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Abstract

Mammoth Cave National Park is home to thirteen species of bats, seven of which are afflicted by White Nose Syndrome (WNS), a disease devastating bat populations in the northeastern United States and eastern Canada. In an intensive monitoring effort driven by public health concerns, transect and entrance observations were carried out daily throughout the winter of 2015 along visitor use areas.

This monitoring captured trends in the observable bat population on all routes – the numbers would increase, peak in late February/early March, and then decline. We believe that this is due to the aberrant behaviors exhibited by bats afflicted with White Nose Syndrome. As the winter progresses, tri-colored bats are moving out of their normal hibernation sites into entrances and cold areas where they are observed along the monitored transects. After early March, the bat numbers decline.

While we did not see flying bats during the day in our entrance observations, 12% of dead bats collected throughout the winter season were collected from the surface. Flying bats were often documented within the cave, with a large portion reported from the Domes and Dripstones route despite it housing considerably fewer bats. The Domes and Dripstones route is also where the majority of bat-human contacts have occurred and looking into this discrepancy in activity levels compared to bat numbers observed is an opportunity for further research.

Dead bats collected throughout the winter season were analyzed for both rabies and WNS. Out of 75 submissions, none tested positive for rabies. While the analysis for WNS is still occurring, it appears likely that they will all test positive. Mammoth Cave National Park is the first year-round NPS show cave to contend with this disease; this presents an amazing opportunity to gain knowledge on this disease and spread the lessons learned to other land managers. While we have learned a lot from this intensive monitoring, it has also opened up more avenues of inquiry.

Introduction

Mammoth Cave National Park is home to nine different species of cave bats and four species of tree bats. Out of the ten species that utilize the caves within the park to hibernate, mate, and raise their young, seven are affected by a new disease that has been devastating bat populations across the northeastern United States and eastern Canada: White Nose Syndrome. Through traditional park monitoring in association with the Cumberland Piedmont Network

(see S. Thomas paper in this volume), up to an 80% loss in four of the seven affected species has been documented as of 2015. This sets a grim stage for understanding WNS-influenced bat behavior within the National Park Service.

The presence of WNS was first confirmed in Mammoth Cave, KY in January 2013 at colonial *Myotis* sites (Carson 2013). It was found along several cave routes and entrances the following year which are used to accommodate over 400,000 visitors annually who venture into the longest cave in the world. This year-round usage places Mammoth Cave in a unique position to investigate the effects of WNS on bat populations and tour operations.

As the first year-round show cave in the National Park Service to contend with this disease, Mammoth Cave is acting as a leader in the management of WNS, the bat populations it affects, and the visitors coming to experience their national park. The lessons and investigations done here can serve as a tool for other land managers as they formulate management plans for their own sites.

Background

As bats hibernate and are affected by WNS, they exhibit several aberrant behaviors such as moving into colder areas by cave entrances, increased activity such as flying in the cave or on the landscape even in the day or mid-winter, decreased responsiveness to human disturbance, and death (Coleman 2011). At Mammoth Cave National Park, in addition to the biological concerns, the aberrant behavior that garnered the most attention from a public health perspective is the increased activity. Would WNS affected bats flying along the toured routes put visitors at an increased risk of bat-human contacts and rabies exposure? Bats with WNS, having large open wounds, are not able to control their flight and behave erratically – symptoms that mirror bats with the rabies virus. In 2014, Mammoth Cave had 11 bat-human contacts occur. While this is a very small percentage of the over 410,000 visitors, researchers, and employees that utilize the cave, the park evaluated the situation diligently. In December 2014, an NPS Disease Outbreak Investigation Team composed of experts across fields including veterinary medicine, wildlife, public health, and epidemiology met to evaluate the situation (Wong 2015).

As part of their investigation and final report, daily monitoring was implemented along toured routes to understand bat behavior and see if there were any identifiable predictors for bat-human contacts. Park operations and the public health components of the work dictated many of the monitoring choices. The areas to be given the highest priority in monitoring corresponded with the Division of Interpretation's tour schedule and areas of visitor use: the Historic Route, Domes and Dripstones Route, Carmichael Entrance Decline, Great Onyx Cave, and caves near high density surface locations like picnic areas or the Visitor Center.

The Historic section of Mammoth Cave has three to four separate tours offered during the winter monitoring season. These tours include the Historic, Mammoth Passage and Discovery Self-Guided tours. By late spring, Gothic Avenue is added. These tours have lengths that range from three-quarters of a mile to two miles in length, with in cave-times ranging from one hour to one hour and forty-five minutes.

