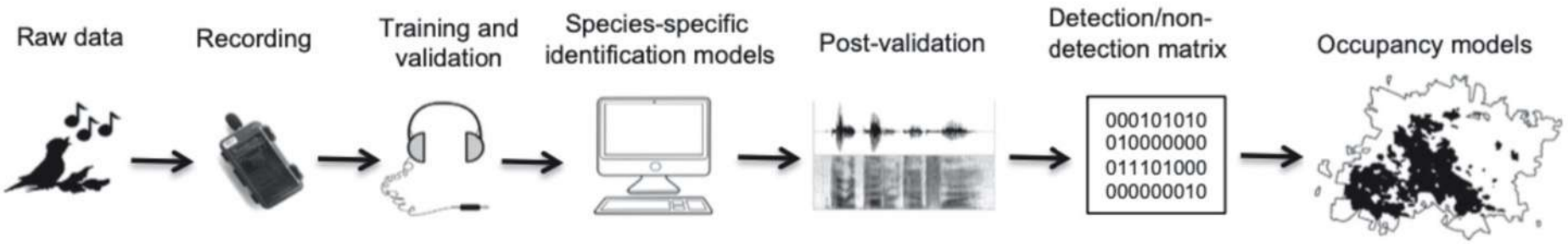
Bioacoustics:
Hardware
Software
Survey Design



Bioacoustics: how to record? Which Direction?

@abr_eco

Handheld Recorders

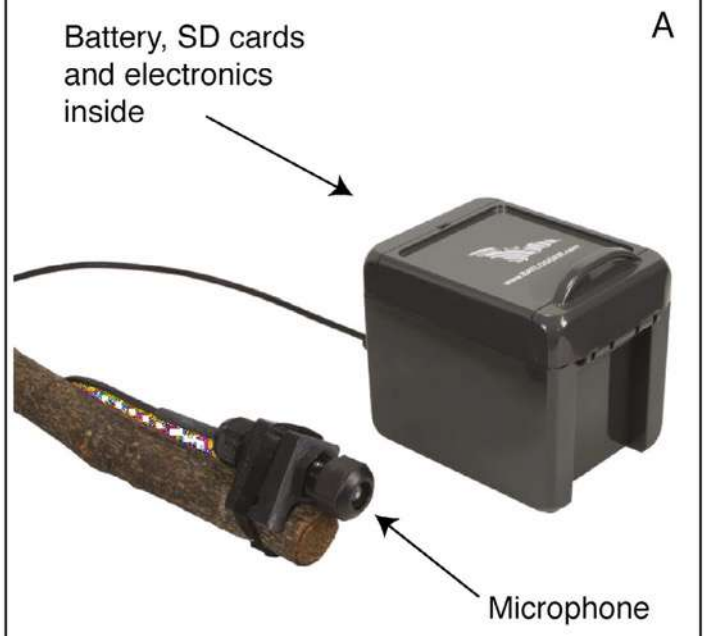
- Stereo/mono microphones
- Shotgun or parabolic
- (also lavaliers, pairs, mid-side, ambisonic etc…)
- Hydrophones!
- Separate recorder unit

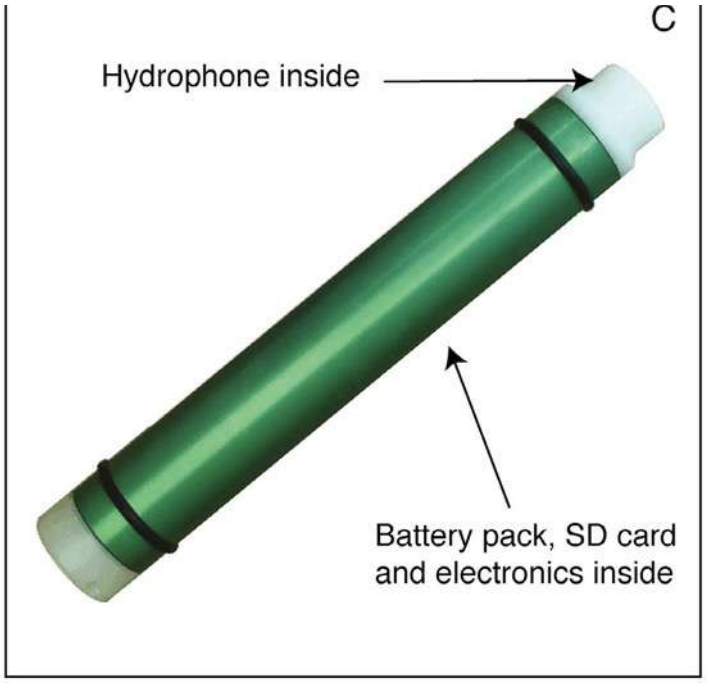
Automated Recorders

- Full spectrum recorder
- Stereo/mono microphones
- SD card slots
- Internal batteries
- Dynamic scheduler
- GPS link
- Fully waterproof

@abr_eco

Automated Recorders





Low-cost acoustic/ultrasonic logger

CASE STUDY

Audiomoth

Who wants to join a group buy?

In 2017, our members began using **WILD**LABS to coordinate large group orders of the open-source Audiomoth acoustic recorder, bringing the cost down from $700 to $50 per device.

It's $50, the size of a credit card, and can record uncompressed audio at 384,000 samples per second. The AudioMoth, designed and developed by the Open Acoustic Devices team, offers researchers and acousticians access to high quality recording at an entry level price point.

In contrast to commercial devices, AudioMoth uses a low-cost sensitive MEMS microphone mounted directly on the printed circuit board to provide a single-board solution that requires minimal packaging prior to deployment. A low-power, 32-bit microcontroller provides sufficient computational resources to run acoustic detection algorithms to trigger recordings, and yet allows long-term deployments with just three AA batteries. These devices have been used in a number of deployments to record insects, bats and birds, and to detect gunshots from illegal hunting in tropical forests in Belize.

Today, if you wanted to have a single AudioMoth produced for you using on-demand manufacturers to fabricate the device, you'd be looking at a cost of around $700. That's because the amount of effort and preparation to load the components necessary to manufacture the device on the factory floor is time consuming, and therefore expensive.

If, on the other hand, you were to order 400 devices, you'd be looking at $27 per device. And there is the root problem – users who only need a few devices are priced out, and those wishing to buy many hundreds do so privately, as there isn't an efficient way to purchase devices together as a community of users.

Alasdair Davies and the Arribada Initiative saw a need to bring independent buyers together, so we could move forward as a community, resulting in everyone having access to an affordable device – and so, the first group purchase of the AudioMoth was crafted.

Map of Audiomoth group purchase activity on WILDLABS. The shaded countries indicate number of users viewing the audiomoth discussions, and the orange markers indicating participants in the group buy.

GroupGets was selected as the payment service and distributor, and **WILD**LABS as the platform that enabled the Arribada team to get the word out beyond their immediate network to the wider conservation technology community to bring enough people together to make it viable. By word of mouth, the team knew of a handful of people who collectively wanted 100-200 devices, but through the **WILD**LABS network they connected to field conservationists all over the world keen to join the group buy.

The first group purchase round sold 400 devices to 50 users at $50 per device. This price included a small margin added to the manufacturing costs that generated proceeds of ~$4,500 that can be put back into development activities to refine existing hardware, and to help build a community of users by providing funding to technologists for small projects to develop new firmware and hardware for specific deployments.

To date, there have been four sell-out rounds with a total of 2,000 audiomoths sent around the world over the past six months. To put this in perspective, this time last year the same amount of money would have purchased roughly 100 commercial accoustic recorders. This is the start of something transformative for the conservation sector: leveraging community to get affordable tech into the hands of people that need it.

