenced photography (north, south, east and west) should be taken to capture current surrounding vegetation. Each of the four vegetation quadrats should be photographed.

Resources

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Acoustic recording for bats

Methodology

Author: Dr Nick Littlewood (SRUC)

Bat activity is monitored through processing information about their calls. These are mostly calls used for echolocation though also include social calls, feeding buzzes and other vocalisations. The overwhelming majority of bat vocalisations are ultrasonic (i.e. at frequencies above those that can normally be heard by humans).

A range of devices are available for detecting and/or recording bat vocalisation. Some can replay calls in real time with frequency reduced to audible ranges. These, though, can only monitor a narrow frequency range at any one time. This note considers solely full-spectrum recorders. These can monitor all frequencies that bats may call at and save data are sound files. Some are designed for hand-held use for walking transects. Others, as considered here, are designed for static remote operation. These are referred to here as Automated Recording Units (ARUs).

Recordings from full-spectrum ARUs are typically analysed using software that matches the calls to a library of calls from know species. The pool of candidate species that such programmes will match to can be pre-defined to cover just those considered likely to be present and thus reduce the chance of spurious matches to exotic species. Specific identifications have an associated confidence score.

Analysis of full-spectrum recordings does not give information on numbers of individuals present but, instead, can show acoustic activity. Unlike in-person field surveys for bats, they are not impacted by surveyor skill. This method is most suited, therefore, to comparing acoustic activity between locations that are sampled with the same parameters or between different times at a location.

Most full-spectrum ARUs are expensive (typically £1000 or more) making coverage of large sites with multiple devices impractical. In recent years, low-cost devices have been developed. The most widely adopted in the AudioMoth. These became available from around 2018 and were developed by OpenAcoustics, a collaboration between Oxford and Southampton Universities (Hill et al, 2018). They were developed principally as research tools and launched with open-source hardware and software. They are configured via a free computer app that allows setting of recording time during any 24-hour period. Sampling rate can be set according to intended taxa of interest (with higher frequencies used for bats). Filters are available such that recordings are only saved if a certain amplitude of noise is detected frequency filters diminish the sound signal in defined frequency ranges.

Equipment

Full-spectrum Recording Units (ARUs): AudioMoths or other acoustic recorders, capable of remote deployment over extended periods.

Device housing: AudioMoths are supplied without a housing though a dedicated AudioMoth housing, with acoustic membrane positioned in front of the microphone, can be bought separately. This is resistant to rain and can protect against temporary submersion. Home-made housings may be considerably lower cost are frequently used though should be tested alongside

AudioMoth housing to check that sound is not attenuated if different solutions are used for acoustic transparency.

Batteries: AudioMoths use three AA batteries. Lithium batteries provide the longest recording duration. Alkaline batteries are lower in cost though provide shorter recording durations. Rechargeable batteries can be used, though necessitate more frequent visits to change these. The configuration app shows estimated power drain for the proposed settings (in mAh), enabling an estimate of running time on fresh batteries.

Storage cards: AudioMoths use micro-SD cards. Typically, cards with 64 GB or 128 GB capacity are used.

GPS-enabled mobile phone: To record coordinates of deployment location and obtain geo-referenced photographs of ARUs in-situ.

Process

Study design

A number of protocols have been proposed for carrying out passive acoustic monitoring of bats. These, though, may focus on adequate coverage to detect rare species (BCT, n.d.) or on large-scale deployment at widely spaced location to detect regional or national trends (Newson et al., 2021). The survey design described here borrows elements of these along with Collins et al. (2016) and are aimed at optimising ability to detect changes at a site over time.

The number and layout of AudioMoths or other ARUs will depend on resources and the size and shape of the study area. To minimise overlap in recordings (bats appearing on multiple recorders in fast succession) separation of at least 200 m is recommended. Maximum separation should be no greater than 1 km. Hence, the optimal design is a grid based on spacing between these two limits. In all studies, sampling should aim for roughly equal spacing while adequately covering the variation in habitat types and taking account of access constraints.

The timing of recordings involves trade offs of data storage capacity, battery life and frequency of visits to ARUs. There are three scales of timings of recording to consider; time of year, time of day and whether recordings are continuous or periodic samples within times of interest. Bats can be active at any time of year though activity is highest in the warmer months. Bat surveying can be carried out from April to October though with May to September may also be suitable. BCT (n.d.) recommends obtaining recordings of 300 seconds long with 5-second sleep duration over three nights while Collins et al, (2023) recommend recording from 30 minutes before sunset to 30 minutes after sunrise. A suggested approach would be to record for three nights on one occasion each month from May to September.

A sample rate of 384 kHz is recommended to optimise recording quality.

Installation

Sample location target coordinates should be generated as part of the study design process. In the field, these points should be located and ARUs placed in the closest suitable locations. A maximum permitted deviance from the identified point should be determined. Optimal locations for maximising sound quality are usually those in the open and with the device positioned 2 m above the ground. In woodlands, this may mean locating devices long rides or in clearings or at edges of woodland blocks. A pole or strong cane can be used if a natural fixing point is not available. On open sites with few visitors, this form of deployment may be achieved. However, this may attract unwanted human attention at some sites, so devices may be partially shielded by light vegetation, such as being partially hidden by a bush. There is a risk of sound attenuation (degradation of the sound signal) with concealed deployment, which is greater for ultrasonic frequencies than for lower frequency noises, and this is increased in cluttered environments. However, this trade off may be necessary for device security.

When positioning a unit in the field, a grid reference for the location should be noted and a photograph taken of the unit in situ, to aid relocating it. One may use an app, such as MerginMaps, to design a metadata form for collating geo-referenced positional data on a GPS-enabled phone.

Data processing

The most efficient way to process sound files for bird call analysis is by using an automated classifier. Several are available for British bat calls. These typically analyse 5-second segments of recordings and return the closest match species to sound featuring in that segment along with a confidence score for the identification. An online resource is the Acoustic Pipeline operated by the British Trust for Ornithology (BTO). Recordings are uploaded as wav files and results of analyses downloaded typically a few minutes later. There is an allowance for a limited quantity of data to be analysed free using Acoustic Pipeline if consent is given to use of those data in analyses by the BTO and partners. Charges are made per GB for data exceeding this limit. Higher charges are made if consent is not given for the data being used by BTO. Another popular classifier is Kaleidoscope. This is downloaded software that requires an annual license and which can be used for a wide range of acoustic analyses.

Metrics generated

Identifications are returned as a spreadsheet. With each identification is a certainty score, ranging from zero to one. To avoid returning lots of low probability identifications, a threshold is usually selected below which identifications are discarded. A frequently adopted confidence threshold in research is 0.7 though this selection is arbitrary.

A selection of calls around the chosen confidence threshold should be checked for validation by an expert. This can be done directly in Kaleidoscope or, if using BTO Acoustic Pipeline, recordings can then be located using free software, such as Audacity, which enables manually scrolling through recordings to the desired time point. Spectrograms of vocalisations can then be examined visually and compared with identification guides (e.g. Russ, 2012). Protocols and thresholds for checking calls should be decided on and applied uniformly across recordings at all time periods.

Data can be used to compare acoustic activity with reference sites, either as number of 5-second segments in which calls are detected for each species or more simply as the number of ARUs in the study on which a species was detected. Few UK sites will have potential for more than 10 bat species so a change in activity levels or in areas of a site used by a species is likely to be more instructive than overall species change across a whole site.

Actions to improve validation

Consistent location - note the exact spatial location of ARU deployment (at least eight-figure grid reference). It may help to physically mark monitoring points such as by attaching small metal tree tags. ARUs and SD cards should be numbered with marker pen and this information noted at time of deployment to avoid later mix-up and also to help identify which recordings may be affected if faults in ARUs are later discovered.

Georeferenced photography – to enable validation each audio device should be photographed with georeferenced photography, ideally viewed from the four cardinal directions. This may enable identification of changes to the immediate environment on future deployment occasions.

Consistent equipment – the availability of AudioMoths has revolutionised the ability to monitor multiple monitoring points in a cost-effective manner. New low-cost devises are becoming available that may provide similar or improved operation and it is likely that these will be more widely used in future years. It is desirable to use identical devices between recording periods. Note should also be made of firmware versions, especially if updates affect recording quality. If it is not possible to replicate devices across the whole sampling network, running old devices alongside a sample of the new devices will enable some degree of comparison of effectiveness.

Calibration – ARUs devices will degrade over time, especially when heavily used. Microphone calibration is desirable for devices on which this is possible. Simpler devices, such as AudioMoths, should be checked at least annually to ensure that they perform within acceptable limits.

Consistent timing – the timing of device deployment should remain constant between survey years. Configuration of devices should be consistent.

Consistent use of classification software – automated classifiers are recent developments. The performance of these is likely to continually improve. While analysis of recordings at the start of a project will enable establishment of a benchmark, sound files should be retained and re-analysed alongside recordings from later periods. using the optimal software available at that time.

