Gray Bat (*Myotis grisescens)* Thermal Infrared Monitoring in Missouri, 2008-2011

William R. Elliott, Derek Shiels, Shelly Colatskie, and Christin Dzurick
Missouri Department of Conservation, Resource Science Division
April 27, 2011

Thermal infrared image of gray bats emerging from the pit entrance of Coffin Cave, Laclede County, Missouri, April 13, 2011.

Gray Bat (*Myotis grisescens)* Thermal Infrared Monitoring in Missouri, 2008-2011

William R. Elliott, Derek Shiels, Shelly Colatskie, and Christin Dzurick
Missouri Department of Conservation, Resource Science Division

Abstract

We report the results of three years of thermal infrared (TIR) video monitoring of gray bats, *Myotis grisescens*, in Missouri. From 2008-2011 we visited 14 caves, including 13 maternity caves and one major hibernaculum, taking 50 videos and 5 guano estimates. The mean outflight was about 42,000 bats, and the largest was more than 311,000. We recorded an aggregate of 2,115,000 gray bats with TIR and the Thermal Target Tracker (T^3) program. Comparing three methods we have used, we found that for accuracy and reliability we prefer the methods in this order: TIR/T^3 method over our own near-infrared (NIR) method over guano measurements. Our NIR method is less expensive and reasonably accurate for outflights up to about 100,000. Guano measurements may still be used at some caves as a backup method if the guano piles are distinct and especially if there was poor weather or insufficient time to record TIR at the cave at the right time. We conclude that gray bat numbers in Missouri are generally stable or increasing, and that there are mass migrations in late summer from the Lake of the Ozarks area in central Missouri to Boone County and other areas. We are extending the TIR/T^3 method further to count bats in fall swarms or emerging from hibernation in the spring.

Introduction

Since 1975 the Missouri Department of Conservation (MDC) has systematically monitored and counted the endangered bats, *Myotis sodalis* (Indiana bat), and *M. grisescens* (gray bat). Missouri's gray bats, the focus of this report, decreased for many years, but are now stable or increasing in some protected caves. However, for various reasons, many other caves remain abandoned. At bottom, Gray bats lost at least 67% of their maximum past population, as measured in 56 important caves, and 53% of the caves were abandoned. The maternity population of gray bats is currently estimated at approximately 635,000, but it may have been >1,700,000 in the past. The three largest gray bat hibernacula were censused in 2006 and totaled 773,850 (Elliott 2008).

The gray bat is a key species in Missouri ecosystems, providing nutrient input to some cave animal communities and significant control of night-flying insects, some of which are agricultural, forest, or health pests. Although there has been a general increase, many maternity colonies are still threatened by intruders and vandals, so further conservation work is needed.

In this study we recorded bat flights from May 2008 through April 2011. Gray bat maternity colonies were estimated using guano area measurements, exit counts, or other methods. MDC began experimenting with near-infrared (NIR) video imagery to count bats in 1999, but our method did not mature until 2004. In 2005 we worked with Bruce Sabol, U.S. Army Corps of Engineers (USACE), and Bob Currie, U.S. Fish & Wildlife Service (FWS), at four Missouri caves to compare our NIR method to their developing thermal-infrared (TIR) method. We

continued to expand our NIR counts after that because the method was practical and less expensive (<$1,500) than the TIR method then available (>$30,000).

In May 2008 a TIR workshop was held in Missouri by Bob Currie, Bruce Sabol and Eddie Melton for multiple state and federal agencies. The new FLIR Photon camera was provided (cost about $7,000) to record bat flights, and we learned how to use TIR imagery with the T^3 (Thermal Target Tracker) program provided by the Corps. T^3 can count the entire outflight of bats from a cave, generally with a smaller error rate than our statistically-sampled visual counts from NIR, which used a type of cluster analysis. Since then we have used the TIR/T^3 method for most summer gray bat estimates in Missouri.

Video technology has allowed us to ask several questions that were not easily answered before:

1. Does the TIR/T^3 method provide better estimates of gray bat populations?
2. Are gray bats increasing in Missouri?
3. Which maternity colonies are recruiting young, and which are not?
4. What is the pattern of inter-cave migrations?

Materials and Methods

Our NIR method was described by Elliott (2006a, 2006b). The NIR method entails a tripod-mounted Sony® camcorder with the Nightshot® (near-infrared) feature, wide-angle lens, and two large infrared LED lamps driven by 12VDC batteries. Using two or three observers with thumb counters, we play back the imagery in the laboratory on a television,. The screen is divided by narrow tape into zones, and the observers count bats going into or out of their zone for 20 seconds every two minutes, usually in slow motion. The results are calculated in a spreadsheet using cluster analysis, developed by MDC biometrician Mike Wollendorf, which provides an outflight estimate and a 95% confidence interval. We began by using randomized 20-sec. samples, but we soon determined that there was enough variance throughout the flight that we could take regular 20-sec. samples every 2 mins. and have a statistically valid estimate.

In summer 2008 Elliott, assistant Christin Dzurick, and volunteers visited 11 different Missouri caves, and shot TIR imagery on 38 visits. We used a FWS kit with a FLIR Photon thermal camera, tripod, and JVC mini-DV camcorder, GR-X5U, for image capture (Fig. 1). The data were transferred to a Hewlett Packard Pavilion EV-8000 laptop computer with Windows XP operating system, 120 GB internal hard drive, and 300 GB external hard drive, then we processed the imagery with T^3. The process sometimes takes several hours to upload the imagery to the computer, process it, then do counts using different scenarios and threshold (sensitivity) settings to arrive at a reliable estimate.