> I'm looking at presence, population density, seasonal occurrence and burrow occupancy of petrels on Macquarie Island. All part of monitoring recovery post eradication of invasive species.
>
> Huge thanks for developing such an in demand product, and disseminating it so well. Shows what a gap there's been for affordable #Tech4wildlife.
>
> Jez Bird

Methods in Ecology and Evolution

Application

Solo: an open source, customizable and inexpensive audio recorder for bioacoustic research

Robin C. Whytock ✉, James Christie

Articles

AURITA: an affordable, autonomous recording device for acoustic monitoring of audible and ultrasonic frequencies

Richard D. Beason ✉, Rüdiger Riesch & Julia Koricheva

Received 12 Dec 2017, Accepted 03 Apr 2018, Published online: 19 Apr 2018

Download citation https://doi.org/10.1080/09524622.2018.1463293 Check for updates

Recording Systems - Terminology

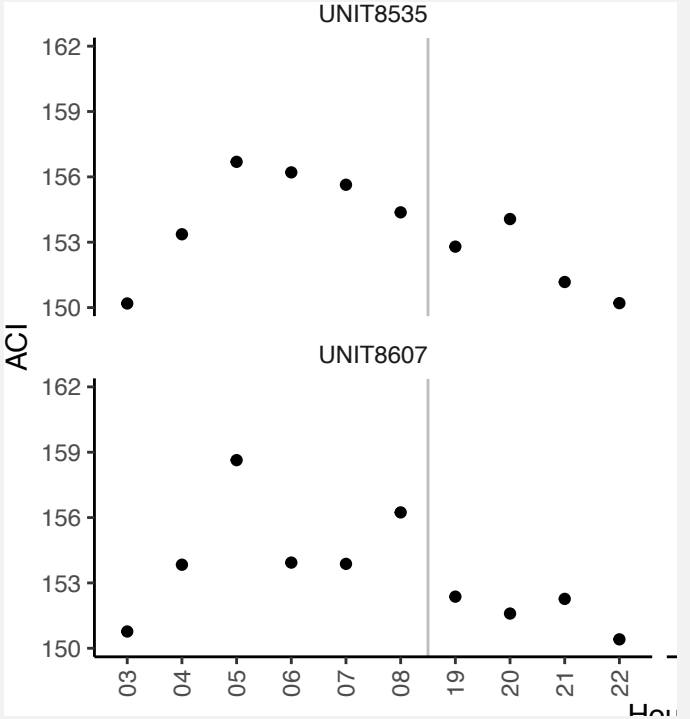
- **Recorder types**
  - **Heterodyne**
  - **Frequency Division**
  - **Zero-crossing**
  - **Time-expansion**
  - **Full-spectrum**

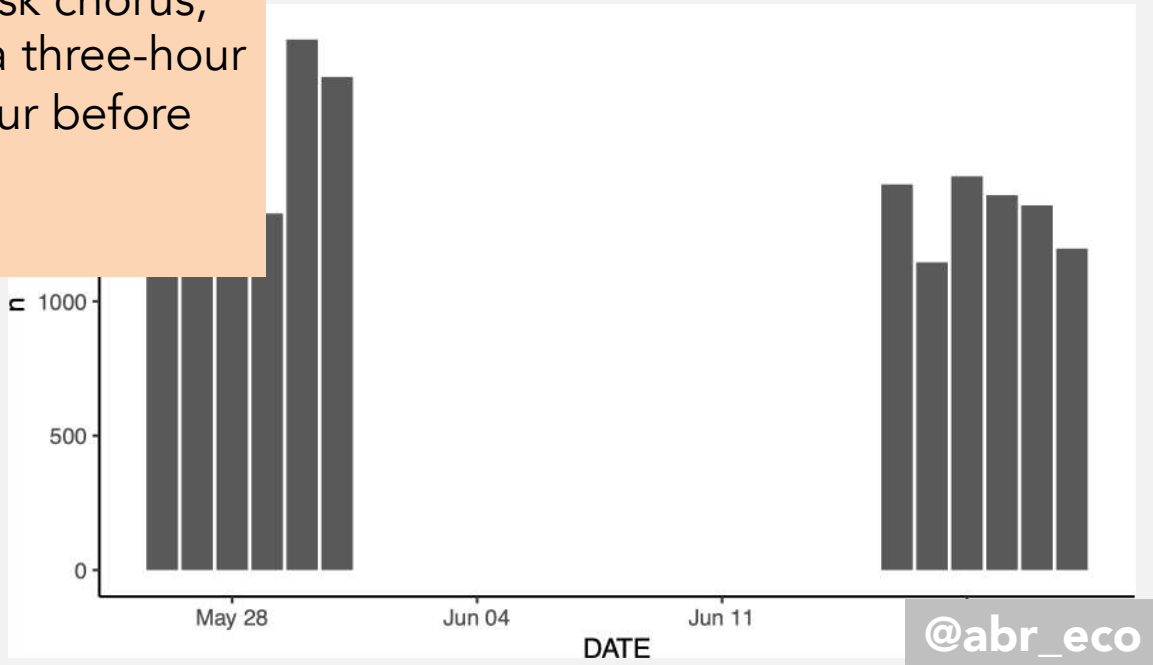
- **Sample rate**
- **Bit depth**

SURVEY DESIGN - EXAMPLE

Survey effort and timing

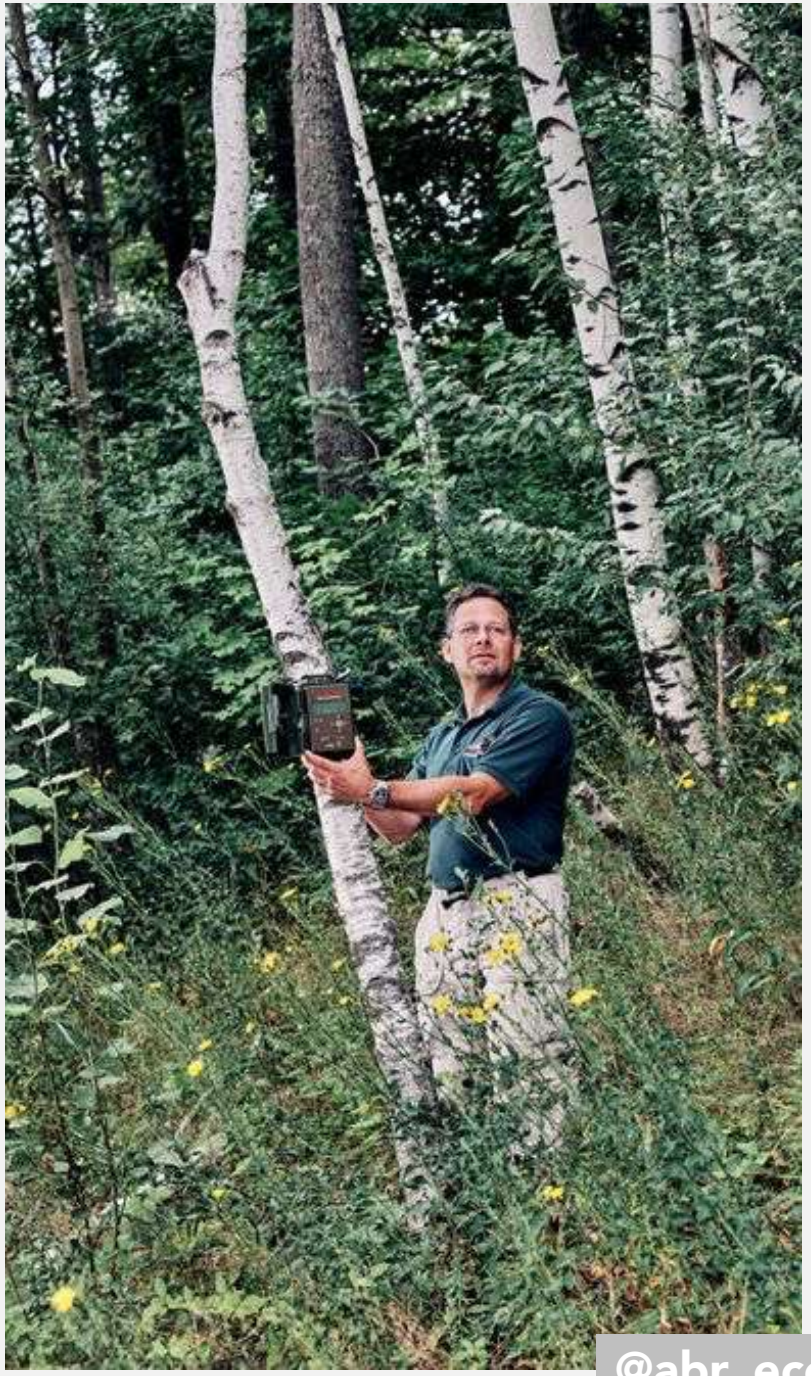
- Surveys should include a minimum of two deployments, in April to mid-May, and mid-May to end of June, with a four-week gap between deployments.
- Recording should cover a five-hour period from two hours before sunrise until three hours after, with a one minute sample taken every ten minutes.
- Each 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.





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.

