

Cumberland Piedmont Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure 4

Winter Cave Roost Sampling—Version 1.2

Please cite this as:

Cumberland Piedmont Network. 2023. Winter cave roost sampling—Version 1.2. Cumberland Piedmont Network Standard Operating Procedure NPS/CUPN/SOP—4. Cumberland Piedmont Network, Mammoth Cave, Kentucky.

Summary

This standard operating procedure (SOP) provides direction on conducting winter sampling focused on counting several species of bats which hibernate in caves. These censuses are used to assess abundance, infer population trends, and determine spatial distribution within winter caves for certain bat species within sampled sections. The methods in this SOP focus on biennial in-cave counts conducted by a small number of observers. Monitoring procedures were compiled from various published and unpublished sources. In particular, an SOP from Lava Beds National Monument (Thomas 2013) and a multi-agency protocol (Hicks et al. 2009), and a chapter on colony counts from a program plan for the North American Bat Population Monitoring Program (Loeb et al. 2015) were borrowed from greatly.

This SOP gives step-by-step instructions that field crew leaders and crew members should follow to conduct winter cave roost sampling at four parks in the Cumberland Piedmont Network (CUPN). These parks include Chickamauga and Chattanooga National Military Park (CHCH), Cumberland Gap National Historical Park (CUGA), Mammoth Cave National Park (MACA), and Russell Cave National Monument (RUCA).

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
December 2015	Steven Thomas	Minor edits made to field data form and instructions for filling out the form.	Minor edits made following external peer review and during database development.	1.1
June 2021	Steven Thomas	Minor edits—multiple throughout document. Added description of pilot changes to methods for Long Cave for Winter 2022.	Minor edits made following 2020 annual review of protocol	1.2

Contents

	Page
Step by Step Instructions	4
Digital Photography	7
Introduction	7
Equipment Needs.....	8
Batteries.....	8
Lasers.....	8
Protect your Equipment.....	8
Prevent Condensation.....	8
Changing Lenses	8
Settings.....	9
Composing the Image.....	9
Framing.....	9
Perpendicularity and Depth of Field	9
Close up photographs.....	10
Shooting Strategy.....	10
Crew size	10
Additional Bat Counting Methods	10
Quadrat/Grid.....	11
LiDAR.....	12
Filling in the Field Data Forms.....	12
Literature Cited.....	21

Step by Step Instructions

The recommended counting method for each bat species likely to be encountered was established and is provided in the Field Information Sheet (see template in Figure 1 in SOP 2 *Pre-field Sampling and Safety*—Version 1.3 [CUPN 2023a] and example in Appendix E in a Supplemental Materials package which is available on the Cumberland Piedmont Network internal server, or by request to the network) for each cave scheduled for winter monitoring. Below is a sequential list of substantive tasks the field crew should complete during each *sampling event*.

1. Project leader or designated field crew leader will file a trip plan with a CUPN contact (i.e., someone in the office during the trip) and the park (Figure 3 in SOP 2 [CUPN 2023a]) before the trip.
2. Project leader or designated field crew leader will establish a surface contact person (“surface watch”), what time to expect the crew to return (or call-in), and whom/when to notify (i.e., the response lead) in the event the crew does not return (or call-in) on time after attempting to contact the crew. The contact person will be given a copy of the detailed trip plan, the Field Information Sheet(s), travel route map(s), and a list of all team members and emergency contact phone numbers. The contact person will also be instructed to monitor weather channels/radar for approaching severe weather and to alert the field crew with adequate time to take safe action.
3. Project leader or designated field crew leader will conduct a pre-field sampling briefing for crew member(s) to cover such things as the sampling plan, any potential safety hazards/concerns (e.g., weather, check-in time, particular hazards expected), and gage how the crew is doing (SOP 1 *Training Sampling Crew*—Version 1.2 [CUPN 2023b]).
4. Before leaving office, field crew leader should review the Field Information Sheet and supplies/equipment checklists (Tables 8 and 9 in SOP 2 [CUPN 2023a]) to help alleviate any confusion in the field. Selected photos of data loggers in situ and permanent landmarks should be printed on a supplemental Field Information Sheet(s) to help locate these items in the field.
5. If necessary, use the GPS unit and field map included with the Field Information Sheet to navigate to the entrance of the cave to be censused.
6. Near the entrance, suit up with caving gear and prepare the monitoring equipment, data form(s), Field Information Sheet, and Cave Section Map.
7. Refer to the Field Information Sheet (see template in Figure 1 in SOP 2 [CUPN 2023a] and example in Appendix E in a Supplemental Materials package which is available on the Cumberland Piedmont Network internal server, or by request to the network) and Cave Section Map (Figure 2 in SOP 2) to navigate through the cave and determine the most efficient counting route.