Validation of identification by experts – A sample of species recordings should be checked by an expert.

Limitations

ARUs sample acoustic activity, not abundance. Acoustic activity as detected by the recorder can be influenced by volume of vocalisation, bat movements, distance from the uinit and how frequently the species calls. Some species, suich as Brown Long-eared Bat, have particularly quiet calls, Hence, these can under-represent on recordings. Some species, such as Noctule, can be detected at up to 100 m distance. Thus, comparisons cannot be made in relative abundances between species.

Automated identification software issues a confidence score. Identifications are not flagged as "certain". Confidences are usually lower for species with vocalisations that are more similar to other species. This is especially the case for species in the *Myotis* genus, which can be difficult to sepertae from one another.

However, recordings obtained from AudioMoths are lower quality than those from more expensive units, including having a lower signal to noise ratio (there is more background noise on recording files so bat calls are less distinct) and greater attenuation at high and low frequencies. However the low cost of AudioMoths make deployment of multiple units a more practical option and this enables comparisons of activity over wide areas.

Alternative methodologies

Bat surveys most often involve either monitoring roost sites or measuring activity away from roosts. Roose site monitoring may include directly visiting roosts, including inspections in artificial sites such as bat boxes, or it may involve counting bats emerging from roosts at sunset or returning to roosts sites at dawn. Activity monitoring will involve use of handheld bat detectors. This may include using Heterodyne detectors to monitor seelcted species in real time or using full-spectrum recorders hand held on a transect route, sometimes with a GPS unit attached so locations of recordings are georeferenced. Lower cost ultrasonic microphones are available that act in a similar way and are attach to mobile phones, where recordings are stored and processed.

Methods that involve human presence will entail some degree of person-to-person variation such as in speed walked, angle that hand-held units are held at, differences in direct counts, etc. and these are reduced by using ARUs. However, the biggest advantage of ARUs is ability to record simultaneously over long periods at multiple points. Together with geo-referenced documentation of deployment locations, this enables verification of data collected.

References

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Acoustic recording for birds

Author: Dr Nick Littlewood (SRUC)

Methodology

A growing range of digital programmable acoustic recorders, widely known as Autonomous Recording Units (ARU) is becoming available. They include devices that are housed in weather-resistant casing and that can be set to record at predetermined times and can be left unattended in the field. Data, in the form of sound files, are written to SD cards and, depending on settings, devices can be left in the field for several months at a time.

Recordings from ARUs are typically analysed using software that matches the calls to a library of calls from know species. The pool of candidate species that programme will match to can be pre-defined to cover just those considered likely to be present and thus reduce the chance of spurious matches to exotic species. Specific identifications have an associated confidence score.

ARUs do not give information on numbers of individuals present but, instead, can show acoustic activity. Detectability of species will vary with how loud they are, with the frequency of their vocalisations and with the distinctiveness of their songs and calls compared to other species. This method is most suited, therefore, to comparing acoustic activity between locations that are sampled with the same parameters or between different times at a location.

Equipment

Several ARUs that are optimised for long-term remote monitoring are available, including those in the SongMeter range Wildlife Acoustics) and Titley Chorus range. This protocol focuses primarily on **AudioMoths** as their low cost has driven their widespread adoption in acoustic monitoring surveys where multiple units are deployed simultaneously. However, it can be adopted for other ARUs.

AudioMoths are low-cost full-spectrum acoustic recorders that became available from around 2018 and were developed by OpenAcoustics, a collaboration between Oxford and Southampton Universities. They were developed principally as research tools and launched with open source hardware and software. They are configured via a free computer app that allows setting of recording time during any 24-hour period. Sampling rate can be set according to intended taxa of interest (with higher frequencies used for bats while lower frequencies, that have lower battery demand and use less storage card space, can be used for birds). Filters are available such that recordings are only saved if a certain amplitude of noise is detected frequency filters diminish the sound signal in defined frequency ranges.

AudioMoths are supplied without a housing though a dedicated AudioMoth housing, with acoustic membrane positioned in front of the microphone, can be bought separately. This is resistant to rain and can protect against temporary sumersion. Home-made housings may be considerably lower cost are frequently used though should be tested alongside AudioMoth housing to check that sound is not attenuated if different solutions are used for acoustic transparency.

AudioMoths use three AA batteries. Lithium batteries provide the longest recording duration. Alkaline batteries are lower in cost though provide shorter recording durations. Rechargeable batteries can be used though necessitate more frequent visits to change these. The configuration app will show power drain for the proposed settings (in mAh), enabling an estimate of running time on fresh batteries.

Recordings are stored on the device to a micro-SD card. Typically, cards with 64 GB or 128 GB capacity are used.

Process

Study design

The number and layout of AudioMoths or other ARUs will depend on resources and the size and shape of the study area. To ensure independence of recordings (i.e. to avoid recording the same bird at the same time on multiple recorders) separation of 250 m is regarded as adequate for small passerines that represent the most numerically abundant territorial songbirds. Hence a grid based on this degree of spacing may be the optimal design. For large areas where this would involve a larger quantity of ARUs than are available, sampling should aim for roughly equal spacing while adequately covering the variation in habitat types and taking account of access constraints.

Configuration

Different devices have different sample rate options, with 48 kHz being a widely adopted standard.

There is not a widely adopted standard strategy for determining when units should be recording and decisions usually involve trade offs of data storage capacity, battery life and frequency of visits to recorders. There are three scales of timings of recording to consider; time of year, time of day and whether recordings are continuous or periodic samples within times of interest.

For most recording programmes the priory time of year is likely to be the bird breeding season. This will vary with latitude but April and May will generally be key months and should capture activity of most vocally active species. However, some territories of some species may not be occupied until into June. Longer recording periods, even year-round, will increase resolution of the data.

Unless particular species are targeted, recording across the 24-hour period is optimal. Recording durations and periodicity (e.g. recording 1 in 5 minutes or first five minutes of every hour) should then be determined to maximise the quantity of recordings that can be obtained raking into account data storage capacity on the device, battery power and visit frequency.

Installation

Once the broad study design has been decided, decisions will need to be made in the field as to the precise location of deployment. Optimal locations for maximising sound quality are usually those in the open and with the device positioned on a thin pole, at around 1.5 to 2 m above the ground. However, such locations may attract unwanted human attention so devices may be partially shielded by light vegetation, such as being partially hidden by a bush. There is a risk of sound attenuation, though this is relatively a smaller concern at normal bird vocalisation frequencies than at ultrasonic frequencies. Attachment to wide tree trunks may reduce sound transfer from behind, so narrower branches are favoured where possible. Fence posts can provide suitable locations when positioned away from areas frequently accessed by people provided that devices are not at risk of damage by livestock.

When positioning a unit in the field, a grid reference for the location should be noted and a photograph taken of the unit in situ, to aid relocating it. One may use an app, such as MerginMaps, to design a metadata form for collating positional data.

Data processing

The most efficient way to process sound files for bird call analysis is by using an automated classifier. At the time of writing, the only widely available tool for classifying the full range of bird species in NW Europe is BirdNET Analyzer. This is free software that draws on sound libraries compiled by Cornell University. It analyses 3-second segments of recordings and returns the closest match species to sound featuring in that segment. Common anthropogenic noises also form part of the sound library against which recordings are compared.

BirdNET Analyzer can match calls to over 6,000 species worldwide. To reduce the risk of spurious matches to species that solely occur outwith the area of study, the candidate species list is usually constrained. This can be done by entering latitude and longitude ad time of year with the software then selecting candidate species based on occurrence data from the global citizen science bird recording platform, eBird. Alternatively, one can define a bespoke candidate species list. The selection is a trade off in that a wide list increases the chance of misidentification while a narrow list increases the chance of missing species whose presence was not anticipated.

Metrics generated

Identifications can be returned by BirdNET Analyzer in a range of formats, including as a spreadsheet. With each identification is a certainty score, ranging from zero to one. To avoid returning lots of low probability identifications, it is normal to set a threshold below which identifications are not reported. One option is to set a threshold of 0.5 for returning results and a higher threshold (e.g. 0.7) for subsequent analysis. This may aid with verifying identifications (see below).

A selection of calls should be checked for validation by an expert. BirdNET Analyzer can return results in a style suitable to locating calls in Raven Pro, software for visualising and saving sounds. Audacity is free software that enables a similar approach through manually scrolling through recordings to the desired time point. Protocols and thresholds for checking calls should be decided on and applied uniformly across recordings at all time periods.