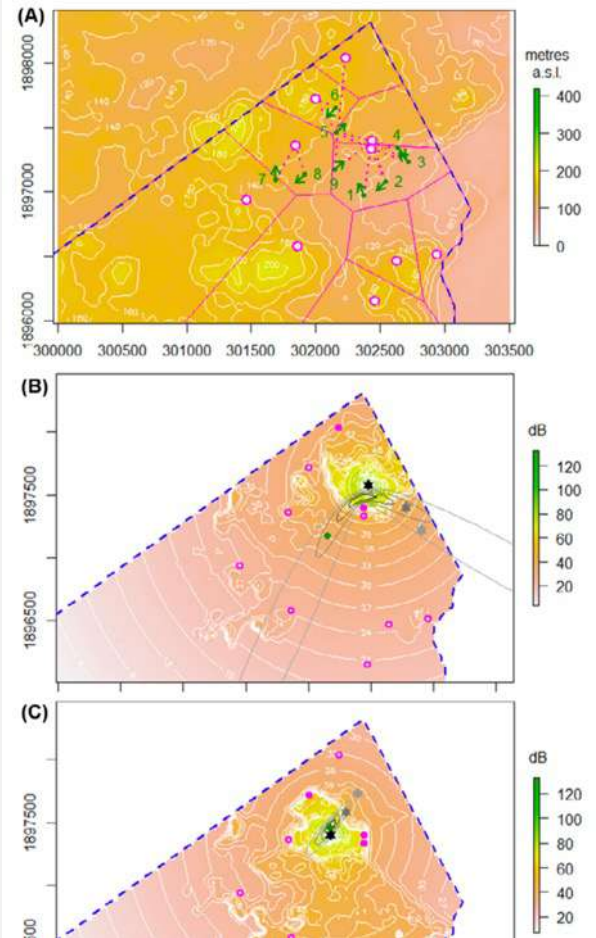


Remote Sensing in Ecology and Conservation
Open Access
ZSL LET'S WORK FOR WILDLIFE

ORIGINAL RESEARCH

Optimization of sensor deployment for acoustic detection and localization in terrestrial environments

Evelyn Piña-Covarrubias[1], Andrew P. Hill[2], Peter Prince[2], Jake L. Snaddon[3], Alex Rogers[4] & C. Patrick Doncaster[1]



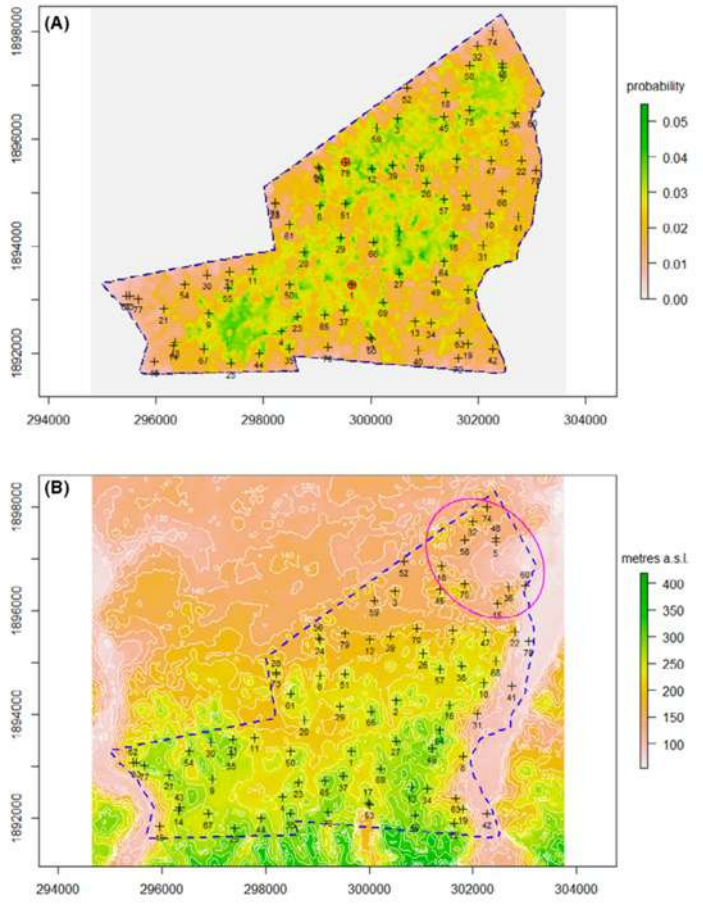


Figure 4. Near-optimal placement of AudioMoths within TMNR predicted by the greedy-heuristic algorithm, given function *g*

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).

AVIAN CONSERVATION & ECOLOGY

VOLUME 12, ISSUE 1, ARTICLE 9

Turgeon, P. J., S. L. Van Wilgenburg, and K. L. Drake. 2017. Microphone variability and degradation: implications for monitoring programs employing autonomous recording units. *Avian Conservation and Ecology* 12(1):9. https://doi.org/10.5751/ACE-00958-120109

Methodology, part of a Special Feature on Advancing bird population monitoring with acoustic recording technologies

Microphone variability and degradation: implications for monitoring programs employing autonomous recording units

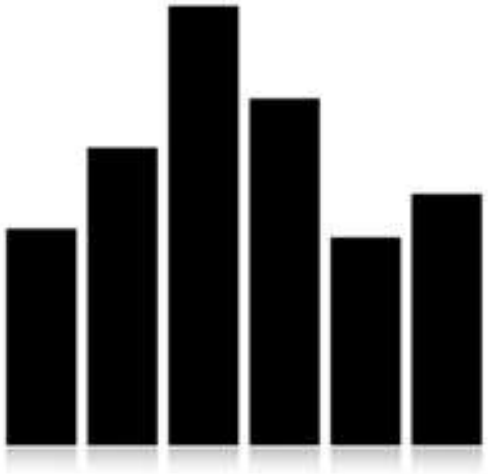
Patrick J. Turgeon [1], *Steven L. Van Wilgenburg* [2] *and Kiel L. Drake* [1]
[1]Bird Studies Canada, [2]Environment and Climate Change Canada, Canadian Wildlife Service

ABSTRACT. Autonomous recording units (ARUs) are emerging as an effective tool for avian population monitoring and research. Although ARU technology is being rapidly adopted, there is a need to establish whether variation in ARU components and their degradation with use might introduce detection biases that would affect long-term monitoring and research projects. We assessed whether microphone sensitivity impacted the probability of detecting bird vocalizations by broadcasting a sequence of 12 calls toward an array of commercially available ARUs equipped with microphones of varying sensitivities under three levels (32 dBA, 42 dBA, and 50 dBA) of experimentally induced noise conditions selected to reflect the range of noise levels commonly encountered during avian surveys. We used binomial regression to examine factors influencing probability of detection for each species and used these to examine the impact of microphone sensitivity on the effective detection area (ha) for each species. Microphone sensitivity loss reduced detection probability for all species examined, but the magnitude of the effect varied between species and often interacted with distance. Microphone sensitivity loss reduced the effective detection area by an average of 25% for microphones just beyond manufacturer specifications (-5 dBV) and by an average of 66% for severely compromised microphones (-20 dBV). Microphone sensitivity loss appeared to be more problematic for low frequency calls where reduction in the effective detection area occurred most rapidly. Microphone degradation poses a source of variation in avian surveys made with ARUs that will require regular measurement of microphone sensitivity and criteria for microphone replacement to ensure scientifically reproducible results. We recommend that research and monitoring projects employing ARUs test their microphones regularly, replace microphones with declining sensitivity, and record sensitivity as a potential covariate in statistical analyses of acoustic data.

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.

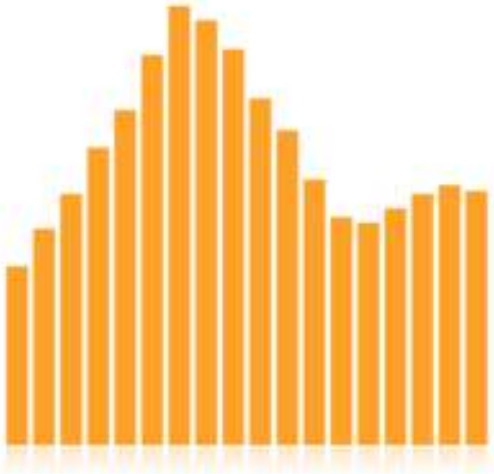
```
Audio Settings:
-Sample rate    16000
-Channels       Stereo
-Compression      Off
-Gain left   + 0.0 dB
-Gain right  + 0.0 dB
-Advanced settings
```