The T^3 software is proprietary to the USACE, but they provide a license allowing MDC and other government agencies to use the software, and we share data with USACE. T^3 works in several steps: upload data from the recording device, image differencing, detection/tracking, tracking list, and post-processing (counting). The processing sequence of T^3 involves differencing sequential frames to enhance bats and suppress stationary background, detecting bat pixels based on thresholding the difference image, using a region growing technique to convert bat pixels to individual bats, and assigning tracks to detections in subsequent frames using a modified Kalman filter, a mathematical method for reducing noise. The output is a track file that

Fig. 1. TIR equipment typically used during this study.

contains the location and size of each bat in each frame as it traverses the field of view. The first and last positions of each bat track are examined to determine whether the bat's path represented an emergence, a return, or neither. There is no statistical estimate, rather a total count, however the error rate usually is about 7%, based on empirical tests by the USACE.

The computer had a fast processor of >2 GHz speed, and there was no problem keeping up with the data stream. Sometimes we encountered problems with the computer in which we had to repeatedly defragment the internal hard drive because Microsoft Windows writes fragmented files across the hard drive. Thus programs that require fast sequential access to large files will run slower. Periodically running a good hard drive defragmentation program will improve the file access speed. For larger outflights breaking the imagery into parts also avoids problems.

We were interested in comparing methods, so we compared NIR vs. TIR counts at two caves, a visual/statistical count vs. T^3 count of the same TIR video at one cave, and TIR counts vs. traditional guano measurements at four caves.

William R. Elliott and Anthony Elliott obtained a State Wildlife Grant in 2009 to purchase TIR equipment for approximately $10,400. While the grant was being processed, we continued to use the USFWS's TIR equipment in summer 2009. The new TIR equipment was acquired during fall 2009.

In addition to the FWS equipment, we use our own FLIR Photon thermal camera on a tripod with accessories connected to a mini-DV camcorder, currently a 2005-vintage Sony DCR-HC42. We ordered a new Sony HDR-XR500 camcorder with a 120 GB hard drive, Nightshot® (near infrared), 12 MP still-photo capability (even in Nightshot), and other desirable features. We soon discovered that recent consumer camcorders no longer can dub a video signal from an external source like our old ones did, and the newer Nightshot may use a variable frame rate. So we

continue to use the older mini-DVs. For backup we also purchased a Sony Multi-function DVD recorder, VRD-MC5, which can dub from many different sources, operate on 120 VAC or 12 VDC, and record up to 6 hours. However it will play back only to its own small screen and not out the video or USB ports. Imagery must be dubbed from a standard DVD player to a mini-DV for processing by T^3.

Our new computer for T^3 processing had the following parameters: Dell Latitude® E5500 laptop, 15.4" screen, Intel Core Duo CPU P8400 @2.26 GHz, 4.0 GB RAM, Windows Vista Service Pack 2, 32 bit (uses 3.0 GB RAM), 300 GB hard drive, 7200 rpm, C: 208 GB, D: 89 GB, two 300 GB Thinkpad USB external secure hard drives for video and T^3 data.

We were not certain if T^3 would work with Windows Vista, but working with our IT staff we found that under the usual network configuration, logged onto the MDC network using a password, the T^3 program worked to a point, and we were able to capture video from the Sony mini-DV camera, even when the screen saver came on. But the program later stalled while counting bats when the network security system locked the keyboard after 30 minutes or more, which stopped the IO. We were not at the computer to enter keystrokes or move the mouse, so it locked up. One would have to log in again to continue, but the processing had quit. IT then provided a local domain administrator configuration (boot up locally with no network access) and we were able to process very large videos with >100,000 bats (Coffin, Rocheport, and Mary Lawson caves). The security locking is now set for two hours, which gives us enough time to let the computer work while we are doing other tasks. So, T^3 works with Windows Vista at least as long as one does not have issues with security software locking the system. We have not tested T^3 with Windows 7 yet. MDC's Vista computers use Symantec Endpoint security software, and IT reports it has not caused any software interference that they know of. We have not seen the computer stall because of disk fragmentation yet.

Results

Table 1 summarizes the overall results of our studies from 2008-2011. Each year is treated below. See Table 4 at the end for detailed results.

trips 2008-2011	55
caves	14
videos	50
guano estimates	5
average outflight	42,290
largest outflight	311,525
aggregate video estimate	2,114,507
aggregate guano estimate	235,068
aggregate bat estimate	2,351,630

2008 Results

From May 5-September 10, 2008, MDC's cave biology program (William R. Elliott and Christin Dzurick) obtained counts at 11 gray bat caves in Missouri, using NIR, TIR, and guano measurements. One TIR trip to Lower Burnt Mill Cave resulted in a visual count only because very few bats emerged there. There were 38 different estimates from 17 video trips, but additional comparisons could be made with different TIR scenarios (threshold settings). Counts ranged from 98 to 92,367. We also made six guano estimates from four caves. At the end of the 2008 season, comparing three methods we have used, we found that for accuracy and reliability we preferred the methods in this order: TIR/T^3 method over our own near-infrared (NIR) method over guano measurements. Guano measurements may still be used at some caves as a backup method, if the guano piles are distinct and especially if there was poor weather or insufficient time to record TIR at the cave at the right time.

