THE MDC METHOD: COUNTING BATS WITH INFRARED VIDEO

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Abstract

A relatively inexpensive method is presented for recording bat emergences with Digital8® or mini-DV camcorders and near-infrared lamps. The recordings may be visually counted or automatically counted with a computer program. The Missouri Department of Conservation developed a statistical sampling method, in which 40 percent of the video sequence is counted by one or two observers. This "MDC method" is discussed, in which a total estimate of the emergence is made with 95 percent confidence limits. A bat stopwatch counting method also is given. Some preliminary information is reported on a more expensive thermography method for counting bats.

Review of Bat Emergence Counting Methods

It is quite a challenge to accurately count bats as they emerge from a cave or a mine. It soon becomes too dark to count bats with the naked eye without illumination or night vision technology. The speed and size of bats can also present problems. These aspects combine to make resolution of individual bats during an emergence difficult. Finally the fluctuation in the number of bats exiting at any given moment frustrates attempts at simple rate estimates.

Besides methods for counting bats in their roost, a few emergence count methods have been used:

- Wild guessing (must have been a million of them!)
- Flight duration (weather, season, and hunger-dependent)
- Counting on fingers and toes (tend to run out of them)
- Educated guessing (or uneducated)
- Counting on clickers (wear out your thumb)
- Skip-minute counting with night-vision or headlamp (good)
- Stopwatch method with several observers (better)
- Near-infrared (incident light) videography (better)
- Far-infrared thermography (excellent)

Considering the good methods, Elliott developed his stopwatch method, which involves several observers (Appendix A). However, large flights can overwhelm the observers' counting ability, and like

most counting methods this may result in inaccurate estimates. He believes that visual estimates are usually conservative if done carefully. However, a consistent method may be all that is needed to monitor bat populations for changes. Although trained individuals can be proficient in conducting visual emergence counts (Sabol and Hudson 1995), years of experience may be necessary.

Materials and Methods

This study used relatively inexpensive Digital8® or mini-DV camcorders, near-infrared lamps, and slow-motion playback. The rationale is that humans and bats cannot see in the infrared spectrum (Table 1), so using commercially available near-infrared lamps will not disturb the bats, and we can record their emergences without altering their behavior. A small amount of red light is emitted by the near-infrared lamps, but this does not seem to alter the bat flight. Using a cluster-sample counting technique, it is possible to conduct emergence count surveys at a reasonable cost and calculate a statistical confidence interval for the estimate.

Spectral Region	Wavelength in nm
Human and bat vision	400-700
Near-infrared (near-infrared)	700-1400 Nightshot® 400–1400, peak 800
Mid-infrared	3,000-5,000
Far-infrared (FIR, thermal)	7,000–14,000 or more Indigo camera 8,000–9,000

Table 1. Human and bat vision compared to the infrared spectrum.

I began using a Sony® Digital8 video camera (Model DCR-TCRV310) in 2000 to record emergences of gray bats, *Myotis grisescens*, from Missouri caves. I used a Sony wide-angle lens to record the full width of an entrance (usually). Initially I used a Kodak® near-infrared gel filter on a powerful, 12-volt DC spotlight. The light was uneven, so I used pieces of a plastic milk jug or drafting mylar as a diffuser. The heat eventually melted the filter. I tried other light sources with an industrial, high-temperature, near-infrared filter, which was better.

However, most of the light energy was filtered out, and there was insufficient illumination at large cave entrances.

In 2004 Steve Samoray, Sara Gardner, and I used Sony's small, near-infrared infrared lamps with AA batteries, but two or three of them were insufficient at large entrances. In 2005 we purchased two lamps from David Dalton at Wildlife Engineering, available in 20° or 40° beams. Steve Samoray, Jim Kaufmann, and I used the latter for close-in work at larger entrances with good results. The cost was about $600 for two lamps and a rechargeable 12-volt DC battery. Although many cameras can record in low light, the results are grainy, so it is important to have good illumination for clarity and contrast.

We generally set up at least 30 minutes before sunset at 5 to 10 meters outside the cave entrance with the camera on a tripod (Figure 1). Usually the camera was inclined upwards 20 to 30° to view the bats as they exited over the top of a half gate or through a chute gate (Figure 2). The ideal set up is to be inside the cave aiming at a relatively flat ceiling or wall with the camera oriented as perpendicular to the flight path as possible. It is important to avoid sky or vegetation in the field of view as the emergences begin in bright twilight, which overwhelms the near-infrared illumination.

In 2004 one Sony near-infrared lamp was mounted to the camera tripod and illuminated the center portion of the entrance, while the other two were placed on independent tripods. These independent tripods were placed 2 meters on either side of the camera and the near-infrared emitters aimed at opposite sides of the entrance to eliminate shadows. In 2005 the Wildlife Engineering lamps were mounted on tripods on either side of the camera to eliminate shadows as much as possible. A custom bar can be built to hold the camera and two lamps on one tripod.