MP3

44kHz, 16bit 128kbps

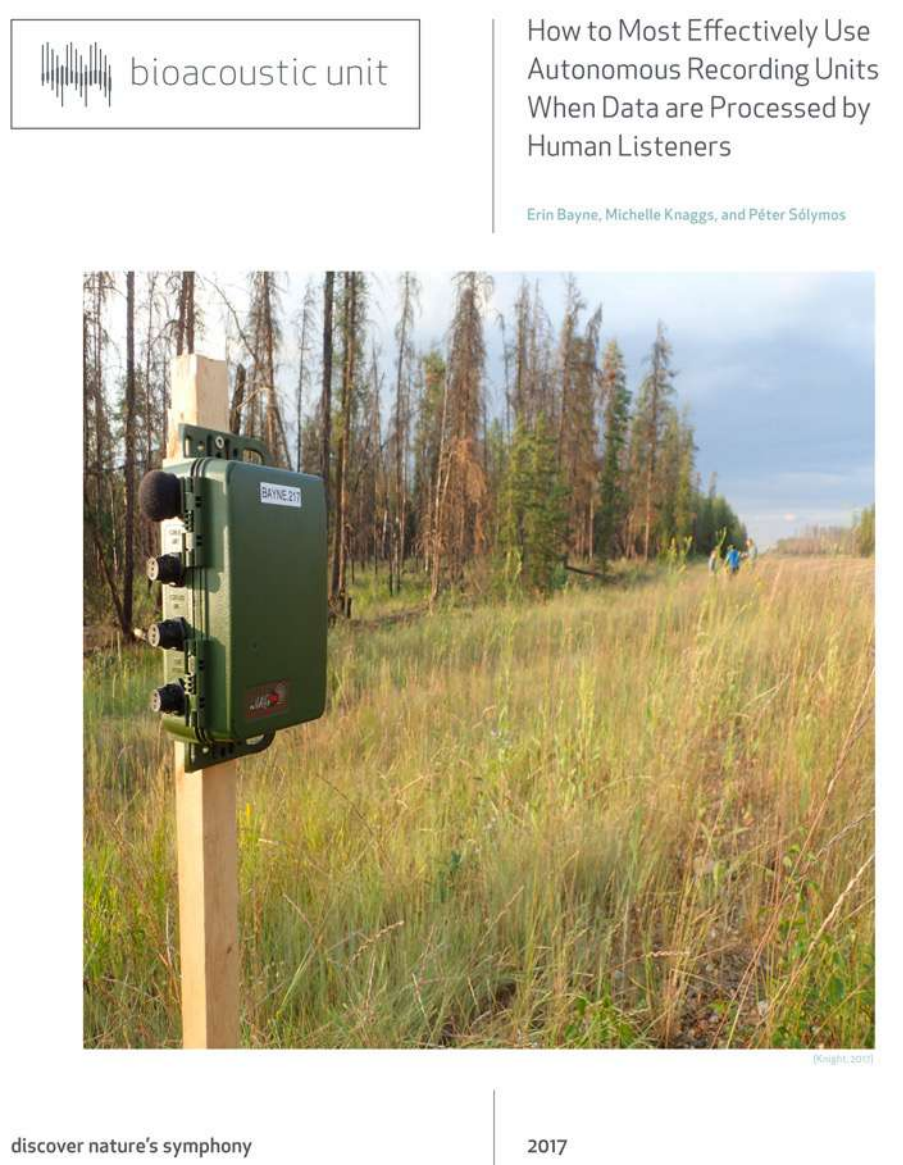
- vs -



WAV

96kHz, 24bit 4096kbps

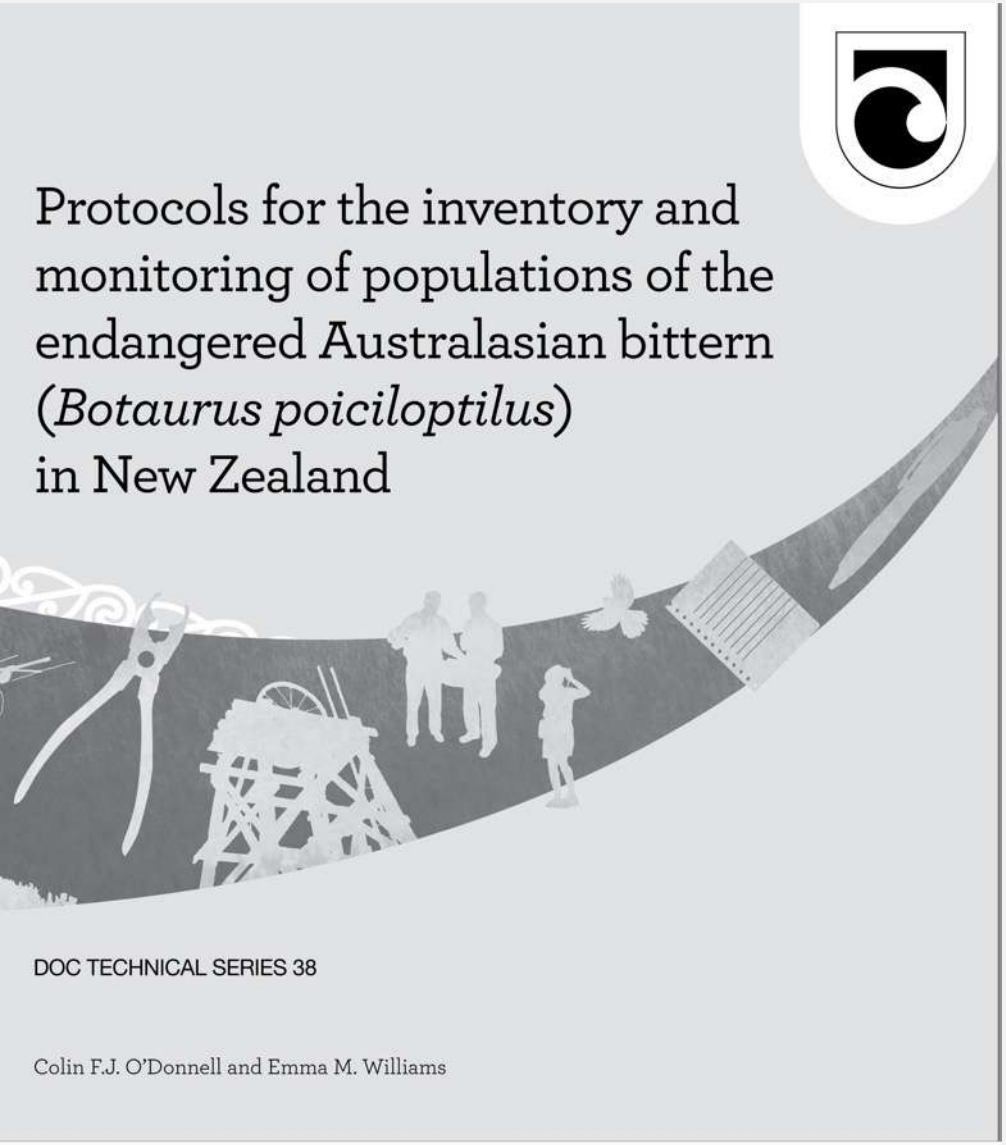
Other Bird Protocols



Overall recommendations:

a. How long you place an ARU and how much data you process depends on your objective. Thus, there is no one answer that optimizes results for all species or for all questions.
b. For passerines, there is strong evidence that shorter duration point counts (1-minute) will increase detection rates and allow for greater number of recordings from different days to be processed. This will result in more species found faster.
c. No firm recommendation on whether the total time should be 3,5, or 10 minutes per recording processed at this time. However, we do strongly recommend that listening in 1-minute time blocks within any longer interval provides the greatest flexibility in methods from an ARU and highest return on listening investment.
d. A single day of recording does not seem to be the best way to estimate occupancy or assess probability of occurrence. Leaving an ARU for several days seems to provide a reasonable balance in getting detections from species that hold territories close to an ARU while also increasing the probability of getting rarer species with larger home ranges

Other Bird Protocols



Estimate (index) of the number of booming males using Acoustic Recording Devices (ARDs) (inventory & monitoring)

• Measures: Automated dawn counts of booming male call rates using recording devices as a one-off inventory or for longer term monitoring. Counts can be repeated in the same way annually to obtain data on:

