Passive Acoustic Monitoring Protocol for Bat Species in Northern Nevada

Elko Biodiversity Program, NDOW, and BLM

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1. Pre-Survey

1.1. Determine Survey Objectives

The objective of stationary acoustic monitoring is to provide information on bat species occupancy and richness within the survey area. Currently, acoustic calls captured by stationary detectors cannot be used to estimate the number of bats detected during a monitoring night.

- If the objective of the survey is to record a *specific* species of interest, discuss appropriate site selection, survey methods and detector settings with BLM/NDOW before initiating survey efforts. Refer to the NA Bat Plan Chapter 2, table 2.2 for more details about the best way to monitor specific western bat species (appendix 2).
- If the area surveyed will provide baseline for a project impacting or consuming AML workings, refer to Managing Abandoned Mine Lands for Bats (Sherwin et al, 2009). Become familiar with this document before determining survey objectives.

1.1.1. Limitations of Passive Acoustic Surveys

Understanding the limitations of passive acoustic surveys is essential to obtaining the best results possible. Acoustic surveys alone are unlikely to result in capturing 100% of the species richness of bats in an area. Despite improving technology, combining survey methods is still recommended to obtain more accurate species richness results (Flaquer et al, 2007; Schratz et al, 2017). Many bat species are not reliably recorded using passive acoustic methods (appendix 2). In northeastern Nevada *Corynorhinus townsendii* (Townsend's big eared bat) is rarely detected using passive acoustic monitoring and is more frequently detected using mist nets or roost counts.

Acoustic detections may also be limited by software, detector type, detector placement, and microphone type. Each of these elements are impacted differently by factors such as temperature and humidity. False positives may also occur frequently when only using acoustic methods (Clement et al, 2014).

1.2. Define Survey Area

The survey area will be determined by the BLM/NDOW based on the following:

- Project activity/type
- Project location
- Project size/magnitude
- Habitat conditions (*e.g.*, known information of area, potential habitat, etc.)
- Other information (*e.g*., guidelines from the literature, biologist knowledge, accepted species distribution modelling, etc.)

1.3. Acoustic Analysis

Before surveys take place, determine who will be conducting post processing and manual vetting of acoustic data. Some parts of the acoustic analysis process do not require training to complete, but the final step will require an individual who is experienced in the identification of bat species by acoustic characteristics. See Chapter 6 (Species Identification of Acoustic Recordings) of the NA Bat protocol for more details about conducting acoustic analysis.

2. Passive Acoustic Monitoring Surveys

2.1. Survey Timing and Duration

2.1.1. Number of Surveys and Timing

Acoustic monitoring efforts will take place during the active period for bats, which includes spring, summer, and fall. Surveys should take place during each season to account for temporal variations in landscape use by bats, totaling **three (3)** distinct survey events. Each survey event must be separated by a period of 30 days to best capture these seasonal differences. The active period for bats in northeastern Nevada generally begins May 1st and ends no later than October 31st.

2.1.2. Monitoring night

Each seasonal survey will last a minimum of **six (6)** monitoring nights. A monitoring night will start 15 minutes prior to sunset and end 15 minutes after sunrise the following day. Reporting on bat occupancy using a single method requires 6-8 nights of effort to obtain the best species occupancy results. This has been tested across many different geographical regions and habitat types (Diaz-Frances and Soberon, 2005; Moreno and Halifter, 2000; Weller and Lee, 2007).

2.2. Environmental Conditions

Acoustic monitoring surveys must be conducted during six consecutive nights of seasonally optimal weather conditions. Bat activity is greatest when nightly temperatures are warm, wind is limited, moonlight is reduced, and there is no precipitation. If optimal weather does not occur during the six-night survey period, leave detector in place for additional nights, totaling 6 optimal weather nights by the end of the survey period.

If detector deployment takes place during the appropriate environmental conditions, equipment does not need to be weatherproofed. Weatherproofing materials can degrade call quality, reducing the overall number of identifiable calls (Britzke et al, 2010; Kaiser and O'Keefe, 2015).

2.3. Site Selection

Site selection is essential to obtaining a more complete inventory of the bat species occupying an area. When possible, choose a diversity of ideal sites listed below. Choosing a single site type will limit the observed bat species to those which use that specific habitat type. For example: If the survey area includes abandoned mine sites and passive acoustic detectors are only placed outside these structures, you will restrict the survey to cave roosting bats, eliminating most crevice, rock face, and tree roosting species. Therefore, it is important to set up detectors at sites utilized by a diversity of bat species.

Ideal sites for acoustic detector deployment will vary considerably depending on the survey area. However, a high-quality site for deploying acoustic detectors will include at least one of the following landscape features:

- A water source; including springs, streams, troughs, etc.
- An opening in cluttered or difficult-to-navigate terrain, also known as a flyway
- An ideal foraging area, such as a wet meadow or marsh

When possible, choose one of the ideal setup sites that is also near known roosting habitat such as old growth trees, talus slopes, Abandoned Mine Lands, caves, etc.

*See NABat Chapter 4.3 (appendix 3) for more detailed guidance on detector site selection.

2.4. Detector Placement

After selecting the deployment site, placement of the detector and microphone must be carefully considered. A variety of factors influence call quality, including:

- Microphone orientation
- Clutter (ex. obstructions like dense vegetation, boulders, etc.)
- Reflective surfaces (water, metal siding, sheer cliffs, large tree trunks, etc.)
- Sources of high-frequency noise such as powerlines
- Visibility of the detector on landscape

**See Bat Conservation and Management (https://batmanagement.com/blogs/acoustic-monitoring/tips-for-siting-bat-detectors) and NABat Chapter 4.4 (appendix 3) for more detailed information on detector placement.

2.4.1 Microphone Orientation

The angle and orientation of the microphone are two of the most important aspects of detector placement. **Angle** refers to the angle at which the microphone is fixed in relation to the ground, while **orientation** refers to the direction the microphone points in relation to the landscape. Microphone angle is the angle between the ground and the microphone and microphone orientation is the cardinal direction (north, south, east, west, etc.) that the microphone is facing.

Appropriate angle depends on the directionality of the microphone in use. Directional microphones have a cone-shaped area in which calls can be captured, and benefit from being fixed at a 45° upward angle (0/180° being parallel to the ground, 90° being perpendicular facing away from the ground, 270° being perpendicular facing towards the ground). Omnidirectional microphones record in a sphere around the microphone, and benefit from a 45° upward or 90° angle. Angle can be created at the point of attachment using rubber bands, tape, etc, and helps to reduce sources of audio distortion like echo.

Appropriate orientation depends on a variety of factors at the site, but in general microphones should always point **away** from clutter and high frequency noise and **parallel** to reflective surfaces, explained in more detail in the subsections below.

2.4.2 Clutter

Clutter reduces call quality by interrupting echolocation and generating interfering noise as branches rub together, leaves rustle, etc. Calls captured in high clutter will look 'fuzzy', making distinctive call features difficult to discern**.**

Horizontal Distance from Clutter: For the best-quality calls, detector microphones must be set up 3-5m away from clutter for directional microphones and 5m+ for omnidirectional microphones. For example, if trees are present at the site, the microphone should be at least 3m away from the foliage edge of the closest tree.

Vertical Distance from Clutter: The microphone should be a minimum of 2m above the ground for directional microphone, 2m+ for omnidirectional microphones. However, it is important to take clutter height into consideration. If the site has dense, tall vegetation, it is better to raise the microphone 2m above the highest clutter.

