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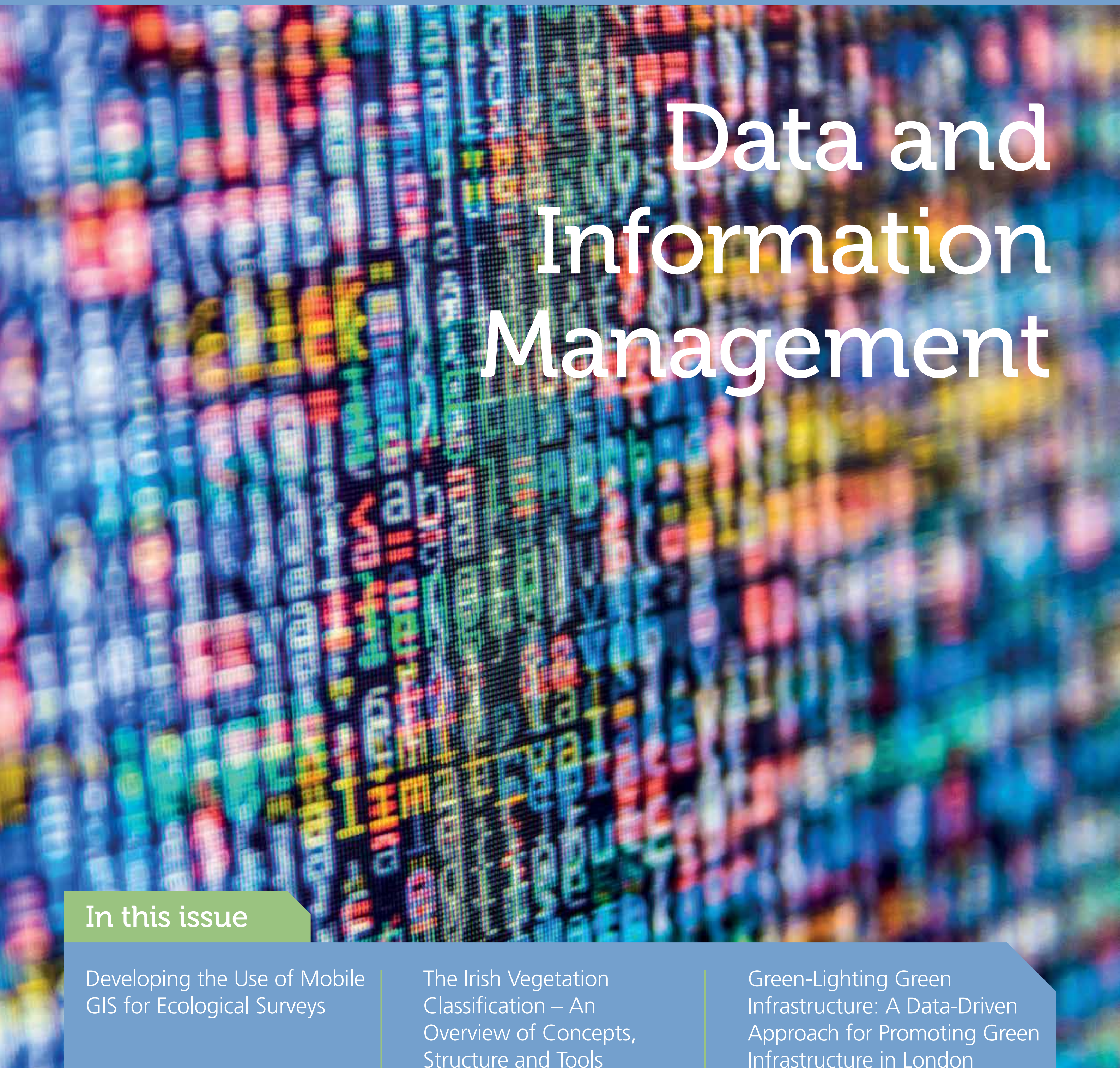