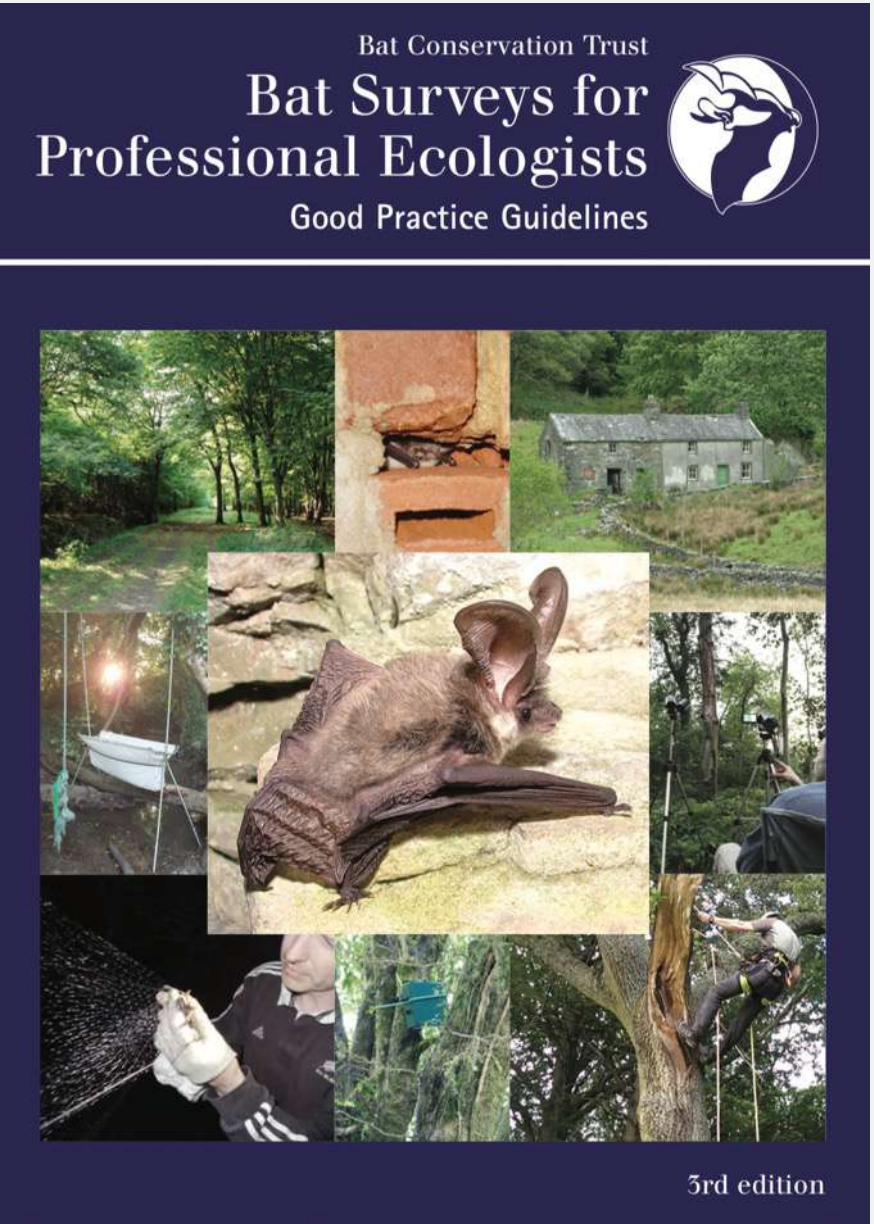
– Changes in the mean calling rates of birds detected

– Occupancy (site occupancy of a standard number of recording stations)

• Means of detection: Detects the calls of breeding males (booms) using automated recorders.

Suitability: This method is particularly suitable for large wetlands where it is not possible to map the locations of bitterns or across a network of sites. In these situations, an index of call activity is used as a surrogate for estimating actual numbers (E. Williams et al. unpubl. data). ARDs can also be used for one-off inventories.

Bat Protocols

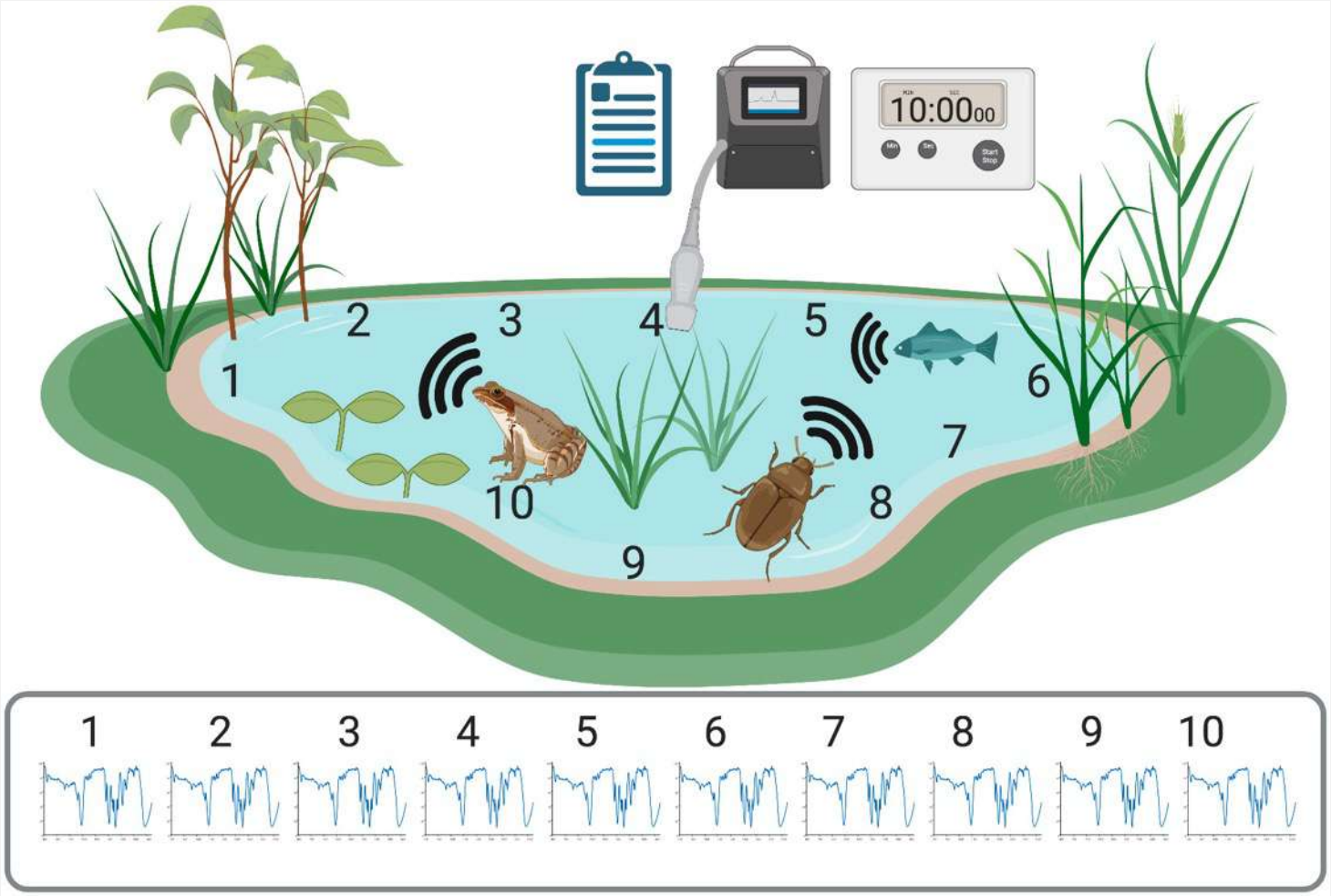


BATS AND ONSHORE WIND TURBINES:
SURVEY, ASSESSMENT AND MITIGATION

Version: January 2019

This document has been prepared jointly by Scottish Natural Heritage, Natural England, Natural Resources Wales, RenewableUK, Scottish Power Renewables, Ecotricity Ltd, the University of Exeter and the Bat Conservation Trust (BCT) with input from other key stakeholders.

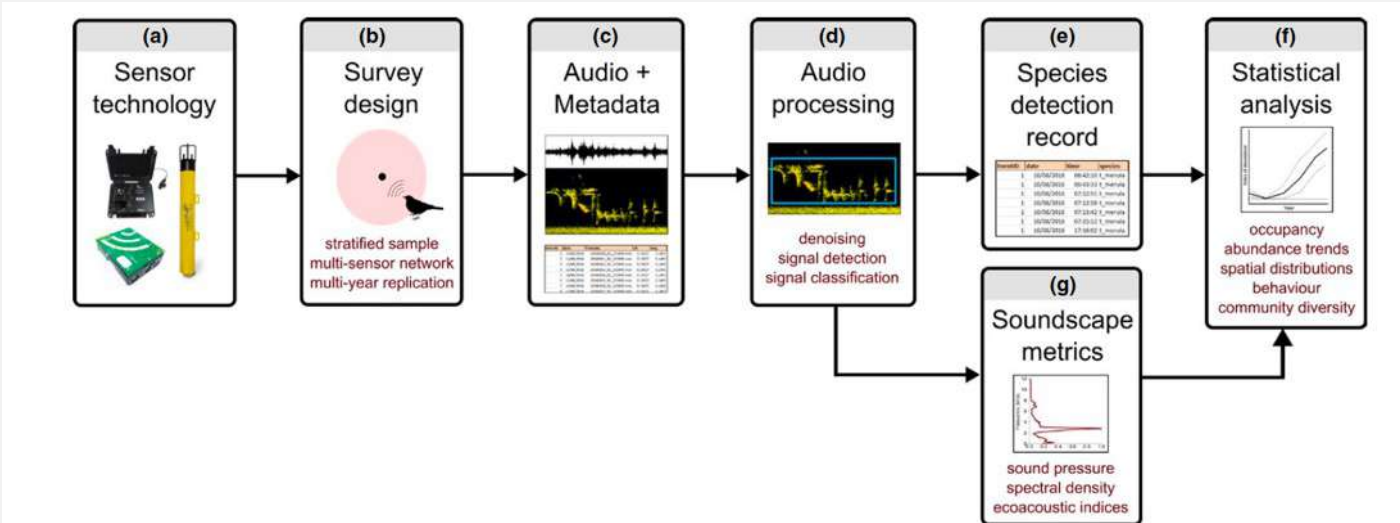
Pond Protocol



Abrahams, C, Desjonquères, C, Greenhalgh, J. Pond Acoustic Sampling Scheme: A draft protocol for rapid acoustic data collection in small waterbodies. *Ecol Evol*. 2021; 00: 1– 12. https://doi.org/10.1002/ece3.7585