8. Note the time of arrival at the cave entrance and the data recorder completes the fields from “PARK CODE” to “TIME COUNT STARTED” on page 1 of the Winter Bat Roost Monitoring Data Form.
9. Record meteorological conditions at the start (e.g., sky/weather, temperature), as well as the method used to obtain the temperature (i.e., digital thermometer, laser thermometer on paper, mercury thermometer, nearby weather station, smartphone, or weather radio).
10. Indicate whether any evidence of recent human disturbance was seen at the cave entrance area.
11. Enter the cave, moving cautiously and staying as quiet as possible.
12. Typically a single field crew member serves as the data recorder. Additional crew members may serve as spotters, counters, or photographer (if necessary). It is important for the project leader or field crew leader to establish roles in advance and maintain good communication in the cave to ensure accurate counting. Using clear, agreed upon hand signals is helpful. Talking should occur only when absolutely necessary. When talking, use a low voice but avoid whispering, which can produce high frequency sounds that may increase disturbance potential.
13. If multiple personnel will be counting, split passages evenly. If only one person is counting, then proceed down and across passages to ensure all sections are checked.
14. Traveling through the cave, stop often to thoroughly search the ceilings and walls. It is often necessary to turn around and scan the ceiling from different directions in order to see into alcoves and cracks.
15. When necessary, use binoculars to confirm species identifications and conduct cluster counts instead of approaching bats. Handling bats for species identification should only be done in limited circumstances.
16. Record each bat and cluster of bats, by species, separately on page 3 of the data form in the appropriate cave section. A cluster is defined as two or more bats in contact with one another. A solitary bat is recorded as a one. During the count, the field crew leader periodically reviews data form(s) to ensure data are accurately and completely recorded.
17. For clusters that are large enough that an accurate count is difficult (usually ≥ 25 bats), or for any size cluster roosting at a distance of roughly ≥ 30 feet (9.1 meters [m]), use a camera with flash and zoom lens (if necessary) to photograph the cluster. If necessary, use a spotlight to help illuminate bats for photography. Attempt to take photos that look straight on at the faces of the bats, which makes photo counting easier. For more detail see the “Digital Photography” section of this SOP. Currently, the primary use of photography is for enhancement of the direct visual count, not for a complete photo count of all bats observed.

18. Indicate each photo on the data form (in the proper cave section) by estimating the cluster size and drawing a square around the number of bats recorded, followed by the frame number(s) of the photo(s) inside brackets. Additionally, a photo of the field data form can be taken after multiple photos of a cluster or group of clusters are completed and the data recorded; this photo can serve as a marker.
19. For other counting methods used on a site-specific basis or when appropriate, see the “Additional Bat Counting Methods” section of this SOP.
20. In each cave section, record on page 2 of the data form rock and air temperature and percent relative humidity (RH) adjacent to the most substantial concentrations of bats (i.e., all bats do not need to be in physical contact) of each species (at as many separate concentrations as is practicable), when possible. If a section within the cave only contains bats roosting singly (i.e., not in physical contact), then measure each parameter adjacent to individually-roosting bats that are located as closely as possible to the majority of other bats of that species in that section of the cave. Visually estimate the **relative** concentration (high, medium, or low) of bats at which temperature and RH measurements are being taken; this concentration level will be relative to the other concentrations of bats of that species observed in that section of the cave during that sampling event. Use a laser thermometer to measure rock temperatures adjacent to the bat cluster, being careful not to touch bats with the laser. To measure air temperature, use a calibrated digital thermometer, thermo-hygrometer, temperature and RH probe, or similar instrument held away from observers’ bodies to avoid artificial temperature increase due to body heat. Relative humidity (RH) should be obtained via a thermo-hygrometer, temperature and RH Probe, or similar instrument held away from observers’ bodies (to avoid artificial humidity increase due to exhalation and vaporization). For more detail see the “Opportunistic Grab Sampling” section of SOP 5 *Cave Meteorological Sampling*—Version 1.2 (CUPN 2023c).
21. Banded bats that are easily accessible should only be handled long enough to read their band numbers and only then if this can be done in a timely manner without disturbing a large number of additional bats. Note that it is sometimes possible to read band numbers without touching the bat. All individuals who directly handle bats must have an up-to-date rabies pre-exposure prophylaxis (vaccination) and must adhere to all current bat handling and decontamination protocols.
22. If in the unlikely event a bat mortality or serious injury to a bat occurs, this must be reported to the project leader immediately following completion of the count. As previously mentioned, all people handling live and freshly dead bats must have up-to-date rabies pre-exposure inoculations and use gloves that will prevent penetration of bites. A freshly dead bat must be double-bagged in two labeled plastic bags for transport to the office where it will be refrigerated while the project leader decides what should be done with it. A mortally injured bat should be euthanized in the field by the project leader. Anyone performing euthanasia must have received NPS training to humanely euthanize bats. Mortality or injury to a

federally listed species must be reported to the U. S. Fish and Wildlife Service (USFWS) within five calendar days.

23. When the count is complete, exit the cave quickly and move cautiously (in a safe manner).
24. Record the time the crew returned to the entrance as the “TIME COUNT ENDED” and record meteorological conditions (e.g., sky/weather, outside temperature) at the end of the count. Use the same method that was used to measure temperature at start.
25. Record any notes related to the sampling event. Comments may include: evidence of recent human disturbance seen at the cave entrance area, bats flying at or outside entrance, dead bats, dying bats, bats collected for testing, evidence of recent flooding, types of equipment used for counting, instrument problems, and reasons why a section(s) was not surveyed.
26. Secure all cave gates and locks as required.
27. Inform surface contact person of party exiting cave ASAP (e.g., via cell phone, radio, or satellite communicator).
28. Before leaving the cave entrance, all field data forms will be reviewed by someone (usually the project leader or field crew leader) other than the individual who filled them out, if possible. Review the Field Information Sheet and suggest any changes to be considered by the project leader.
29. Follow all applicable gear decontamination procedures as described in the White-nose Syndrome section of SOP 2 *Pre-field Sampling and Safety*—Version 1.3 (CUPN 2023a).
30. For a remote cave: upon arrival at the vehicle, office or place of lodging, immediately contact the designated surface contact person via cell phone, radio, or satellite communicator.

Digital Photography

The following summary is based on guidance developed by the New York State Department of Environmental Conservation (NYSDEC; Hicks et al. 2009). Additional guidance from the NYSDEC, including technical specifications, is provided in Hicks et al. (2009).

