ENVIRONMENTAL MONITORING METHOD:

Bat Monitoring with Audio Recording Units

About This Method

This document helps you to monitor bats by recording their calls with Autonomous Recording Units (ARUs). This method has been adapted from: Passive acoustic monitoring in ecology and conservation, E. Browning, R. Gibb, P. Glover-Kapfer & K. jones (WWF-UK) and Standardisation in bat acoustic research: a review of reporting practices in Australia, Sheldrick, K., Hill, D. A., Fleming, P. A., & Steven, R. You can find more information on the Monitoring Country website: monitoringcountry.org.au or scan the QR code.

This method has three parts: **1. Get Ready**, **2. Out on Country** and **3. Back in the Office.** Each part can be undertaken separately but you must complete all three parts to finish the method. At the end of the document, you will find guidance for all the gear you need - **Gather Your Gear – Complete List**.

We recommend you read the whole document before you start.

Part 1: Get Ready

GATHER YOUR GEAR

Equipment required for this part:

- ☐ Tablets/phones with:
  - ability to take photos
  - data collection and navigation apps
  - ARU app (optional)
- ☐ Laptop/computer with software for:
  - mapping
  - setting up ARUs (optional)
- ☐ GPS device (recommended)
- ☐ Autonomous Recording Units (ARUs; 1 per site). Check that each has:
  - blank SD card with > 32 GB capacity
  - charged batteries
  - weather-proof casing
- ☐ Permanent marker

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Bat Monitoring with Audio Recording Units

KEEP IN MIND

Why?

Make sure there is a clear monitoring question and that the method you have selected will answer the monitoring question.

If this is the first time you are monitoring, you will need to design the survey: what are you monitoring, where will you survey, and when and how often you will survey?

When?

Prepare well before heading out on Country so that you have time to gather gear or train staff, if needed.

Who?

1 ranger/staff to plan and prepare

Training and skills

Staff involved in planning are trained and competent in:

- ☐ Mapping software (like QGIS or Google Earth) and/or monitoring point generator
- ☐ Navigation systems (like Avenza app or GPS device)
- ☐ Data collection systems (like Fulcrum app or paper datasheets)
- ☐ Setting up Audio Recording Units (this will depend on the type of ARU you buy and use)

Check permissions

Consult with Traditional Owners, landholders and relevant government agencies and authorities, to determine appropriate access and approvals for environmental monitoring:

1. Where you can go – consult with the owners/managers of the land.
2. What you can do – check if you need scientific licences or ethics permits
3. What or who can you take photos of
4. What can be done with data and photos – who owns them, where will they be stored and how will data be interpreted and communicated.

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ACTIONS

Design the survey

If you have done this monitoring before, it is best to do the surveys at the same time and same sites so that you can compare the data to previous surveys and see if there have been changes.

1. Decide whether you want to monitor one or all bat species in your study area
   - This will guide where your sites are, when you will survey, and how long the ARUs will be deployed for
2. Gather species of interest records in your area
   - Such as from Traditional Owners, Atlas of Living Australia (ALA) or government databases
   - This can identify which species you might detect or which habitat the species you are interested in might live in
3. Learn about the species you plan to monitor:
   - Check that their calls can be identified reliably via acoustic recordings, which species are hard to tell apart, and the frequency range of their calls
   - Find out what kind of habitat and landscape features they use or live in, such as waterbodies, forests, gorges and caves
   - Find out when they are most active, migrate or change behaviour (time of night, season or time of year)
4. Decide what ARUs and other equipment you will use. See buying guides for advice on which brand and model may be suitable to buy.
   - There are many options, like Song Meters, AudioMoth or Titley Chorus
   - Check if the device can record the ultrasonic frequencies of the bats you are interested in.
   - It is best to use the same type/model of ARU across all sites
5. Decide on a consistent mounting height for your ARUs, either:
   a. 1.5 metres above the ground using standard star pickets OR
   b. 3 to 5 metres above the ground using extension poles if you need to get the microphones into flying "tunnels" beneath tall forest canopies
6. Decide what time of year and how often you will do the survey
   - The timing of the survey should be when the target species are most active. Bats can migrate or change their behaviour throughout the year:
     - Insectivorous bats are usually most active in warmer months when insects are abundant