Start (s)	End (s)	Scientific name	Common name	Confidence
1002	1005	Haematopus ostralegus	Eurasian Oystercatcher	0.7991
1005	1008	Periparus ater	Coal Tit	0.6024
1008	1011	Pandion haliaetus	Osprey	0.5515
1008	1011	Periparus ater	Coal Tit	0.5257
1011	1014	Periparus ater	Coal Tit	0.7613
1026	1029	Haematopus ostralegus	Eurasian Oystercatcher	0.8938
1029	1032	Haematopus ostralegus	Eurasian Oystercatcher	0.8477
1032	1035	Haematopus ostralegus	Eurasian Oystercatcher	0.9776
1035	1038	Haematopus ostralegus	Eurasian Oystercatcher	0.5541
1047	1050	Haematopus ostralegus	Eurasian Oystercatcher	0.5672
1098	1101	Larus canus	Common Gull	0.84
1122	1125	Larus canus	Common Gull	0.8349
1125	1128	Larus canus	Common Gull	0.6255

Example output from BirdNET Analyzer. In this example, the record of Osprey is likely to be erroneous (and should be manually checked) given its low confidence score and the fact that the 3-second periods immediately before and after are matched to Coal Tit.

Actions to improve validation

Consistent location - note the exact spatial location of ARU deployment (at least eight-figure grid reference). It may help to physically mark monitoring points such as by attaching small metal tree tags.

Georeferenced photography – to enable validation each audio device should be photographed with georeferenced photography.

Consistent equipment – there has been rapid development of ARUs. It is likely that further improved devices will be available in future years. It is desirable to use identical devices between recording periods. If it is not possible to replicate devices across the whole sampling network, running old devices alongside a sample of the new devices will enable some degree of comparison of effectiveness.

Calibration – ARUs devices will degrade over time, especially when heavily used. Microphone calibration is desirable for devices on which this is possible. Simpler devices, such as AudioMoths, should be checked at least annually to ensure that they perform within acceptable limits.

Consistent timing – the timing of device deployment should remain constant between survey years.

Consistent use of classification software – automated classifiers are recent developments. The performance of these is likely to continually improve. While analysis of recordings at the start of a project will be worthwhile to identify a benchmark, the sound files should be retained and re-analysed alongside recordings from later periods using the optimal software available at that time.

Validation of identification by experts – A sample of species recordings should be checked by an expert.

Limitations

ARUs sample acoustic activity, not abundance. Acoustic activity as detected by the recorder can be influenced by volume of call, bird movements, distance from recorder and how frequently the species calls. Hence inferences cannot be made about relative abundances of different species.

Alternative methodologies

Bird surveys have typically been carried out by fieldworkers based on a range of methods that standardise by controlling for effort (time, distance/area or a combination of these). This includes point counts, transects or other routes that standardise time spent in an area. Such surveys require personnel with a high skill level in identifying birds by sight and sound as well as in navigation and estimating distances and are vulnerable to variations in these.

An advantage of direct fieldwork is that areas can be explored in more detail and, for example, sedentary species with quiet calls can be directly sought out. Species-specific surveys may aim to illicit responses from secretive bird species by playing their call through a speaker and listening for a response. Direct surveys can also generate population density estimates for species by modelling detectability of species. Disadvantages include the lack of opportunity for verifying data along with shortage of suitably skilled observers and lack of methods for adjusting for relative observer skill. Additionally, direct fieldwork gives a snapshot at the time that the observer is present while ARUs can be more successful at detecting species due to longer duration of operation.

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Point count for birds

Author: Dr Nick Littlewood (SRUC)

Methodology

Bird surveys typically involve fieldwork undertaken by skilled ecologists. A wide range of methods has been developed which are standardised by observer effort (either in terms of duration of survey or area of ground covered, or both). Some methods are more suited to specific habitats or to specific species or species group than are others. Some, such as point counts, can be used across a range of terrestrial habitats, though effectiveness may still vary by environment.

Point counts involve recording birds detected over a fixed period of time from a static position. They require fieldworkers to have a high skill level in bird identification and in some habitats, especially woodland, most detections and identification are based on bird song and calls. There is no single standard method for point counts, so the protocol described here is a proposed approach for carrying out surveys in woodland and peatland environments.

Equipment

Site map, GPS/Phone: To accurately identify monitoring points and capture photographs.

Binoculars: As point counts involve direct identification of birds in the field, this is the main specialised equipment normally.

Range finder: For assisting with estimating distances to birds that are seen.

Clipboard, notebook or voice recording device: For recording data in the field.

Phone with bird call app (e.g. Merlin): These may be used to help suggest identifications in the field. However, these need sounds to be clear and they can suggest erroneous identifications for species where calls might be similar. They should be considered as an occasional back-up rather than a primary tool for data recording.

Acoustic recorder (e.g. AudioMoth): A device may be run alongside the fieldworker (see protocol for using acoustic recorders for bird). However, microphones on these devices usually have a more limited directional range of detection than do human fieldworkers. Also, it is harder to estimate distance of the bird from the unit (see below) compared to during live fieldwork, so again these are back-up tools.

Warm clothing: As point counts involve recording from a static position, this is especially important to enable full concentration on data collection.

Process

Study design and timing

A first step is to determine spacing and location of sample locations. See *Survey Design Overview* but note that sample points should be spaced at least 200 m apart to minimise the number of birds that are recorded at more than one point (i.e. double-counting).

Surveys should take place in the bird breeding season with an aim to assess populations of species that breed on the site, or which could potentially do so. Each point should be visited twice, once in April to mid-May and once in Mid-May to the end of June. There should be at least four weeks between visits. Repeat visits in subsequent years should aim for similar timing to initial surveys, as far as is possible.

Fieldwork should be conducted between dawn and 9am. It should only be carried out in fine weather. Counts should not be conducted during period of rain. Wind speed should be no greater than Beaufort force 5. Visibility should be moderate or good.

Conducting the survey

Upon arriving at a point, the observer should remain static for 5 minutes before starting the count, to give some time for birds disturbed in the process of reaching the point to resume normal behaviour. The count itself should last for 10 minutes. This duration is a trade-off between seeking to maximise the individuals and species detected against risk of counting the same bird more than once as it moves around the area.

During the count, all birds detected should be recorded except those solely flying over the area and making no further use of it (such as gulls moving between feeding areas or migrating geese). Each bird that lands or that makes short movements within the area being monitored should be identified and noted once. The observer should take care to note birds moving about, to avoid double-counting. Some judgements as to whether detections refer to the same or different birds are arbitrary. During the 5-minute observation period, the observer should rotate from time to time to optimise effectiveness of detecting birds from different directions.

The horizontal distance that each bird is from the survey point should be estimated. This should be the distance that the bird was first detected. If there is a clear line of sight, a range finder can be used to assist with this. In enclosed habitat, such as woodland, this may not be possible, especially for birds detected solely by vocalisation, in which case, a best-judgement estimate should be made. Distances should be recorded in bands of 0-20 m, 20-40 m, 40-60 m, 60-80 m and over 100 m.

Metrics generated

The simplest metric that enables comparison over time is the number of birds of each species detected. This enables comparison of relative populations of species between visits. It does not enable estimation of actual population size or density or of comparisons between different species.

By using also the distance estimates, a range of numerical methods is available for calculating estimates of population densities. These are based on the premise that detectability declines with distance from the sample point and that the rate of this decline differs between species. Some of the methods for calculating density estimates are mathematically complex and requiring advanced computer modelling skills. A simplified method is described by Bibby et al (1992). Whichever approach is used, the same method should be used to generate density estimates from each visit and it should be noted that estimates will be more robust for species with a greater number of records in the dataset.

Restorative actions may not necessarily result in an increase in abundance or richness of bird species. Instead, metrics may focus on the presence/absence of key indicator species, or a change in the structure of assemblages. Community similarity indices can be used to detect the similarity of the community against a reference site (e.g. a pristine habitat).

Actions to improve validation

Training in distance estimation – this will help improve consistency and accuracy which in turn, improves accuracy of density estimates.

Assessing observer competence – as a high level of fieldworker skill is crucial, it may be appropriate to test potential fieldworker's ability to identify birds by sound.

Consistent observer – it may not be possible to use the same observer in different field seasons but if it is possible, this will reduce variability due to observer skill.

Consistent timing – survey dates should be as close as practicably possible between field seasons.

Consistent location: The exact spatial location of each point should be mapped and marked to ensure consistency. The spatial location should be noted using eight figure grid reference, and/or What3Words.

Georeferenced photography: Four-point georeferenced photography (north, south, east and west) should be taken to capture surrounding vegetation.

Limitations

As survey data are reliant on direct fieldwork and the skill level of the observer, data cannot normally be independently verified. Conspicuous and distinctive species may be recorded more reliably than those that are harder to detect or identify. Furthermore, species that are not normally active during the fieldwork period, such as nocturnal species, may especially be under recorded.

Point counts may be less robust in open environments compared to woodlands, as there is a greater risk in these areas of disturbing birds whilst walking to the survey point and these may then move away before the survey commences. In all environments, point counts are based on an assumption that the observer does not influence the spatial distribution of birds and that they are able to determine if birds detected are the same as or different from those already noted. This can be challenging, especially if there is a lot of bird activity. Judgement calls made by observers at these times, combined with variability in accuracy of distance estimation, have potential to impair accuracy of data collected.