Introduction

This document describes the method of using DSLR (digital single-lens reflex) photography to document and count hibernating Indiana bats as employed by New York Department of Environmental Conservation. The method is the result of years of refinement and incorporates many hard-won lessons. It is not presented as the final word on the matter, but rather as a snapshot of the current version.

Equipment Needs

You should have an adequate camera, flash, and, depending on the ceiling heights, multiple lenses, a flash extender, and at least three laser pointers per team. You will need back-up batteries for both the camera and flash and high-capacity memory cards (ideally ≥ 1 GB).

Batteries

High capacity rechargeable NiMH batteries are the best choice for high power applications such as camera flashes, offering more flashes per charge and faster refresh times between flashes than alkaline batteries. However, traditional NiMH batteries require regular maintenance (regular and appropriately applied charge/discharge cycles) to maintain their optimum performance.

Lasers

Autofocus cameras require light to focus. When used in dark areas, camera flashes typically have a built-in focus-assist light that works well at close distances. Aiming a laser pointer at what you want to shoot will allow the camera to focus successfully at distances beyond what you can effectively use to count bats. Using two to three laser pointers speeds the process considerably. Lasers in the hands of the primary staff on a team allow you to quickly identify your target of interest so that everyone is looking at the same bat.

Often the use of a laser raises concerns that the bats might be injured in the process. Although there probably isn't any data available as to how bats might be affected, recent evidence suggests that the risk to the human eye from transient exposure to lasers of the type used in commonly available pointers is negligible. Still, there are steps you can take to minimize the possibility of injuring bats. First of all, get the least powerful red laser that you can find. Lasers are rated on a scale that ranges from class I, the lowest, to class IV. In the US, commercially available laser pointers are limited to class IIIa, although it might be possible to purchase a non-compliant, more powerful pointer from some internet sources. Use caution employing lasers not intended to be used as pointers as they could be more powerful.

Protect your Equipment

You need to be concerned about mud, dust, and trauma. You also need to be concerned about contamination of both the camera and the case by WNS-associated fungus. Consider a hard case, which can be easily cleaned, but is more difficult to carry around. When practicable, wear latex or nitrile gloves while handling the cameras. Replace gloves as needed to help keep the camera clean.

Prevent Condensation

Moisture will condense on the outside (and inside) of your lens if you bring a freezing cold camera into a warm, moist cave environment. Keep the camera sealed in a plastic bag until it reaches cave temperatures. On cold days, try to keep it warm by carrying it close to your body until you are in the site.

Changing Lenses

Minimize changing lenses and minimize exposure to dust and dirt when you have to change them. If possible, assign a camera with a big lens to high ceiling areas and one with a smaller lens to low ceiling areas.

Settings

Be exceedingly familiar with the gear before starting surveys. You may find it helpful to create an abbreviated manual or “cheat sheet” including the essential functions of the camera and the flash (changing mode, shutter speed, ISO, aperture, image format, reviewing images) and keep it with the camera just in case you forget the normal settings.

- Image format: We recommend that you use the “jpg” format unless you have prior experience using “raw” images.
- ISO setting: ISO 100 is standard. Use the highest setting that conditions allow. When light is inadequate switch to ISO 200 before changing the aperture.
- Metering: Use center-point metering when possible, center-weighted when not.
- Mode: Camera on manual, flash on ETTL.
- Aperture: f-11 is standard, but might need f-8 or 5.6 at long distances.
- Shutter speed: 1/200 is a typical standard; it is primarily lens dependent.
- Focus: use auto focus.

Composing the Image

Framing

- Fill the frame with bats to the extent possible. Rotate the camera body and adjust the zoom so the larger dimension of the image just includes the largest dimension of the cluster.
- For large clusters, shoot an overall image that provides coverage of the entire cluster and then shoot multiple overlapping tiled shots at a longer focal length for details (i.e., enough detail that one can still count individual bat noses). Make sure the tile shots include cluster edges, the unique edge characteristics will allow you to identify where images overlap. Also, shoot all tiled images from the same spot, so that the perspective in each image is the same. It’s often possible to count bat noses in a 1,000-bat cluster (e.g., 3 × 1 foot size [0.91 × 0.30 meters]) in a single photo, but the work goes faster and can be more accurate if you also have some close-up shots.
- When possible, within each hibernaculum section take some bat cluster photos with a known distance/measure in the frame so a packing density can be estimated. An engineer’s ruler or a laser caliper is typically used to achieve this.
- When you cannot fill the image (small clusters or single distant clusters), and the background is light colored, you may have to increase the flash power to properly expose the cluster.

Perpendicularity and Depth of Field

- Always try to position yourself so that you are shooting on a line perpendicular to the plane of the cluster. This avoids depth-of-field issues and minimizes the number of hidden bats.

- If a cluster is not arrayed in a single plane, then you should shoot multiple images, each perpendicular to the surface of interest and clearly overlapping adjacent shots.
- Use the smallest aperture that the situation allows to maximize depth of field, generally f-11 to compensate for uneven surfaces of clusters. Minimize the problem by getting absolutely perpendicular to the cluster whenever possible.

Close up photographs

When shooting images to document some anomaly on an individual (e.g., white fungus/WNS):

- maximize the depth of field (f-20 or f-22)
- make sure the ISO setting is 100
- Use a reflective device (e.g., aluminum clipboard or data form) to soften shadows. Set reflector as close to the bat as possible without including it in the image. It should be nearly on the opposite side of the bat from the flash and angled so that the reflected light will fill in the shadow areas created by the flash.