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    - Some cave-dwelling species gather in roosts in winter
  - Repeating the survey in different seasons throughout the year or across years may improve the story the data tells
7. Decide on the ARU recording schedule, standard settings are:
    a. Night recording, start 30 minutes before sunset and finish 30 minutes after sunrise
    b. Set devices to “trigger” mode where the device records when it hears a sound
    c. Set the post-trigger window to 2 seconds so the end of the call isn’t lost
    d. Survey for a minimum of 4 nights
8. Use the monitoring point generator or mapping software to select your sites
  - Target preferred flyways and landscape features where bats are most likely to travel based on their flight style and call range. For example, choose narrow creek lines and vegetation gaps for small, high-pitched bats, or large open waterbodies for low-pitched, fast-flying bats
  - If you are targeting one species:
    - Space your ARUs based on how far that bat travels each night (their home range) so that individual bats aren't recorded more than once
    - Put your ARUs in areas where you are likely to detect them based on records or habitat type
  - If you are interested in the whole bat community:
    - Have equal numbers of ARUs in each of the major habitat types. Try to have more than one site in each habitat type (replicates)
    - Space ARUs based on the type of habitat you are surveying and the home ranges of the species you expect to find. For example, at least 500 metres apart for smaller forest bats, or 1 to 2 kilometres apart for fast, wide-ranging species
9. Give each site a unique name, and export and save the location data in your data management system
10. Plan how you will process and analyse the audio recordings (manually and/or auto-recognition software)
  - There are many free and accessible audio processing software options like Kaleidoscope, Raven, WarbleR, and Arbimon
  - Training is required for each software but there are usually guides and videos

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Bat Monitoring with Audio Recording Units

Make a plan and prepare for the survey

1. Plan which dates you will put the ARUs out and collect them
   - Aim for periods with no rain, low wind, and warmer overnight temperatures, as bats don't fly or call during heavy rain, high winds or unseasonable cold events
   - Batteries, SD card size, air temperature and recording settings will change how long the ARUs will keep recording
   - If you are leaving ARUs out for a long time, plan to service ARUs (change SD cards and batteries) at some point during the survey
   - Check the weather forecast before finalising your dates.
2. Prepare maps of sites and load sites onto navigation devices
3. Plan how you will record information on Country (electronic data forms or paper datasheets)
4. Plan your data management system (how you will store sound recordings and ARU deployment data
   - Audio recordings can take up a large amount of memory/space, so it is best to keep them in a cloud-based server (online) and have a local back-up copy (hard drive)
5. Check **GATHER YOUR GEAR** lists for **Get Ready**, **Out on Country** and **Back in the Office** (complete list on last page) and get any equipment you don't have.
   - See buying guide(s) for advice on which ARUs may be suitable to buy
6. Charge electronic devices (tablets/phones, power banks, GPS) and batteries

Train

1. Check the **Training and skills** requirements for **Get Ready**, **Out on Country** and **Back in the Office** steps and arrange any training or expertise that you need
2. Consider whether you will need expert help in identifying species from calls
   a. Identifying calls can be difficult if you are not familiar with the species
   b. There are online libraries of bat calls like Australian Bat Acoustic Data Collection
   c. You can contact experts who may be able to help identify species in your area
3. Run everyone involved in the survey through the plan
   - Be clear on how many people will be involved, what everyone will be doing, and what they will need to do the survey
4. Run a training session for all rangers involved in the survey to learn or refresh:
   a. How to use the devices (like tablets/phones and GPS)
   b. How to use data collections apps and record data
   c. How to program ARUs