We compared TIR/T^3 to our own NIR recording with statistical/visual counts at Tumbling Creek Cave on May 6, 2008, and they were within 7% of each other. At Tumbling Creek Cave on May 8 the comparisons were unclear because we did not get all the thresholds from the other students. At Tumbling Creek Cave on July 17 we got a TIR count of 23,621 (threshold 9), and a visual count from the same tape of 21,234, within 10% of each other.

At River Cave on June 4 , we got a TIR/T^3 count of 25,507 during the maternity period, threshold 15. Our NIR video was too low in contrast to count, so we visually counted the TIR video and got 17,903. On September 11 we measured guano and found that pile #1, the likely maternity roost, represented about 24,457. So, the TIR and guano pile estimates were within 4% of each other. On July 14 at River Cave the TIR count was 37,919 (threshold 9), which was within 0.1% of the total guano estimate of 37,952. The best threshold setting for this site varied from 10-15 because of changing thermal contrast from solar heating of the entrance sinkhole. We were able to calculate an apparent recruitment of about 13,000 at this cave. We concluded that guano measurement is reliable only if the guano is well-defined, and it may be used when reliable TIR or NIR is not available. Our four main guano sites came out as follows:

Mary Lawson Cave–Guano estimates were vague, strung out in narrow passages, and lower than TIR counts.

River Cave–Guano was well-defined and estimates were close to TIR counts.

Smittle Cave–Guano estimates were vague and higher than TIR counts. Most guano was in the stream channel and was partially washed out by high water this year.

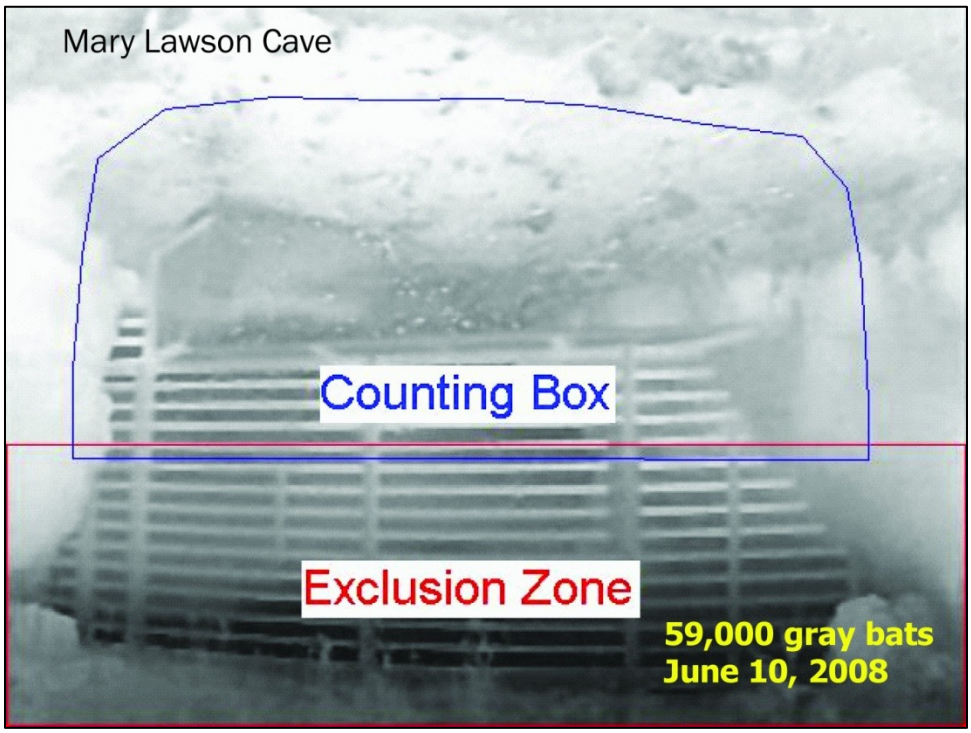
Toby Cave–Guano estimates were vague and lower than TIR counts. Toby was Missouri's biggest summer colony in 2008, about 92,000.

2009 Results

From May 28 to August 11, 2009, William R. Elliott, Derek Shiels, and Steven Munoz monitored and counted gray bats with TIR at 8 caves on 16 trips, using borrowed FWS equipment. Counts ranged from 348 to 124,956. The overall results indicated large population movements among caves in central Missouri. Some caves near Lake of the Ozarks contained far more bats than usual during maternity and nursery periods (May-June), while two caves in Boone County had few bats. More bats appeared at the two Boone County sites in July and August after the young were weaned and volant.

In September we used TIR/T^3 and NIR at Pilot Knob Mine, Iron County, Missouri, to experimentally estimate the fall swarm of several species including, Indiana bats, little brown bats, and northern bats from three mine portals. The fall swarm work is a new departure for the TIR/T^3 method, as it gives us a nonintrusive method of estimating bat colonies without having to enter the cave or mine. However, it cannot by itself give numbers for each species. Those results will be published in another report.

Fig. 2. T^3 counting box and exclusion zone applied to the TIR imagery from Mary Lawson Cave, June 10, 2008.



2010 Results

Derek Shiels made a TIR recording at Coffin Cave, Laclede County, on March 18. Coffin is the largest bat hibernaculum in Missouri. About 9,600 gray bats emerged in 69 minutes, but we were not able to return in April for the expected major emergence.

