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ORIGINAL ARTICLE

BioBlitz as a Tool for Uncovering Changes in Forest Bat Communities in the Southeastern United States

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ABSTRACT

BioBlitzes, rapid field studies conducted by a collaborative team of scientists and conservation professionals in specific geographic areas, offer an opportunity to enhance research capabilities, foster partnerships, and provide learning opportunities for scientists, conservation professionals, and non-professional volunteers. Since the detection of white-nose syndrome (WNS) in North America, populations of cave-dwelling bats have declined significantly. However, most studies documenting declines have occurred in the core of the WNS-affected area in the eastern United States. To examine changes in capture rates along the periphery of the WNS-affected region, we examined captures from Bat Blitz events (i.e., a subset of a BioBlitz focused exclusively on bats) in northern Alabama and Georgia, USA, before (n = 2; 2008, 2010) and after (n = 2; 2022, 2023) WNS detection. Pre-WNS detection, we captured 676 bats from 11 species, contrasting with post-WNS, where only 283 bats from seven species were captured. Our results show significant declines in captures of the federally endangered northern long-eared bat (*Myotis septentrionalis*) and the proposed endangered tricolored bat (*Perimyotis subflavus*), with decreases of 99,4% and 87,7%, respectively. While other common species showed no significant changes, eastern red bat capture rates declined by 35,4%, and captures of big brown and evening bats increased by 8,0% and 15,0%, respectively. In addition, we observed decreases of > 99% for most myotis species. Overall, our results support documented declines observed for WNS-affected species in northern regions, emphasizing the urgent need for conservation measures for northern long-eared and tricolored bats. Furthermore, we highlight the value of BioBlitz events to conduct surveys at broad spatial and temporal scales efficiently.

INTRODUCTION

North American bat species face several conservation challenges, including habitat loss and modification, pesticides, and mortality associated with wind energy development (Mickleburgh et al. 2002, Voigt & Kingston 2016, Frick et al. 2020). Since the detection of white-nose syndrome (WNS), populations of cave-dwelling bat species have declined dramatically. First identified in 2006 in New York (Blehert et al. 2009), WNS has rapidly spread, reaching 40 U.S. states and nine Canadian provinces (USFWS 2022). Caused by the fungus *Pseudogymnoascus destructans* (*Pd*), WNS primarily affects bats during hibernation, suppressing immune responses and resulting in physiological consequences such as wing damage, dehydration, fat store depletion, and altered torpor-arousal cycles (Meteyer et al. 2009, Blehert et al. 2009, Reichard & Kunz 2009, Cryan et al. 2010, Reeder et al. 2012, Warnecke et al. 2013). The impact varies among bat species (Langwig et al. 2012, 2016), with some exhibiting no signs of disease while others experience mild to severe lesions and sometimes death (Cryan et al. 2010, Reeder et al. 2012). Northern long-eared (*Myotis septentrionalis*), little brown (*M. lucifugus*), and tricolored bats (*Perimyotis subflavus*) are among the most susceptible species, with winter counts in WNS-positive regions declining by more than 90% since the arrival of WNS to hibernacula (Cheng et al. 2021).

Bats that survive WNS during hibernation may still face repercussions. Lower body mass and wing damage could impact foraging ability and subsequent survival (Reichard & Kunz 2009). Bats recovering from WNS may experience lower reproductive success (Francl et al. 2012, Pettit &

O'Keefe 2017). For instance, WNS has been found to impact reproduction in species of federal concern such as Indiana (*M. sodalis*), little brown, and northern long-eared bats, leading to increased proportions of non-breeding individuals and decreased proportions of lactating females (Reynolds et al. 2016, Pettit & O'Keefe 2017). Thus, the aftermath of WNS may result in both direct mortality and indirect effects, such as reduced recruitment, for affected populations. Furthermore, substantial population declines in some WNS-affected species could influence non-susceptible species through competitive release (Bombaci et al. 2021), leading to spatial and temporal niche partitioning in sympatric bat species, particularly in foraging areas (Arlettaz 1999, Arlettaz et al. 2000, Kunz 1973, Nicholls & Racey 2006). These changes may reshape the structure of bat communities in response to declines in WNS-affected species (Francl et al. 2012, Johnson et al. 2021, Petit & O'Keefe 2017, Thalken et al. 2018, Perry & Jordan 2022).