2.4.1. Reflective Surfaces

Reflective surfaces cause echolocation pulses to bounce and warp, creating echoes that can imply multiple bats are present in a single call, or elongate call features until diagnostic ID is impossible. This may seem counter-intuitive, as water sources are listed as a requisite of high-quality sites; however, there are ways to mitigate the effect of echolocation reflecting off water.

Point microphones **parallel to water sources** as opposed to perpendicular (i.e. point the microphone along the shore of a lake instead of out over the water). This will reduce the area of the microphone exposed to echo while still capturing bat activity as they move into the site to drink or forage. Making sure the microphone is **high above the reflective surface** will also improve call quality. The more time it takes an echo to reach the microphone, the clearer the actual call pulse will appear.

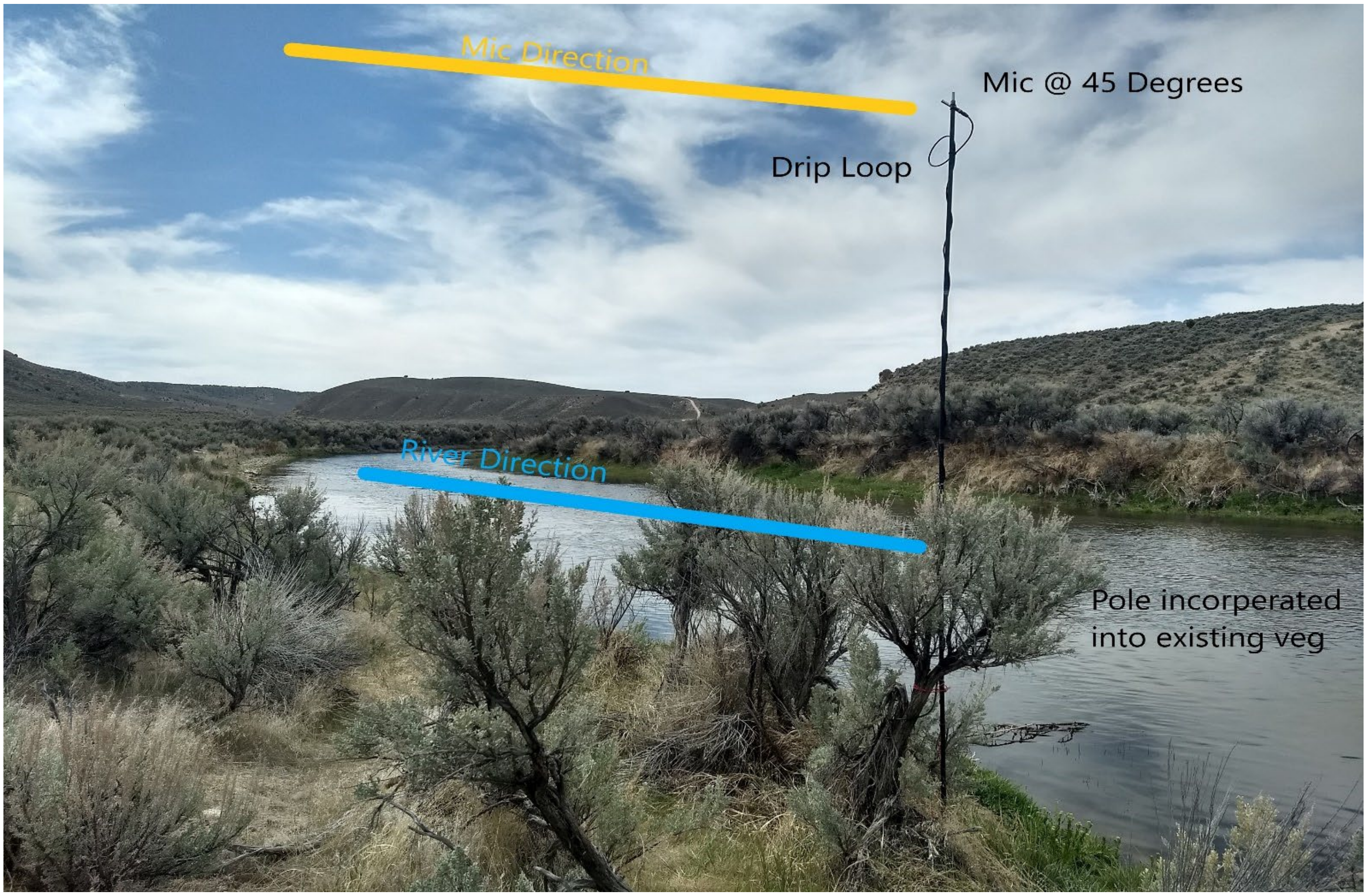
2.4.2. Sources of high frequency noise

Sources of high frequency noise, including electricity running through power lines, insects, and some rodents, will be captured alongside echolocation on acoustic monitoring detectors. These noises can sometimes be confused for bat call pulses, or mask echolocation by quieter bat species. In general, **acoustic monitoring should not take place in areas with extraneous high-frequency noise,** as there are limited ways to mitigate this interference. If areas of high frequency noise cannot be avoided, consult with BLM/NDOW.

2.4.3. Detector Visibility

The visibility of the detector can result in fewer identifiable call pulses as bats circle and investigate the microphone. The most diagnostic echolocation type is observed during navigation, but when bats encounter a new or strange feature, they can transition to search-phase calls which are less easily assigned to species. To limit investigation by bats, **camouflage the detector and microphone** using vegetation or other materials at the site. Attach the microphone directly to an exposed branch, place the microphone pole within a bush, etc. The less obvious the detector setup, the less interruption of normal bat activity. Also, keep in mind distance from clutter requirements during this process.