On the other hand, woodlands typically make species less visible, and consequently there is a greater reliance on audio cues. As the reliance on audio versus visual cues can change as woodlands develop, this can impact the species recorded and the accuracy of the data collected.

Alternative methodologies

Automated Recording Units (ARUs) can be used to monitor vocalisations over long time periods. These can be set in a similar spatial arrangement around the survey area as point counts. ARUs are more effective than a human fieldworker for recording birds that call infrequently or, for example, nocturnal species (e.g. Zwart 2014). They also enhance verifiability of data collection. However, the distance of a source of sound from an audio recorder cannot reliably be determined so absolute density estimates cannot be calculated. Furthermore, as they depend on bird vocalisations, they will under-record quieter species.

The principal alternative active fieldwork method is through using transects – either straight lines, where possible, or routes adapted according to accessibility. In upland areas, a method based in walking around survey squares in a fixed time period (Brown & Shepherd, 1993) is widely used. This was devised for surveying waders but has been widely adopted for a wider range of upland bird species (e.g. Littlewood et al, 2019). Populations can be estimated based on territory mapping over repeated site visits but robustness varies widely among species as no account is taken of different detectability of different bird species.

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Pan traps for monitoring flower-visiting insects

Author: Dr Lorna J Cole (SAC Consulting)

Methodology

Pan traps are brightly coloured bowls designed to attract flower visiting insects (primarily pollinators). Different insects are attracted to different colours of pan traps and thus a combination of coloured traps is recommended (Hutchinson et al., 2022). Traps typically contain water and a small amount of scentless detergent to break the water's surface tension increasing trapping efficiency. Insects are attracted to the traps bright colours where they become trapped in the water. Pan traps collect a wide range of insects and are particularly good for surveying bees, wasps and flower visiting flies such as hoverflies. Pan traps are easy to implement by non-experts and equipment is readily sourced. Installing and collecting the traps requires no expertise. Most invertebrate taxa are difficult to identify and thus processing the samples requires taxonomic expertise or DNA based methods.

Pan traps are widely used in research to survey pollinators and form a component of the UK Pollinator Monitoring Scheme (POMS) which runs a network of 95 pan-trapping locations.

Equipment

Site map, GPS/Phone: To accurately identify monitoring points.

Pencil, recording sheet: To record relevant information

Pan traps: Robust plastic bowls approximately 10-12 oz. For example, reusable dessert bowls. Avoid biodegradable bowls as they deteriorate over time. Bowls should be primed and spray painted with UV paint several weeks ahead of installation to avoid fumes interfering with trapping efficiency. If spray paint begins to flake off, bowls should be resprayed.

White primer spray paint: To prepare the plastic bowls for spray painting.

UV reactive spray paint: Blue, yellow and white UV spray paint to paint the bowls.

Pan trap supports: These can be purposed from galvanised steel all round band and butterfly screws/wing nuts. This band is fashioned into three metal hoops and provides a means of attaching pan traps to the wooden stake with a butterfly screw allowing the pan traps to be raised and lowered to align with vegetation height.

Wooden stakes: Stakes should be of sufficient height to allow for pan traps to be established at the height of the vegetation (e.g. 90 cm x 32 mm).

Tent peg: To enable pan holders to be secured on the ground in short vegetation (<10 cm).

Mallet: To hammer the wooden stakes into the ground.

Unscented washing up liquid: To add to the water to break its surface tension.

Container of water: To add to the pan traps. Approximately 100 ml per trap.

Tea strainer: To drain off excess fluids.

Muslin squares: These should be precut to fit the tea strainer. These are placed inside the tea strainer allowing for samples to be easily transferred to the storage vials.

Forceps and paintbrush: To help transfer the sample into the storage vials.

Preprinted labels: Laser printed labels on robust paper with site grid ref, pan trap number and colour.

Spare blank labels: In case of lost labels.

Preservative: Mixture of 80% ethanol or industrial denatured alcohol (IDA) and 20% water. To protect delicate insects 5% glycerol can be added. For DNA-based identification methods 95% ethanol should be used.

Wide neck storage vials: airtight collecting vials with wide necks to allow for easy transfer of the catch (e.g. 30 mL, 50 mL or 70 mL depending on catch size).

Process

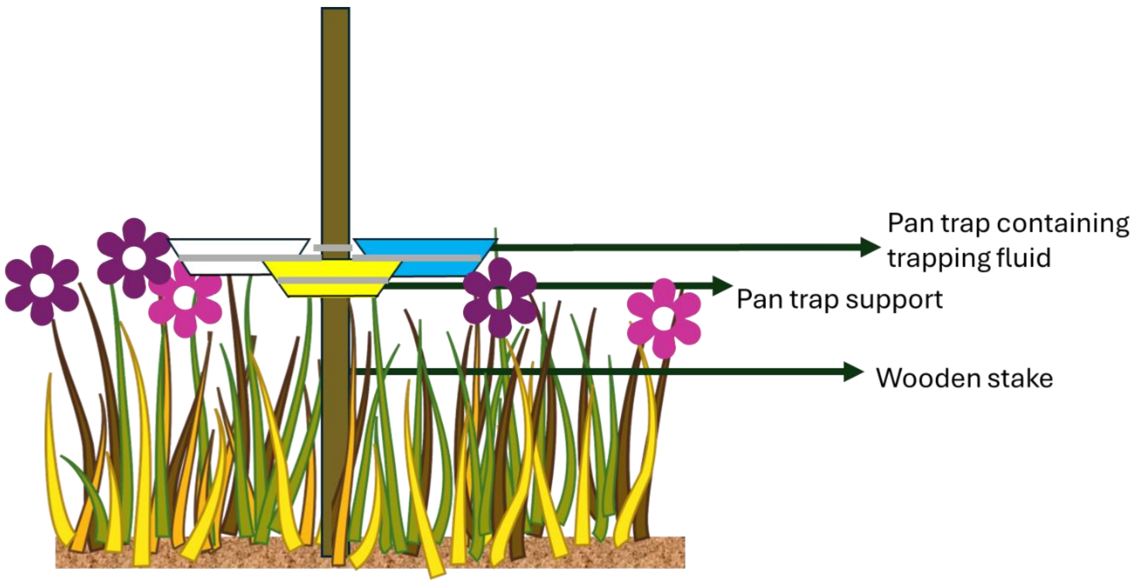
Study design and timing

Several protocols exist for surveying pollinators using coloured pan traps. These include the UK Pollinator Monitoring Scheme (POMS) and The Food and Agriculture Organization of The United Nation's Protocol to Detect and Monitor Pollinator Communities. The methodology described here draws on these providing flexibility to suit site and resource specific aspects.

The exact sampling protocol will depend on the size and dimensions of the site, in addition to the type and complexity of habitats present. Each monitoring point should have a minimum of three differently coloured pan traps (yellow, white and blue). We recommend a minimum distance of 300 m between monitoring points.

The time that traps are left in situ will be dependent on resources. We recommend a period of between six hours (coinciding with the UK POMS) and 48 hours (to prevent the degradation of the sample). For time periods of less than 28 hours, the traps should be established during peak pollinator activity (10.00 hrs – 17.00 hrs). Surveys should be conducted during suitable weather conditions. Specifically, a minimum temperature of 13°C if the sky is clear or 15 °C if cloud cover is over 50%, avoiding high wind speeds (i.e. five on the Beaufort scale) and the forecast should indicate little to no rainfall. Recognising that it can be difficult to reach these conditions in exposed upland locations, particularly early or later in the season, temperatures may be reduced to 11 °C when clear and 13°C if over 50% cloud cover.

To align with the UK's POM and to avoid queen bee emergence, where resources permit we recommend monitoring on four occasions during the following two-week survey periods: 7 April - 10 May; 1 - 14 June; 6 - 19 July and 17 - 30 August.



Pre-sampling visit

It is important to visit the area prior to the installation date to determine the suitability of the proposed monitoring points. Traps should be accessible without danger to surveyors and should be established in relatively open habitat near the predetermined monitoring point. Any monitoring point deemed to be unsuitable (e.g. grazing livestock/deer present, heavily shaded locations, or areas that are likely to be disturbed by the general public) should be altered. It is important to consider how shading may change throughout the day and season. In situations where it is not possible to avoid grazing livestock/deer, risk of them interfering with traps can be reduced by narrowing the survey window (e.g. six hours). Alternatively, where vegetation is short (and is likely to remain short for the entire survey period) a wire hanging basket may be secured over the traps on the ground to protect them against grazing animals. Any measures taken to protect against grazing animals must be kept consistent over the entire monitoring period.

