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The Activity of *Myotis sodalis* and *Myotis septentrionalis* Changes on the Landscape of Mammoth Cave National Park Following the Arrival of White-nose Syndrome

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Abstract

White-nose Syndrome (WNS) was detected at Mammoth Cave National Park in January 2013, and population estimates have declined for two federally-listed bat species, *Myotis septentrionalis* (northern long-eared bat) and *Myotis sodalis* (Indiana bat). Presently, there is no evidence for any decline in summer activity of these species across the landscape at the Park. Our objective was to document the annual levels of activity of these species prior to and concurrent with the arrival of WNS. Transects of acoustic detectors (Anabat II) were used to monitor bat activity for 6 years (2010-2015) across a variety of habitats (n = 74 detector locations). Recordings were classified to species level using an automated classifier (Bat Call ID v.2.7c). Classifications were limited to bat passes containing ≥ 5 pulses, and species were identified at the ≥ 95% confidence interval. Our response variables for analyses were the number of passes / night of each species. Using these settings, we recorded a total of 8,478 bat passes (consisting of 101,942 echolocation pulses) over 1,594 detector / nights for the six year period, of which 677 passes (consisting of 5,406 pulses) and 61 passes (consisting of 421 pulses) were classified as *M. septentrionalis* and *M. sodalis*, respectively. Activity of *M. septentrionalis* and *M. sodalis* declined after the detection of WNS ($P < 0.05$). These data indicate a significant change in bat community composition in forested habitats in the Park.

Introduction

White-nose Syndrome (WNS) is a disease associated with the psychrophilic fungus, *Pseudogymnoascus destructans*, and has resulted in the death of more than six million bats (Gargas et al. 2009; Frick et al. 2010; Coleman & Reichard 2014). WNS was discovered during the winter of 2006-2007 in New York and has currently spread to 30 states and 5 Canadian provinces (USFWS 2011; Alves et al. 2014). To date, seven cave hibernating bat species have been confirmed to be affected by WNS (USFWS 2015a). Several *Myotis* species are severely affected by WNS, including the federally listed *Myotis sodalis* (Indiana bat) and *Myotis septentrionalis* (northern long-eared bat).

Myotis sodalis was listed as an endangered species in 1967 (USFWS 2006) and is currently protected under the Endangered Species Act of 1973. Factors contributing to population declines of this species include: habitat destruction, disturbance during hibernation, disease, and predation (USFWS 2006). *M. sodalis* is an insectivore that roosts singly or in maternity colonies during the summer, and hibernates in caves or mines during the winter (Davis 1974; Thomson 1982). Since *M. sodalis* has been listed as an endangered species for many years, a prodigious amount of research has been focused on its recovery and monitoring. Past recovery efforts for *M. sodalis* have largely concentrated on preventing habitat

destruction and human disturbance during hibernation (USFWS 2006). WNS poses a different threat to the survival of this species due to limited knowledge of the causal effects of the fungus, and the difficulty of preventing the spread of the disease. The effect of WNS on populations of *M. sodalis* has been well documented through hibernaculum counts and summer surveys. Population estimates for *M. sodalis* fell from 635,349 individuals in 2007 to 523,636 individuals in 2015 (USFWS 2015b). While the decline of *M. sodalis* has been well-documented, less sound estimates exist for some species, including *M. septentrionalis.*

Myotis septentrionalis was listed as a federally-threatened species in April 2015 (USFWS 2015c). WNS has spread across 60% of the distribution of *M. septentrionalis,* and has resulted in unprecedented declines for this once common species (USFWS 2015c). *M. septentrionalis* is an insectivore that roosts in live or dead trees during the summer, either singly or in maternity colonies (Caceres & Barclay 2000; Reid 2006). This species is not a colonial hibernator. Instead it hibernates singly in crevices or cracks of cave walls (Davis 1974). *M. septentrionalis* are often overlooked during hibernaculum counts, rendering accurate population estimates difficult to achieve (Steve Thomas, pers. comm.). Populations of this species were thought to be stable until the arrival of WNS; now this disease poses a serious threat to the persistence of *M. septentrionalis* (Coleman & Reichard 2014; USFWS 2015c).