2.4.4. Examples

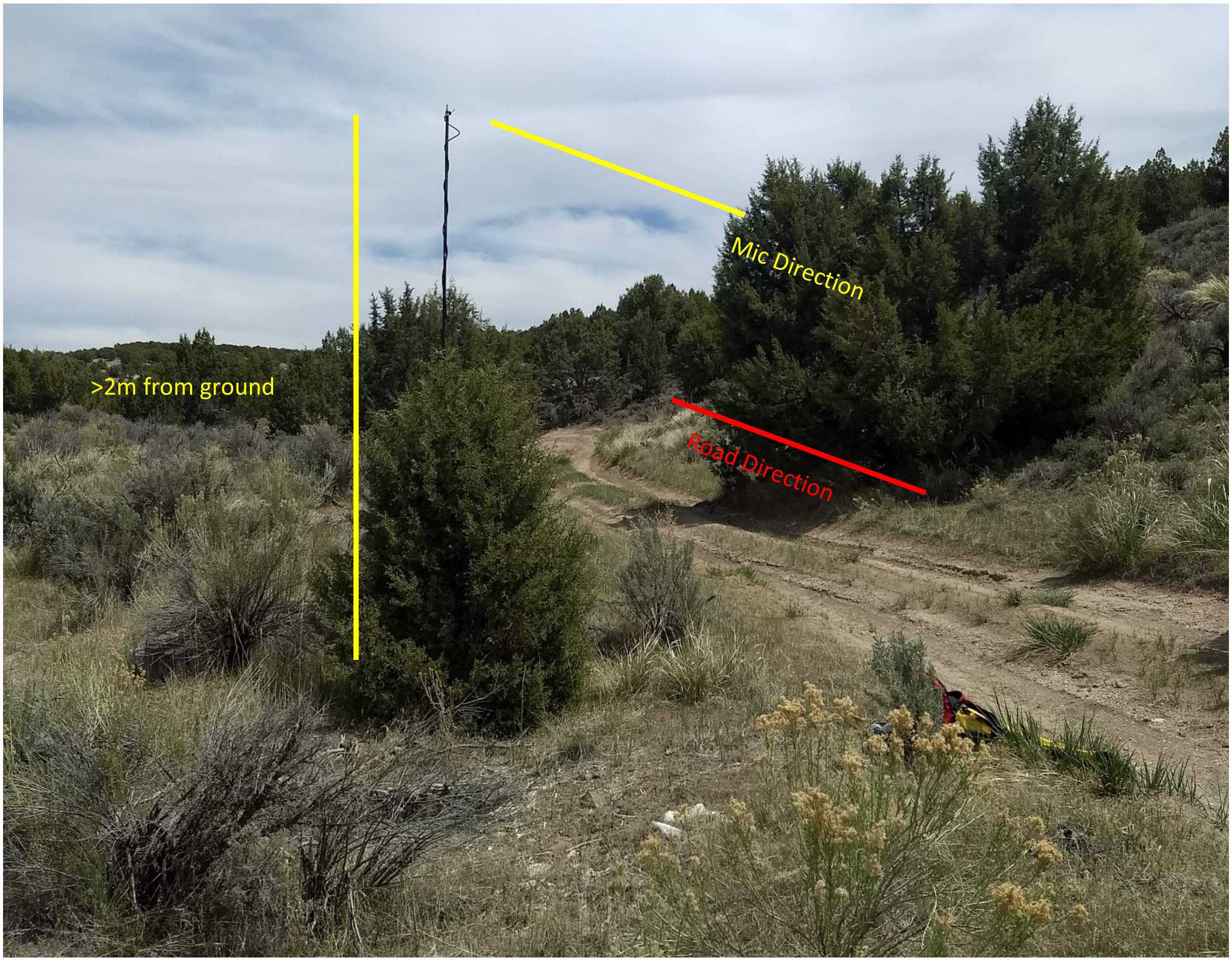


Detector Placement Example 1

Microphone has been incorporated into existing vegetation along streambank and is at least 2m above the highest canopy (vertical distance from clutter), the microphone is pointed parallel to the river. Height and parallel orientation will prevent echoes from the reflective surface of the water and will provide longer, diagnostic call sequences as the bats search along the river corridor. Microphone is pointed up at a 45-degree angle to allow water or condensation to run down the microphone and cord, and drip from the drip loop, preventing damage to the acoustic recorder.

Detector Placement Example 2

Microphone has been incorporated into existing vegetation in an otherwise open space and is at least 2m above the ground (vertical distance from clutter), 5m from the tree (horizontal distance from clutter), and the microphone is pointed parallel to the river corridor. Diagnostic call sequences will be recorded here as the use bats use search phase calls along the river corridor and adjacent meadow. There will be no impacts on call quality from reflective surfaces. Microphone is pointed up at a 45-degree angle to allow water or condensation to run down the microphone and cord, and drip from the drip loop, preventing damage to the acoustic recorder.



Detector Placement Example 3

Microphone has been incorporated into existing vegetation in an otherwise open space and is at least 2m above the ground (vertical distance from clutter). The microphone is pointed parallel to a road which is acting as a flyway- bats navigate through the juniper forest via this break in vegetation. Diagnostic call sequences will be recorded here as the use bats use search phase calls through the corridor. There will be no impacts on call quality from reflective surfaces. Microphone is pointed up at a 45-degree angle to allow water or condensation to run down the microphone and cord, and drip from the drip loop, preventing damage to the acoustic recorder.

2.5. Detector Settings

For the purposes of this protocol, detector settings will be conservative. This reduces poor-quality bat calls and expedites the manual-vetting process to obtain species richness information for a site. A majority of detector settings should follow NA Bat recommendations in *Guide to Detector Settings v1.0*, and common detectors (made by Pettersson, Titley, and Wildlife Acoustics) have been included in appendix 4 in this document. **If using the SM4Bat by Wildlife Acoustics, use the settings listed below**. If using an older version of the Wildlife Acoustics Song Meter, please consult BLM or NDOW staff to discuss appropriate settings.

SM4 Recording Settings

Feature	Setting	Reason (Northern NV)
Gain	12dB	Helps capture quiet bats
High Filter	Off	Filters out bats/noise below 16kHz, *Euderma maculatum* has a characteristic frequency of 12kHz
Sample Rate	384kHz	Better call resolution
Min Duration	2ms	Higher quality calls with more confident auto ID
Max Duration	300-400ms	Best for preventing non-bat triggers
Min Trig Freq	5kHz	*Euderma maculatum* can have an f_c as low as 6kHz
Trigger Level	24db	You will obtain fewer calls with higher quality, more diagnostic calls
Trigger Window	1sec	Longer trigger window only needed in *Eumops* habitat
Max Length	5sec	Longer times only needed for voucher calls

2.5.1. Survey Data Requirements

This information is required for **each detector** set up on every project. It needs to be collected on site during set-up and removal of the acoustic detectors. Datasheets and required summary forms for acoustic surveys can be found in appendix 1.

Required for ALL SURVEYS	Completed?
Completed Acoustic Monitoring Datasheet	
Photos of Detector Placement Pre and Post Survey	
GPS Coordinates for Deployed Detectors	

All fields on the acoustic monitoring datasheet must be filled out completely and accurately. Including the **full name** of any observers. Photos should be taken of the detector and surrounding habitat. At least one photo should include landscape features in the background to allow another observer to set up a detector in the exact same spot in the future (a photo point). Additional photos may be taken of important nearby landscape features. GPS coordinates should be entered into the acoustic detector (if possible) as well as recorded on the datasheet.

3. Post-Survey

3.1. Acoustic Analysis

Analysis of bat call files is a multi-step process. After retrieving survey data from the acoustic detector, relevant metadata must be appended to each file. Metadata must include information recorded on your survey datasheet:

State. County. Owner. Project name. Location (UTM). Elevation. Recorded by. Detector Name/Number. Start Date. End Date. Detector Make. Detector Model. Software Version. Mic model. Mic height. Mic orientation. Mic weatherproofing. Average Temps. Site Description. Notes (clutter, habitat, anything that can influence bat ID).

Example:

Elko County. Nevada. Happy Valley Mine Exploration. 543210 E, 4456778 N. 5789 ft elevation. Observers: Redah H. Chillipepper and Buena Charlotte. Detector #6. Survey start 2019.05.06. Survey End 2019.05.10. Wildlife Acoustics Songmeter. SM4. Software version 3.0. U1 Microphone. Mic placed 10 ft above ground, parallel to ground, facing north toward marshy area. Avg high temp 80 F, avg low temp 40 F. Mountainous area in sagebrush steppe, moderate clutter 100 m behind mic with tall deciduous trees, some standing water nearby in aspen stand.

Note: If you have Sonobat software, use the Sonobat Wizard to append your metadata. Include Detector name/number in the notes section in the Wizard.

If you have a program with an auto ID feature: once the program has assigned a species ID, **every file must be manually vetted by an experienced professional** to confirm or reject the classification. Only **one (1) strong, diagnostic call per location per survey event** is necessary to confirm species occupancy, however more diagnostic calls increase confidence in the identification. Software with auto ID features will often miss bat species when they are only observed in tandem with other bat species, it is important to look at every file to obtain a complete species assessment in an area. More information on acoustic analysis can be found in the NA Bat Plan, section 9.1.