From May 21 to July 28, 2010, William R. Elliott, Derek Shiels, and Shelly Colatskie (then Shelly Dey) recorded observations of gray bat outflights from 10 different caves on 15 trips. We monitored and counted gray bats using MDC's TIR equipment and borrowed FWS equipment. Statewide counts of gray bats ranged from 939 to 115,367, and we noted a generally stable or increasing statewide population. A few colonies were reduced during the summer from flood disturbances or other problems.

In September we again used TIR/T^3 and NIR at Pilot Knob Mine, which will be reported elsewhere.

Shelly Colatskie and Anthony Elliott recorded the fall swarm of gray bats at Coffin Cave on October 3, 2010, with a count of 311,525 ±21,807. This count reassures us that the hibernating colony is in good condition. The count is a significant proportion of the 2006 visual estimate in the cave of approximately 561,000, but we would not have expected this number to emerge on one night.

2011 Results

We visited Coffin Cave three times in April to learn more about the spring emergence of gray bats. No TIR video was made on April 5 because of missing equipment, but we estimated about 2,000 emerged. The TIR image on the cover of this report, taken on April 13, 2011 at Coffin Cave, shows one frame of an outflight of 310,000 gray bats. On April 20 only 401 bats emerged, so we probably bracketed the spring emergence from this cave over a two-week period. We believe that the bats gradually leave over several weeks, so one night's imagery would not estimate the entire colony, but a peak emergence may represent the majority.

Discussion

We have assembled two maps, two graphs, and three tables (below) to summarize trends over three years, dividing the results into spring and summer counts. Eleven caves were represented, however we reduced that to comparisons of two sets of four caves where we had adequate data for spring or summer. The spring counts (Fig. 3, Table 2 and) represent maternity colonies of gray bats before the young are volant, and summer counts (Fig. 4 and Table 3) are after the young are volant. The spring counts probably are more reliable to estimate each colony because mothers are more committed to staying at that roost, whereas bats begin to migrate to other caves soon after the young are volant, starting in July.

We were not able to use the same set of caves for spring and summer comparisons because of the timing of field trips and personnel limits. However, both subsets of data indicate a generally stable metapopulation, if the four large colonies in each subset are representative of the western subpopulation of gray bats. We have observed that individual colonies have their own trends, no doubt related to many biological and nonbiological factors.

Disturbance of the colonies is a concern. River Cave, Ha Ha Tonka State Park, Camden County, has been well-protected from human intruders by a chute cave gate since 2005, but large floods in 2010 brought an influx of gravel into the upper entrance of the cave and even into the main entrance sinkhole by overland flow. These events may have altered air flow through River Cave, or may have provided an opportunity for humans to climb through the chute because of the raised floor of the sinkhole, thus disturbing the bats. Smittle Cave, Alva Fuson Conservation Area, Wright County, has had a decrease in gray bats over several years, perhaps caused by intruders or Barn Owls over the half-gate there; the latter were seen and heard at the cave in summer 2010. The pattern at Tumbling Creek Cave has decreased in spring but increased in summer. Devil's Icebox and Smittle caves appear to have lost many bats. Devil's Icebox Cave has had fewer gray bats for two years, possibly caused by high water in the cave, which can isolate the bats beyond a sump in the stream passage, or else cause them to flee. The Great Scott and Mary Lawson colonies increased so much that we believe that bats probably immigrated there in addition to local recruitment.

Fig. 3. Map of spring results (before young are volant), 2008-2010, at 11 gray bat caves.

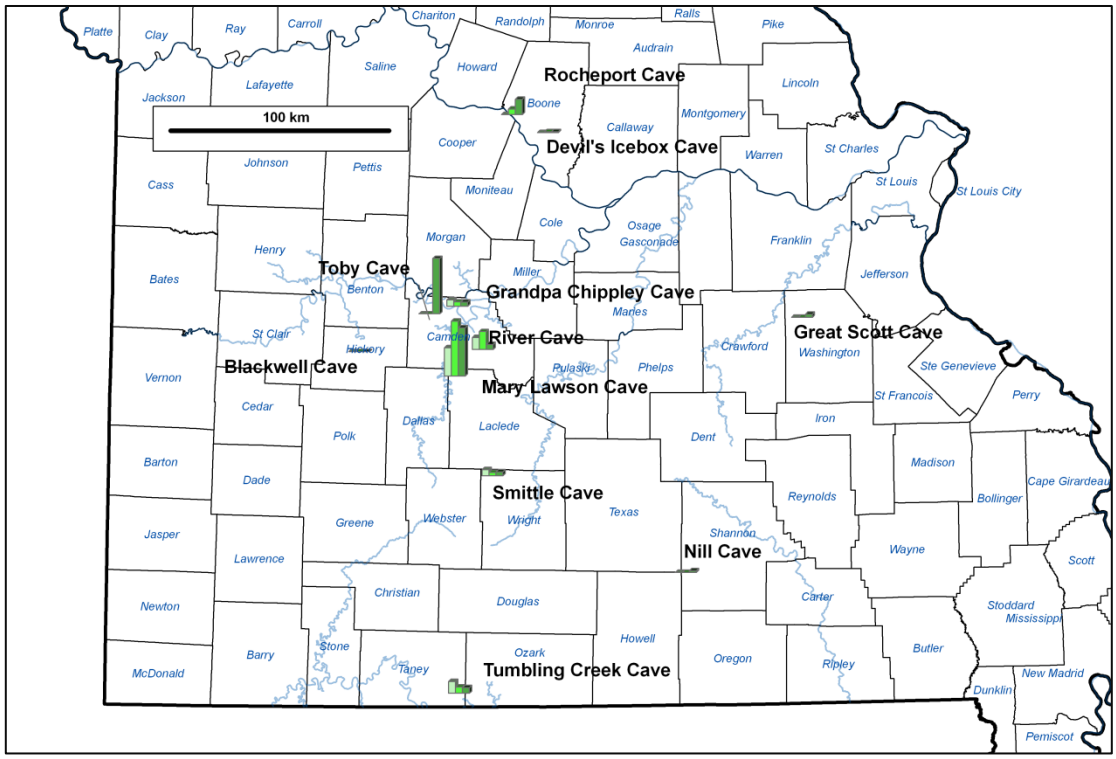


Fig. 4. Map of summer results (after young are volant), 2008-2010, at 11 gray bat caves.