Shooting Strategy

The most efficient strategy can best be described as “Shoot first, ask questions later.” For example, it’s usually easier and faster to shoot everything you see rather than to spend time trying to decide if that cluster 30 feet (9.1 m) above your head includes the target species. To minimize disturbance to the bats, get your shots as quickly as possible, even if it means you take more photos. Remember, image storage space is cheap compared to how much you are spending on manpower.

Crew size

The ideal camera crew is composed of three people: the “spotter,” a “data recorder,” and the “shooter.” The spotter keeps track of what has been photographed, decides what to shoot next, and puts the laser on (or adjacent to) the next target. It is often helpful if the spotter keeps an eye on the perpendicularity of the shot because the shooter often loses perspective given the degree of attention he has to place on framing and exposure. A helpful tip is to have the camera’s audible focus beep engaged. When the spotter hears the beep he can remove the laser spot without being told to do so by the shooter. The data recorder keeps track of image numbers and records whatever other information the shooter deems necessary about the location of the images, visual estimate of cluster numbers, numbers of bats counted but not photographed, etc.

Additional Bat Counting Methods

Hibernating bat populations in **most** CUPN caves will be censused using direct visual counts, photography, or both—except the large (approx. 300,000) colony of gray bats (*Myotis grisescens*) in Long Cave at Mammoth Cave National Park. When direct counts or photography are not possible for estimating the number of roosting bats (i.e., Long Cave gray bats arouse from torpor too quickly), other approaches may be used: (1) estimating the surface area covered by the clusters and the average

density of bats, (2) using a terrestrial Light Detection and Ranging (LiDAR) laser scanner to remotely count roosting bats, or (3) a combination of two or more methods.

Quadrat/Grid

A standard-size and shape (e.g., meter square) quadrat will be used to estimate average density and total area of roosting bats in each section in the cave (Kunz et al. 1996; Tuttle 2003). The quadrat or grid should be divided into quarters (Figure 1) which also allows for density estimates of smaller clusters. The grid will be used to give counters a “frame of reference” to visually estimate the number of grids with similar densities of bats throughout the hibernaculum. For example, a section within a hibernaculum may contain visual estimates of: 10 grids of high density, 2 grids of medium density, and 5.5 grids of low density of roosting bats. The grid will also be used to estimate average bat densities (e.g., high, medium, low) by placing it as close to the hibernating bats as possible without touching them and taking representative digital photographs of between 2 and 4 clusters for each density present (e.g., high, medium, low). The idea is to minimize disturbance by taking as few photographs as possible and to move as quickly as feasible to obtain visual grid estimates before the bats arouse and take flight. A sturdy telescoping pole can be firmly attached to the grid in order to reach distant bats. If necessary, representative photographs of bats inside the grid are taken within each section of the hibernaculum because clustering density may change. Photographs will be returned to the office where average density estimates (e.g., high, medium, low) will be calculated for each section after counting bats inside the grid in the photographs. For example, a section may contain the following calculated average density estimates: high=1,023 bats/square meter (10.8 square feet [ft²]); medium=643 bats/square meter; and low=207 bats/square meter.

The estimated total number of bats will be calculated for each section by multiplying the number of visually estimated grids of bats with similar densities by the average density estimates obtained from representative photographs. Continuing the examples from above, a section may contain visual estimates of: 10 grids of high density multiplied by the calculated average high density estimate of 1,023 bats/m² (10.8 ft²) equals an estimate of 10,230 bats (high density); 2 grids of medium density multiplied by the calculated average medium density estimate of 643 bats/square meter equals an estimate of 1,286 bats (medium density); and 5.5 grids of low density multiplied by the calculated average low density estimate of 207 bats/square meter equals an estimate of 1,138.5 bats (low density). Finally, the estimated numbers of bats for each density are summed: 10,230 bats (high density) plus 1,286 bats (medium density) plus 1,138.5 bats (low density) to obtain the estimated total number of bats for the cave section of 12,654 bats (rounded).

A modified approach may be piloted during winter 2024 at Long Cave. One proposed change is to use five standard density categories (as done with similar-sized bat colonies in Tennessee) instead of the three categories currently used. A second proposed change is to compile and use a photo reference library representing each of the five standard density categories instead of taking reference photos at the start of each sampling event. Using these printed and laminated (or digital) reference photos should standardize estimates among all field crew leaders, speed up data collection (by not having to take reference photos), and cause less initial disturbance of hibernating bats.