3.2. Deliverables

Below is the list of deliverables required for all acoustic surveys. Please submit all materials via flash drive or establish a file sharing platform before submitting required information.

Item Per Detector	**X**
1. Passive Acoustic Survey Data Sheet (appendix 1)	
2. Labeled photos of each site	
3. All recorded acoustic calls	
4. Appended acoustic calls	
5. Vetting table	
6. BatAmp Excel File (Acoustic Monitoring Call Analysis Summary Table, see appendix 1)	
Item Per Project	
6. Summary Report of Results	

4. Collecting Additional Data

Additional data may be collected at project sites when monitoring for a specific species of bat or observing bat habitat which cannot be surveyed with passive acoustic methods. Consult with BLM/NDOW to determine if the methods below are appropriate for your project.

4.1. Driving Transects

Driving transects are an excellent way to supplement stationary passive acoustic surveys. These transects can provide information about species distribution and habitat use across an area. Protocol examples for driving transects can be found in The North American Bat Plan, Chapter 5 and examples of project specific driving transect protocols can be provided by the BLM. Consult the BLM/NDOW to determine if a driving transect is appropriate for your project.

4.2. Capture

Acoustic monitoring is not an effective method for monitoring all bat species. Using mist nets and harp traps can supplement acoustic datasets in an area and provide more information about bat populations with information like sex, age, reproductive status, white nose syndrome, etc. If you would like to capture bats for a survey, please first discuss with BLM/NDOW. This survey method requires permits, training, vaccinations, decontamination protocols, and equipment specific to bat capture.

4.3. Roost Counts

Roost counts can provide valuable information for *Corynorhinus townsendii* (Townsend's big eared bat), maternity colonies, and AML use. Exit counts, hibernacula surveys, and colony counts can be essential to understanding bat use in an area. Consult the North American Bat Plan (2015), Managing Abandoned Mine Lands for Bats (Sherwin et al, 2009) and the BLM/NDOW to determine if these methods are appropriate for your project.

5. Literature Cited

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Appendix 1

Passive Bat Acousitc Survey Data Form

Data QC Name________________________

Date_______________

Datasheet Updated 6/4/21

Survey Site Information	Observers			Set-up Date
Project	County	Site Name	Site #	Removal Date
UTMs (NAD 83) Easting	Northing	Elevation f/m		Total Nights
Set Up Conditions: Time	Temp	Wind**	Clouds** / High Temp	Survey #
Removal Conditions: Time	Temp	Wind**	Clouds** / Low Temp	Survey Season
Moon Effect:	Land Use: Urban/Agriculture/Forest/Water/Wetland/Barren/Sagebrush Steppe (describe):			

Detector Information	Detector Name / #				Weatherproofing	Habitat Use	Weather Event(s)	Date
Make	Model	Mic	horn*	h-AGL*				

gain	trigger level	trigger window	HP Filter*	clutter*	Max file length	Start Time	Metadata written by:		
						End Time			

Site Description:	Site Sketch

Passive Bat Acousitc Survey Data Form

Data QC Name________________________
Date________________

Datasheet Updated 6/4/21

Data Processing Summary	Software Used	Version	AutoID Y/N	Auto Classification Suite
Manual Vetting Analyst(s)		Date processed		Date manually vetted
Manual Vetting Analyst(s) Qualifications				
Project Name	Total Number of Files		Total Number of Identified Calls	
Notes				

Vetted Data must be recorded in the BatAMP Datasheet. This MS Excel datasheet can be found at batamp.databasin.org (download spreadhseet template), or it may be obtained from your BLM/NDOW contact. Datasheet must be sumbitted electronically to the BLM/NDOW. You may need to type in appropriate species to the template. Known species to occurr in the Elko BLM District include:

Code	Scientific Name	Common Name	Code	Scientific Name	Common Name
ANPA	*Antrozous pallidus*	Pallid bat	**MYYU**	*Myotis Yumanensis*	Yuma myotis
COTO	*Corynorhinus townsendii*	Townsend's big eared bat	**PAHE**	*Parastrellis hesperus*	Canyon bat
EPFU	*Eptesicus fuscus*	Big brown bat	**TABR**	*Tadarida brasilliensis*	Brazilian free-tailed bat
EUMA	*Euderms maculatum*	Spotted bat	**40KM**	40k Myotis Species	
LABL	*Lasiurus blossevillii*	Western red bat	**HIFU**	High frequency (above 40k) unknown bat	
LACI	*Lasiurus cinereus*	Hoary bat	**LOFU**	Low frequency (bleow 40k) unknown bat	
LANO	*Lasionyteris noctivagans*	Silver-haired bat	Definitions		
MYCA	*Myotis californicus*	California myoits	**Clouds**	**0**: <25% cover, **1**: 25-50% cover, **2**: 50-75% cover, **3**: overcast	
MYCI	*Myotis ciliolabrum*	Western small-footed myotis	**Winds**	**0**: calm (<1mph), **1**: light (1-7), **2**: moderate (8-18), **3**: strong (19+)	
MYEV	*Myotis evotis*	Long-eared myotis	**horn**	Directional horn on microphone? Yes or No	
MYLU	*Myotis lucifugus*	Little brown myotis	**h-AGL**	Height of microphone above ground level- cirlce ft or m	
MYTH	*Myotis thysanodes*	Fringed myotis	**HP Filter**	High-pass filter enabled? Yes or No	
MYVO	*Myotis volans*	Long-legged myotis	**clutter**	Degree of clutter surrounding detector: High, Medium, or Low	

Table 2.2—Methods for monitoring bats in western North America

	Spring, summer, fall			Winter		
Species	**Acoustic point**	**Mobile transect**	**Roost**	**Acoustic point[a]**	**Mobile transect[b]**	**Hibernaculum or roost**
Antrozous pallidus	X	X	?	—	—	X
Choeronycteris mexicana	—	—	?	—	—	?
Corynorhinus townsendii	—	—	X	—	—	X
Eptesicus fuscus	X	X	—	X	X	X
Euderma maculatum	X	X	—	—	—	X
Eumops perotis	X	X	—	—	—	—
Eumops underwoodii	X	X	—	—	—	—
Idionycteris phyllotis	X	X	—	—	—	X
Lasionycteris noctivagans	X	X	—	X	X	—
Lasiurus blossevillii	X	X	—	—	—	—
Lasiurus borealis	X	X	—	—	—	—
Lasiurus cinereus	X	X	—	—	—	—
Lasiurus xanthinus	X	X	—	—	—	—
Leptonycteris nivalis	—	—	X	—	—	—
Leptonycteris yerbabuenae	—	—	X	—	—	—
Macrotus californicus	—	—	?	—	—	X
Mormoops megalophylla	X	X	X	—	—	—
Myotis auriculus	X	X	—	—	—	X
Myotis californicus	X	X	—	X	X	X[c]
Myotis ciliolabrum	X	X	—	X	—	X
Myotis evotis	X	X	—	X[d]	—	X
Myotis keenii	X	—	X	—	—	X
Myotis lucifugus	X	X	?	X	—	X
Myotis occultus	X	X	—	—	—	X
Myotis septentrionalis	X	X	—	—	—	X
Myotis thysanodes	X	X	—	—	—	X
Myotis velifer	X	X	X	—	—	X
Myotis volans	X	X	—	—	—	X
Myotis yumanensis	X	X	?	X	—	X
Nyctinomops femorosaccus	X	X	—	—	—	X
Nyctinomops macrotis	X	X	—	—	—	—
Parastrellus hesperus	X	X	—	—	—	X
Tadarida brasiliensis	—	X	X	X	X	X

Note: Due to lack of knowledge for many species, the ranking approach used for eastern bats was not used.