WNS has continued to spread across North America, and threatens *M. sodalis* and *M. septentrionalis* across the majority of their distributions. Hibernaculum counts have confirmed population declines of both species in winter (Coleman & Reichard 2014), but the presumed decline of these populations across Kentucky's landscape in summer remains largely undocumented. We had a unique opportunity to compare bat activity prior to and following detection of WNS at Mammoth Cave National Park (MACA). Our objective was to determine the effect of WNS on the activity of these *Myotis* species across the landscape. We hypothesized there would be a decrease in activity of *M. septentrionalis* and *M. sodalis* across the landscape of the Park following the detection of WNS.

Methods

Mammoth Cave National Park is a 23,000-ha parcel of land located in portions of Barren, Edmonson, and Hart counties on the edge of the Crawford-Mammoth Cave Uplands of the Interior Plateau of Kentucky (Woods et al. 2002). MACA has extensive limestone cave systems, in which *M. sodalis* and *M. septentrionalis* are known to hibernate (NPS 2012; Lacki et al. 2015). The first detection of WNS in Kentucky was in Trigg County during the winter of 2011-2012 (Hines & Armstrong 2014). In response to this, MACA implemented its own WNS management plan (NPS 2012), and WNS was detected in the Park in January 2013 (NPS 2013).

We monitored bat activity prior to detection of WNS (2010-2012) and after detection of WNS (2013 – 2015). Bat activity was assessed from April-September each year using Anabat II acoustic detectors (Titley Electronics, Colombia, MO). Detectors were housed in plastic protective cases and powered with external batteries, with microphones deployed 1.5-m above ground (Dodd et al. 2013). Acoustic surveys spanned multiple consecutive nights to account for nightly variation throughout the growing season. Detectors were deployed at

randomly established transect sites across a variety of habitats at MACA (n = 74 detector locations) and regularly calibrated (Fig. 1) (Dodd et al. 2013).

We used Kaleidoscope v.1.2 (Wildlife Acoustics, Maynard, MA) to download acoustic data (zero-crossing format) collected from sunset to sunrise during our surveys. We used an automated program (Bat Call ID v.2.7c) to classify recorded bat passes according to phonic group and species. Bat passes containing ≥ 5 pulses were assigned classifications. Classification of the *Myotis* phonic group and species were conducted at ≥ 70% and ≥ 95% confidence levels, respectively. Our subsequent response variables were the number of passes per detector / night for the *Myotis* phonic group, *M. septentrionalis*, and *M. sodalis*; these variables were considered in relation to WNS arrival to the Park (pre-detection vs. post-detection). We did so using the program 'R' v.3.1.2 (R Development Core Team 2012) and performed Student's t-tests.

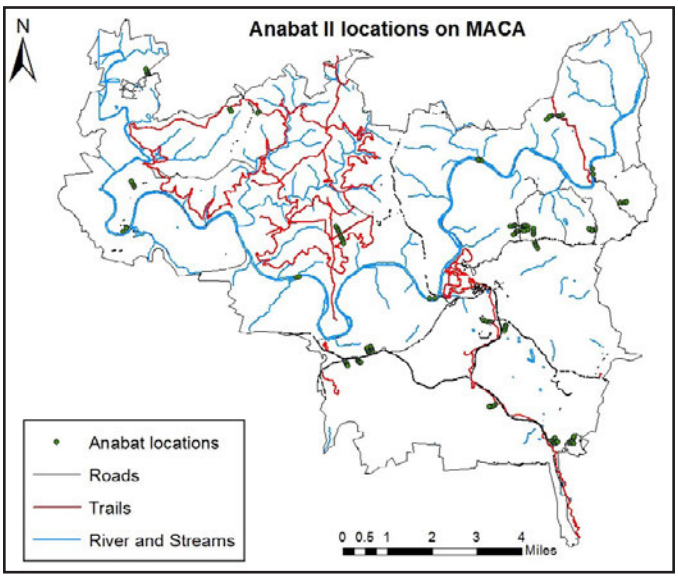

Figure 1: A map of Mammoth Cave National Park, including acoustic detector (Anabat II) locations (n = 74) used for bat activity monitoring from 2010 - 2015.