Installation

Navigate to the first monitoring point. Hammer the wooden stake into the ground. If the vegetation is short (e.g. 10cm or less) it is possible to establish the pan traps directly on the ground in the pan trap support and secure with a tent peg. For taller vegetation, the pan trap support should be secured to the wooden stake at a height that aligns with the top of the vegetation. Insert the three different coloured pan traps (i.e. blue, white and yellow) into the hoops and ensure that the traps are secure and level). Add approximately 100 ml of water into each trap alongside a few drops of scentless detergent. Water should completely cover the bottom of the bowl to a depth of 2-3 cm. Gently swirl the liquid to ensure the detergent is mixed. Gently nudge the stake to ensure that all traps are secure and level.

Collection and processing

When arriving at the survey location check for signs of disturbance. For example, pan traps removed from their support, contents spilling out, trapping fluid evaporated, or bird droppings indicating birds have been feeding from the traps. Any signs of disturbance should be noted on the recording sheet. Remove each trap from the pan support. Place the muslin square inside the tea strainer and carefully sieve the sample through the strainer. Gather the muslin square and place in the collection vial alongside the label. Use the paintbrush/forceps to move any remaining insects present in the pan trap to collection vial. Top up the vial with preservative (see above). If timing on site is limited, pan traps can be poured into an airtight collection tub, and processed as above by straining the fluid within 12 hours of collection.

Samples can be processed either via identification by an expert using a high-power stereo microscope and relevant keys (e.g. Stubbs and Falk (2012) for hoverflies and Falk (2019) for bees) or using DNA methodologies. Processing by experts typically focus on key taxa which are identified to species level and counted. DNA methodologies may identify all insects trapped (Cuff 2022).

Additional data to collect

Pan traps are heavily influenced by floral resources in the surrounding landscape. Consequently, we would recommend surveying floral resources within a 2 m radius of each set of pan traps. For verification purposes we recommend that four permanent 1 x 1 m quadrats are established north, south, east and west of each set of traps. Information should be gathered on species and the number of flower units for each species (i.e. excluding grasses, sedges and rushes). A flower unit is defined as a single flower (e.g. tormentil, daisy), compact inflorescence (e.g. thistle, clover), umbel (e.g. common hogweed, yarrow) or spike/raceme (e.g. foxglove, willowherb). Flower units can be quantified on the following scale 1 = 1-2 floral units, 2 = 3 – 30 floral units, 3 = 31 – 300 floral units, 4 = 301 – 3000 floral units, 5 = over 3001 floral units.

Additionally, as pollinators are influenced by weather conditions, information on wind speed, temperature and rainfall should be collected. This can be undertaken when installing and collecting the traps, or capturing data on temperature, windspeed and rainfall from the MET office.

Finally, the approximate height of the pan traps should also be noted.

Metrics generated

The resultant data can be used to generate several different metrics such as the abundance or number of species (i.e. species richness) of pollinating taxa (e.g. bees, hoverflies) or indeed Shannon diversity (a metric that integrates richness and the dominance of different taxa). Restoring peatland may not necessarily result in an increase in abundance or richness of flower visiting insects. Instead, metrics typically focus on the presence/absence of key indicator species, or a change in the structure of assemblages.

Similarity indices can be used to monitor progress of restorative action, benchmarking the restored site against a reference site. Reference sites should be carefully selected to reflect the desired end point. This maybe a pristine area of peatland, or a peatland which has successfully undergone restoration in the past (e.g. 30 years ago). Alternatively, when resources are limited it may be possible to benchmark against existing database for pristine or successfully restored peatlands (where available).

Actions to improve validation

Consistent location - note the exact spatial location of each monitoring point including the stake location and the four quadrats. Spatial location should be noted using eight figure grid reference, and/or What3Words. Leaving the wooden stakes hammered into the ground can ensure consistency of locations. In exposed areas, a smaller (e.g. 30 cm) brightly coloured stake could be used to mark the location at the end of the season.

Georeferenced photography – to enable validation pan traps should be photographed with georeferenced photography. Four-point georeferenced photography (north, south, east and west) should be taken to capture current surrounding vegetation. Each of the four vegetation quadrats should be photographed.

Consistent equipment – do not change the pan trap type or dimensions or the brand of scentless detergent.

Consistent timing and weather conditions – the timing and weather conditions during sampling should remain constant. The number of hours the traps are left in place should be consistent. Some flexibility of exact dates of trapping is permitted to ensure weather conditions are suitable.

Surveyor information: All surveys should note the name and expertise of the surveyor/surveyors.

Validation of identification by experts – if invertebrates are identified by experts, a photograph of all samples should be taken prior to identification. This photo should display the sample identification label clearly capture all target invertebrates. The name and expertise of the identifier should be noted in the data collecting sheet, alongside a signature. Following identification all samples should be stored in airtight storage vials in suitable preservative, or pinned in insect boxes.

Validation of identification by DNA Methods – As above a photo of all samples should be taken prior to identification with the photo clearly showing all target invertebrates alongside the sample identification label. **'Blank' PCRs (sterile water rather than DNA) should be used to monitor for contamination alongside positive control samples to increase confidence in the results.**

Limitations

Pan traps are strongly influenced by the availability of floral resources in the surrounding landscape. For example, in floristically rich landscapes pollinators may meet their resource requirements in a smaller area making them less likely to encounter traps. Additionally, traps are less visible/attractive to pollinators in areas of dense floral coverage. Collecting information on floral resources in the immediate vicinity of the pan traps, alongside focussing primarily on changes to assemblage structure rather than changes in abundance or species richness will help to control for this weakness.

Pan traps do not collect pollinators from a known area, and as such they do not accurately measure the density of flower-visiting insects. However, they do provide a standard means of surveying populations over time, or in different habitats.

Pan traps provide a lethal survey method indiscriminately catching insects that are attracted to the trap's bright colours. While studies suggest this has minor detrimental effects on local populations (Gezon et al., 2015), use early in the season when queen bumblebees are emerging should be avoided.

Pan traps are occasionally interfered with by grazing animals, birds or people and obvious signs of disturbance should be noted. Additionally, unexpected winds or rain can interfere with trapping (e.g. pan traps can be blown out of their holders or flooded). In some instances, it may be necessary to repeat the survey.

Alternative methodologies

Alternative methods include transect walks or observation plots (including flower-insect timed counts). These methods provide more accurate information on the density of key taxa and information on plant pollinator interactions. Both methods, however, require training and are highly influenced the surveyor's expertise with respect to both taxonomic and netting skills. They can also be influenced by the surveyor's pre-conceived ideas. Pan traps reduce surveyor bias to provide a consistent and standardised means of surveying flower-visiting insects particularly for longer term studies where surveyors are likely to change. Additionally, pan traps provide a sample of all invertebrates surveyed for future validation.

Malaise traps provide an alternative lethal method of trapping flying insects. These do not specifically target flower-visiting insects and are more expensive to purchase and difficult to install (LeBuhn et al., 2012).

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Standardised transect walks for pollinators

Author: Dr Lorna J Cole (SAC Consulting)

Methodology

Standardised transect walks provide an active survey technique to monitor insect pollinators and are widely used for butterflies and bumblebees. The recorder typically walks along a predetermined route at a steady pace recording pollinators at a fixed distance either side and above (i.e. monitoring in an imaginary moving box around the recorder). It is important that the recorder does not linger on hotspots and that care is taken to avoid double counting.

Transect walks require little in the way of equipment and bumblebee and butterfly transects can be conducted following basic training with most specimens easily identified in the field. For tricker taxonomic groups such as solitary bees and hoverflies a higher level of expertise is needed, with most species requiring identification under a microscope.

Transect walks provide a good means of surveying an area with a variety of microhabitats, and floral resources. However, they are highly influenced by the surveyor's experience.

This is one of the most frequently used methodologies in research. The Bumblebee Conservation Trust's Beewalk Survey Scheme and the United Kingdom Butterfly Monitoring Scheme (UKBMS) both use this approach.

Equipment

Site map, GPS/Phone, Compass: To accurately identify transect areas and capture photographs.

Anemometer: To ensure temperature and windspeed complies with base requirements.

Meter stick or tape measure: To help gauge the distance you will be observing either side of you.

Pencil, recording sheet: To record relevant information

Butterfly net: To capture tricky specimens for a closer look, or for taxa such as hoverflies and solitary bees that cannot accurately be identified in the field.

Storage vials: Airtight collecting vials for any specimens that require identification in the laboratory. These should include a wide mouthed vial to observe pollinators briefly to identify them before releasing them.

Preservative: Mixture of 75% ethanol or industrial denatured alcohol (IDA) and 25% water. For DNA-based identification methods 95% ethanol should be used. Butterflies should be photographed on site.

Blank labels: To label location and date that any specimens were collected.

Process

Study design and timing

This methodology draws strongly from existing frameworks (i.e. Beewalk Survey Scheme and the UKBMS), alongside the research to provide flexibility to suit site and resource specific aspects.