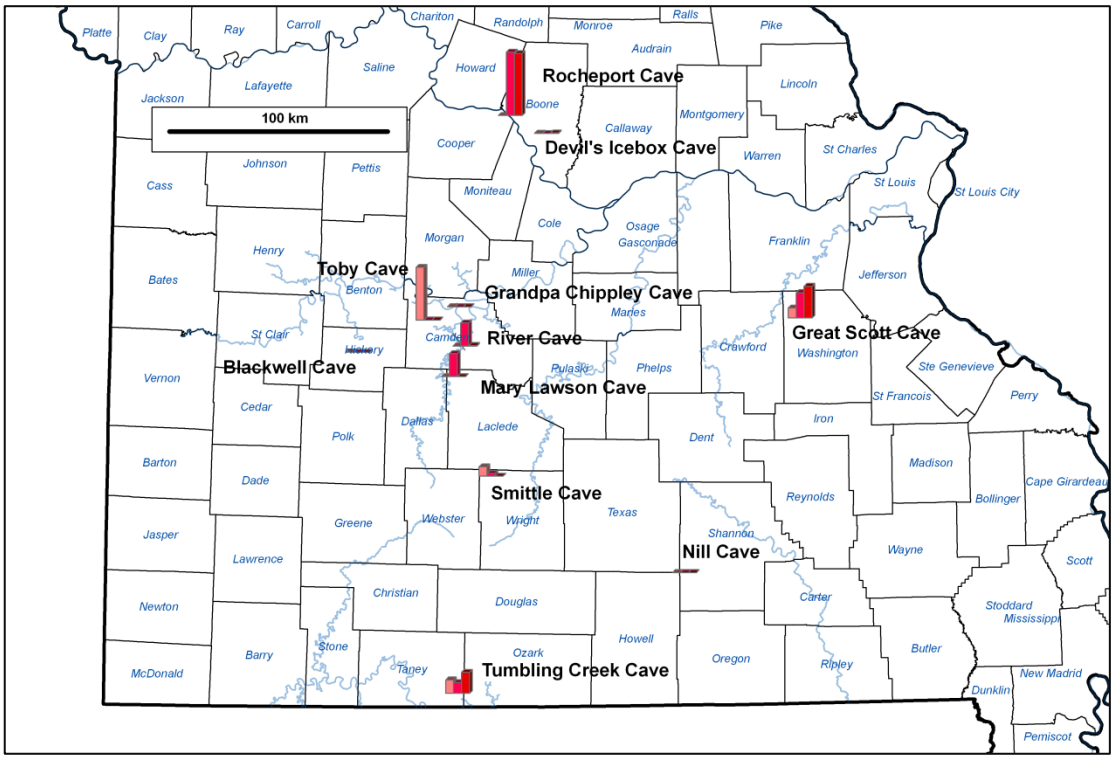


Table 2. Spring counts for 2008-2010.

Cave	Spring 2008	Spring 2009	Spring 2010	3-yr trend
Mary Lawson	58,914	114,485	100,538	up
River	25,057	37,579	10,489	down
Smittle	12,800	7,072	8,179	down
Tumbling Creek	22,811	13,230	11,725	down
Totals	**119,582**	**172,366**	**130,931**	stable

Fig. 5. Spring counts for 2008-2010.