Gray bats were usually observed milling about the entrance for a few minutes before a flight began. Recordings started shortly after sunset or after observation of several exits without re-entry were counted. The recordings continued until a limited number of bats were exiting (for example, five bats per minute) or the number of exits and entrances were equal. At many caves, after emergences, internal surveys were conducted to check if all bats had exited.

Although a continuous count of the entire

Figure 1. Video set up with Sony Digital8 video camera and Wildlife Engineering NIR lamps.

Figure 2. Gray bats emerging from the chute gate at Tumbling Creek Cave. Up to 41,000 bats were observed in 2005.

a high level of accuracy. The method uses collections or clusters as individual sampling units and is frequently used in situations when aspects of a population, such as total number, are difficult to obtain. In addition, the method was chosen because the rate of bats exiting varies greatly throughout the emergence. A graph of the emergence, using either the Stopwatch or the MDC Method, often appears as a jagged, normal distribution with an obvious peak of intensity during the middle and lower numbers on either side (Figure 3). Simple random sampling may indicate this pattern, but may also be affected by it. Cluster sampling allows for the intensity fluctuations and equally samples through the entire length of the emergence.

We divided the video into 10-minute periods. We then randomly selected four one-minute segments from each 10-minute period. We connected the camera to a large television with an S-video cable and divided the screen in half with a vertical tape. This allowed two observers to concentrate on much smaller areas and reduced the number of bats counted per observer. In many cases we also placed a horizontal tape for a visual starting line, so that bats that were crossing from one side to the other could be seen in advance. We then played back the tape at full speed or in slow motion (depending on

taped out-flight would yield the most precise estimate of the colony, this can be very time and labor intensive. Mike Wallendorf, biometrician, helped us develop a statistical sampling method in which 40% of the playback sequence was counted by one or two observers.

A cluster sampling method was used to reduce the number of minutes counted, but still maintain
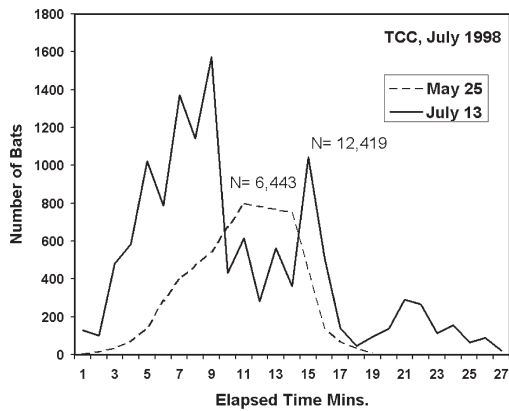
Figure 3. Comparison of gray bat emergences counted with the Stopwatch Method, Tumbling Creek Cave, 1998. The May 25 emergence (dashed line) represents pregnant females probably exiting from a single roost. The July 13 emergence represents mothers and young probably emerging from multiple roosts, and is less "monolithic."
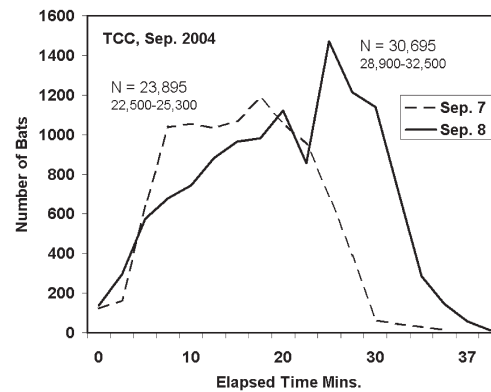

Figure 4. Comparison of two consecutive Gray bat emergences using the MDC Method, Tumbling Creek Cave, September 7-8, 2004. During this transient period the emergences can differ significantly from night to night. The 95% confidence intervals are given after the total estimates, N.

the exit rate) and counted the same four segments per period using hand-held tally meters. This resulted in four cluster groups overall.

All data were recorded on a data sheet, then entered into a computer spreadsheet, where we calculated the mean of the cluster groups and the estimate of the total number of bats. Sample variance among the clusters was calculated, and a finite population correction was applied to obtain a total variance. This was then used to calculate the 95% confidence intervals for the total count.