The number and length of pollinator transects will depend on the size and dimensions of the site, in addition to the type and complexity of habitats present. We recommend selecting a standard transect length for the entire site, and that this length should be 200 m and 1 km. The area should be clearly marked to ensure that the same transect area is walked each visit. Butterflies and bumblebees should focus on recording 2 m either side of the observer. Due to their smaller size, transects for hoverflies and solitary bees should focus on recording 1 m either side.

While transects for butterflies and bumblebees can be conducted following basic training in methodology and identification, transects that also focus on solitary bees and hoverflies should only be conducted by experts to reduce surveyor bias.

Transect walks should be conducted between 11.00 – 16.00 hrs during suitable weather conditions. Specifically, a minimum temperature of 13°C if the sky is clear, 15°C if cloud cover is over 50%, and 17°C if cloudy. Recognising that it can be difficult to reach these conditions in exposed upland locations, particularly earlier or later in the season, temperatures may be reduced to 11°C when clear and 13°C if over 50% cloud cover. High wind speeds (i.e. five on the Beaufort scale) should be avoided and transects should not be conducted when rain is forecast.

We recommend monitoring is conducted on four occasions during the following two-week survey periods: 7 April - 10 May; 1 - 14 June; 6 - 19 July and 17 - 30 August.

Pre-sampling visit

A pre-sampling visit should be conducted to determine the suitability of the proposed and establish transects. Transects should be accessible without danger to surveyors. As pollinators are influenced by shade, heavily shaded transects should be avoided. It is important to consider how shading may change throughout the day and season. To ensure reproducibility the same transect area should be walked on each occasion and as such transects should be carefully mapped and wooden stakes hammered into the ground at the start and end point.

Conducting the survey

Navigate to the transect start. Using the phone/compass establish the direction of the transect. To gauge your monitoring window, measure the distance either side that you will be conducting your observations.

Walk along the route at a slow steady pace (e.g. approximately 10 m per minute) taking care not to linger at hotspots (i.e. areas of dense flowers that attract a high number of pollinators) or deviate from the transect route.

It is recommended that butterflies and bumblebees are recorded at a distance of 2 m in front, above and either side of the observer while hoverflies and solitary bees should be recorded 1 m in front, above and either side.

While all butterflies flying through the transect should be recorded, all other pollinators should only be recorded if they are observed actively foraging. Noting the flower species that pollinators were observed foraging on provides additional information.

Species should be identified to species level and bumblebee casts (i.e. worker, queen or male) noted. Difficult species should be trapped with a net and identified either on location (butterflies and some bumblebees) or put in a collection vial and taken back to the laboratory (hoverflies and solitary bees). Where estimates have to be made (when numbers are too large to count accurately) please make sure a figure is recorded (e.g.46 rather than 40+). All samples brought back to the laboratory should be clearly labelled with transect number, date, observer.

It is important to avoid double counting, for example if a butterfly is flying up and down the transect it should only be recorded once.

Surveys should be conducted on dry, warm days. If it does start to rain, then all recording should be stopped. It is possible to wait out short showers, after the shower is finished you should wait at least five minutes before restarting the transect from the point you had reached before the shower.

When two people are present the second person should walk behind the main recorder and only specimens observed by the main recorder should be recorded.

Additional data to collect

As transects are heavily influenced by floral resources, we recommend surveying floral resources within the transect area. Dicotyledonous plants (i.e. excluding grasses, sedges and rushes) actively flowering should be identified to species level and quantified either as a percentage of the transect area covered by that species or the number of flower units noted. A flower unit is defined as a single flower (e.g. tormentil, daisy), compact inflorescence (e.g. thistle, clover), umbel (e.g. common hogweed, yarrow) or spike/raceme (e.g. foxglove, willowherb). Flower units can be quantified on the following scale 1 = 1-2 floral units, 2 = 3 – 30 floral units, 3 = 31 – 300 floral units, 4 = 301 – 3000 floral units, 5 = over 3001 floral units. Floral resources should be quantified in the same way across all surveys.

Additionally, as pollinators are influenced by weather conditions, information on wind speed, temperature and rainfall should be collected alongside information on the percentage of transect in shade.

Metrics generated

The resultant data can be used to generate several different metrics such as the abundance or number of species (i.e. species richness) of pollinating taxa (e.g. bees, butterflies) or indeed Shannon diversity (a metric that integrates richness and the dominance of different taxa).

Restorative actions may not necessarily result in an increase in abundance or richness of flower visiting insects. Instead, metrics may focus on the presence/absence of key indicator species, or a change in the structure of assemblages.

Similarity indices can be used to monitor progress of restorative action, benchmarking the restored site against a reference site. Reference sites should be carefully selected to reflect the desired end point. For example, this maybe a pristine area of peatland, or a peatland which has successfully undergone restoration in the past (e.g. 30 years ago). Alternatively, when resources are limited, it may be possible to benchmark against existing database for pristine or successfully restored peatlands (where available).

Actions to improve validation

Consistent location: The exact spatial location of each transect should be mapped and marked with wooden stakes to ensure the same area is walked on each visit. The spatial location should be noted using eight figure grid reference, and/or What3Words. Leaving the wooden stakes hammered into the ground can ensure consistency. In exposed areas, a smaller (e.g. 30 cm) brightly coloured stake could be used to mark the location at the end of the season. If multiple people are to undertake the surveys, it is advised that these people walk the transects together to ensure consistency in the area walked.

Georeferenced photography: To enable validation transects should be photographed with georeferenced photography at regular intervals (e.g. every 50 m). Four-point georeferenced photography (north, south, east and west) should be taken to capture surrounding vegetation.

Consistent timing and weather conditions: The timing and weather conditions during sampling should remain constant. Weather conditions should comply with those indicated above. Some flexibility of timing is permitted to ensure weather conditions are suitable.

Surveyor information: All surveys should note the name and expertise of the primary surveyor. Training surveyors in techniques and identification of focal taxa can help to increase the robustness of data collection. If multiple people are present during a survey, only the primary surveyor should note their observations down.

Validation of identification by experts: if invertebrates are brought back to the lab and identified by experts, a photograph should be taken displaying the sample identification label. The name and expertise of the identifier should be noted in the data collecting sheet, alongside a signature. Following identification all samples should be stored in airtight storage vials or pinned in insect boxes.

Validation of identification by DNA Methods: As above a photo of all samples should be taken prior to identification with the photo clearly showing all target invertebrates alongside the sample identification label. 'Blank' PCRs (sterile water rather than DNA) should be used to monitor for contamination alongside positive control samples to increase confidence in the results.

Limitations

Transect walks are strongly influenced by the experience of the surveyor with more experienced surveyors being more likely to observe, capture and correctly identify pollinators. Training surveyors in the necessary techniques (including how to net insects) and identification can reduce this bias.

Invertebrates are largely identified on site and consequently samples to verify and validate identifications are lacking. Taking photographs, particularly of rare species, or species not previously identified for the site, provides a means of validation.

Slight differences in weather conditions, time of day and level of shade present along the transect can all influence pollinator activity. Care should therefore be taken to keep these factors consistent between different survey dates where possible.

Alternative methodologies

Alternative methods include observation plots (including flower-insect timed counts) or pan traps. As with transect walks, observation plots are also influenced by surveyor experience and with pollinators largely identified on site they lack samples for verification and validation. In focussing on a constrained area, it is easier to ensure that the same location is surveyed on each visit. However, they are highly impacted by change to that area and are less effective at reflecting the habitat parcel as a whole.

Pan traps are less influenced by surveyor experience and in providing samples allow for validation and verification of all insects by experts or DNA techniques. In situations where surveyors are likely to change (e.g. long-term monitoring regimes) pan traps are likely to provide a more standardised means of monitoring pollinators. Pan traps, however, are known to be impacted by floral resources in the immediate and surrounding vicinity which can result in unexpected trends. For example, pan traps are less attractive in floristically rich habitats, and consequently they have been found to be less effective at trapping pollinators in such habitats.

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Pitfall trapping for surface active invertebrates

Author: Dr Lorna J Cole (SAC Consulting)

Methodology

Pitfall traps are small plastic containers that are dug into the ground so that the lip of the container is flush with the soil surface. Ground active invertebrates such as rove beetles, ground beetles, ants and spiders fall into the traps into killing fluid/ preservative. Pitfall traps provide a low-cost effective means of catching such invertebrates and equipment is easily sourced. Pitfall traps sample an undefined area and consequently they are considered a relative sampling method. This means they do not provide information on the density of invertebrates per unit area, instead they let you draw comparison between different areas.

Pitfalls are widely used in research and form a key component when monitoring terrestrial biodiversity (specifically ground beetles and spiders) in The Environmental Change Network. This is collaborative that monitors long-term environmental changes across various ecosystems.