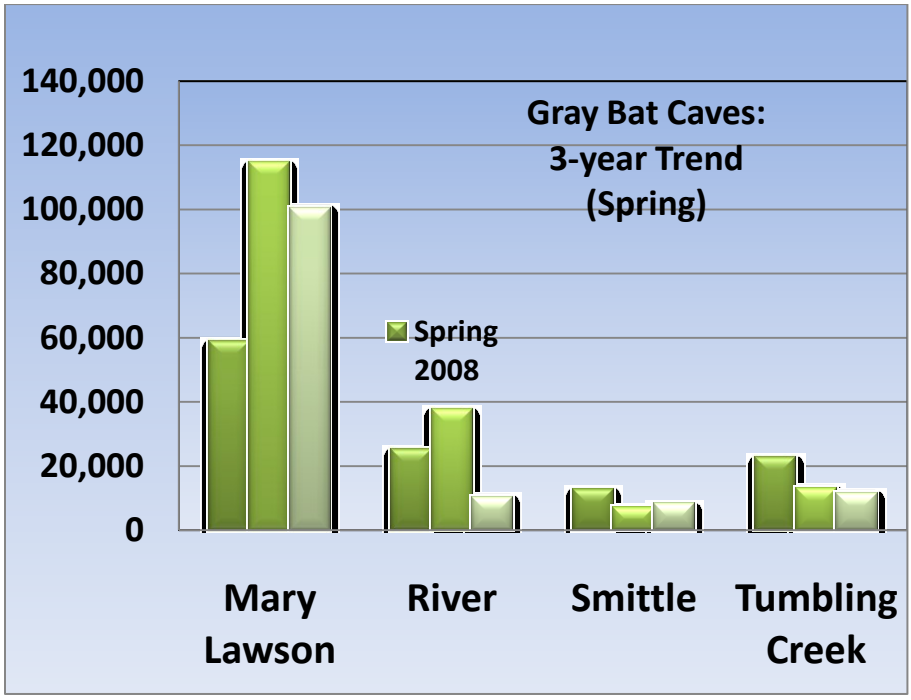
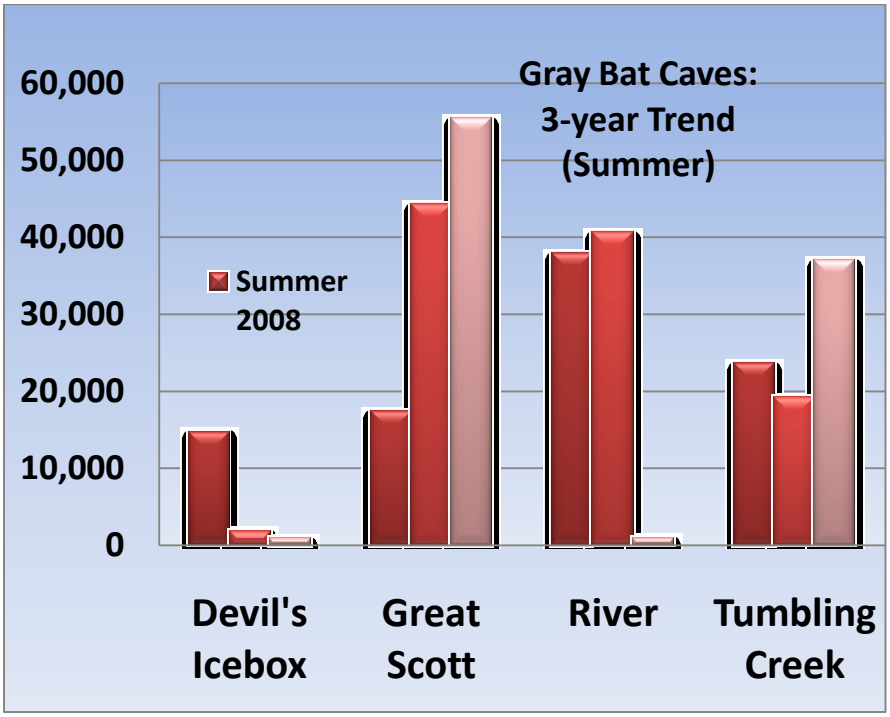


Table 3. Summer counts for 2008-2010.

Cave	Summer 2008	Summer 2009	Summer 2010	3-yr trend
Devil's Icebox	**14,734**	1,896	939	down
Great Scott	17,418	44,290	55,391	up
River	37,919	40,624	969	down
Tumbling Creek	23,621	19,195	36,963	up
Totals	**93,692**	**106,005**	**94,262**	stable

Fig. 6. Summer counts for 2008-2010.



Our four questions posed in the introduction can be answered as follows:

1. Does the TIR/T^3 method provide better estimates of gray bat populations?

Yes, although the TIR videos are one-night "snapshots" of the emergence at each cave. We know that the emergence can vary significantly from night to night, especially after the young are volant (Elliott 2008). If enough videos are done, however, one can get an idea of the dynamics at each cave, including recruitment and mass migrations. Guano measurements sometimes provide a reliable estimate where the piles are distinct; the estimate also is integrated over a whole season, thus smoothing out nightly fluctuations but probably missing mass migrations. Guano can still be used when necessary at some caves where the maternity roost is well-defined, but not at other roosts where the guano is spread out during late summer intra-cave movements by the bats. NIR video is still a good method, and it is less expensive than TIR, but it probably underestimates colonies of >100,000 bats.

2. Are gray bats increasing in Missouri?

Grays are stable or increasing, but some caves are losing bats, perhaps because of floods or human and animal disturbances.

3. Which maternity colonies are recruiting young, and which are not?

From our 2008-2009 work it appeared that River Cave and Tumbling Creek Cave were consistently recruiting new bats each summer, but River lost many bats in 2010. Mary Lawson Cave also is increasing, but the picture there is less clear because the bats usually begin leaving the site in early July, earlier than some sites. Devil's Icebox and Smittle lost bats recently,

possibly because of high water in ther former, or human disturbances at either, or Barn Owls in the latter; both have had permit caving allowed during parts of the year, but that ended at Smittle in 2010. We also witnessed ~125,000 gray bats in late summer 2009 and 2010 at Rocheport Cave, indicating mass movements to that cave, but the springtime colony may not have recruited many young.

4. What is the pattern of inter-cave migrations?

Elder and Gunier (1978, 1981) and Laval and Laval (1980) conducted wing-banding and other studies of Missouri bats, and they noted large migrations among caves in Missouri and adjacent states. Laval and Laval recovered wing bands among many of the same caves we studied, many of them originating from Coffin Cave, the major hibernaculum for gray bats in central Missouri, especially since Marvel Cave, Stone County, lost most of its gray bats. Because of conservation concerns wing banding is now more careful and limited.