Results and Comparison to Other Methods

Since 2000 we have recorded 48 flights at 22 Missouri caves. At Tumbling Creek Cave, where we did most of our work, in 2004–2005 the error rate of this method was about ±7% of the estimate, varying from 0.5–15% over 15 emergences. A later improvement to the method involved counting 20-second segments every two minutes, reducing our sampling effort from 40% to 17%, with even narrower 95% confidence intervals. The lack of random sampling was not a problem because of the inherent variance in the bat flight itself. In general, we believe this method to be acceptable for monitoring population trends in gray bats and other bats, especially as the emergences vary significantly anyway from one night to the next in late summer (Figure 4). The variance increases after the young begin flying and the colonies are more mobile and enter a transient period for the autumn. We have

Cave	County	Date	MDC Method	Sabol Method
Smittle	Wright	July 13	16,418 ± 1,970	16,400
Mary Lawson	Laclede	July 14	71,615 ± 2,408	49,010
Beck Cave	Hickory	July 15	1 entrance = 736 ± 15	2 entrances = 1,705
Tumbling Creek	Taney	July 16	poor recording	31,985

Table 2. Comparison of the MDC and Sabol methods at gray bat emergences in Missouri, 2005.
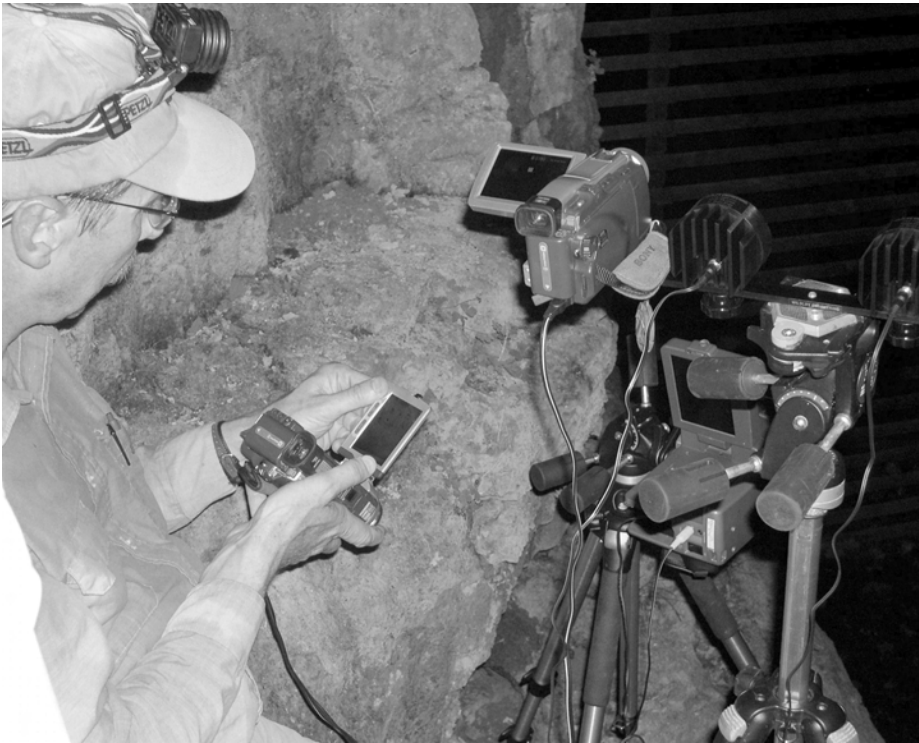
Figure 5. Bruce Sabol holds a mini-DV camera to record the output from the Indigo® thermal (FIR) camera, turned sideways at center right. Near-infrared lamps are mounted on a tripod at far right. The larger mini-DV camera on the left tripod is recording in near-infrared using Sony Nightshot®.

(pers. comm.) uses high-contrast video taken with an Indigo® thermal (FIR) camera, recorded on a mini-DV tape. Sabol's thermal camera usually is set to the side of the entrance for a view nearly perpendicular to the emergence. With no wide-angle lens for the special optics, the camera is turned sideways to obtain a cross-section of the flight. The results are transferred to a computer for video processing in two steps. The first step compares one video frame to the next to obtain moving bat vectors. In another program the researcher then draws a polygon counting frame in or around the entrance, and the program counts the bat vectors leaving the frame for a total count. In Missouri, we obtained two good simultaneous recordings to compare our methods, summarized in Table 2.

noticed at other caves that the error rate of the method itself can be high if the total is less than about 2,000, in which case it is better to count the entire tape. A different cluster sampling method might lessen the error in some estimates.

We also are comparing our method to the traditional guano measurements used in the cave at the end of summer. The Missouri Department of Conservation has many years of accumulated guano-based estimates, collected by Rick Clawson and many others. More field work is needed; however, at Mary Lawson Cave on June 21, 2004, we obtained a video estimate of 39,450 ± 3,400. On the same night after the bats emerged we obtained a guano area estimate of 54,400, 27% higher than the video estimate.