Equipment

Site map, GPS/Phone: To accurately identify monitoring points.

Pencil, recording sheet: To record relevant information

Pitfall trap: Robust rigid/relatively rigid plastic beakers for example food containers with tamper proof lids provide easy installation and collection. Recommended dimensions: 520 ml, height = 113mm, Top diameter = 97mm, Base diameter = 74mm.

Killing agent/preserving fluid: approximately 100 ml of 99% propylene glycol per trap. Salt water (3 tbs of salt per 1L water with unscented detergent) provides a suitable alternative for short periods but is not recommended for DNA-based methods due to deterioration of genetic material.

Square mesh/chicken wire: square of 15 mm mesh size of approximately 110 mm x 110 mm. This prevents grazing animals interfering with the trap and small mammals/ amphibians entering the trap. Additionally, if desired, a plant pot saucer can be secured above the trap to provide a rain guard.

Large metal staple: to secure square gauze in place. This can be made from bending fence a length of fence wire (e.g. 1.6 mm).

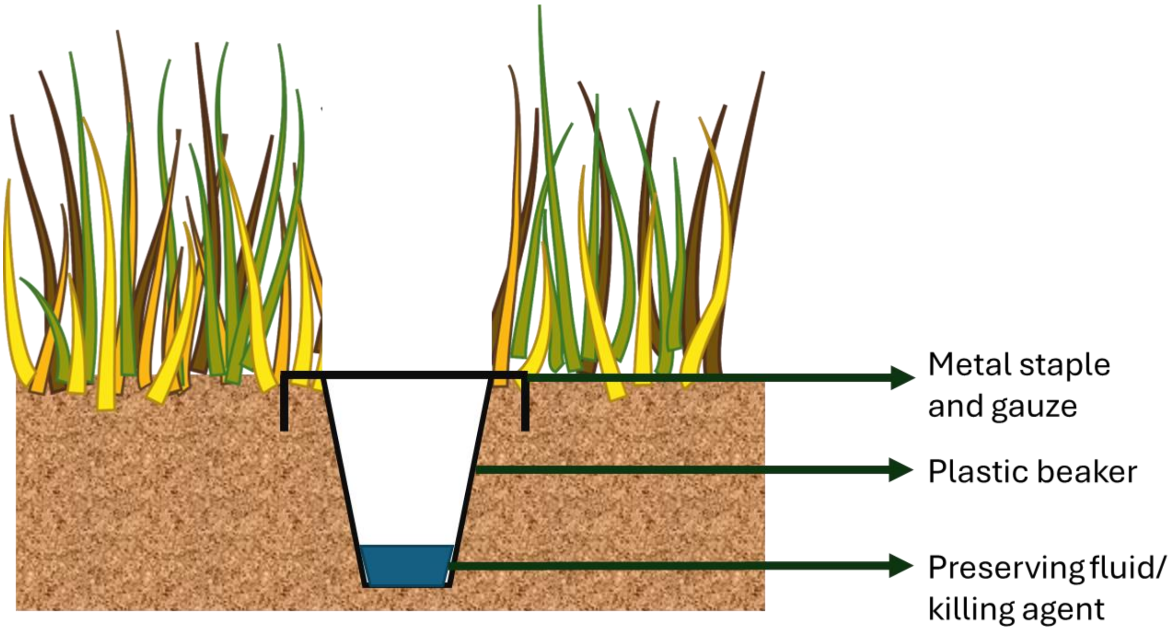
Wire cutters: to cut and bend the fence wire.

Soil corer/bulb planter: to create a whole for the pitfall trap.

Tea strainer: To rinse sample following collection.

Preservative for storage: 70% ethanol or industrial denatured alcohol (IDA) and 30% water. To protect delicate insects a mixture of 70% ethanol/IDA, 5% glycerol and 25% water is recommended. For DNA-based identification methods > 95% ethanol should be used.

Wide neck storage vials: airtight collecting vials with wide necks to allow for easy transfer (e.g. 30 mL, 50 mL or 70 mL depending on catch size).



Process

Design and timing

The number and layout of the pitfall traps will depend on both resources and the size and shape of the habitat patch in question. For example, pitfalls could be placed along a transect (e.g. ten traps with 10 m spacing between the traps: ECN standard methodology) or in a square (e.g. four traps representing the four corners of a square). Transects are more suitable for large areas or narrower strips of habitat while a square design would suit smaller areas of habitat. We recommend a minimum distance of 10 m between pitfall traps.

It is recommended that pitfall traps are left in situ for 14 days. Typical survey window is between May and October. Surveying should avoid periods of extreme heat which could reduce invertebrate activity, or rainfall which could result in traps flooding. With species differing slightly over the season it is recommended to survey May, July and September where resources permit.

Pre-site visit

It is important to conduct a pre-visit to determine the suitability of pre-determined monitoring points. Any monitoring points deemed not to be suitable (e.g. insufficient soil depths to install pitfalls, atypical vegetation) should be repositioned.

Installation

Dig a hole using the soil corer/bulb planter and place the pitfall trap (i.e. plastic beaker in the hole) in the hole ensuring that the rim of the pitfall is flush to the ground. All gaps around the rim should be filled with soil using the trowel. To prevent soil entering the pitfall another beaker should be placed inside when packing the gaps round the pitfall. This beaker is then removed. Add approximately 100mL of killing agent/preservative. This will prevent insects from escaping and deteriorating. To protect the trap from grazing animals and prevent small mammals/amphibians entering the trap place a square gauze over the pitfall trap mouth, and secure with the metal staple. Mark the pitfall with a can for easy detection and record its position (e.g. using GPS or What 3 Words).

Collection and processing

During collection use the pliers to carefully remove the trap taking care not to spill contents. Add identification label both inside and outside of the trap which should include a code relating to exact location, date and person collecting the trap.

Within 24 hours of collection use the tea strainer to sieve the catch, rinse the catch first with water before transferring the contents into the storage vials using the storage preservative.

Samples can be processed either via expert identification using a high-power stereo microscope and relevant keys (e.g. Luff (2007) for carabids or Nentwig et al. (2021) for spiders) or using DNA methodologies.

Additional data to collect

Ground active invertebrates are influenced by both soil and vegetation properties. As such aspects such as soil compaction (measured via a soil penetrometer), soil moisture (measured via soil analyses) and vegetation type and height (measured via a sward stick) provide valuable additional information.

Additionally, the activity of ground active invertebrates can be influenced by temperature and rainfall and this information should be collected from the MET office.

Metrics generated

A number of metrics are generated from the data including the activity abundance of invertebrates, the number of species of a particular taxon, or the Shannon diversity of a particular taxa (i.e. a measure that takes into account both abundance and richness). However, the restoration of woodlands or peatlands does not result in a predictable and consistent change in either the abundance or richness of ground beetle and spider assemblages. Instead, restoration is accompanied by a change in assemblage structure, and it is this change we want to capture.

To determine the success of restorative action, we therefore need to determine how closely the assemblage structure reflects assemblages in habitats with the desired end goal. Consequently, we want to compare the similarity of the species present with either existing database for pristine (or successfully restored sites) or where this information is not available surveying should be conducted is a suitable reference site in the local area. This reference site should reflect the desired end point of the restoration. Similarity indices are therefore used to compare the current assemblage structure at the site undergoing restoration, with that at the reference site. This allows us to track the change in the assemblage structure towards the desired endpoint.

Actions to improve validation

Consistent location - note the exact spatial location of each pitfall trap (eight figure grid reference, What3Words). Where this is difficult to do accurate (e.g. woodlands or areas with poor coverage) locations can be marked with wooden stakes hammered into the ground.

Georeferenced photography – to enable validation each pitfall should be photographed with georeferenced photography. Additionally at the midpoint of the monitoring point, four-point georeferenced photography (north, south, east and west) should be taken to capture current surrounding vegetation.

Consistent equipment – do not change pitfall trap type or dimensions, trapping fluid or protective gauze.

Consistent timing – the timing of sampling should remain constant. This includes the date traps are set alongside the time traps are left in place.

Surveyor information: All surveys should note the name and expertise of the surveyor/surveyors.

Validation of identification by experts – if invertebrates are identified by experts, a photograph of all samples should be taken prior to identification. This photo should display the sample label and clearly capture all target invertebrates. The name and expertise of the identifier should be noted in the data collecting sheet, alongside a signature. Following identification all samples should be stored in airtight storage vials in suitable preservative.

Validation of identification by DNA Methods - Identification should following guidelines established in Rees et al. (2022). As above a photo of all samples should be taken prior to identification with the photo clearly showing all target invertebrates alongside the sample identification label. 'Blank' PCRs (sterile water rather than DNA) should be used to monitor for contamination alongside positive control samples to increase confidence in the results.