Another highly visited area is the New Entrance to Mammoth Cave section. Tours that utilize this area include Domes and

Dripstones, Frozen Niagara, portions of the Introduction to Caving, and portions of the Wild Cave tour. The New Entrance section has man-made entrance and exit points that include loosely sealed bunker style entrances with one inch access holes included for wildlife use. This allows bats to enter and utilize these areas. These tours have a walking length ranging from one-quarter of a mile up to one mile.

The Carmichael Entrance Decline consists of 183 stairs along a two hundred and twenty foot blasted entrance way. This is utilized by the Wild Cave tour on weekends. Great Onyx Cave covers one mile and is occasionally utilized by the Park's Environmental Education program to conduct school field trips. Dixon Cave is un-toured and is primarily a hibernacula for Gray Bats (*Myotis grisescens*) and Indiana Bats (*Myotis sodalis*), but other bat species can be found within the cave during winter as well. Dixon Cave is within two tenths of a mile from the Historic Entrance, within one hundred yards of the picnic area, and is situated along a major surface trail route behind the Visitor Center.

Methods and Materials

During the winter monitoring season of 2015, running from January 1 to May 1, 2015, bat monitoring consisted of two main activities: bat transects and surface tier 3 observations.

Bat transects were conducted along the Historic Route (daily), Domes and Dripstones Route (three times/week), and the Carmichael Entrance Decline (weekly). These observations included conducting a bat census (counting and identifying roosting bats along the route); noting active bats, flying bats, and bats with visible fungus; and logging dead bats and collecting them for testing if possible. Active bats and bats with visible fungus were counted as a subset of presumed alive bats. This means that on the data sheet, bats that were alive and had visible fungus or were active would be tallied once in each category. In the same manner, collected dead bats were tallied as a subset of dead bats observed. Collected bats were sent to the Biological Resource Division of the National Park Service in conjunction with Colorado State University Testing Lab, for rabies and White Nose Syndrome analysis.

Each route was divided into sections based on environmental conditions for ease of monitoring and to assess bat utilization of various cave areas. The Historic Route was split into 11 sections; Domes and Dripstones into 12 sections; Carmichael into 6 sections and Violet City Entrance (not toured, but assessed due to ease of access and proximity to the Carmichael Entrance Decline). All observations in each section were made using minimal gear: a bright cave light, clipboard, datasheet, pencil, and proper PPE including a cave helmet, backup light, and leather and nitrile gloves. Ziploc bags, a sharpie, and a ruler were also used in the collection and processing of dead bats.

Surface tier 3 observations were also conducted at Dixon Cave daily according to protocols established in the 2011 White Nose Syndrome Management Plan. These observations consisted of standing at the entrance and visibly observing any bat activity. Data collected during these observations include: number of bats flying, number of bats observed per minute, surface temperature using a digital thermometer, temperature to the cave from the observation area using an infrared thermometer, and weather conditions.

Once a week, recorders would perform a 'gate check.' These involved looking for bats

moving towards the entrance, bats roosting outside the cave gate, and dead or moribund bats. Other data collected included cave air flow (inhaling/exhaling/stagnant) and any unlawful human disturbance. Gate checks were conducted with equipment similar to that used for transects.

Opportunistic data, looking at bat activity, was also collected in cooperation with other park staff (mainly interpreters). They were asked to note any flying bats that may have occurred during their cave tours and in what section of the cave they were observed. In both our main transect data and these more opportunistic observations, if a flying bat left your field of vision and subsequently re-entered your view, it was tallied as a separate bat.

Data and Discussion

Bats counted in each transect along the routes increased from the beginning of winter, peaked in late February or early March, and fell until the end of observations on May 1, 2015. This holds true for all three routes, despite having various entrance types (natural versus artificial) and significantly different bat numbers overall.

The Domes and Dripstones route peaked at 17 bats on Feb. 24, 2015; the Carmichael Entrance Decline held 31 bats at its peak on Feb. 27, 2015; and Historic, which held the highest number of hibernating bats, peaked at 118 bats on Mar. 14, 2015. While the lowest counts on the Domes and Dripstones route and the Carmichael Entrance Decline resulted in no bats observed along the route, in the Historic section there were always bats present along the route with the lowest set of observations tallying 7 bats. These bell-curve shaped trends are shown in Figures 1 - 3 for the Historic Section, Domes and Dripstones route, and Carmichael Entrance Decline respectively.