Data Storage and Metadata

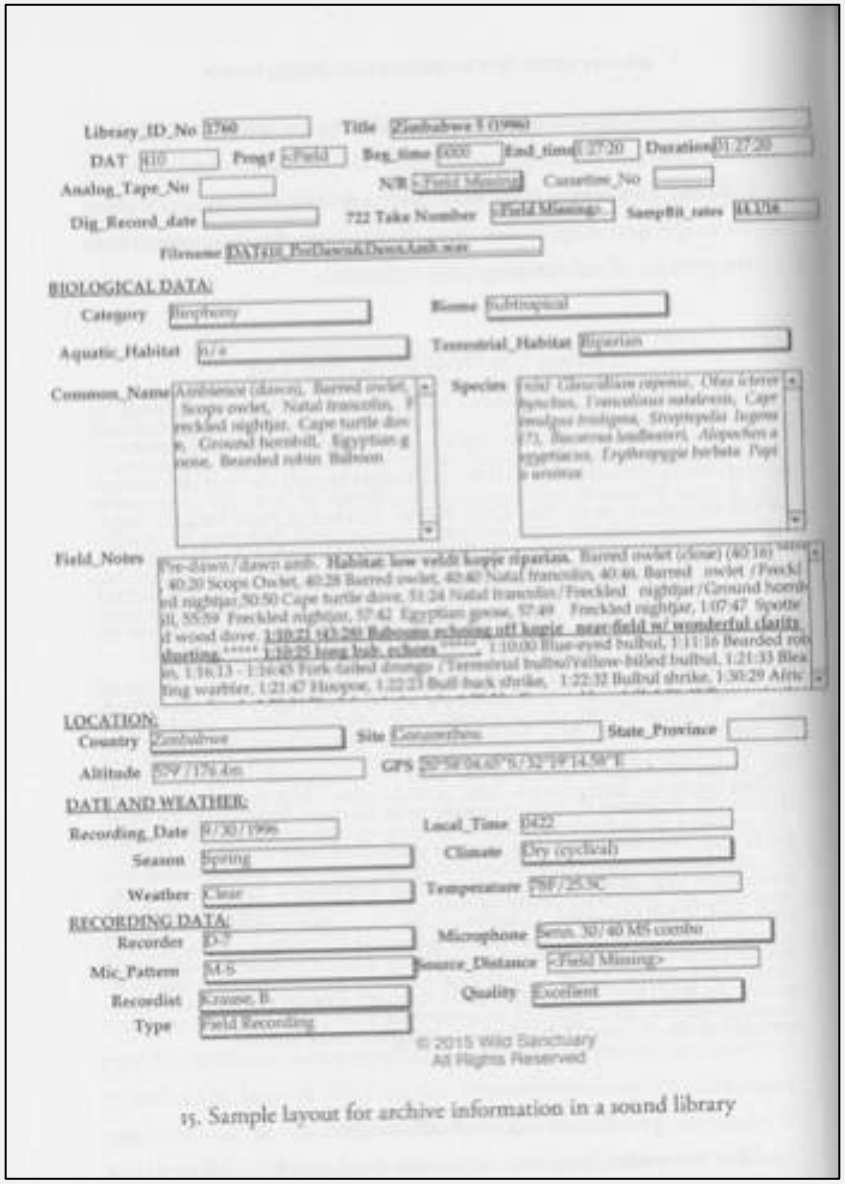
- Plan in advance how the data mountain will be managed and analysed.
- Design a clear workflow – storage, processing, analysis
- Test with representative dummy data



Metadata & Slating

- Most recording systems will automatically apply some metadata to .wav files (GUANO?)
- For acoustic recording you should add to this.
- Slate and add notes

- What data is important to you?



15. Sample layout for archive information in a sound library

Kaleidoscope Metadata

Ecological Informatics
Volume 31, January 2016, Pages 122-136

Management of acoustic metadata for bioacoustics

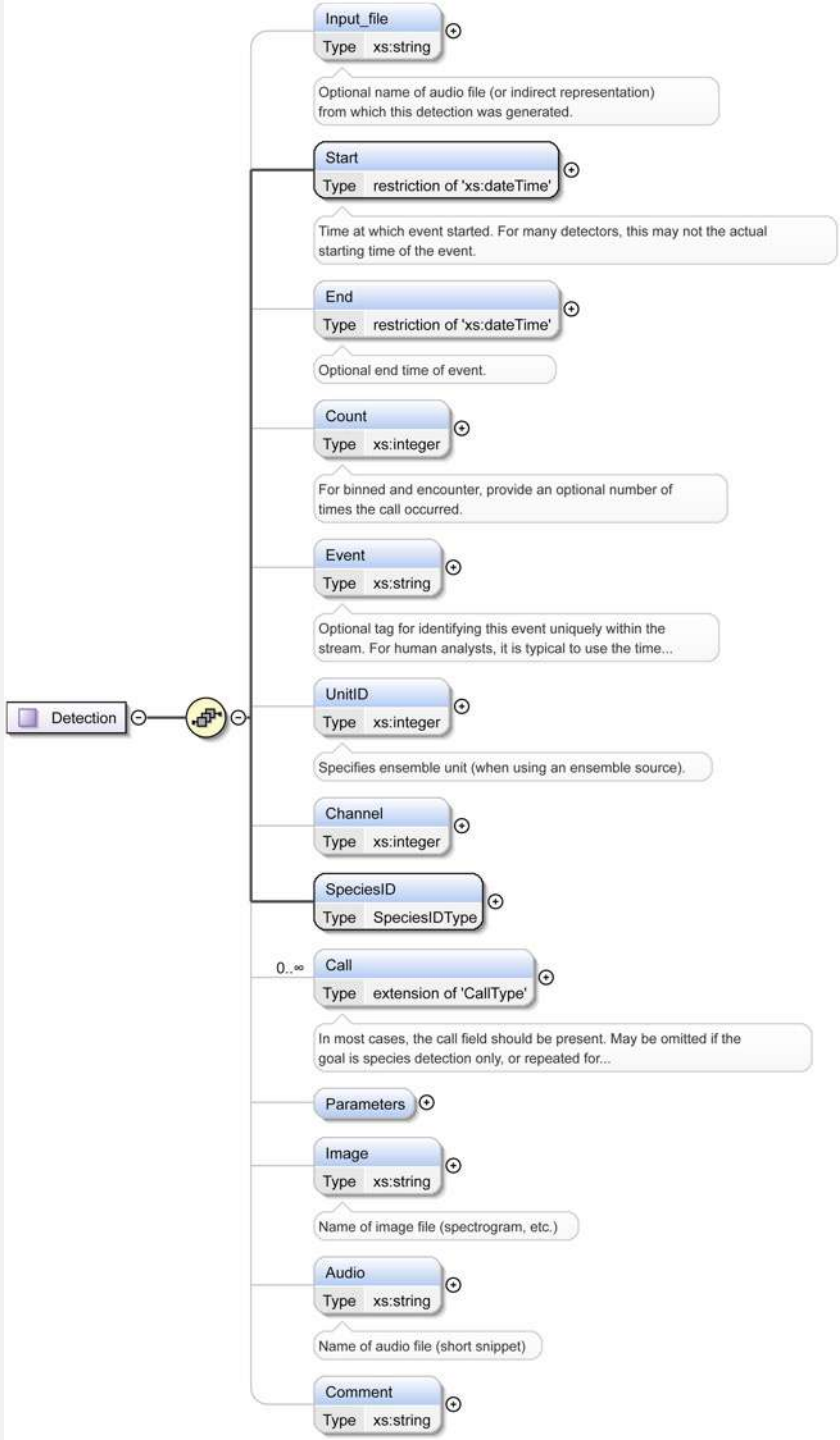
Marie A. Roch [a], Heidi Batchelor [b], Simone Baumann-Pickering [b], Catherine L. Berchok [c], Danielle Cholewiak [c], Ei Fujioka [d], Ellen C. Garland [c], Sean Herbert [b], John A. Hildebrand [b], Erin M. Oleson [c], Sofie Van Parijs [c], Denise Risch [c], Ana Širović [b], Melissa S. Soldevilla [c]

Show more

https://doi.org/10.1016/j.ecoinf.2015.12.002

Highlights

- A method of representing bioacoustic metadata in a consistent manner is proposed.
- Consistent representation enables merging results from multiple studies for large spatiotemporal analyses.
- A client-server workbench implements the proposed metadata representation and enables access to a large body of Internet-available geophysical, biological, and astronomical data products.