Methods are designated as: X = appropriate method, ? = possibly appropriate method, and — = not appropriate or not known. Designations are based on input from bat biologists working in western North America.

[a] Acoustic points in winter generally entail passive detectors at a source of open winter water (standing) such as the entrance of a creek to a lake, or a detector mounted as close as possible to terrain with rock crevices/mines/caves/outcrops that remain relatively snow free.

[b] Road transects in winter should be conducted near open winter water sources in areas of high-density rocky terrain during weather conditions that support high bat activity.

[c] This species is active at low-elevation mines even though they often do not roost in these mines.

[d] Acoustic point should be within a few hundred meters of potential or known rock crevice hibernacula.

Appendix 3

USDA

United States Department of Agriculture

A Plan for the North American Bat Monitoring Program (NABat)

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Forest Service
Research & Development
Southern Research Station

General Technical Report SRS-208

4. Stationary Point Acoustic Survey Protocols

4.1

4.1 Types of Detectors

Side view of a long-eared myotis. (© Daniel Neubaum, Colorado Parks and Wildlife)

Many types of bat detectors are available for continuous recording of bat echolocation calls. Britkze and others (2013) and Parsons and Szewczak (2009) reviewed differences among types and present advantages and disadvantages. Detector technology is continuously improving over time, and because each detector type has different limitations, NABat does not specify a particular type of detector to be used. However, whatever detector is used must be capable of recording continuously for the required number of nights and detecting species anticipated to be present in the region that can be detected acoustically (see tables 2.1 and 2.2). If it becomes necessary to change technology or settings, it is important to carry out calibration trials to compare detectability with the old and the new technologies or settings. Model types discussed below are the most commonly used detectors in North America to date.

Detector types most commonly used for species identification are zero-crossing frequency division (e.g., Anabat™ CF–ZCAIM, SD1/SD2, Express; Wildlife Acoustics® SM2BAT+™ or SM3BAT™ on ZC mode), time expansion full-spectrum (e.g., Pettersson D240X), and direct recording full-spectrum detectors (e.g., Binary Acoustic Technology AR125™, FR125™, iFR-IV™, Pettersson D500x, Wildlife Acoustics® SM2BAT+™, SM3BAT™, or EM3+™). Time expansion systems stretch the signal out by a factor of *n* while transferring the data to the recording device (Britzke and others 2013, Parsons and Szewczak 2009), and the system cannot record new sounds while this is occurring. Because future analytical approaches may be able to estimate abundance by using the number of files or passes recorded (see ch. 9), the use of time expansion detectors is not recommended. Thus, any frequency division zero-cross or full-spectrum direct recording bat detector that has a time-date stamp for each file can be used for stationary point surveys. However, because acoustic technology changes rapidly, new detector types may be available in ensuing years that may also be suitable for stationary point surveys.

When choosing a detector type, the type of microphone must also be considered. Microphones can be classified as omnidirectional or directional depending on how they are constructed and how they are deployed. An omnidirectional microphone that is not placed into a housing or shield will pick up bat activity in all directions, but it may also record more noise because it picks up sound from a greater volume of space, particularly from the ground and surrounding vegetation. A more directional microphone (either by design or by using a housing, horn, or shield) will mainly record bats in front of the detector, with some "side lobes" of detection of lower frequencies. Directional microphones often detect bats at a greater distance on the central axis of the microphone than omnidirectional microphones. In general, the larger the microphone diameter, the more directional it tends to be. For example, the Anabat™ SD2 has a much larger diameter microphone than the Anabat™ Express, so the Express detector is far more omnidirectional, especially when the microphone is mounted on a cable away from the body of the detector. In addition, some detector manufacturers offer microphones with different frequency response curves, specifically varying sensitivities at low or high frequencies. For example, the Anabat™ "lo" (white) microphone is more sensitive in the audible range than is the standard (black) microphone; the green "hi" microphone has the same frequency response as the standard microphone, but should be used when using the microphone off the detector body (e.g., when mounting it on an extendible pole). The Wildlife Acoustics® SMX–UT™ microphone for the SM2Bat+™ records higher frequencies and is more sensitive than the SMX–US™; the SMM–U1™ is more sensitive than either of the SMX microphones. Some microphones are manufactured within more consistent ranges of sensitivities than others. For example, the Anabat™ stainless microphones are factory calibrated so that each microphone is within a narrow range of sensitivities. Whatever microphone is used, it is critical that they are used consistently at sites over time. Using the same type of microphone and periodically checking for microphone performance will help to ensure this consistency (see sec. 4.2.1).

4.2 Detector Sensitivity and Settings

4.2

Long-term monitoring requires the surveyor to minimize and account for variability among detectors and settings. Therefore, it is critical that settings be consistent within and between years, and documented in the Bat Population Database (BPD).

4.2.1 Sensitivity

4.2.1

The sensitivity of bat detectors can vary both within and among detector types (Adams and others 2012, Larson and Hayes 2000). Full-spectrum recording is inherently more sensitive than frequency division zero-cross because full-spectrum detectors record signals within the ambient noise, whereas zero-cross detectors record only the loudest signal above the noise floor (Corben 2002). However, during deployment of full-spectrum detectors, sensitivity is often lowered to reduce the number of files recorded with no bats and to reduce recording extraneous noise, thus reducing memory requirements (i.e., a louder signal above the noise floor is required to initiate recording).

For full-spectrum detectors, gain and signal-to-noise ratio settings affect sensitivity of the detector. Sensitivity can be adjusted manually with a dial for all Anabat™ models except the Anabat™ Express, but the numbers on this dial are not consistent among units or models and thus should not be used as a way of equalizing sensitivities (see below). The sensitivity (low, medium, or high) for the Anabat™ Express can be set through Anabat™ Toolbox utility software. Some detectors also allow frequency band filters to target some frequencies; these filters should be adjusted for the local bat community, be documented in the BPD, and be used consistently from year to year at a monitoring site.

The signals of bat calls must exceed the noise floor for zero-cross detectors (e.g., Wildlife Acoustics® detectors set on ZC mode or SMZC; Anabat™ II, SD1, and SD2) to record them. The ambient level of noise can vary over time (e.g., wind or rain increases the noise floor), and detectors that track the ambient noise level and adjust accordingly will have varying sensitivity over time (auto-level). For example, Wildlife Acoustics® SM2BAT+™ and SM3BAT™ detectors auto-level when in zero-cross mode, and thus their sensitivity can vary daily or even within the night depending on how the detector is programmed. Anabat™ detectors use a consistent noise floor as long as the sensitivity knob is not changed or the internal digital setting has been applied in the automated equalization process (Anabat™ Equalizer, see below).