This trend is clearly tied to the tri-colored bat (*Perimyots subflavus*). While the numbers of big brown bats (*Eptesicus fuscus*) and *Myotis* bats both peaked at 17, the numbers of tri-colored bats peaked at 85. The higher quantity of tri-colored bats contributed to their ability to form the trend. In addition, while the *Myotis* bats exhibit a similar trend, but peaking earlier (on Feb.27, 2015), the number of big brown bats fluctuates more irregularly, as can be seen best in Figure 1. The main trend, driven by the tri-colored bat, is interpreted to reflect the characteristics of this particular species and aberrant behaviors due to White Nose Syndrome.

The tri-colored bat is a species that hibernates singly. Because of their roosting behavior, it is hard to get an accurate population count on this species. Prior to WNS they were typically spread throughout the warmer regions of the caves where temperatures are between 8-14 °C (46-57 °F). They are one of the species hit the hardest by WNS. Because they were so common before the onset of WNS, there is no record of attempts to even document the levels of tri-colored bats throughout their range.

As the winter progresses, WNS afflicted tri-colored bats are moving towards the entrance into unusually cold areas of the cave, an aberrant behavior resulting from disease. This behavior is the most likely factor driving the trend observed along all three routes. As more bats are afflicted and begin to exhibit symptoms, they are coming out of the more obscure warm areas of the cave and increasing in density by entrances and along tourist routes where the observations occurred.

The subsequent decreasing trend in bats observed could be due to WNS mortality.

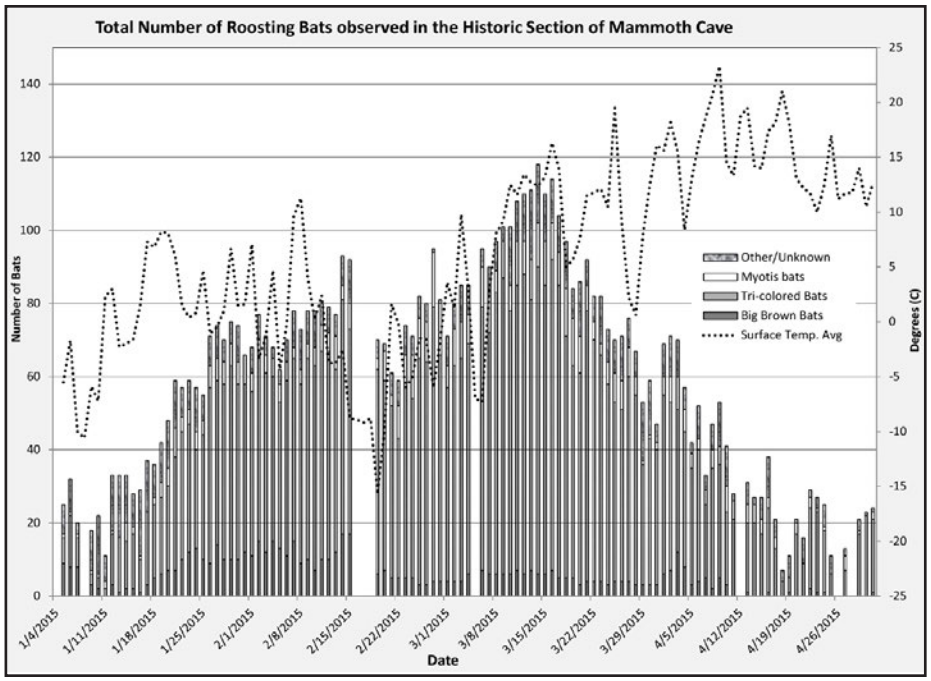

Figure 1: This graph depicts the number of bats presumed alive that were observed along the Historic Section of Mammoth Cave transect in 2015 split by species according to the date. The average surface temperature is also plotted as an indicator of climactic conditions.