Bioacoustic software - a variety of analysis approaches

IEEE Access
10.1109/ACCESS.2020.2978547, IEEE Access

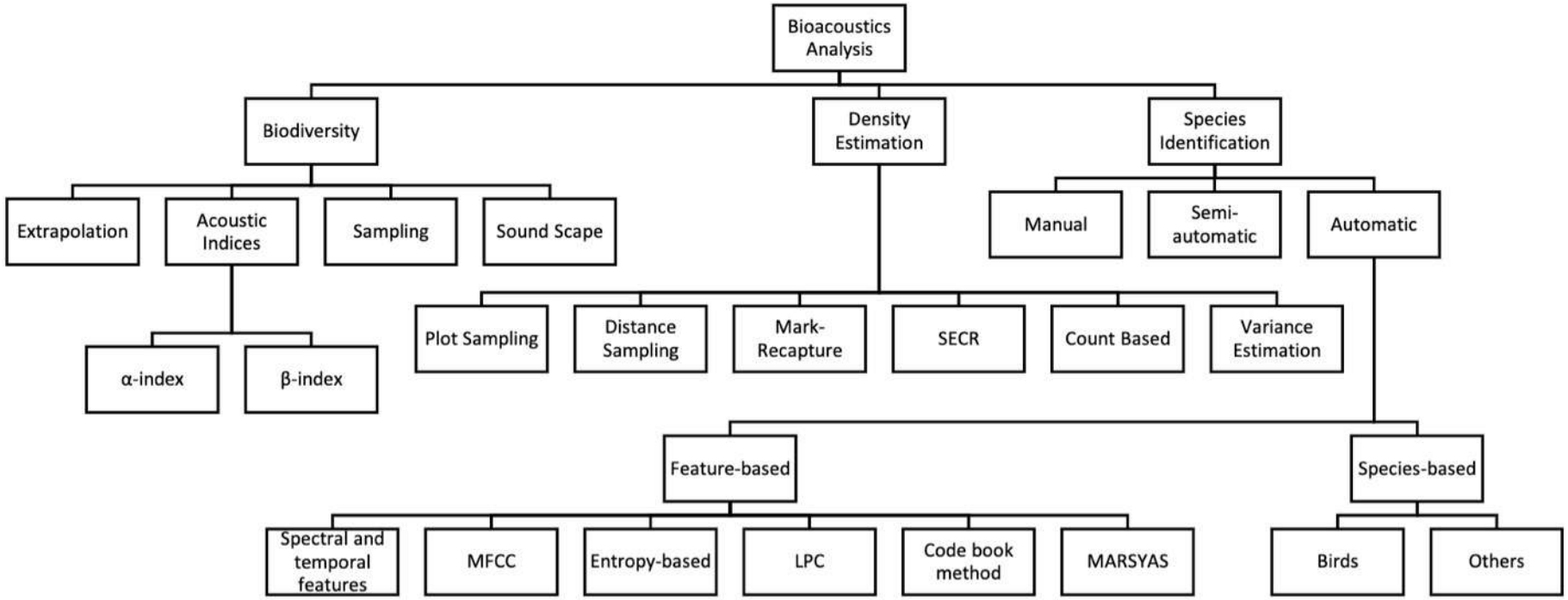


FIGURE 2. Analyses Taxonomy

Display, edit, analyse data…

Many different software packages available:

- Audacity
- Kaleidoscope
- R (seewave, etc)
- Luscinia
- Raven
- Tadarida
- Arbimon
- PAMguard
- MATLAB
- BTO Pipeline
- Wavesurfer… etc

Check Wikipedia - https://en.wikipedia.org/wiki/List_of_Bioacoustics_Software
And Cornell Lab Tutorials at: https://www.macaulaylibrary.org/resources/audio-editing-tutorials/
And Tessa Rhinehart listing on github: https://github.com/rhine3/audiomoth-guide/blob/master/resources/analysis-software.md
Audacity Guide at: https://www.xeno-canto.org/article/146
Kaleidoscope tutorials and manual at: https://www.wildlifeacoustics.com/products/kaleidoscope-pro

...and all these...

Software	Availability	Summary	Website
ARBIMON II	Free initially, charges apply for larger quantities of data	Cloud-computing based bioacoustics storage and analysis platform (Aide 2013); features include visualising and annotated recordings, soundscape analysis and automated call detection via pattern matching.	arbimon.sieve-analytics.com
Audacity	Free, open source	Intuitive, general-use audio software that enables listening, viewing spectrograms, subsetting and annotating files.	www.audacityteam.org
AudioTagger	Free	Free audio software for listening, viewing and manually annotating large volumes of audio files.	github.com/groakat/AudioTagger
AviSoft	Proprietary (AviSoft-SASLab Pro); free (Lite)	Bioacoustic analysis software, functions include visualisation and annotation, automated classification tools (spectrogram cross-correlation), geo-referencing tools and noise analysis.	www.avisoft.com
BatScope	Free	Free software for visualising and analysing full-spectrum bat recordings, including automatic species call classifiers.	www.wsl.ch/dienstleistungen/produkte/software/batscope/index_EN
iBatsID	Free	Free software tool for classifying European bat call recordings to genus and species (Walters *et al.* 2012); requires call parameters extracted by SonoBat (see below).	ibatsid.eu-west-1.elasticbeanstalk.com
CPOD.exe	Free	Free software for analysing data collected by T-PODs and C-PODs. Reads raw data from the C-POD SD cards and detects trains of cetacean clicks and classifies into groups (e.g. narrow-band high frequency clicks and other cetaceans).	www.chelonia.co.uk/cpod_downloads.htm

Ishmael	Free	Specialised bioacoustics software from CIMRS, with a marine emphasis. Includes visualisation and annotation tools and functions for aquatic sound localisation and automated call recognition.	www.bioacoustics.us/ishmael.html
Kaleidoscope	Proprietary (Kaleidoscope Pro), however spectrogram viewer tool is free	Software package by Wildlife Acoustics for bioacoustic analysis, including methods to visualise and annotate files, tools for cluster analysis and classifier training, batch processing, and bat call classifiers.	www.wildlifeacoustics.com/products/kaleidoscope-software
PAMGUARD	Free, open-source	Open-source package for bioacoustic research, with an emphasis on marine mammals. In addition to core acoustic analysis functionality, a variety of plugins are available for more complex signal processing and analysis, including detection, classification and localisation.	www.pamguard.org
Pumilio	Free, open-source	Open-source application for managing bioacoustic recordings, including visualising, annotating and manipulating sound files (see Villanueva-Rivera *et al* 2012).	ljvillanueva.github.io/pumilio
Raven	Proprietary (Raven Pro); free (Raven Lite)	Sound analysis software from Cornell Lab of Ornithology, with functions including visualisation/annotation, call detection and spectrogram correlation.	www.birds.cornell.edu/brp/raven/RavenOverview.html

Seewave (R package)	Free, open source	Package for the open-source statistical environment R, providing a range of tools for bioacoustic analysis including visualisation, annotation and calculating acoustic indices.	rug.mnhn.fr/seewave
Song Scope	Proprietary	Software by Wildlife Acoustics for spectrogram visualisation, including over long timescales.	www.wildlifeacoustics.com/products/song-scope-overview
Sonobat	Proprietary	Software for analysis of full-spectrum bat recordings; features include visualisation, call detection, parameter extraction and species classification.	www.sonobat.com
SonoChiro	Proprietary	Software for automated analysis of full-spectrum bat recordings, designed for use with large volumes of data. Includes automated species classifiers for Europe and the Neotropics.	www.biotope.fr/fr/accueil-innovation/sonochiro
Soundecology (R package)	Free, open source	Package for R providing functions to calculate soundscape indices from spectrograms.	cran.r-project.org/web/packages/soundecology/index.html
Tadarida	Free	Open software and code for developing and applying an acoustic classifier.	github.com/YvesBas (Bas *et al.* 2017).
WarbleR (R package)	Free, open-source	Package for R providing a range of functions for batch processing of bioacoustic signals, including spectrogram visualisation, feature extraction, cross-correlation functions and recording quality assessment	cran.r-project.org/web/packages/warbleR/index.html

KALEIDOSCOPE PRO ANALYSIS SOFTWARE

ANALYZE TERABYTES OF ACOUSTIC OR ULTRASONIC RECORDINGS QUICKLY AND EASILY.

Kaleidoscope Pro is an integrated suite of software tools that let you cluster and visualize recordings, automatically identify bats, and analyze sound.