Calibrating detectors among each other by adjusting their recording sensitivities can reduce variation in detection volumes among detectors. Some manufacturers provide hardware and software that allow the user to calibrate across and within detectors (e.g., Anabat™ Equalizer for Anabat™ SD1 and SD2), while others provide equipment that allows the user to test the performance of their equipment against system standards

(e.g., Wildlife Acoustics® Ultrasonic Calibrator™). Larson and Hayes (2000) described a method for calibrating Anabat™ II detectors against each other. Currently, there is no method for testing the performance of Anabat™ Express microphones, but a method is expected in the near future.[1]

Microphone sensitivity can vary over time, making detector calibration and performance tests very important, particularly for a long-term monitoring program. Testing the performance of microphones and detectors before and during the recording season is important to detect any loss in sensitivity. When loss of sensitivity occurs, microphones may need to be replaced. Environmental conditions can also affect microphone sensitivity. For example, if Wildlife Acoustics® SMX microphones with mesh windscreens get soaked with water, their sensitivity diminishes.[2]

To ensure consistency, it is imperative that the same detector or detector type, microphone, and settings are used at a site each year to reduce variation caused by equipment differences. However, if equipment needs to be replaced or if new detectors are used, they need to be calibrated against the older equipment. Having old and new equipment recording side by side for at least one season is the most effective way to develop correction factors and allow monitoring to continue with new equipment after calibration.

4.2.2

4.2.2 File Recording Settings

A "triggered" bat detector does not record constantly, but starts and stops based on input. A triggered detector begins recording when it detects an ultrasonic signal. If a trigger window has been set, recording will end after a specified amount of time has passed in which no signal is detected. For example, Anabat™ defaults to 5 seconds unless the time between calls (Max TBC) setting is changed in CFCRead utility software. In contrast, Wildlife Acoustics SM2BAT+™ and SM3BAT™ and Binary Acoustics AR125™, FR125™, and iFR-IV™ allow the user to specify the trigger window. To standardize recordings, it is recommended that a 2-second trigger window and a maximum file length of 15 seconds be used. Each detector may refer to these settings differently. The Binary Acoustics Technology AR125™ and FR125™ refers to "Duration" for max file length and "Idle setting" for trigger window. For Anabat™ detectors, the trigger window is the "Max TBC;" the file size is set at 15 seconds and cannot currently be changed.

With full-spectrum recorders, it is also possible to record continuously through the night and then use software to scan the recordings to detect bat calls. This approach takes advantage of the full sensitivity of the recorder and can lead to substantially increased detection probabilities. However, it also has much larger memory requirements and requires increased processing time to analyze the data. As with other methods, this approach is acceptable provided that the same approach is used consistently over time. In this case, not only the recording parameters but also the algorithms used to extract calls from the recordings can affect detection probabilities, and both need to be standardized. However, if the original recordings are retained, it may be possible to reanalyze them in the future if improved detection algorithms become available.

[1] Personal communication. 2014. K. Livengood, Office Manager, Titley Scientific USA, 601 Business Loop 70 W, Suite 110, Columbia, MI 65203.

[2] Personal communication. 2014. S. Snyder, Product Manager, Wildlife Acoustics, Inc., 3 Clock Tower Place, Suite 210, Maynard, MA 01754-2549.

The division ratios for frequency division zero-cross detectors can be adjusted. Because a frequency division detector considers only every n^{th} wave, the lower the division ratio (n) the more information is recorded. However, file sizes will also be larger. A low division ratio is recommended (e.g., ≤8) in areas with target species that have audible, low frequency components to their echolocation calls such as the spotted bat (*Euderma maculatum*). However, a division ratio of 8 or 16 should be used in areas where bat species produce high frequency calls [e.g., Californian myotis (*Myotis californicus*)] because of the risk of inaccurate high frequency representation with low division ratios.[3] Division ratio settings should be consistent between years.

4.3 Site Selection and the Influence of Clutter on Bat Echolocation 4.3

With only two to four detectors in a cell, it is not cost effective, practical, or desirable to position detectors randomly within the cell. Rather, detectors should be placed in areas that maximize the number and quality of recordings. In areas with heterogeneous habitats suitable for bats, detectors should be placed to maximize the diversity of species likely to be detected. Whenever possible, one detector should be placed in each 5- by 5-km quadrant of the cell.

Site selection for deployment of detectors can affect the quantity and quality of echolocation calls recorded (Britzke and others 2013). It is important that biologists consider the bat species in the area and their habitat associations when selecting sites for stationary point samples. Because sites will be surveyed each year of the monitoring program (see sec. 3.6), it is critical that good sites are selected. Thus, knowledgeable biologists should put considerable thought into the site selection process and conduct on-the-ground reconnaissance.

Several features in the environment affect the quality and quantity of calls recorded by bat detectors (table 4.1). One of the most important features is the amount of clutter, defined as the density of obstacles in the flight environment (e.g., tree branches, leaves, or water surfaces) (Fenton 1990). For example, transmission of 25 kHz sounds is lower in intact forests than in thinned forests (Patriquin and others 2003), and detectors oriented away from clutter record more calls than those oriented towards clutter (Weller and Zabel 2002) due to multiple reflections off of vegetation. Further, bats adjust their echolocation calls while in clutter. Echolocation calls in clutter are

[3] Personal communication. 2014. C. Corben, Acoustic Biologist, Titley Scientific USA, 601 Business Loop 70 W, Suite 110, Columbia, MI 65203.

Table 4.1—Factors that may impact the quantity and quality of bat echolocation calls recorded by acoustic detectors, the problems associated with each factor, and ways to reduce the effects

Factor affecting call quality	Associated problems	Ways to reduce effects
Dense vegetation (classic "clutter")	Poor quality calls (e.g., fragments) Bats change their call structure	Place detectors in more open areas Orient microphone toward more open areas
Other bats	Bats change their call structure	Place detectors in areas where there are not dense concentrations of bats (e.g., avoid recording directly at watering holes or close to a roost)
Echoes off hard surfaces	Diffuse or spectral echoes	Place detectors so that they are not directly over hard surfaces such as still water, pavement, or bridges

shorter duration, higher frequency, and have greater bandwidths than those produced in more open areas (Broders and others 2004, Wund 2006). Thus, identification of calls recorded in cluttered environments based on known calls from open areas could be erroneous (Britzke and others 2013). Other bats in the area can also represent a form of clutter to echolocating bats, and bats will adjust their individual calls for echo recognition when many other bats are in their foraging space (Obrist 1995).

Echoes off surfaces can also affect the quality of recorded calls by distorting the sound (Parsons and Szewczak 2009). Bat detectors generally record two basic types of echoes: diffuse echoes and specular echoes (fig. 4.1). Ultrasound reflected off a rough surface, such as a tree trunk, will produce a diffuse echo; smooth surfaces produce a specular echo, which is a near-perfect reflection of the original bat pulse. Echoes can make species identification more difficult and inflate the number of calls in a file. This is especially a concern for automatic species-identification software. Thus, when recording occurs in close proximity to flat, reflective surfaces (e.g., still water, pavement, or bridges), call quality may be reduced.

Bats use various types of habitats to forage, drink, roost, and commute. Ponds or wetlands are often used for drinking and foraging (Seibold and others 2013, Stahlschmidt and others 2012), and edge habitats such as along trails and forest roads, forest openings, and rock cliffs are often used by bats that are commuting between foraging and roosting areas (Jantzen and Fenton 2013, Morris and others 2010, Verboom and Huitema 1997). Areas with suitable roosting sites such as mature trees, snags, rock crevices, anthropogenic structures (e.g., homes, barns, and log cabins), caves, and mines are also potential habitats. Bats are less likely to be found in wide-open places, such as the middle of a cultivated field (Crampton and Barclay 1996, Grindal and Brigham 1999). They also avoid very fast flowing streams or creeks that produce too much competing noise (Mackey and Barclay 1989, von Frenckell and Barclay 1987) or creeks and wetlands with dense vegetation that reduces access to prey and water (Ober and Hayes 2008).