From the fluctuating numbers in the six major caves we studied as a whole, there were remarkably large inter-cave migrations in 2009 and 2010. We infer that after the young became volant in early to mid-July, there probably were large migrations of gray bats from caves near Lake of the Ozarks to Rocheport Cave, Boone County, and probably to other caves. Possible explanations include flooding, human disturbances, better conditions in other areas for the bats, avoidance of parasite loads, and other factors.

This study was not intended to take us into major new research areas, but only to provide better population estimates for conservation management. Much more could be learned by combining the TIR/T^3 method with wing banding, radio tracking, acoustic monitoring, and other methods, which would require a larger workforce and much more funding.

In spring 2010 three species of bats were found in Missouri with the genetics of the fungus, *Geomyces destructans*, on them, indicating the potential for White-nose Syndrome (WNS) infection. Those discoveries included gray bat, little brown bat, and northern bat. No WNS infections or even fungal evidence were found in 29 caves that we monitored in the winter of 2010/2011. With the approach of WNS from the eastern USA, we need good bat estimation methods to be able to detect die-offs of bats. WNS may also cause bats to flee from certain sites, and video counting methods may be able to detect large population changes or movements from such migrations.

Acknowledgments

The Missouri Department of Conservation and the U.S. Fish & Wildlife Service provided equipment and support for this study. We are grateful to the following individuals for their help: Steve Munoz, Anthony Elliott, Bruce Sabol, Eddie Melton, Bob Currie, Steve Samoray, Sara Samoray, Adrienne Shiels, Greg Stoner, Josh Campbell, Chris Simpson, Kevin Hedgpeth, Dwayne Hillhouse, Ryan Diener, Justin Gailey, Lee Hughes, Mike Leahy, David Ashley and students, Bryan Allan and students, Roxie Campbell, Jim Gast, Mike Wollendorf, Ivan Vining, Jim Kaufmann, Norman Murray, Charlie Scott, Paul McKenzie, Anne Froschauer, Scott House, Mark Miller, Ron Colatskie, NBC Nightly News film crew, and other volunteers.

Literature Cited

Clawson, Richard L., William R. Elliott, and Debra Burns. A Bat Management Plan for the Missouri Department of Conservation. 68 pp., 2 app.

Clawson, Richard L., William R. Elliott, and Debra Burns. A Bat Management Plan for the Missouri Department of Conservation. Missouri Department of Conservation, *Science Notes.*, 2(8):2 pp.

Elder, William H. and Wilbur J. Gunier. 1978. Sex ratios and seasonal movements of gray bats (*Myotis grisescens*) in southwestern Missouri and adjacent states. *The American Midland Naturalist*, 99(2):463-472.

Elder, William H. and Wilbur J. Gunier. 1981. Dynamics of a gray bat population (*Myotis grisescens*) in Missouri. *The American Midland Naturalist*, 105(1):193-195.

Elliott, William R., Stephen T. Samoray, Sara E. Gardner and James E. Kaufmann. 2006. The MDC Method: Counting bats with infrared video. Pp. 147-153 In G.T. Rea (ed.), *Proceedings of the 2005 National Cave & Karst Management Symposium*, Albany, NY, Oct. 30-Nov. 4, 2005

Elliott, William R. 2006. Counting bats with infrared video. Missouri Department of Conservation, *Science Notes.*

Elliott, William R. 2008. Gray and Indiana Bat population trends in Missouri. pp. 46-61 *in* Elliott, W.R. (ed.): *Proceedings of the 18th National Cave and Karst Management Symposium, October 8-12, 2007, St. Louis, Missouri.*

Frank, J.D., T. H. Kunz, J. Horn, C. Cleveland, and S. Petronio. 2003. Advanced infrared detection and image processing for automated bat censusing. Pp. 261–271 *In: Proceedings of the International Society of Optical Engineering*, vol. 5074. Infrared Technology and Applications XXIX.

LaVal, Richard K., and Margaret L. Laval. 1980. Ecological studies and management of Missouri bats, with emphasis on cave-dwelling species. *Terrestrial Series* #8, Missouri Department of Conservation, 53 pp.

Martin, C.O. 2007. Assessment of the population status of the gray bat (*Myotis grisescens*): Status review, DoD initiatives, and results of a multi-agency effort to survey wintering populations at major hibernacula, 2005-2007. ERDC/EL TR-07-22. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Melton, R.E., B.M. Sabol, and A. Sherman, 2005. Poor man's missile tracking technology: thermal IR detection and tracking of bats in flight. Pp. 24–33 *In*: Proceedings of the International Society of Optical Engineering (SPIE), 5811.

Melton, R.E., and B. Sabol. 2007. A thermal IR processing technique for detecting and tracking objects in motion. Pp. 501-508 *In: Proceedings of the InfraMation Conference, 2007*.

Sabol, B. M., and M. K. Hudson. 1995. Technique using thermal infrared-imaging for estimating populations of gray bats. *Journal of Mammalogy*, 76(4):1242–1248.

Table 4. Detailed results for 2008-2010. TH = T^3 threshold value, ET = elapsed time. Further details may be requested from the Missouri Department of Conservation.