EXPLORE KALEIDOSCOPE PRO:

- Cluster Analysis
- Auto-ID for Bats
- Kaleidoscope Viewer
- Managed Cloud Accounts
- Noise Analysis
- Easy Report Generation

Available for Windows, Mac and Linux operating systems at a 12-month Professional subscription of $399. University subscription of $299 is also available. Contact Sales for University purchases.

Audacity®

Search ...

HOME ABOUT DOWNLOAD HELP CONTACT GET INVOLVED DONATE COPYRIGHT

Free, open source, cross-platform audio software

Audacity is an easy-to-use, multi-track audio editor and recorder for Windows, Mac OS X, GNU/Linux and other operating systems.

Developed by a group of volunteers as open source.

DOWNLOAD AUDACITY

Latest version : 2.3.2

View Release Notes

Documentation

R Resources

Seewave
SoundEcology
Monitor

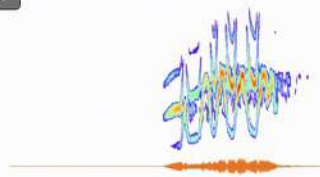
Warbler
tuneR

Bioacoustics in R SEARCH RESOURCES ▼ MARCELO ARAYA-SALAS AUTHOR'S HOME

Bioacoustics in R

R code for the analysis of animal acoustic signals

Screenshot



Marce10.github.io

The advantage of R over most common sound analysis software (e.g. Raven, SAP, Avisoft) is its higher flexibility, which allows the implementation of custom made analyses that better fit the research questions and the characteristics of the vocalizations. However, this requires some proficiency in R coding that may dissuade beginners. Hopefully the codes I make available here will encourage bioacousticians to take advantage of this powerful tool.

Most of the tools I have developed for acoustic analysis are now available in the package warbleR. I will also post R scripts to detail the usage of new addtions to this package. Check out the article describing warbleR. Please cite this paper when using any of the package functions.

Sound analysis in R has been made possible owing to the awesome package seewave. Take a look at seewave's website to learn more about its different tools. I will also post code containing functions from the packages monitoR and tuneR.

Use R!

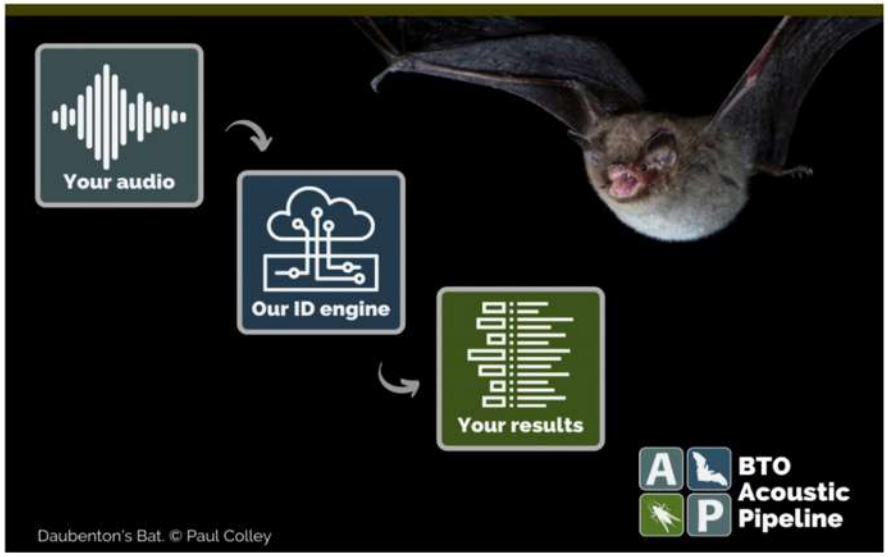
Screenshot

© 2018

Sound Analysis and Synthesis with R

Authors: **Sueur**, Jerome

Details sound analysis and synthesis principles



GO TO DATA ENTRY

Join the project

NEW TO BTO?
Create account first

HAVE AN ACCOUNT?
Log-in & sign-up

Time / skill required

A few minutes to set up your account and start uploading data.

Our Desktop Client and Data Portal are simple to use. You will need a PC running at least Windows 7 (or above) or Apple OS X 10.10 (or later).

The BTO Acoustic Pipeline brings cutting-edge sound identification of bats and other nocturnal wildlife to your desktop.

It provides the infrastructure to allow audio recordings (wav files) to be uploaded to a secure remote server in the cloud, to be processed to find and identify biological sounds, and to return results back to your computer.

Project Lead

Stuart Newson

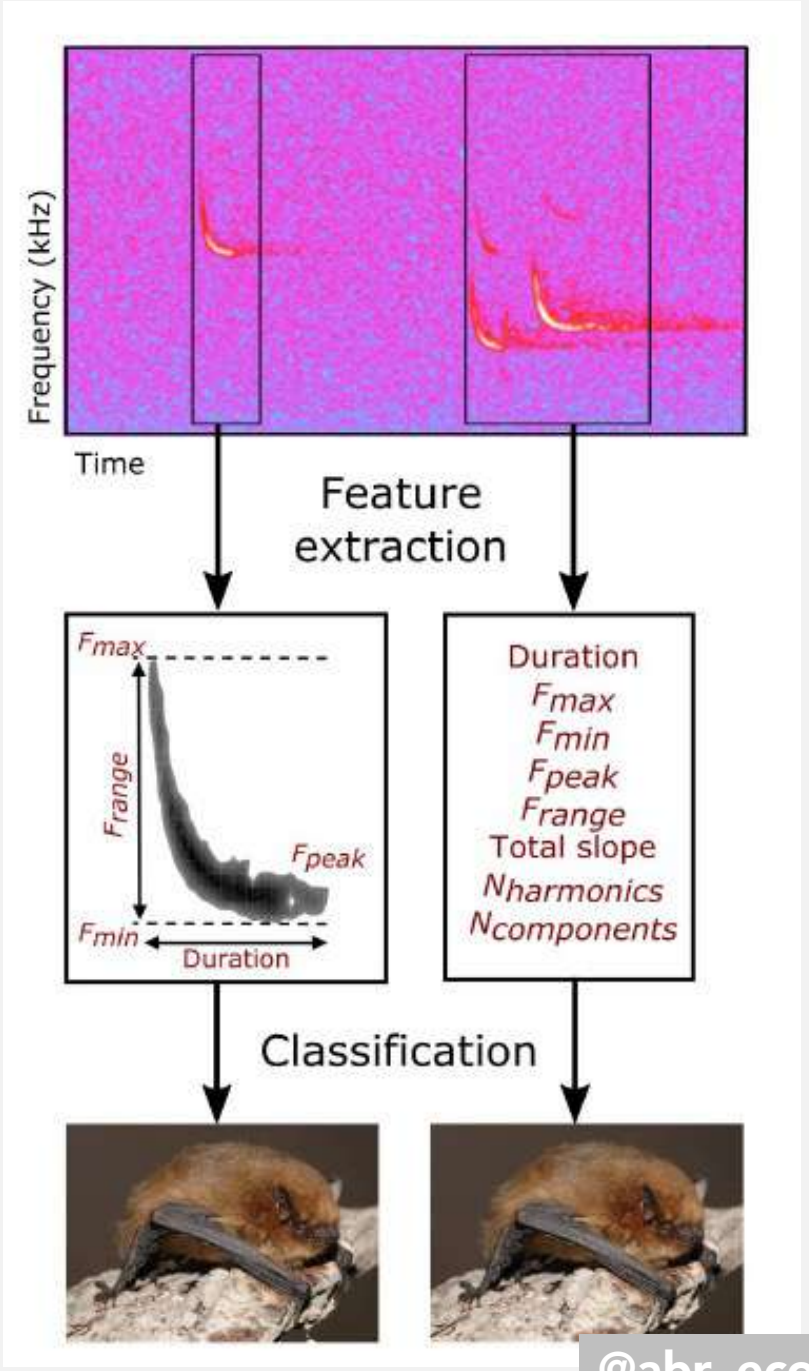
Email Contact

acoustic.pipeline@bto.org

Analysis and interpretation

- Process:
  1. Denoise/selection
  2. Signal detection
  3. Signal classification
  4. Analyse dataset

- Recognizers/Classifiers



Gibb et al.. (2018). doi.org/10.1111/2041-210X.13101

Kaleidoscope Pro

- Cluster analysis
- Cluster recognition
- Recogniser construction

CLUSTER ANALYSIS

LABEL RECORDINGS AND CREATE CUSTOM CLASSIFIERS, FAST.

Within minutes, Kaleidoscope Pro can quickly analyze thousands of ultrasonic or acoustic recording files. The software detects similar vocalizations, and groups them into Clusters. This innovative feature eliminates hours of tedious listening, making it much easier to examine vocalizations and label recordings.

For acoustic recording files, Kaleidoscope Pro's clustering technology lets you build your own classifiers from known recordings to help you find matching patterns in new recordings.