Bat species vary in habitat use due to differences in maneuverability, foraging mode, ecology, and properties of echolocation call structure (Aldridge and Rautenbach 1987,

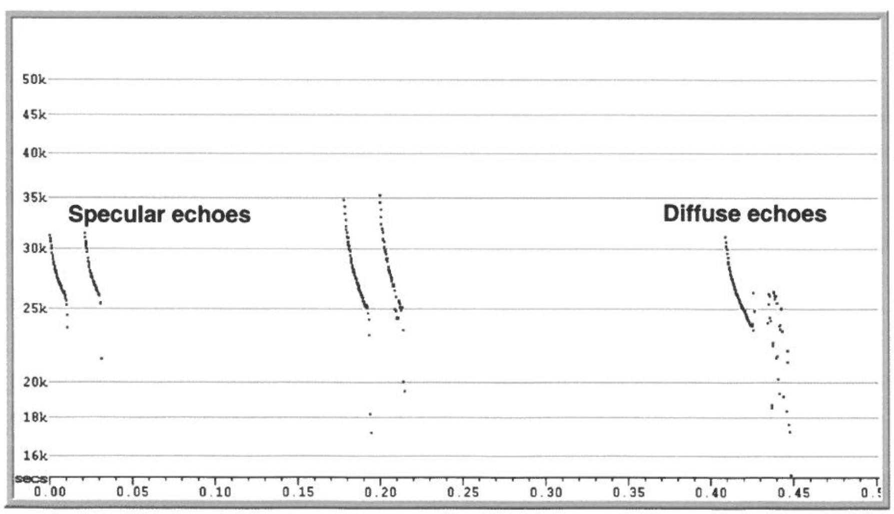

Figure 4.1—Specular and diffuse echoes of Brazilian free-tailed bat (*Tadarida brasiliensis*) echolocation calls recorded with an Anabat™ detector. (recording courtesy of C. Corben, Titley Scientific)

Fenton 1990). In general, large fast-flying bats use habitats that are more open, whereas smaller, more maneuverable species use more cluttered or edge habitats. Thus, it is important to consider the composition of the bat community in the survey area when selecting suitable sampling sites.

When placing detectors in the 100-km² grid cells, it is desirable to monitor bats in a variety of habitats. For heterogeneous landscapes, place up to four detectors such that they sample different habitat features, preferably one within each quadrant of the cell (fig. 4.2). For example, if a cattle watering tank is selected for one sample point, consider selecting other habitat types such as larger bodies of water, small roads, or a forest opening. Although fewer individual bats may be recorded by deploying detectors away from areas where bats may concentrate or other sources of clutter such as water tanks or roosts in buildings, a higher percentage of calls may be identifiable (fig. 4.3).

If the habitat within a grid cell is more homogeneous, fewer detectors (minimum of two) may be sufficient to capture the potential bat diversity in the cell. However, if the surveyor is not familiar with the area or the bat community, we suggest setting up three or four detectors to ensure capturing as much of the species diversity in the area as possible. Although it is good to place detectors so that a high number of species are recorded, sampling should be conducted to maximize detection of all species within cells across all detectors. Thus, in some cases it may be desirable to place one or two detectors in habitats that may be used only by one or two species if those habitats are the most likely area to host those species. For example, northern myotis (*M. septentrionalis*) are more likely to forage in closed canopy forests (Henderson and Broders 2008), and placing at least one detector in these habitats may increase the probability of detecting them, although doing so may lower the probability of detecting other species (Carroll and others 2002).

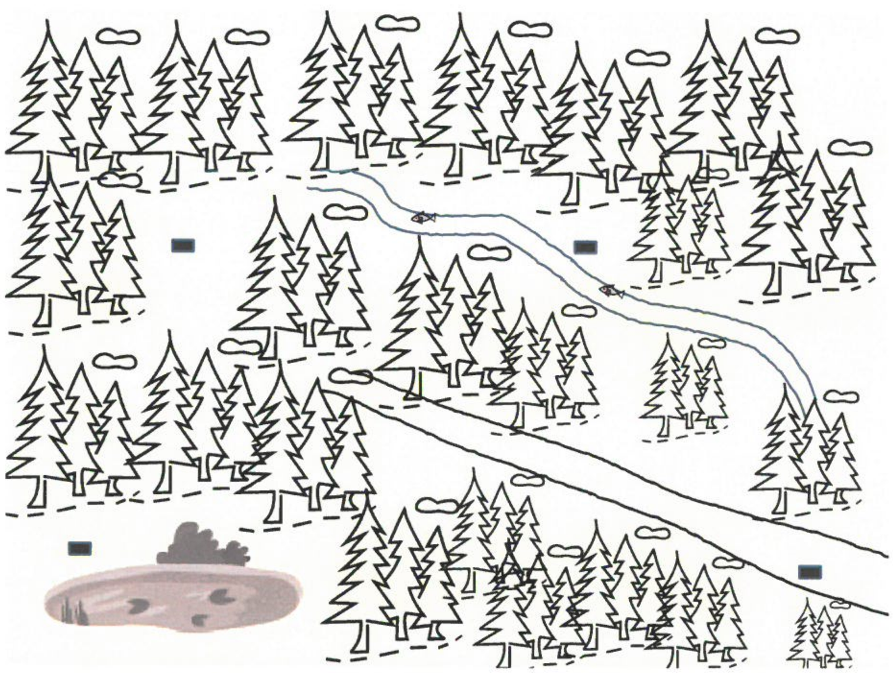

Figure 4.2—Example of stationary detector placement in a 100-km² grid cell. Detectors (black rectangles) have been placed in four diverse habitat types (clockwise from top left): a forest opening, along a stream, along a forest road, and near a pond.

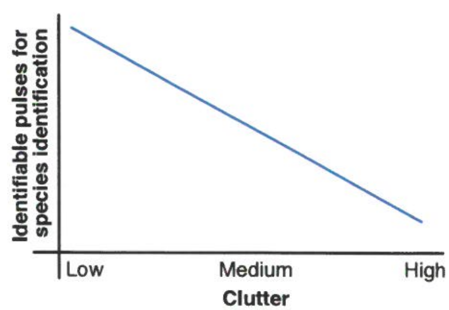

Figure 4.3—Relationship between clutter and probability of successful species identification for species that are difficult to acoustically differentiate from others. Note: clutter may be reduced by increasing horizontal set-back from clutter and/or vertical height of microphone.

4.4

4.4 Equipment Setup

4.4.1

4.4.1 Placement Relative to Clutter, Height above Ground, and Orientation

Bats tend to respond to clutter within a few meters. Thus, detectors should be a sufficient distance and oriented away from clutter such as forest edges, buildings, cliff faces, and the ground to reduce echoes and the effects of clutter on bat behavior and sound quality. Unfortunately, little research has been done on an ideal set-back distance of microphones from clutter. In general, 3 to 5 m is likely to be enough to reduce the effect of clutter when a directional microphone is used and is oriented away from the clutter. A greater set-back distance will be needed for omnidirectional microphones unless they are contained in housings that make them more directional and are oriented away from the clutter. The set-back distance from clutter depends on the sensitivity and range of the microphone being used. It is recommended that microphones be elevated as high as possible off the ground; directional microphones should be at least 1.4 m above ground (Weller and Zabel 2002), and omnidirectional microphones should be placed even higher to reduce background noise and echoes from the ground. Detectors or microphones can be mounted on tripods or elevated on poles (fig. 4.4). Caution should be used when elevating some microphones on fiberglass poles, as they may short out due to static electricity unless the poles are grounded.