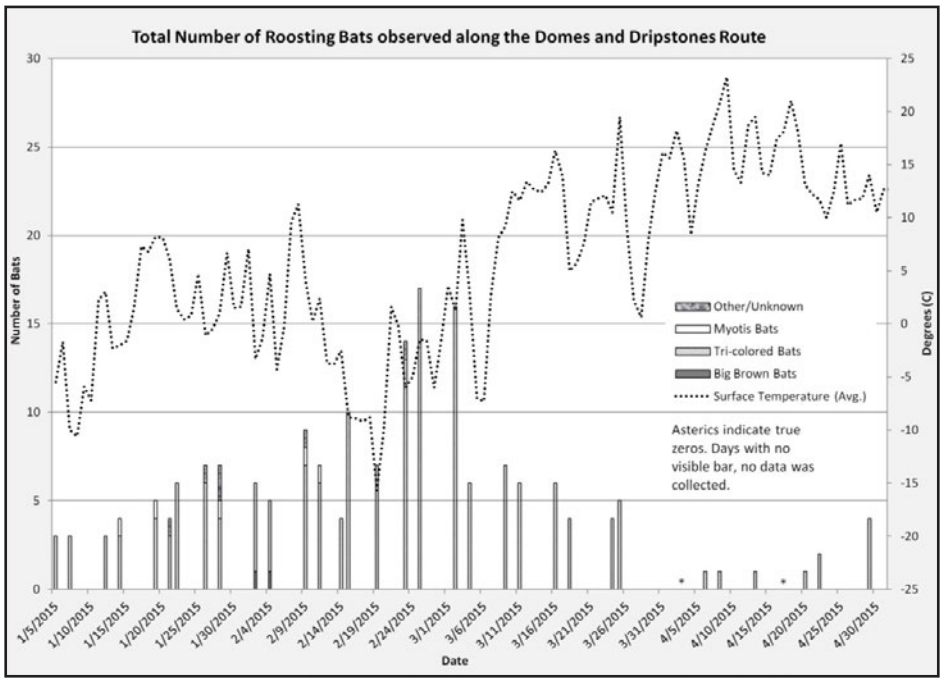

Figure 2: This graph depicts the number of bats presumed alive that were observed along the Domes and Dripstones route transect in 2015 split by species according to the date. The average surface temperature is also plotted as an indicator of climactic conditions.

We collected 75 dead bats from all sources over the course of our monitoring, and an additional unknown number could have exited the cave and died on the landscape, died in an area of the cave where they were not visible, or been consumed.

While death on the landscape is well documented in other parks, it has been observed with less frequency at Mammoth Cave National Park. The surface tier 3 Observations conducted at Dixon Cave yielded no unusual flying bat activity except for one isolated day.

On this day we saw four flying bats, but we had also concluded the biennial population count at Long Cave, approximately 4.5 miles away, an hour previous to the Dixon Cave observations. As both of these caves harbor the same species and are in close proximity, it is a logical conclusion that the flying bat observations in this case were due to human disturbance at Long Cave rather than due to WNS aberrant behavior. Flying bats were not observed on any other day in the 2015 season.

Despite the absence of aberrant flying behavior in our tier 3 observations, we do see isolated incidents of dead or moribund bats being found on the landscape and called in to the Science and Resource Management Division for recovery. Out of the 75 dead bats collected throughout our observations, 9 (12%) were from parking lots or other high visitor use areas across the landscape of Mammoth Cave National Park. This discrepancy presents an opportunity for further research.

Though in our formal tier 3 observations we did not see flying bats, there is a fair level of activity occurring throughout the

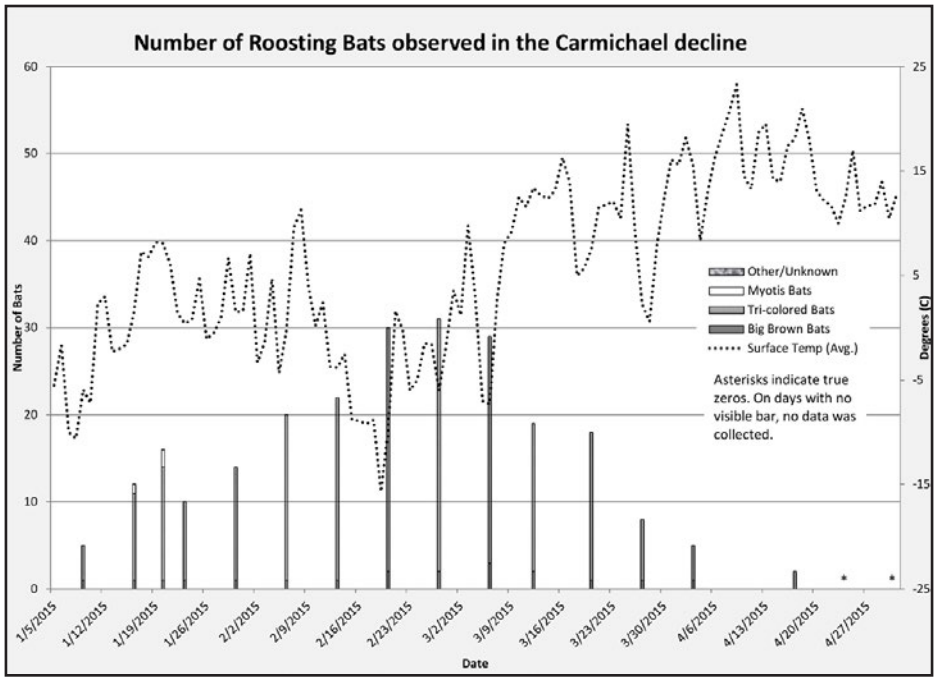

Figure 3: This graph depicts the number of bats presumed alive that were observed along the Carmichael Entrance Decline transect in 2015 split by species according to the date. The average surface temperature is also plotted as an indicator of climactic conditions.

winter within the cave that can be attributed to WNS when you combine the flying bats from the regular transect route with the flying bat data collected by the Division of Interpretation (Figure 4).