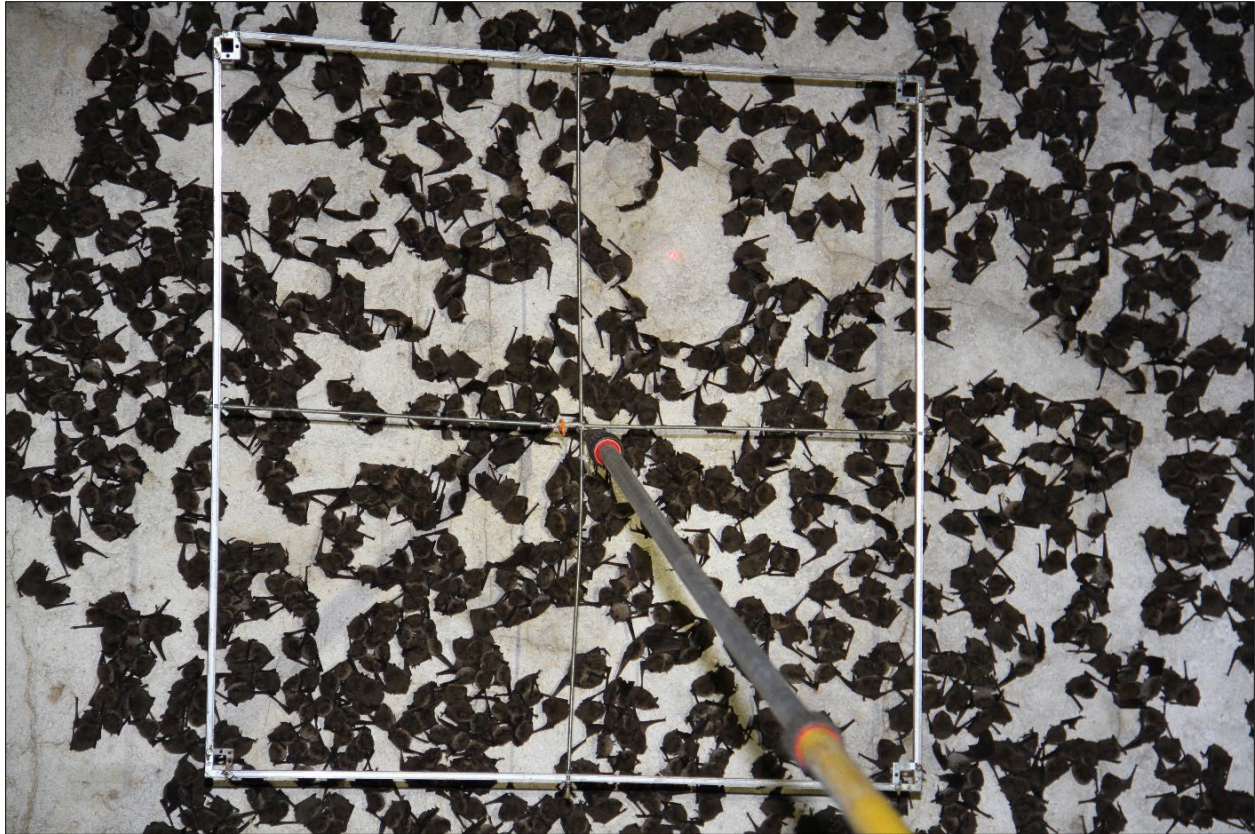


Figure 1. Grid used to estimate average density of hibernating gray bats. NPS photo.

LiDAR

Use a terrestrial LiDAR laser scanner to remotely count roosting bats. This application of laser scanning technology is novel (Azmy et al. 2012), was pilot-tested in two MACA caves in early 2013, and its long-term use in CUPN bat roosts is unknown at this time. Another approach to estimate roosting bat numbers with LiDAR involves scanning roosts twice—with and without bats present—to calculate volume estimates. The difference in volumes between the two scans is obtained. Finally, the known volume of a single bat is used to calculate an estimate of the total number of bats in the scanned roost. A field test of this approach was initiated during the winter of 2012–2013 at a cave in the southwestern United States that is the summer home of millions of Brazilian free-tailed bats (*Tadarida brasiliensis*; K. Gillies, Bat Conservation International, personal communication). This volumetric approach was attempted in a MACA cave in February and September 2013; results were promising (Schaefer et al. 2015).

Filling in the Field Data Forms

A detailed list of descriptions for each field on pages 1, 2 and 3 (Figures 2, 3 and 4) of the Winter Bat Roost Monitoring Data Form is provided in Table 1.

Office Only: data entered by _____ on ____/____/____ CUPN_Cave_Bats_Winter_Data_Form_20190731
 validated by _____ on ____/____/____ scan made by _____ on ____/____/____ Protocol Version #: _____
 Sampling Event Purpose: Scheduled monitoring Special project Periodic assessment (circle one)

Winter Bat Roost Monitoring Data Form

Cumberland Piedmont Network

PARK CODE: CAVE NAME:

OBSERVERS NAME(S):

[List Field Crew Leader first] (first name last name, first name last name, ...)
[circle name(s) of the bat counters]

DATE (mm/dd/yyyy): / / **TIME OF ARRIVAL (hhmm, 24-hr format):** **Local ST**

SKY/WEATHER CONDITIONS AT START: 0 1 2 4 5 7 8 (circle one)

Sky/Weather Condition Codes: 0=clear or few clouds; 1=partly cloudy/variable; 2=cloudy/overcast; 4=fog/smoke; 5=drizzle; 7=snow; 8=showers

TEMPERATURE ON SURFACE AT START: °C or °F (circle one)

Method Used for Temperature on Surface:

Human Disturbance Seen at Cave Entrance Area? Yes or No (circle one) (if "Yes" is circled, include details in Comments section below)

TIME COUNT STARTED (hhmm): _____ Local Standard Time

TIME COUNT ENDED (hhmm): Local Standard Time

SKY/WEATHER CONDITIONS AT END: 0 1 2 4 5 7 8 (circle one)

TEMPERATURE ON SURFACE AT END: °C or °F (circle one)

COMMENTS:

Data recorder initials _____ Reviewed by: _____

Page 1 of

Figure 2. Page 1 of field data form for winter roost (hibernacula) counts for CUPN parks.

Measure and record Temperature and % Relative Humidity near the most substantial concentrations of bats in each section, if possible. Relative Concentration of Bats is relative to the other concentrations of bats of this species observed in this section of the cave during this sampling event. Note: can have measurements for more than one concentration of bats per species per section.

[illegible]

Figure 3. Page 2 of field data form for winter roost (hibernacula) counts for CUPN parks.

Winter Bat Roost Monitoring Data Form Cumberland Piedmont Network

PARK CODE: _____ CAVE NAME: _____ DATE (mm/dd/yyyy): ____/____/____

Record each bat or cluster size (≥ 2 bats in contact) per species separately within each section of the cave. For example: 1-1-2-1-7-15-1-3.