Data and Information Management

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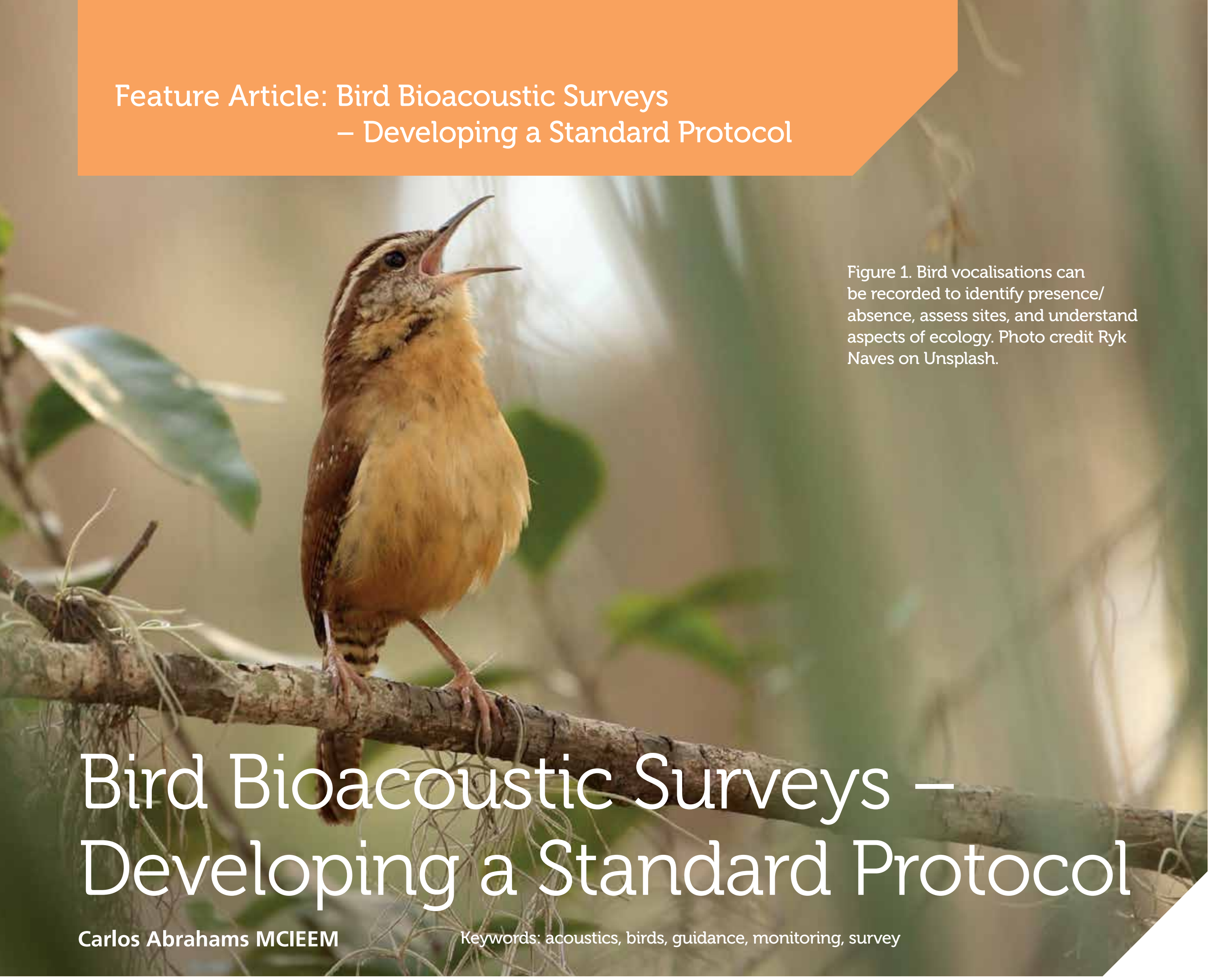

Figure 1. Bird vocalisations can be recorded to identify presence/absence, assess sites, and understand aspects of ecology. Photo credit Ryk Naves on Unsplash.

Bird Bioacoustic Surveys – Developing a Standard Protocol

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Keywords: acoustics, birds, guidance, monitoring, survey

Bioacoustic surveys can be used to capture useful and robust data on bird vocalisations to inform studies on avian distribution and ecology. However, currently there are no recognised standard methods for their use in the UK. This article sets out a draft protocol for testing and adoption, and invites feedback from CIEEM members to further develop good practice.

Introduction

Animals produce sound. Birds, amphibians, fish, invertebrates and mammals sing, squeak, click, snap, crackle, pop, rattle and hum. As ecologists, we can use these signals to detect animals in the dark or at remote locations, identify what species are present, and work out what they are doing (Figure 1). Ornithologists have always used this capacity to tell the difference between species yet, unlike bat workers, do not routinely make recordings of birds in the field as part of standard survey practice. We're missing a trick.