Previous studies successfully used thermal imaging to record emergences (Frank *et al*, 2003; Sabol and Hudson, 1995; Melton *et al.* 2005). We worked with Bruce Sabol, U.S. Army Corps of Engineers, in 2005 to compare our methods (figure 5), simultaneously recording bat emergences at four Missouri caves (Table 2). Sabol's method

The videos for Beck and Tumbling Creek could not be compared. The two estimates of the Smittle Cave emergence are within 0.1% of each other. However, the two estimates for Mary Lawson differ by 31.6% agreement, or 22,605 bats. We do not believe that the MDC estimate of 71,615 for Mary Lawson is wrong. We suspect that our current cluster sampling method, in this instance, could cause an underestimate, so we are trying a different method that samples more frequently and provides a higher estimate for a larger emergence. We are also looking for a method of estimating the instantaneous exit rate at many times throughout the flight, which could increase the accuracy and reduce the labor required for the estimate.

We can only speculate about the large difference in estimates at Mary Lawson Cave. Perhaps the difference in vantage point between Sabol's and our camera was important, especially with larger

emergences where bats might obscure each other in a lateral view instead of an upward or frontal view. There could be other reasons why the two recordings resulted in different estimates.

The next step will be to refine these estimation methods and calibrate them against each other and other methods, if possible. Although many biologists would want to use the Indigo camera, available from FLIR Systems, it currently costs about $30,000. The mini-DV and near-infrared lamps we currently use cost about $1,500. Sabol is investigating other thermal cameras in the $8,000–15,000 range. Both of these methods are still being developed, but they are promising.

Acknowledgments

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Appendix A. Stopwatch Bat Counting Method

This is a modified "skip minute" method using headlamps and stopwatches. I originated this method in Texas for counting *Myotis velifer* (cave myotis) at Government Canyon Bat Cave, where I did two emergence counts in 1995. On one trip I entered the cave after the outflight to measure the fresh guano area, and estimates from the two methods were within 13% of each other. Since 1998 I have used this method for counting *Myotis grisescens* (gray bats) at Tumbling Creek Cave and McDowell Cave, Missouri.

I use two or three observers to count, each with his/her own electronic watch. The reason for this is that each can operate his own watch by touch in the dark. An alternate method would have the team leader time the count out loud by his own watch, but that would require looking at his watch for the exact time, and this causes a loss of data.

This method is satisfactory for small to medium bat emergences, but the observers can be overwhelmed by larger flights and may not be able to keep up. With no statistical analysis this method is only an approximation, but it seems to be self-consistent among observers and it is better than wild guessing or just timing the flight. Some flights can stretch out because of cool temperatures, rain or other factors. Considering various error sources, I believe that this stopwatch counting method usually results in a slight underestimate, because one cannot see all of the bats and one can fall behind in counting. If the observers are careful, it will not overestimate the number of bats.

Procedure:

1. Have two or three people count, each with a stopwatch or stopwatch function on their wristwatch, a headlamp, and something comfortable to sit on.

2. One person is the team leader who will call the

count intervals and record data. Later he will do the spreadsheet calculations. It is best to do that right away before your memory fades.

3. Arrive just before sunset and find comfortable spots above the entrance to sit. You might even want to take something to cut limbs and brush away for better viewing. This method works only at entrances where you can sit above the entrance so your headlamps won't shine in the bats' eyes. Don't bother with red filters — you would not be able to see well. Use moderately bright headlamps with wide beams, not flashlights.

4. Record date, personnel, location, official sunset time, temperature, moon and weather conditions. When the bats start to fly, usually about 15–30 minutes after sunset, record the start time. Usually they start with just a few scouts who come out and go back in for a few minutes. Try to scan your light side to side and get a count of the whole flight path if possible. This way each person is a different estimate of the whole thing, not part of the thing.

5. Record observations every two minutes. When enough are coming out steadily, call the first stopwatch count. You say something like "Let's count five bats. Ready. Go!" Each person silently counts five bats while starting and stopping his watch. Then each calls in his data, and you record them in columns like in the spreadsheet. You could start with 10 or 20.

6. As the flight increases, step up to 50 or 100 bats. Just gauge it so the count does not go over a minute. This gives you a little time to write data and quietly discuss things before the next two-minute count.
7. If you get behind, decrease the size of the count. At 50 or 100 bats you should count by 5s or 10s, not each one. Also, you are estimating the net number that fly out. In the first part of the flight they mill around and go back in, and you have to estimate the net number that came out (for example ten flew out but five went in, so the net is five out.) As the flight increases almost none go back in. At the end when the flight drops off, some mill around again and go back in.

8. Enter the data into a spreadsheet, which averages the count over the different observers for each time segment, obtains a rate of bats per two minutes, then totals the all the two-minute estimates. This is then graphed. I can provide an example Excel file upon request.

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