Draw a box - - around direct counts of photographed clusters and record frame numbers. For example: 1-3-25[P00645]-2-9-31[P00646-649].

Indicate each bat with visible signs of white-nose syndrome with a "w". For example: 1-2-1w-5-1-12(2w)-3. Indicate each dead bat with a "d".

For example: 1d-2-1w-5-1-12(2d)-3. Record unique band/tag identification number, sex, visible signs of white-nose syndrome, dead, and apparently healthy ("h") for each recaptured bat per species within each section of the cave. For example: [KY F&W A12563-♂-w] or [KY F&W A12563-♀-h].

Bat Species	In-Cave Section # _____	☐ No bats present ☐ Survey not attempted	Totals (In the Office)	Photo Analysis
Bands/Tags:		Direct count subtotal: w/o Box= ____ Box= ____	Direct count (D) = ____	
			Photo count (P) = ____	
Bands/Tags:		Direct count subtotal: w/o Box= ____ Box= ____	Q/Grid count (G) = ____	
			LIDAR count (L) = ____	
Bands/Tags:		Direct count subtotal: w/o Box= ____ Box= ____	D= ____	
			P= ____	
Bands/Tags:		Direct count subtotal: w/o Box= ____ Box= ____	G= ____	
			L= ____	
Bands/Tags:		Direct count subtotal: w/o Box= ____ Box= ____	D= ____	
			P= ____	
Bands/Tags:		Direct count subtotal: w/o Box= ____ Box= ____	G= ____	
			L= ____	
B/T:		Direct count subtotal: w/o Box= ____ Box= ____	D= ____ G= ____	
			P= ____ L= ____	
B/T:		Direct count subtotal: w/o Box= ____ Box= ____	D= ____ G= ____	
			P= ____ L= ____	
B/T:		Direct count subtotal: w/o Box= ____ Box= ____	D= ____ G= ____	
			P= ____ L= ____	
B/T:		Direct count subtotal: w/o Box= ____ Box= ____	D= ____ G= ____	
			P= ____ L= ____	

Data recorder initials _____ Reviewed by: _____

Page ____ of ____

Figure 4. Page 3 and following of field data form for winter roost (hibernacula) counts for CUPN parks.

Table 1: Data form field descriptions for winter cave roost sampling.

Page Number	Field Name	Field Description
Page 1: Winter Bat Roost Monitoring Data Form	Park Code	Unique 4-letter park acronym (i.e., CHCH, CUGA, MACA, RUCA)
	Cave Name	The unique name of the cave being sampled.
	Observers Name(s)	First and last names of all involved in the field data collection. List the Field Crew Leader first. Circle names of individual(s) who directly counted bats.
	Date	The date that data are being collected in mm/dd/yyyy format (e.g., 05/17/2011).
	Time of Arrival	The time, to the nearest minute, (using the hour and minute format shown) when crew arrived at the cave entrance. A 24-hour format should be used. All four digits should be filled in. Examples: 0630 (6:30 am) and 1350 (1:50 pm). Use local standard time and make sure to use correct time zone.
	Sky/Weather Conditions at Start	Circle the National Weather Service Weather Condition Code number that best represents sky/weather conditions at the start of sampling. Codes and descriptions listed in text box. Adapted from USGS Breeding Bird Survey.
	Temperature on Surface at Start	The ambient temperature outside the entrance, but not directly influenced by the entrance, at the start of sampling. Scale used (i.e., Celsius or Fahrenheit) should be circled. Celsius is preferred.
	Method Used for Temperature on Surface	The method used to obtain temperature readings outside the cave at start and end of sampling. Possible methods used include: digital thermometer, smartphone, nearby weather station, weather radio, laser thermometer on paper, or mercury thermometer.
	Human Disturbance Seen at Cave Entrance Area?	Circle "Yes" if any recent human disturbance observed around the cave entrance and record details in the Comments section at the bottom of the page. Examples include: damage to gate; missing or damaged lock(s); attempts to circumvent the gate by digging; tools for digging, cutting, prying; digging in the vicinity (artifact searching). Circle "No" if none seen.
	Time Count Started	The time, to the nearest minute, (using the hour and minute format shown) when crew begins sampling within the cave entrance. A 24-hour format should be used. All four digits should be filled in. Examples: 0630 (6:30 am) and 1350 (1:50 pm). Use local standard time and make sure to use correct time zone.
	Time Count Ended	The time, to the nearest minute, (using the hour and minute format shown) when crew returned to the entrance after finishing sampling within the cave. A 24-hours format should be used. All four digits should be filled in. Examples: 0630 (6:30 am) and 1350 (1:50 pm). Use local standard time and make sure to use correct time zone.