Results

We recorded a total of 8,478 bat passes (consisting of 101,942 echolocation pulses) over 1,594 detector / nights across all years. For *M. septentrionalis*, 677 passes (consisting of 5,406 pulses) were recorded before the detection of WNS and no pass was recorded after the detection of WNS. For *M. sodalis*, 60 passes (consisting of 416 pulses) were recorded before the detection of WNS and only a single pass (consisting of 5 pulses) was recorded after the detection of WNS. The number of passes classified as the *Myotis* phonic group decreased from 3,867 passes (consisting of 44,604 pulses) before the detection of WNS to 70 passes (consisting of 755 pulses) after the detection of WNS. Analyses demonstrated the number of bat passes per detector / night classified as the *Myotis* phonic group, *M. septentrionalis*, and *M. sodalis*, all decreased significantly following arrival of WNS ($P < 0.01$, Table 1, Fig. 2).

Discussion

Since the detection of WNS, activity of *M. septentrionalis*, *M. sodalis*, and the *Myotis* phonic group have significantly declined across the forested landscape at MACA. Though we observed a decline in activity after the detection of WNS, some of this change could be a result of recorded bat passes being incorrectly classified. However, given the extent of change observed, it is more likely that the declines in *Myotis* activity were due to the impacts of WNS on this genera as a whole. WNS produces mortality in affected bat species by increasing arousal times from torpor, leading to dehydration and depletion of fat reserves, resulting in death of infected bats (Reeder et al. 2012; Willis et al. 2011). WNS has increased the levels of overwinter mortality of these species in MACA, resulting in declines in winter

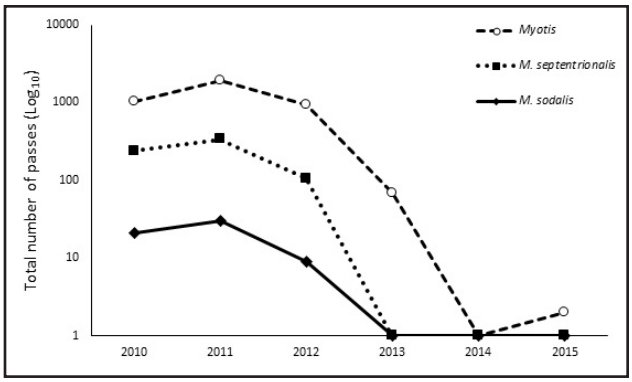

Figure 2: Trends in Myotis activity (bat passes / year) at Mammoth Cave National Park from 2010-2015, as classified using BCID. White-nose syndrome was detected in the park in January of 2013.

populations (Thomas 2016). These species are primary predators of nocturnal insects (Davis 1974), and their recent declines could lead to adverse effects throughout the entire Park ecosystem (Boyles et al. 2011).

Our findings at MACA are consistent with acoustic surveys conducted before and after the detection of WNS in other localities (Coleman et al. 2014; Dzal et al. 2011). WNS can have an indirect impact on bat species which are not susceptible to WNS infection. The decline of *Myotis* species can potentially alter niche partitioning of bat species within a forest community (Jachowski et al. 2014), with bat species not affected by WNS expanding their use of habitats previously occupied by WNS impacted species. Decreasing populations of *Myotis* species could potentially increase the amount of resources available to other bat species through reduced levels of competition.

Through acoustic monitoring, we have recorded declines in activity of two federally-listed bat species concurrent with the detection of WNS in MACA. Winter counts in hibernacula have documented the decline of other *Myotis* species in the Park as well (Thomas 2016). Further acoustic monitoring, mist netting, and harp trapping surveys are needed to provide additional data on the persistence of bat populations in the Park.

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Table 1: Mean ± SE passes per detector / night of the *Myotis* phonic group, *Myotis septentrionalis*, and *Myotis sodalis* at Mammoth Cave National Park prior to detection of White-nose syndrome (pre-WNS) (2010 – 2012) and following detection of White-nose Syndrome (post-WNS) (2013 – 2015).

	Mean ± SE Passes / Detector-Night		
Response Variable	**Pre-WNS**	**Post-WNS**	**Test Significance**
Myotis phonic group	3.4 ± 0.3	0.27 ± 0.11	t 1,344 = 9.6, P < 0.01
Myotis septentrionalis	0.60 ± 0.09	0 ± 0	t 1,134 = 6.8, P < 0.01
Myotis sodalis	0.05 ± 0.01	0.004 ± 0.004	t 1,379 = 4.9, P < 0.01

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