The suggested microphone orientation depends on directionality and weatherproofing (see sec. 4.4.2). Orientation relative to the horizontal plane may be important for detectors with directional microphones. For example, Anabat™ II microphones oriented horizontally record fewer calls than those oriented at 45° or greater (Britzke and others 2010). Omnidirectional microphones can be angled horizontally or even below horizontal without use of a reflector plate.

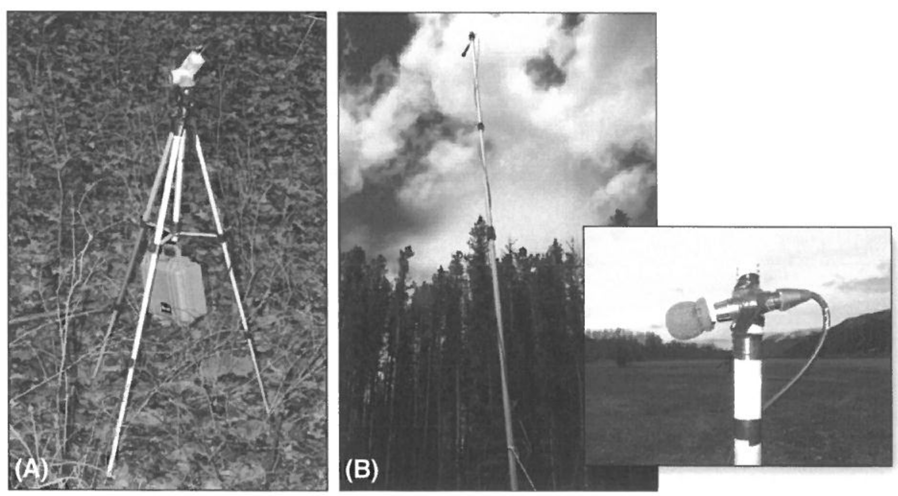

Figure 4.4—An example of a microphone mounted on (A) a tripod (Anabat™ system), and (B) a painter pole (inset: Wildlife Acoustics® SMX-US™ microphone on top of pole). (fig. 4.4A photo courtesy Titley Scientific, other photos by C. Lausen)


A silver-haired bat roosts on a tree trunk.

4.5 4.5 Frequency and Timing of Surveys

Surveys should be conducted during the summer active period prior to the young becoming volant. Associated driving transects (see sec. 5.5) should be conducted while the stationary points are being surveyed. The weeks when this occurs will vary with location (e.g., later in the northern parts of North America and at higher elevations) and possibly with species. Detectors should run the entire night, from 15 minutes prior to sunset to 15 minutes after sunrise, for a minimum of four nights. Stationary acoustic surveys should be conducted at least once per year. When possible, surveys should be conducted when weather conditions are optimal for bat activity: (1) seasonally warm temperatures, (2) low wind, and (3) little or no rain. Specific limits will change depending on the location. For example, in south-central Alaska (lat. 60° N.), bat activity declines below 10 °C (Loeb and others 2014), whereas in Massachusetts (lat. 42° N.), bat activity declines below 15 °C (Brooks 2009). In typically rainy locations, bats may fly in light rain.

4.6 4.6 Collection of Covariates and Ancillary Data

Bat activity and habitat use can be affected by numerous factors, including habitat type, temperature, relative humidity, rainfall, wind, and moonlight. As discussed in sections 4.2 through 4.4, many factors related to equipment placement and setup can also affect the data. Many of these factors can be controlled during the analysis phase if they are known. Thus, it is critical that a number of variables are recorded during the surveys and submitted with the data in the BPD. Variables that should be collected are listed in tables 8.1 and 8.2, and an example data sheet is provided in appendix C.

Appendix 4

Not Recommended for Stationary Point Surveys:
Pettersson M500
Wildlife Acoustics Echometer Touch (any version)

- **If your acoustic detector is not listed in this appendix or in the text of the protocol, please consult BLM/NDOW before use.**
- **Wildlife Acoustics SM4BAT settings can be found in the text of the protocol.**

Charts are from: The NA Bat Plan, Guide to Acoustic Detectors Settings (Reichert et al, 2017). Please consult this document for more information on detector settings for mobile transects.

Pettersson D500

	Stationary Point Surveys	D500x	comments
USER PROFILE	SAMP. FREQ	500	
	PRETRIG	OFF	
	REC. LEN	5	
	HP-FILTER	NO	NO' for recording in areas where low frequency species, such as EUMA and EUPE would be expected. All other instances, you could set this to YES to help in avoiding to record low frequency noise and save disk space.
	AUTOREC	YES	
	T.SENSE	MED	
RECORDING SETTINGS	INPUT GAIN	45	60-80: For recording bats with lower intensity calls or in more cluttered environments.
	TRIG LEV	160	120 For recording bats with lower intensity calls or in more cluttered environments.
	INTERVAL	0	

Titley Scientific AnaBAT Walkabout

	Stationary Point Surveys	AnaBat Walkabout
CAPTURE	Trigger	ZC
	Trigger Min Freq	8 or 16kHz
	Trigger Max Freq	120kHZ
	ZC Div Ratio	8 (ZC only)
	ZC Sensitivity	15-18 (or just below the 'self-triggering' level - lower is better if using external mic rather than built-in mic)
	Crest Factor Threshold	8-10 (but this threshold is not actually being used. Trigger setting should always say ZC)
	Manual Record Length	n/a
	Max File Length	15s
	Record Wave File	(check box)
	Record Anabat File	(check box)
	Deployment	Auto Record Mode (turn off screen and volume if being left for more than a few minutes); internal battery will need recharged daily, and it should be tested to ensure the battery can record for a full night

Titley Scienific AnaBAT Swift

	Stationary Point Surveys	AnaBat Swift
	Date/Time	GPS will set date, time; manually adjust time zone
TRIGGER	Sensitivity	15
	Minimum Event	1ms
	Record Window	2s
	Minimum Frequency	15kHZ if no bats lower than this, otherwise, 8kHz
	Maximum Frequency	120kHz
RECORDING	Div Ratio	8 (ZC only)
	FS/ZC	FS or ZC
	Sample Rate	320k (if using FS)
	Analog Filter on/off	On (unless audible bats are present, then Off)
	Max. File Time	15s (fixed)
	Deployment	Night Only (which records 30 min before sunset to 30 min after sunrise)

Titley Scientific AnaBAT Express

Stationary Point Surveys	AnaBat Express
Recording Format (Fixed)	Zero-crossing
Recording Modes	Night Only (which records 30 min before sunset to 30 min after sunrise)
Date/Time	Attach Express to computer and open ToolBox; adjust time zone of detector
	GPS will set date and time

Titley Scientific AnaBAT SD1 & SD2

Stationary Point Surveys	AnaBAT SD1 & SD2
Audio Div	16
Data Div	8
Sensitivity Dial	tune as necessary to find the 'noise floor'
Date/Time	attach Anabat to computer to set date and time in CFCRead
Post-recording processing	download in CFCRead, set appropriate time zone; run GPS Integration Wizard in Analook to have track file and embed waypoint data into files