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Set up the ARUs

1. Read through the ARU user guide (depending on which units you are using)
2. Give each ARU a unique name (like ARU01) and write it in permanent marker on the cover of the ARU and its matching SD card
    - If you plan to service the ARUs or move them to different sites during the survey, make sure the ARU has another SD card. Write the same name on the card and something to show that it is the second card (like ARU01B)
3. Check that the SD card is empty
4. Insert the SD card into the ARU
5. Put charged batteries into the ARU
6. Turn the ARU on to set it up for recording
    - Use the manufacturers step-by-step user guide for more detail
    - Check all ARUs are updated to the same software (firmware) version
    - Some ARUs have an app or software that can be downloaded to your tablet/phone/computer to help with set up
    - Ensure the settings are identical across all devices, especially volume/sensitivity (audio gain)
7. Set the recording format to .wav, .FLAC or .W4V
8. Set the recording resolution to 16 bits
9. Set the sampling rate to double the maximum frequency of sounds of the target species (generally 200kHz for bats)
10. Set the recording schedule
11. Check that the SD card has space
12. Check that the date and time are correct
13. Turn off the device

The ARU is now ready to be used, and when you turn it on in the field, all of the settings will be retained.

Next Section – Part 2: Out on Country

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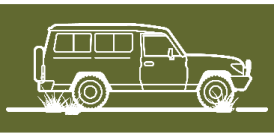
Part 2: Out on Country



GATHER YOUR GEAR

<u>One set</u> of this equipment for <u>each team</u>:

- ☐ Tablets/phones
- ☐ Power bank (optional)
- ☐ GPS device and spare batteries (recommended)
- ☐ Hammer, mallet, or picket driver
- ☐ Multi-tool or side cutter for snipping cable ties
- ☐ Spare batteries (if servicing ARUs)
- ☐ Flagging tape (optional)

<u>One set</u> of this equipment for <u>each site</u>:

- ☐ Autonomous Recording Unit (ARU) with
  - Charged batteries, blank SD card and preprogrammed settings
- ☐ Star picket (at least 1.8 m or 2.1 m if putting in sandy soil)
- ☐ 300 mm x 4.8 mm sized cable/zip ties
- ☐ If sampling heights above 1.5m:
  - Extension pole (3 – 5 m telescopic pole)
  - 3 tension straps or guy lines
  - 3 tent pegs

KEEP IN MIND

Where

If livestock or other wildlife might damage ARUs, you may to need to change the timing of the survey, move the site or have guy lines to keep animals away.

Who?

2 rangers per team

Training and skills

Make sure everyone knows the plan.

Field staff are trained and competent in:

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- ☐ Navigation systems (like Avenza app or GPS device)
- ☐ Data collection systems (like Fulcrum app or paper datasheets)
- ☐ Identifying habitat types for species of interest
- ☐ Deploying ARUs in the field

ACTIONS

Check that your electronic devices (tablets/phones, power banks, GPS, batteries) are charged before you head out.

Ground truth sites

1. If this is your first time doing the survey, go to each site to check that it is:
    a. Accessible – can you access it? Are there creeks, thick vegetation, steep or rocky terrain that prevent you reaching the site?
    b. Suitable habitat – is it a place bats will actually use? Look for natural flight paths like vehicle tracks, gaps in the trees or waterholes where bats come to drink and hunt.
2. If needed, move sites so that they are more accessible and/or in a better bat flyway.
3. If a site is moved, record new location coordinates.