Birds create species-specific sounds that can be readily recorded using automated or manually-controlled recording systems. Such devices allow acoustic surveys to be undertaken for extended periods of time, with data being saved for later analysis using machine techniques and/or human assessors. This bioacoustics approach is familiar to any bat surveyor, as detectors are absolutely vital to pick up ultrasound calls to which human ears aren't attuned. However, birds can normally be seen and heard in the field without the use of specialised equipment. So, why use a bioacoustics approach for bird survey and monitoring?

The benefits of using automated recording, especially alongside traditional surveys, are well documented in scientific research (see Box 1). In particular, the ability to produce a standardised, long-duration, permanent dataset, which can be repeatedly analysed, and subject to quality assurance checks, is a major advantage over standard field surveys (Darras *et al*. 2018). There are some disadvantages – principally the lack of visual cues that would be used by a human surveyor in the field, and the fact that the static bioacoustic approach does not lend itself to preparing the territory maps often used in bird assessments (see Box 2). However, depending on the aims of the survey, bioacoustics methods have many advantages. For example, Zwart *et al*. (2015) found that acoustic recorders offered a 217% increase in nightjar *Caprimulgus europaeus* detection over human surveyors, (with 19 detections in 22 survey periods compared to 6 detections by humans). With these recognised benefits, the use of automated recorders in scientific research has increased significantly over the last ten years (Figure 2).

Human vs. machine

The bioacoustics approach, using static recorders, is equivalent to point-count bird surveys. Several studies have compared point-count data to automated acoustic recording in a variety of habitats such as rainforest (Leach *et al*. 2016), tropical savanna (Alquezar and Machado 2015), temperate woodlands (Holmes *et al*. 2014, Furnas and Callas 2015), and temperate meadows (Tegeler *et al*. 2012). These have shown that the results are comparable in terms of species-richness and bird assemblage composition when used for equivalent lengths of time. However, automated recording can easily provide larger amounts of data than human surveyors, often with less survey effort (Holmes *et al*. 2014). For example, Tegeler *et al*. (2012) gained >1,100 additional hours of data using automated recorders, and recorded more species with a quarter of the personnel effort. Using both methods together often provides the best overall results as their respective strengths and weaknesses are complementary (Klingbeil and Willig 2015, Shonfield and Bayne 2017).

Developing a draft survey protocol

Although there are myriad survey methods for bird assemblages, taxon groups and single species (Gilbert *et al*. 1998), few organisations have yet developed guidance on the use of bioacoustics methods (Darras *et al*. 2018). The World Wide Fund for Nature has recently published an introductory guide (Browning *et al*. 2017), with more detailed methods produced for tropical bird assemblages (Lacher 2008), Canadian forest birds (Saskatchewan Ministry of Environment 2014) and Australasian bittern *Botaurus poiciloptilus* (O'Donnell and Williams 2015).

To start the development of UK guidance, the first national workshop on bird bioacoustics was held in June 2017, attended by more than 40 delegates from academia, consultancies and conservation bodies. Participants were asked to grade the relative pros and cons of the approach (see Boxes 1 and 2), and a draft survey protocol was developed from the contributions (Box 3). Further input on this prototype is sought from CIEEM members, but it is considered to be a sound basis for gathering bioacoustics data for ecological assessments and site management in the UK.

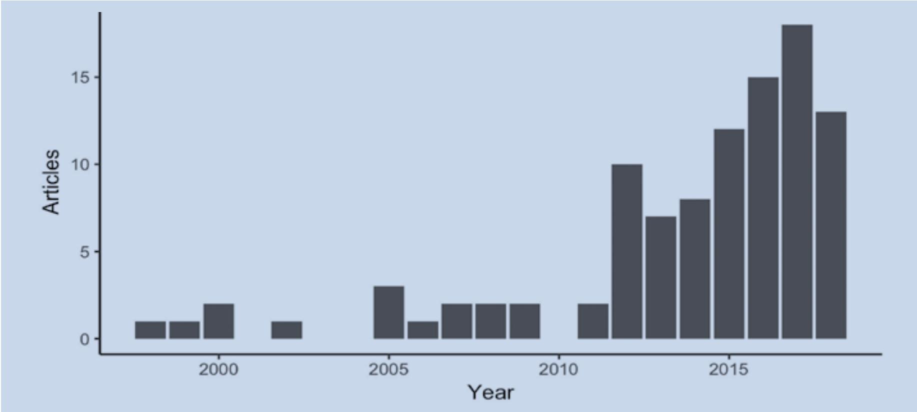

Figure 2. Number of original research articles that used recording units for avian bioacoustic studies. Search conducted on Web of Science database in September 2018 using the following search term: (bird* OR avian) (automated OR autonomous OR *acoustic) (recorder OR aru OR ard).