Page Number	Field Name	Field Description
	Sky/Weather Conditions at End	Circle the National Weather Service Weather Condition Code number that best represents sky/weather conditions at the end of sampling (i.e., immediately after exiting the cave). Codes and descriptions listed in text box.
	Temperature on Surface at End	The ambient temperature outside the entrance, but not directly influenced by the entrance, at the end of sampling. Scale used (i.e., Celsius or Fahrenheit) should be circled. Celsius is preferred. Use the same method that was used to measure temperature at start.
	Comments	Notes related to the sampling event. May include: evidence of recent human disturbance seen at cave entrance area; bats flying at or outside entrance; dead bats; dying bats; bats collected for testing; evidence of recent flooding; types of equipment used for counting; instrument problems; access problems, etc.
	Data recorder initials	Initials of individual filling-out the data form in the field. Occasionally, one (or more) persons will call out data, while another records.
	Reviewed by	Initials of individual who reviewed completed page 1 of data form for winter bat roost monitoring elements. Ideally this should be someone other than individual who filled-out this page of the data form and is intimately familiar with the data forms.
	Page 1 of ____	Total number of field data forms used during this sampling event (including page 1). Recorded by individual reviewing completed data forms.
Page 2: Temperature and % Relative Humidity	Park Code	Unique 4-letter park acronym (i.e., CHCH, CUGA, MACA, RUCA)
	Cave Name	The unique name of the cave being sampled.
	Date	The date that data are being collected in mm/dd/yyyy format (e.g., 05/17/2011).
	In-Cave Section #	The ID number of each section sampled within the cave. Consult the Cave Section Map (Figure 2 in SOP2) or the Field Information Sheet (Figure 1 in SOP2 or Appendix E in a Supplemental Materials package on the CUPN internal server, or by request to the network) for the cave to locate the correct section #. Use multiple rows on data form for the same cave section for each concentration of bats at which temperature and RH measurements are taken. <i>Note:</i> can have measurements for more than one concentration of bats per species per section.
	Bat Species	Bat species ID code (see page 3 below) for concentration of bats at which temperature & RH measurements are taken. List only one species per row. Can use multiple rows for separate concentrations of the same species.
	Relative Concentration of Bats	Record "H" for High, "M" for Medium, or "L" for Low concentration of bats of the species listed in the row relative to the other concentrations of bats of that species observed in that section of the cave at that particular time.

Page Number	Field Name	Field Description
	Rock Temp (°C)	Temperature of rock (e.g., ceiling, wall) adjacent to the most substantial concentrations of bats for a species per section within the cave. Temperature should be obtained via laser thermometer (avoid touching bats with laser) and recorded in Celsius.
	Air Temp (°C)	Temperature of air adjacent to the most substantial concentrations of bats for a species per section within the cave. Temperature should be obtained via digital thermometer, thermo-hygrometer, temperature and RH probe, or similar instrument and recorded in Celsius.
	Relative Humidity (%)	Percent RH of air adjacent to the most substantial concentrations of bats for a species per section within the cave. RH should be obtained via a thermo-hygrometer, temperature and RH probe, or similar instrument and recorded as a whole number (e.g., 90).
	Data recorder initials	Initials of individual filling-out the data form in the field. Occasionally, one (or more) persons will call out data, while another records.
	Reviewed by	Initials of individual who reviewed completed page 2 of data form for winter bat roost monitoring elements. Ideally this should be someone other than individual who filled-out this page of the data form and is intimately familiar with the data forms.
	Page ____ of ____	Page number of particular field data form and total number of field data forms used during this sampling event. Recorded by individual reviewing completed data forms.
Page 3: Bat and cluster counts	Park Code	Unique 4-letter park acronym (i.e., CHCH, CUGA, MACA, RUCA)
	Cave Name	The unique name of the cave being sampled.
	Date	The date that data are being collected in mm/dd/yyyy format (e.g., 05/17/2011).

Page Number	Field Name	Field Description
	Bat Species	Unique 4-letter ID code for species of bat observed in the cave (PESU = <i>Perimyotis subflavus</i>, EPFU = <i>Eptesicus fuscus</i>, MYSE = <i>Myotis septentrionalis</i>, MYSO = <i>M. sodalis</i>, MYLU = <i>M. lucifugus</i>, MYGR = <i>M. grisescens</i>, MYLE = <i>M. leibii</i>, MYAU = <i>M. austroriparius</i>, CORA = <i>Corynorhinus rafinesquii</i>, UNKN for species unknown, and LANO = <i>Lasionycteris noctivagans</i>—occasionally observed hibernating in cave entrances). List only one species per row. In the space provided to the right, record the number of individual live bats or cluster sizes counted within each section of cave sampled (using the format shown in the example). Draw a square around direct counts of photographed clusters and record frame (i.e., image) numbers (within brackets) using format shown in example. Indicate each bat with visible signs of white-nose syndrome with a "w" using format shown in example [e.g., "12(2w)" means a cluster of 12 live bats, 10 of which have no visible signs of WNS and 2 have visible signs]. Indicate each dead bat with a "d" using format shown in example. If both live and dead bats are clustered together, then record the total number of live bats in the cluster followed by the total number of dead bats and a "d" (indicating "dead") enclosed in parentheses [e.g., "12(2d)" means a cluster of 14 bats, 12 of which are alive and 2 are dead]. For quadrat/grid sampling, record the number of quadrats followed by the capital letter representing the density category ("H" for High, "M" for Medium, and "L" for Low density) for each species counted by this method within each section. For example: 5L-3.25H-2M-2L-6.5L-3M-1H. Record frame (i.e., image) numbers (within brackets) of representative photos of bats within grid used for density estimates. For example: M[P00649-652]-L[P00653-656]-H[P00657-662].
	In-Cave Section #	The ID number of each section sampled within the cave. Consult Cave Section Map (Figure 2 in SOP 2 <i>Pre-field Sampling and Safety</i>—Version 1.3 [2023a]) or the Field Information Sheet (Figure 1 in SOP 2 or Appendix E in a Supplemental Materials package on the CUPN internal server, or by request to the network) for the cave to locate the correct section #. Use a separate page of this data form for EACH section of cave in which bats were counted. For additional space, combine rows for a single species and cross-out line between rows (or use another page of this data form for the same section). Note: Check box if "No bats present" in a section and enter "NONE" in the first empty cell under the "Bat Species" field. Check "Survey not attempted" if for some reason (give reason in Comments field on page 1) a section was not sampled and enter "NOSURVEY" in the first empty cell under the "Bat Species" field. Either "NONE" or "NOSURVEY" will be entered into the database for that cave section.
	Bands/Tags	Record unique band/tag identification numbers, sex, visible signs of white-nose syndrome, dead, and apparently healthy for each recaptured (i.e., previously banded or PIT tagged or both) bat per species within each section using format shown in examples. For additional space on the form, extend the rectangle around this field into any unused space to the immediate right (i.e., where numbers of bats/clusters are recorded) or use any unused row below and label it using this example "MYSO Tags".