Limitations

Catches of pitfall traps are strongly influenced by the activity of invertebrates, with more active invertebrates being more likely to encounter a trap and thus fall into it. As a result, it is commonly accepted that pitfall traps do not measure the real density of a population but rather the activity density. Because pitfall traps are influenced by activity levels, they are influenced by factors that alter activity such as vegetation density, food availability and weather conditions.

Pitfall traps are occasionally disturbed by grazing animals, badgers and birds. While the use of the mesh grid, and rain guard reduce this risk, where obvious signs of disturbance are noted, trapping should be repeated.

Alternative methodologies

Alternative methods include hand searching and suction sampling. These methods while providing more accurate information on the density of key taxa, are more time consuming and less effective typically yielding low numbers of invertebrates. While pitfall traps sample both diurnal and nocturnal species, hand searching and suction sampling are biased towards day active species. Hand searching is highly influenced by the surveyor and is biased towards larger more easily seen species. Suction samplers vary in their efficiency at capturing different species, with larger more robust species being underrepresented.

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Vegetation recording

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Methodology

Monitoring vegetation change is crucial to understanding the impacts of actions for restoring habitat and associated species. Techniques for monitoring vegetation are long established. Unlike most other methods described in these protocols, where data are derived later from samples (physical or electronic) collected in the field, vegetation monitoring requires fieldworkers with a high level of expertise, specifically in plant identification.

The methodology described here is based largely on approaches used in National Vegetation Classification (NVC) surveying (Rodwell, 2006).

Equipment

Quadrat: a 2 m x 2 m quadrat for use on bog habitats and 4 m x 4 m for woodland ground vegetation. A range of quadrat types are suitable. Rigid frames (including foldable designs) may be used for the smaller quadrat. Alternatively, a quadrat comprising string, marked in 2-m lengths and attached to pegs may be preferred. The 4-m quadrat may be set up as a cross radiating out from a centre point, with high-visibility markers to show where the corners are. Woodland NVC methodology additionally requires woodland canopy and shrub layers to be considered using a 50 m x 50 m quadrat. This would not usually be delineated entirely on the ground, though a tape measure may be laid along one side.

Metal pegs: To permanently mark quadrat locations.

Metal detector: To relocate permanent markers used for marking quadrats' locations.

GPS-enabled mobile phone or tablet: To record coordinates of deployment location and obtain geo-referenced photographs of quadrats in-situ.

Process

Study design and timing

Surveys should be conducted at times of year considered most optimal for finding the greatest diversity of plant species. Typically, this is May (June in northern areas) to August. Surveys on peatlands in northern areas can extend to September or October. Surveys in subsequent years should aim for repeating similar timings.

The number of vegetation monitoring points must be decided before work commences. The precise study design will depend on the size and shape of the study area. We recommend spacing monitoring points at 100-m intervals where possible. It may be possible to carry out the work alongside other protocols, such as pitfall trapping or pan trapping, though monitoring points for vegetation quadrats should be offset from those for other methods, to reduce trampling impacts from survey visits.

At each monitoring point, five quadrats should be recorded. These can be positioned in a cross shape with one at the centre and one each 10 m away to the north, south, east and west. Quadrats should be aligned so that sides are parallel to latitude and longitude lines with the actual measured location forming the southwestern corner of the quadrat. Corners of quadrats should be marked to enable relocation. Markers should not protrude above the vegetation so as not to attract animals to use them as rubbing posts and potentially altering the vegetation through disproportionately high levels of trampling, browsing and defecation. Metal pegs inserted to flush with the ground may be used and a metal detector used to relocate these. Care should be taken when relocating quadrats to not trample vegetation, especially in peatland. Kneel mats may assist fieldwork in especially wet bog areas.

In each quadrat, all vascular plants, bryophytes and macrolichens rooted or attached within the sample should be accurately identified and listed. Treatment of difficult groups should be described in survey metadata (e.g. recording *Taraxacum* spp. as an aggregate category). NVC methodology requires noting cover on a DOMIN scale. It is suggested here to use a percentage – which can be converted to DOMIN if required (though additional note of plant abundance should be taken of species where cover is less than 5%, to enable matching to the lower DOMIN categories). Common practice is to list all species first and then estimate percent cover. As vegetation layers may overlap (e.g. pleurocarpus mosses growing beneath dwarf shrubs on peatlands) the total will usually exceed 100%. Woodland additionally requires assessing percent cover of canopy trees and scrub within the larger 50 m x 50 m.

Quadrats should be photographed with images being georeferenced. Photographs should be taken in the context of the surroundings, to aid relocation. Additionally, for 2 m x 2 m quadrats in peatland, photographs looking down from above should be achievable by leaning over from the edge of the quadrat. For larger quadrats, a series of images should comprise at least one in each ordinal direction. It is suggested that data collection be repeated at 5-year intervals.

A 2 m x 2 m quadrat laid on a degraded area lowland raised bog, showing mainly *Calluna vulgaris* with areas of *Eriophorum vaginatum* at the upper left and lower right. Some lichens and bryophytes are also visible here though their identify cannot be determined at this scale.

Metrics generated

Collecting data following methodology aligned to NVC surveying enables identification of communities under this system. Software can enable standardised and repeatable analyses of quadrat data to show percentage similarities to the NVC communities (e.g. UK CEH, 2024). This enables assessment over time of vegetation change towards the desired communities. Alternatively, similarity indices can be calculated based on a pre-selected reference site considered to represent a desired target for the outcome of restoration management.

Actions to improve validation

Consistent location - note the exact spatial location of quadrat placement (at least eight-figure grid reference). Mark corners of quadrats (e.g. using metal pegs).

Georeferenced photography – to assist validation each quadrat placement should be photographed with georeferenced photography, ideally viewed from above (2 m x 2 m quadrats) or from the four cardinal directions.

Consistent timing – the time of year of data collection should be similar on different visits.

Skilled fieldworker – Fieldwork must be carried out by a skilled botanist who is able to accurately identify species encountered.

Limitations

Although restoration management can produce rapid initial responses, subsequent changes in vegetation composition may be slow, especially in upland areas (e.g. Hancock et al., 2016). Thus, monitoring should be conducted over a long timescale (e.g. 30 years) to determine direction of change and comply with relevant codes.

Fixed quadrats may not be representative of the wider area and revisits may themselves cause vegetation change. Care should be taken to avoid other monitoring activities falling directly over monitored vegetation quadrats. Representativeness can be increased by increasing quadrat size or by assessing plant composition in a greater number of quadrats, though both add to the time taken to conduct a survey.

Surveys are reliant on fieldworker skill. Whilst photographs of quadrats may enable verification of data on some conspicuous plant species, those that are smaller, less distinct from the background or that mainly grow beneath the surface of the vegetation layer will not be adequately recorded in photographs.

Alternative methodologies

Some metrics of vegetation can be assessed through remote sensed data, including by use of drones. This is a rapidly advancing area of that has potential to upscale monitoring such that data are collected across a site rather than in sample quadrats. Use of the Normalized Difference Vegetation Index (NDVI), derived from satellite data, can assess vegetation greenness and plant density. However, robust methods have not yet been developed for measuring change in vegetation species composition from remote sensing approaches, other than for conspicuous plant species.

Methods for mapping habitats can cover larger areas of ground without reliance on sample areas (quadrats). These include Phase 1 Habitat Survey and UKHab. However, these are not designed to systematically assess vegetation species composition and may overlook subtle responses to restoration management.

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Comparing methods

	Methodology	Cost equipment	Field: Labour costs	Laboratory: Labour costs	Field: Ease of executing without expertise	Lab: Ease of executing without expertise	Repeatability	Validation/ verification
Pollinators	Pollinator transects	Good	Poor	Average	Poor	Poor	Average	Poor
	Flower insect timed counts	Good	Poor	Average	Poor	Poor	Average	Poor
	Pan traps	Average	Good	Poor	Good	Poor	Good	Good
Birds	Remote acoustic monitoring	Poor	Good	Poor	Good	Average	Good	Good
	Bird transects	Good	Poor	Good	Poor	Good	Poor	Poor
	Bird point counts	Good	Poor	Good	Poor	Good	Average	Poor
Plants	Plant quadrats	Good	Poor	Good	Poor	Good	Good	Good
	Plant transects walks	Good	Poor	Good	Poor	Good	Average	Poor
Bats	Remote acoustic monitoring	Poor	Good	Average	Good	Average	Good	Good
	Bat detector transect	Average	Poor	Average	Average	Average	Average	Average
Ground active invertebrates	Pitfall traps	Average	Good	Poor	Good	Poor	Good	Good
	Quadrat searches	Good	Poor	Poor	Average	Poor	Poor	Average
Structural metrics	National Vegetation Classification	Good	Poor	Average	Poor	Average	Poor	Good
	Phase 1 Habitat Survey	Good	Good	Average	Average	Average	Average	Average
	Biodiversity Net Gain Assessment	Good	Average	Average	Average	Average	Average	Average

Good	Average	Poor