Deploy ARUs

1. Choose a spot to deploy the ARU that is:
    a. Facing a clear, open flight path (like a track or water surface) but has a 5 to 10-metre clear buffer zone directly in front of the microphone.
    b. Away from things that will make high-frequency noise, like leaves rustling in the wind or loose flagging tape.
    c. Angled *away* from bare, flat rock walls or fringing reeds, which cause echoes and distort the recording.
    d. Above where long grasses may grow while the ARU is deployed, as tall grass dampens the bat calls.
2. Mark the ARU location on your navigation device
    - Brightly coloured flagging tape can help to locate the site when you come back
3. Hammer in the star picket
4. Attach the ARU with a cable tie/ziptie to the stop of the star picket so that it is:
    a. At your chosen project height (at least 1.5 m above the ground, or higher using an extension pole if sampling beneath a tall forest canopy)

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b. Secure/doesn't move around
c. Microphone pointed down the centre of the clear flight path, track, or waterbody
d. Microphone pointed slightly down (typically at a 45-degree angle)
    i. This allows rain or dew to drain away and prevents water damage
    ii. DO NOT POINT THE MICROPHONE UP
e. If using pole-mounted bat ARUs, Faunatech's step-by-step guide is helpful

5. Snip off the ends of the cable tie/zip tie
6. Turn on the ARU
7. Perform a quick "scratch test" by rubbing your fingers together directly in front of the microphone to ensure it triggers and records properly
8. Check that the ARU has an empty SD card, charged batteries and has preprogrammed recording settings.
9. Record **deployment data**

Service ARUs (optional)

10. Turn off the ARU
11. Eject the SD card and replace it with a new, blank SD card
12. Remove the dead batteries and replace them with charged batteries
13. Check that the ARU is firmly attached, and the star picket is solidly in the ground
14. Clear away any plant growth under the ARU that could cause noise.
15. Turn on the ARU
16. Record **service data**

Collect ARUs

17. Turn off the ARU
18. Cut the cable tie to remove the ARU from the star picket
19. If you don't plan to monitor at the site again, remove the start picket and flagging tape
20. Record **collection data**

RECORD DATA

Data to record when deploying ARUs

What to record	Required?	Notes
Information to record about each ARU deployed		
Project name	Yes	Make it clear which project this data belongs to and its purpose
Date	Yes	Record the date the ARU was put out on Country

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Personnel	Yes	Record the name of the people who put out the ARU - this is helpful if any questions come up about the data
Site name/number	Yes	Record the site name/number where the ARU was put out
Location coordinates	Yes	Record an accurate location of where the ARU was put at the site (using a handheld GPS if possible) (latitude and longitude or eastings and northings)
ARU ID	Yes	Record the name written on the ARU
SD card ID	Yes	Record the name written on the SD card
ARU height	Yes	Record the exact height of the microphone above the ground (e.g. 1.5 m or 4 m on a pole)
ARU gain setting	Yes	Record the volume/sensitivity setting (gain) programmed into the device
Weather	Yes	Note down the general weather forecast for the deployment period (e.g. heavy rain, high winds, or unseasonable cold)
Information to record about each site		
Fire age	Optional	Record the fire history of the site.
Habitat notes and or photo	Optional	Describe or take a photo of the habitat type at the site. Note down specific features like open waterbodies, tree hollows, or clear tracks. Make note of which device it was taken on, and the filename of the photo (usually ends in .JPG)
Signs of disturbance	Optional	Types and causes of disturbance you can see at the site (e.g. signs of introduced predators, vegetation clearing, wrong-way fire)
Stories and notes	Optional	Record information or stories from Elders, and anything else worth noting about the area or animals.

Data to record when servicing ARUs

What to record	Required?	Notes
Information to check is correct when servicing an ARU		
ARU ID	Yes	Check that the name written on the ARU is correct
SD card ID	Yes	Check that the name written on the SD card you take out of the ARU matches the ARU ID
Location	Optional	Check that the location is correct (using a handheld GPS if possible) (latitude and longitude or eastings and northings)
Information to record about each ARU serviced		
Project name	Yes	Make it clear which project this data belongs to and its purpose
Date	Yes	Record the date the ARU was serviced
Personnel	Yes	Record the name of the people who serviced the ARU - this is helpful if any questions come up about the data
Site name/number	Yes	Record the site name/number
SD card ID	Yes	Record the name written on the new SD card you put into the ARU