Interestingly, while the number of roosting bats along the Domes and Dripstones route was only ~3% of the number of bats observed roosting in the Historic Section, ~31% of the reported flying bats came from this route. It also had more bat-human contacts than the Historic Section. Out of the eleven contacts that occurred in winter 2014-15, seven were along the Domes and Dripstones route while three were in the Historic Section. The remaining contact occurred on the surface along Big Hollow Trail.

This leads to an interesting question – why? Could it be due to the Domes and Dripstones route being on the warm end of the tri-color bat's ideal hibernation temperature range? Further research could look into this discrepancy and explore this interesting aspect of WNS bat behavior at Mammoth Cave National Park.

The last component of our data collection is the testing results of the collected dead bats for both rabies and White Nose Syndrome. Out of the 75 dead bats collected throughout the winter and submitted for testing, none tested positive for rabies. The results are not yet complete for the WNS assessment, but it appears likely that they will all tests positive.

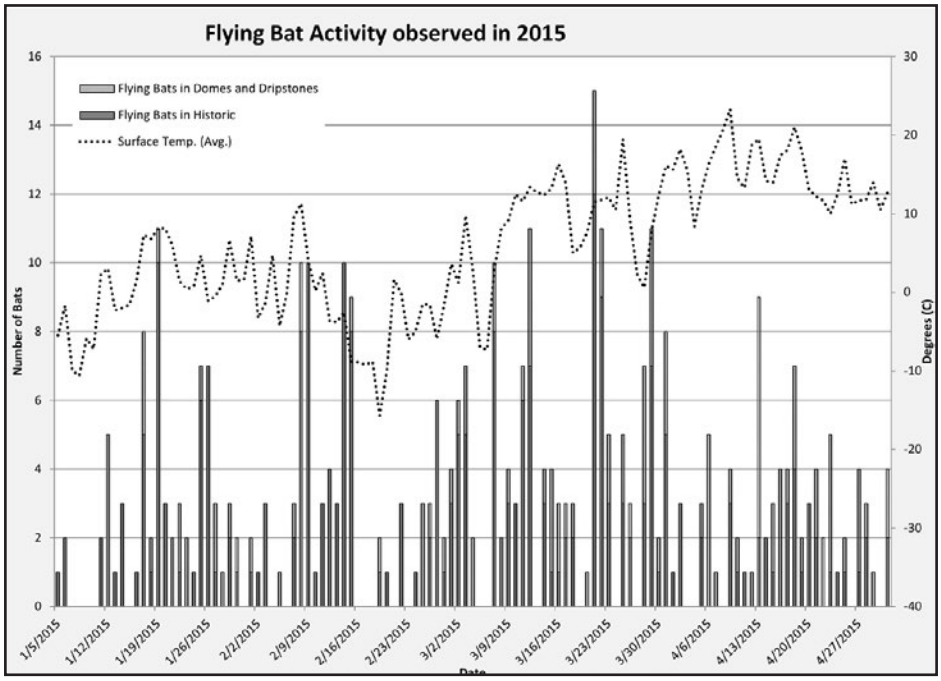

Figure 4: This graph depicts the number of bats observed flying throughout the Historic Section of Mammoth Cave and along the Domes and Dripstones route collected by both the observers completing the transects and Interpreters as they conducted cave tours with the public. The average surface temperature is also plotted as an indicator of climactic conditions.

Conclusion

This monitoring effort was unique and rewarding. It is one of the most comprehensive looks at WNS afflicted bat behavior, and the only data available on bat behavior for a National Park show-cave and how WNS may affect the National Park Service mission. The bats at Mammoth Cave are altering their behavior. We are seeing flying bats throughout the day in-cave, and an interesting trend in the bat populations as WNS influences their roosting choices.

As the only National Park Service site to contend with this disease and manage a year-round show cave operation, there are many lessons to be learned here. As WNS progresses at Mammoth Cave National Park will we continue to see the behaviors and trends observed in our first year of data? Why do the bats in different cave sections exhibit varied activity levels? How can we continue to monitor and preserve the changing bat populations on park without impacting the public's ability to enjoy their public lands?

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