Box 1.

Advantages of bioacoustics	Grade 10=major; 1=minor
Long-duration data capture	7.3
Ability to **repeatedly listen** to and re-analyse data	7.1
Permanent raw data record	6.9
Greater **standardisation** in data collection	6.3
Quality assurance opportunities, with ID verification	6.0
Reduced **subjectivity** and observer **bias**	5.7
Less **disturbance** to surveyed birds	4.5
Opportunities to **share raw data**	4.3
Less reliance on **availability** of expert surveyors	3.5
H&S – avoids **night-time** work, reduces visits to **remote** areas	3.4

Box 2.

Disadvantages of bioacoustics	Grade 10=major; 1=minor
Capital **cost** of equipment	7.1
Need for improvements in **automated classification** systems	6.7
Lack of **expertise/skills** in bioacoustics	6.0
Reduced ability to cover a wide **spatial area** compared to transects	5.9
Data storage requirements	5.5
Potential for **loss of data** if units fail	5.1
Availability of **hardware/software**	4.8
Comparability with established methods	4.8
No **visual recording** of birds	4.8
The method is not yet widely **proven/accepted**	4.3

Survey considerations

1. Survey effort and timing

The recording and data volume requirements of any survey will vary depending on the project objectives and the species concerned (Bayne *et al*. 2017). The seasonal programme and daily timing of recording need to be considered, to maximise the long-term data capture benefits of automated recorders, whilst avoiding an overwhelming data mountain (Klingbeil and Willig 2015).

Bird detection probability normally varies with time of the day, so recording times distributed throughout the day will sample the entire community most effectively

(La and Nudds 2016). Scientific studies have found that a stratified 'on-off' time sampling programme (e.g. recording 1 minute in every 10), can capture comparable data to continuous recording, with consequent benefits in terms of battery life, data storage and processing time (La and Nudds 2016, Bayne *et al*. 2017). This is especially the case when recording is focused on the main dawn and evening chorus times. With prices reducing and availability of data storage increasing, continuous recording, that can be sub-sampled later in the processing stage, is also a realistic option for fieldwork.

2. Recorder placement

For coverage of a site, the aim should be to sample across the range of the habitats and species of interest, with recorders placed to limit overlap of detection radii so that counts are independent (O'Donnell and Williams 2015). The effective radius of most recorders is in the region of 50 m, so a minimum separation distance of at least 100 m should be used (Yip *et al*. 2017). As a recommended standard, a larger 250 m spacing between recorder locations would provide 16 sampling locations/km^2. This is dense enough to provide a good level of survey data, and is also likely to be relevant to the territory sizes of bird species of interest within ecological assessments. However, alternative separation distances between 100-500 m could also be used, depending on survey requirements.

When placing recorders in the field, omnidirectional microphones should be used, located horizontally 1-2 m from the ground (or higher if security is an issue), and in a mounting position that does not block the field of sound or increase the levels of background noise from wind and water (Klingbeil and Willig 2015, La and Nudds, 2016)

3. Recording equipment

There are many options in terms of recording equipment, but the best current approach uses off-the-shelf, single recorder units, which incorporate a microphone, circuitry, power source and recording media in a single unit. Examples of this are the Wildlife Acoustics Song Meters, Cornell Labs Swift or AudioMoth. These are both scaleable and easily available to a range of users.

Recorder model, microphone type, and settings should be standardised across a study and carefully recorded in metadata. Microphone management, calibration and checking is very important before and after field deployments, as degradation in microphone quality over time can significantly affect results.

4. Audio settings

For good quality audio data, a non-compressed digital file format (i.e. .WAV rather than MP3) should be used. If possible, recordings should be in stereo using a sample rate of 48 kHz and 24-bit depth (although 44.1 kHz and 16-bit depth is acceptable). These settings will cover the entire audible range, producing detailed data on frequency and amplitude to produce clear spectrograms and analysis information. If, however, the study is focussed on particular target species, with lower frequency calls, then a lower sample rate can be used to save on storage and battery life.

5. Metadata recording

With each survey deployment, appropriate metadata including location, dates/times, weather, habitat and equipment identifiers should be recorded. This can be done using paper/tablet, or by speaking into microphones while they are recording, so the metadata becomes part of the recorded data itself. This background data is clearly needed to accurately organise and archive recordings, and can be used for any detailed analysis of how environmental characteristics determine the bird acoustic assemblage. It is also important to make acoustic data as comparable as possible across different surveys, allowing use in larger-scale monitoring projects and contributions to databases.