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ARU issues	Optional	Record if anything has gone wrong with the ARU (e.g. dead batteries, full SD card, ARU damaged by stock or rain, vegetation has grown lots)

Data to record when collecting ARUs

What to record	Required?	Notes
Information to check is correct when collecting an ARU		
ARU ID	Yes	Check that the name written on the ARU is correct
SD card ID	Yes	Check that the name written on the SD card you take out of the ARU matches the ARU ID
Location	Optional	Check that the location is correct (using a handheld GPS if possible) (latitude and longitude or eastings and northings)
Information to record about each ARU collected		
Project name	Yes	Make it clear which project this data belongs to and its purpose
Date	Yes	Record the date the ARU was collected
Personnel	Yes	Record the name of the people who collected the ARU - this is helpful if any questions come up about the data
Site name/number	Yes	Record the site name/number
ARU issues	Optional	Record if anything has gone wrong with the ARU (e.g. dead batteries, full SD card, ARU damaged by stock or rain, vegetation has grown lots)

Next section – Part 3: Back in the Office

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Part 3: Back in the Office

GATHER YOUR GEAR

Equipment required for this part:

- ☐ Tablets/phones (or paper datasheets) that you used to record data
- ☐ Data management system
- ☐ Laptop or computer with software for:
  - Spreadsheets
  - Mapping
  - Acoustic recordings analysis, like:
    - Kaleidoscope – free or paid; view, listen to, and label audio recordings
    - Raven – free or paid; view, listen to, and label audio recordings
    - WarbleR – requires use of R statistical software
    - Arbimon – global online platform
- ☐ SD card from the ARUs

KEEP IN MIND

When?

Always try to complete this work as soon as you can after returning from your time on Country so that recordings on the SD cards aren't overwritten or lost.

Who?

1 person to manage the data

Training and skills

Staff managing data are trained and competent in:

- ☐ Mapping software (like QGIS or Google Earth)
- ☐ Spreadsheet software (like Microsoft Excel)
- ☐ Data collection systems (like Fulcrum app or paper datasheets)
- ☐ Data management systems (like databases, cloud storage and external hard drives)
- ☐ Using acoustic recordings analysis software

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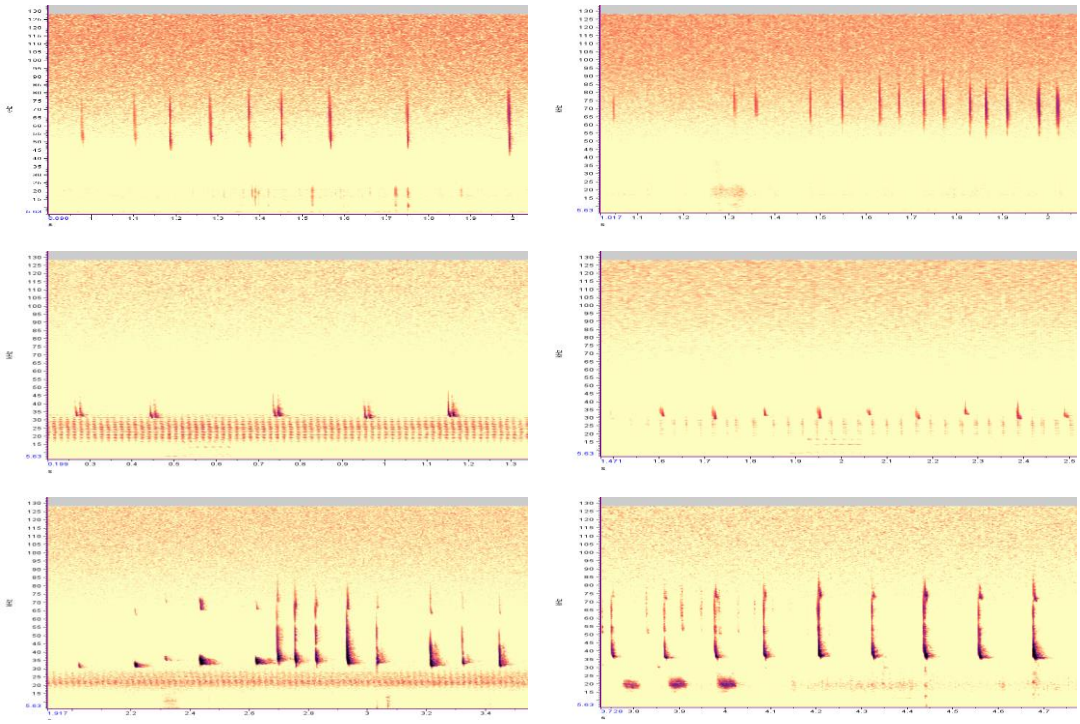
ACTIONS