County & Cave									
Boone, Devil's Icebox Cave									
Date	**Season**	**Method**	**Count**	**TH**	**Start °C**	**End °C**	**Start**	**End**	**ET**
7/28/2008	summer	TIR	565	9	23.6		20:31	21:14	0:43
9/19/2008		guano	8,092						
6/1/2009	spring	TIR	348	9	26.2		20:47	21:47	1:00
6/30/2009	spring	TIR	1,896	12			20:41	21:32	0:51
6/28/2010	spring	TIR	2,030	12	24.5	24.0	20:41	21:27	0:46
7/19/2010	summer	TIR	939	12	25.6	25.1	20:24	21:18	0:54
Boone, Rocheport Cave									
6/3/2009	spring	TIR	11,559	10	21.7		20:57	21:28	0:31
7/13/2009	summer	TIR	43,851	12	19.7	19.2	20:28	21:29	1:01
7/24/2009	summer	TIR/visual	124,956	12	19.8	18.8	20:13	20:38	0:25
8/11/2009	summer	TIR	110,995	12	26.0	24.0	20:18	21:20	1:02
5/24/2010	spring	TIR	32,071	12	27.0	26.0	20:29	21:30	1:01
7/28/2010	summer	TIR	108,324	12	22.8	23.8	20:22	21:23	1:01
Camden, Grandpa Chippley Cave									
6/5/2008	spring	TIR	13,150	10			20:28	21:04	0:46
6/18/2009	spring	TIR	8,724	12			20:43	21:25	0:42
6/22/2010	spring	TIR	8,365	12	22.4	21.4	21:06	21:31	0:25
Camden, Lower Burnt Mill Cave									
6/3/2008	spring	visual	5						1:00

Camden, River Cave									
6/4/2008	spring	TIR	25,057	15	24.4	23.3	20:46	21:33	0:47
9/11/2008		guano	37,952		25.1				
6/4/2009	spring	TIR	37,579	12	17.0	16.0	20:40	21:37	0:57
7/8/2009	summer	TIR	40,624	12	22.1	21.1	20:49	21:25	0:36
5/22/2010	spring	TIR	10,489	12	26.1	23.0	20:58	22:00	1:36
7/13/2010	summer	TIR	969	10	25.2	24.8	20:52	21:15	0:23
Camden, Toby Cave									
7/16/2008	summer	TIR	92,367	12			20:35	21:26	0:51
9/11/2008		guano	87,856		25.1				
6/16/2010	spring	TIR	115,637	12		21.5	20:19	21:25	1:06
Hickory, Blackwell Cave									
7/29/2008	summer	TIR	98	15			20:31	21:03	0:32
Laclede, Coffin Cave									
3/18/2010	winter	TIR/visual	9,600	12	14.5	10.7	19:23	20:32	1:09
10/3/2010	fall	TIR	311,525	15	11.2	8.9	19:10	20:15	1:05
4/5/2011	spring	visual	2,000		23.0	23.0	19:59	20:40	0:41
4/13/2011	spring	TIR	310,000	15	18.5	16.1	19:55	21:48	1:53
4/20/2011	spring	TIR	401	15	10.0	9.2	19:49	20:50	1:01
Laclede, Mary Lawson Cave									
5/7/2008	spring	TIR	7,247	10			20:37	21:19	0:42
6/10/2008	spring	TIR	58,914	9	23.5	20.2	20:41	21:33	0:52
9/10/2008		guano	41,766		16.2				
6/12/2009	spring	TIR	114,485	12	27.9	27.2	20:41	21:36	0:55
7/7/2009	summer	TIR	40,321	9	19.4	18.2	20:40	21:21	0:41

6/3/2010	spring	TIR	100,538	12	22.0	18.6	20:34	21:20	0:46
Pulaski, Great Spirit Cave									
7/24/2008	summer	visual	50		19.5		20:33	21:07	0:34
Shannon, Nill Cave									
6/19/2010	spring	TIR	3,062	12	22.2	22.2	20:49	21:20	0:31
Taney, Tumbling Creek Cave									
5/6/2008	spring	TIR	21,376	9			20:08	21:08	1:00
5/6/2008	spring	NIR	22,811				20:08	21:08	1:00
6/12/2008	spring	TIR	24,529	9					1:21
7/17/2008	summer	TIR	23,621	9	25.8	22.5	20:33	21:25	0:52
7/17/2008	summer	TIR/stat	21,234				20:30	21:22	0:52
5/28/2009	spring	TIR	13,230	11	20.0		20:58	22:15	1:17
7/1/2009	summer	TIR	19,195	12			21:03	22:36	1:33
5/25/2010	spring	TIR	11,725	15	18.0	18.0	20:50	22:35	1:45
7/14/2010	summer	TIR	36,963	11	26.6	24.3	20:50	22:00	1:10
Washington, Great Scott Cave									
7/23/2008	summer	TIR	17,418	9	15.6	15.6	20:23	21:30	1:07
7/23/2009	summer	TIR	44,290	10	14.6	14.6	20:23	21:24	1:01
5/21/2010	spring	TIR	6,536	12	17.7	16	20:20	21:05	0:45
7/22/2010	summer	TIR	55,391	12	15	15.4	20:15	21:15	1:00
Wright, Smittle Cave									
6/11/2008	spring	TIR	12,800	9		26.0	20:48	21:32	0:44
7/18/2008	summer	TIR	16,500	7			20:29	21:04	0:35
9/10/2008		guano	21,760		15.4				
9/10/2008		guano	37,642						

6/11/2009	spring	TIR	7,072	12	21.5	21.2	20:45	21:24	0:39
7/6/2009	summer	TIR	4,942	12	17.0	16.7	20:37	21:14	0:37
6/30/2010	spring	TIR	8,179	6	17.1	17.1	20:42	21:27	0:45