Page Number	Field Name	Field Description
	Direct count subtotal:	Subtotals are recorded in the field only if time permits. First blank: the total number of bats of the species listed in the row that was directly counted without being photographed (i.e., without a box drawn around the number). Second blank: the total number of bats of the species listed in the row that was directly counted/estimated and photographed (i.e., with a box drawn around the number).
	Totals	Totals obtained in the office, NOT while in the field (i.e., leave blank during field review of data form). Totals (for each method used) of bat counts for each species per section of cave censused. Direct count (D) total is calculated by summing the numbers in the "Direct count subtotal" box in the cell to the left. Photo count (P) total is obtained by summing all of the counts of photographed bats after photo analysis is completed and adding that value to the subtotal of bats that were directly counted but not photographed (i.e., from the first subtotal line labeled "w/o Box=___"). This is because currently the primary use of photography is for enhancement of the direct visual count, not for a complete photo count of all bats observed. Note: if no photographs were taken, or photos were unusable, then use the direct count (D) total for the photo count (P) total. Q/Grid count (G) total is a sum of number of quadrats for each density category (i.e., High, Medium, or Low) present multiplied by the average density estimate for each category (obtained from analysis of the representative photos of bats within the grid). LiDAR count (L) total is obtained directly from analysis of the images from the LiDAR scans or from the volume estimates approach.
	Data recorder initials	Initials of individual filling-out the data form in the field. Occasionally, one (or more) persons will call out data, while another records.
	Reviewed by	Initials of individual who reviewed completed page 3 (and following) of data form for winter bat roost monitoring elements. Ideally this should be someone other than the individual who filled-out this page of the data form and is someone intimately familiar with the data forms.
	Page ____ of ____	Page number of particular field data form and total number of field data forms used during this sampling event. Recorded by individual reviewing completed data forms.

Literature Cited

- Azmy, S. N., S. A. M. Sah, N. J. Shafie, A. Ariffin, Z. Majid, M. N. A. Ismail, and M. S. Shamsir. 2012. Counting in the dark: non-intrusive laser scanning for population counting and identifying roosting bats. *Scientific Reports* 2:524. DOI:10.1038/srep00524.
- Cumberland Piedmont Network. 2023a. Pre-field sampling and safety—Version 1.3. Cumberland Piedmont Network Standard Operating Procedure NPS/CUPN/SOP—2. Cumberland Piedmont Network, Mammoth Cave, Kentucky. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2291689> (last accessed January 2023).
- Cumberland Piedmont Network. 2023b. Training sampling crew—Version 1.2. Cumberland Piedmont Network Standard Operating Procedure NPS/CUPN/SOP—1. Cumberland Piedmont Network, Mammoth Cave, Kentucky. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2291684> (last accessed January 2023).
- Cumberland Piedmont Network. 2023c. Cave meteorological sampling—Version 1.2. Cumberland Piedmont Network Standard Operating Procedure NPS/CUPN/SOP—5. Cumberland Piedmont Network, Mammoth Cave, Kentucky. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2291692> (last accessed January 2023).
- Hicks, A. C., C. Herzog, A. Ballmann, and A. King. 2009. Protocol for 2008–2009 hibernacula surveys of cave bats (Revised 5 January 2009). New York State Department of Environmental Conservation Unpublished Report, Albany, New York.
- Loeb, S. C., T. J. Rodhouse, L. E. Ellison, C. L. Lausen [and others]. 2015. A plan for the North American Bat Monitoring Program (NABat). Gen. Tech. Rep. SRS-208. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 100 p.
- Kunz, T. H., D. W. Thomas, G. C. Richards, C. R. Tidemann, E. D. Pierson, and P. A. Racey. 1996. Observational techniques for bats. Pages 105-114 *in* D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. *Measuring and monitoring biological diversity, standard methods for mammals*. Smithsonian Institution Press, Washington, D.C.
- Kunz, T. H., M. Betke, N. I. Hristov, and M. J. Vonhof. 2009. Methods for assessing colony size, population size and relative abundance of bats. Pages 133-157 *in* T. H. Kunz and S. Parsons, editors. *Ecological and behavioral methods for the study of bats*. The Johns Hopkins University Press, Baltimore, Maryland.
- Schaefer, C., A. Addison, B. Osburn, S. Thomas, R. Toomey, S. Marquardt, and K. Gilles. 2015. Counting the night's watchmen. Unpublished poster presentation at 45th Annual Symposium, North American Society for Bat Research, Monterey, CA.
- Thomas, S. C. 2013. SOP – Townsend's big-eared bat winter hibernacula surveys. National Park Service Unpublished Report, Lava Beds National Monument, Tulelake, CA.

Tuttle, M. D. 2003. Estimating population sizes of hibernating bats in caves and mines. Pages 31-40
in: T J. O'Shea and M. A. Bogan, editors. Monitoring trends in bat populations of the United
States and Territories: problems and prospects: U.S. Geological Survey, Biological Resources
Division, Information and Technology Report, USGS/BRD/ITR-2003-0003.