Data entry, analysis and reporting

1. Record a summary of what you did and why, any observations (like weather conditions, fire history and site condition), anything that went wrong or didn't work and things that worked well.
2. Upload the **ARU deployment, servicing and collection data** to your data management system
   - Recommended: get someone else to proof the data to check for mistakes
3. Upload any photos or videos taken during the survey to your data management system
4. Remove SD cards from ARUs and upload to your data management system
5. Use acoustic recordings analysis software to check recordings and identify species calls
   - Contact experts to help confirm calls and check for any that may have been missed - some species have calls that vary a lot and can be easy to misidentify



Example of how the calls look in the processing software (audio visualisations)

6. To help with identifying calls, create bars graph of low, mean, and high frequency ranges from similar call samples can help visualise what may be different species or species behaviours

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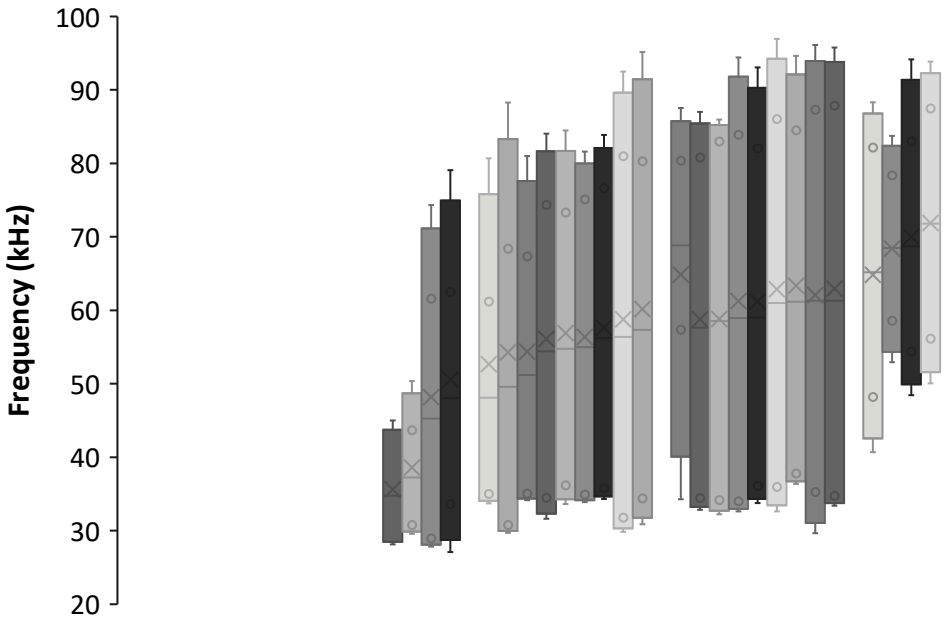
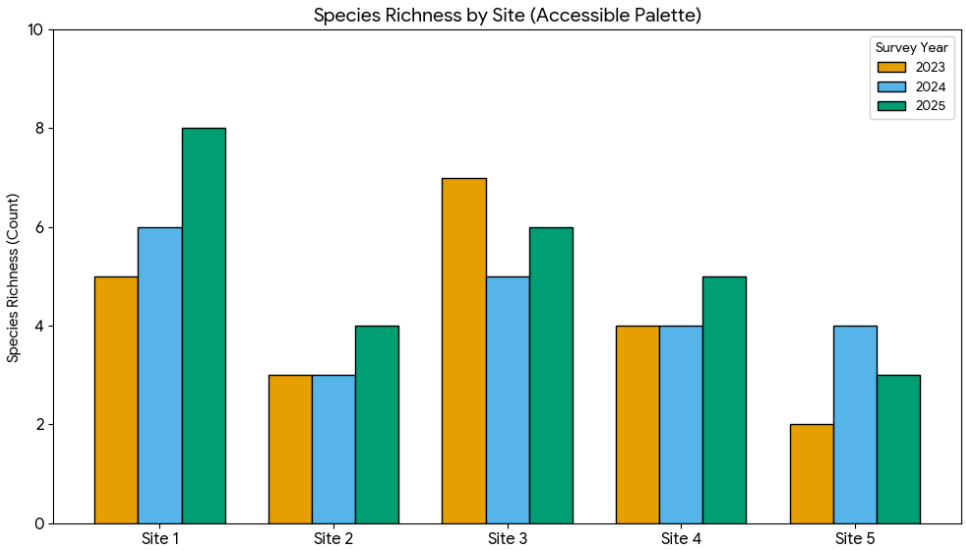