Box 3. Draft Bird Bioacoustics Survey Protocol

1. Survey effort and timing

Surveys should include a minimum of two deployments, in April to mid-May, and mid-May to end of June, with a four-week gap between deployments. Recording should cover a five-hour period from two hours before sunrise until three hours after, with a one minute sample taken every ten minutes. Each deployment should cover a minimum of three days recording. The same methods should be used for evening recording, e.g. for dusk chorus, owls and nightjars, but using a three-hour sampling period, from one hour before sunset, until two hours after.

2. Recorder placement

Use a regular grid-based or stratified random sampling system across the survey area, with a minimum distance between sampling locations of 250 m. Recorders should be located 1-2 m from the ground, on tripods, narrow poles or trees <0.2 m diameter, avoiding branches/leaves around the unit as far as possible.

3. Recording equipment

Commercially available, off-the-shelf, single recorder units should be used to provide consistency in data collected between different studies. The recorder should be a programmable, automated unit, using omnidirectional acoustic microphones, with a flat response across the range of audible frequencies. Recorder and microphones should be individually numbered, checked and calibrated on a regular basis (at least once per year).

4. Audio settings

Recordings should be made as non-compressed .WAV files, ideally with a sample rate of 48 kHz and 24-bit depth. Lower sample rates may be used when surveying for lower-frequency, bird species (e.g. bittern) to save on storage and battery life. Before deployment, ensure that hardware and software settings are recorded and standardised across all units.

5. Metadata recording

At the start of each deployment, record the date/time, surveyor name, sampling location and recorder/microphone identifiers. Photographs of location and set-up should be taken. Weather conditions during the survey period should also be recorded.

6. Data analysis methods

Identify the presence/absence of each species in one minute audio samples and calculate the proportion of samples in which each species is recorded. Provide a summary of species observations per day or sampling event. If using any automated recogniser or clustering process, then the error rates should be checked and reported so that the quality of the recogniser can be properly assessed.

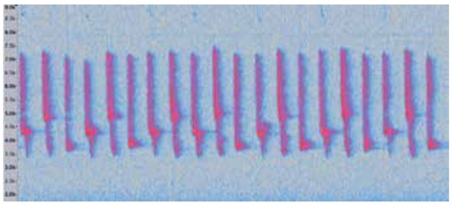

Figure 3. Bioacoustic software can be used to manage, view and analyse recordings, allowing identification of species present in the dataset, such as this chiffchaff *Phylloscopus collybita*. Image credit Carlos Abrahams

6. Data analysis methods

The analysis of data gained from acoustic recorders is perhaps the most difficult area in which to make standardised recommendations. A range of software is available to manipulate, view and analyse acoustic recordings (e.g. Kaleidoscope, Raven, Audacity, Luscinia and packages in R), some of which allow the clustering or automated recognition of bird calls (Figure 3). However, much scientific research has simply relied upon ornithologists listening to audio files and viewing spectrograms. At present, a human-supervised semi-automated process probably offers the best balance between accuracy of call classification and time required for analysis. Whichever method is used, the data analysis protocol should be fully described, and identification error rates calculated, providing metrics such as precision and recall if a recogniser has been used (Knight *et al*. 2017). The simple and robust metric of call activity, as set out in Box 3, will provide a species list for each sampling location, together with the relative vocal activity levels for each species. This presents a basic assessment of the data and will allow comparability between different studies. (Bayne *et al*. 2017).

Conclusion

Although there are still challenges to the widespread adoption of bird bioacoustics in the UK, the approach and technology is well proven around the globe in a wide variety of ecosystems and with a range of species and communities. Fully automated software to allow the recognition of all bird calls has not yet been developed, but this should not stop the use of the methods that are currently available. The draft protocol in Box 3 is targeted at the collection of species assemblage data for a particular site, such as for a breeding or wintering bird survey, but it could equally be used to focus on particular target species. Such single-species (or small group) approaches are extremely valuable, and acoustic surveys have already been conducted for conservation priorities like nightjar, corncrake *Crex crex*, bittern *Botaurus stellaris*, owls and capercaillie *Tetrao urogallus* (Abrahams and Denny 2018).

There is a good scientific basis to bird bioacoustics, great benefits to its use and a useful set of methods to follow. By sharing experience and building the practical evidence, the technique can be taken up effectively by the profession. Please help to test and refine the approach by using the draft protocol and offering feedback to Carlos Abrahams at c.abrahams@bakerconsultants.co.uk

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