Example of observed frequency ranges (mean low and high frequency, minimum frequency, maximum frequency, median) of three distinct vocalisation clusters from bat audio surveys.

7. Import the data into a spreadsheet and:
    a. calculate species richness – the number of species you detected during surveys
    b. Create a simple line or bar graph to compare species richness across different sites and over time



An example of how site level species richness data can be presented in a graph to track changes over time or show differences between sites (Image created with assistance from Gemini, a large language model by Google AI).

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8. Use the mapping software to create a map of
    a. All sites surveyed
    b. Presence and absence maps (Where is the species detected and not detected?)
    c. Presence and absence maps over time (Is where species being detected changing over time?)
9. Discuss with the ranger team or community the results of the monitoring, any reasons for the presence or absence of species of interest, and if there have been any changes to previous years
    - Consider whether trends might be related to your management (like cat control or fire management) to check how well management is working, or if you need to make adjustments
10. Share the data according to any data sharing or funding agreements you have made

Next section – Full Equipment List

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Gather Your Gear – Complete List

The complete **GATHER YOUR GEAR** list for **Get Ready**, **Out on Country** and **Back in the Office**.

Gear List	Required?	Get Ready	On Country	In Office
Tablets/phones: • Ability to take photos • Apps for data collection (like Fulcrum) and navigation (like Avenza)	✓	✓	✓	✓
Laptop or computer with software for: • Mapping (like QGIS or Google Earth) • Spreadsheets (like Microsoft Excel) • Acoustic recording analysis software	✓	✓		✓
GPS device & spare batteries	**Recommended**	✓	✓	
Power bank	**Recommended**		✓	
Audio Recording Units (1 per site) with: • SD card >32GB • Batteries	✓		✓	
Permanent marker	✓	✓	✓	
Star picket (1 per site) (1.8 – 2.1 m)	✓		✓	
300 mm x 4.8 mm cable ties/zipties	✓		✓	
Extension pole (1 per site) • 3-5 metre telescopic pole	**If sampling at heights above 1.5 m**		✓	
Tension straps or guy lines (3 per site)	**If sampling at heights above 1.5 m**		✓	
Tent pegs (3 per site)	**If sampling at heights above 1.5 m**		✓	
Hammer, mallet or picket driver	✓		✓	
Multi-tool or side cutter	✓		✓	
Flagging tape	**Recommended**		✓	
Data management system (like databases, cloud storage and external hard drives)	✓			✓

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