Multiple techniques can be used to assess the composition and richness of bat communities (e.g., mist nets, acoustic or roost surveys) (Flaquer et al. 2007, Loeb et al. 2015, Appel et al. 2021). Trapping methods, such as mist nets and harp traps, offer numerous advantages, such as accurate species-level identification based on morphological characteristics, and allowing for the collection of diverse data like biometric measurements, tissue and/or fecal samples, bodily fluids, and specimens for scientific collection (Flaquer et al. 2007). However, trapping requires continuous researcher presence throughout the sampling period, and simultaneous captures at multiple sites demand more time and personnel in the field, escalating research project costs (Murray et al. 1999, MacSwiney et al. 2008). Acoustic monitoring offers non-invasive alternatives to examine multiple facets of bat ecology (Collins & Jones 2009), including community composition (Flaquer et al. 2007), habitat use (Vaughan et al. 1997), and activity (Russo & Jones 2003). Despite its utility, acoustic monitoring has limitations that must be considered in monitoring efforts. For example, the determination of species presence can vary depending on the detector type and identification algorithms used (Adams et al. 2012, Russo et al. 2018, Perea & Tena 2020). Echolocation calls of individual bats can vary based on habitat, presence of conspecifics, or environmental noise (Walters et al. 2012, Russo et al. 2018), influencing species detection and identification efficacy (Adams et al. 2012, Russo & Voigt 2016).

Limitations of trapping and acoustic methods open the door to BioBlitz events, which involve rapid field surveys in specific geographic areas by teams of professional scientists and conservation practitioners working collaboratively to generate data, improve research capacity, and create working partnerships focused on conservation problems (Parker et al. 2018). Notably, BioBlitz events offer a dynamic platform where scientists and experts from diverse taxonomic backgrounds often organize or are invited to contribute their expertise. In Bat Blitz events (i.e., a subset of a BioBlitz focused exclusively on bats), participants volunteer their time and use their own equipment to survey multiple sites and cover multiple locations rather than traditional mist-netting events, which might be limited in resources or restricted to few sites. This inclusive approach also invites the active involvement of experienced science enthusiasts, less experienced students, young researchers, and non-professional volunteers, creating a mutually beneficial environment that enriches scientific understanding by providing hands-on training while promoting broader engagement in conservation efforts (Meeus et al. 2023). In the southeastern United States, the Southeastern Bat Diversity Network (SBDN) began organizing SBDN Bat Blitzes in 2002 to facilitate these efforts. Since then, these events have continued annually (most years) and are hosted by different states.

In North America, bat species affected by WNS are undergoing rapid population declines. While such impacts are acknowledged in the southeastern United States (e.g., O'Keefe et al. 2019, Grider 2020, Loeb & Winters 2022, Perea et al. 2022, 2024), most published studies examining changes in bat community structure following WNS detection are predominantly from northern regions (e.g., Moosman et al. 2013, Perry & Jordan 2022). Further information is needed to fully document bat community changes in the southeastern United States. However, large-scale data acquisition is logistically and financially challenging. In this context, Bat Blitz events can be of great utility. Therefore, our objective was to assess changes in bat communities in two National Forest in the southeastern United States by comparing data collected at two Bat Blitz events prior to WNS detection and two events a decade after WNS detection. In doing so, we aimed to further emphasize the value of BioBlitzes as a method for assessing changes in bat communities while providing distinctive opportunities for young researchers, the general public, and experienced scientists.

MATERIALS AND METHODS

Study Area

Our study sites were located in the Bankhead National Forest (BNF hereafter) in northern Alabama and the Chattahoochee National Forest (CNF hereafter) in northwest Georgia (Fig. 1). The BNF comprises 72.843,42 ha and is in the Strongly Dissected Plateau sub-region of the Southern Cumberland Plateau within the southern Appalachian highlands (Smalley 1982). Forest types within the BNF are characteristically oak (*Quercus* spp) and hickory (*Carya* spp) upland forests with beech (*Fagus* spp) forests in moist gullies and along streams, except in areas where pine (*Pinus* spp) forests were planted for commercial purposes. The CNF covers 303.946,84 ha in northern Georgia's Blue Ridge and Ridge & Valley ecoregions. This area is composed of a variety of habitats ranging from dry, high-elevation woodlands dominated by oaks and pines to cove forests dominated by eastern hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and understory species such as rhododendron (*Rhododendron* spp) and mountain laurel (*Kalmia latifolia*) (Edwards et al. 2013). Both forests are characterized by a wide variety of vertebrate fauna, including bat predators such as owls (barred owls [*Strix varia*] and great horned owls [*Bubo virginianus*]), snakes (rat snakes [*Pantherophis* spp.]), and mammals (feral cats [*Felis catus*], raccoons [*Procyon lotor*], striped skunks [*Mephitis mephitis*], and Virginia opossum [*Didelphis virginiana*]).

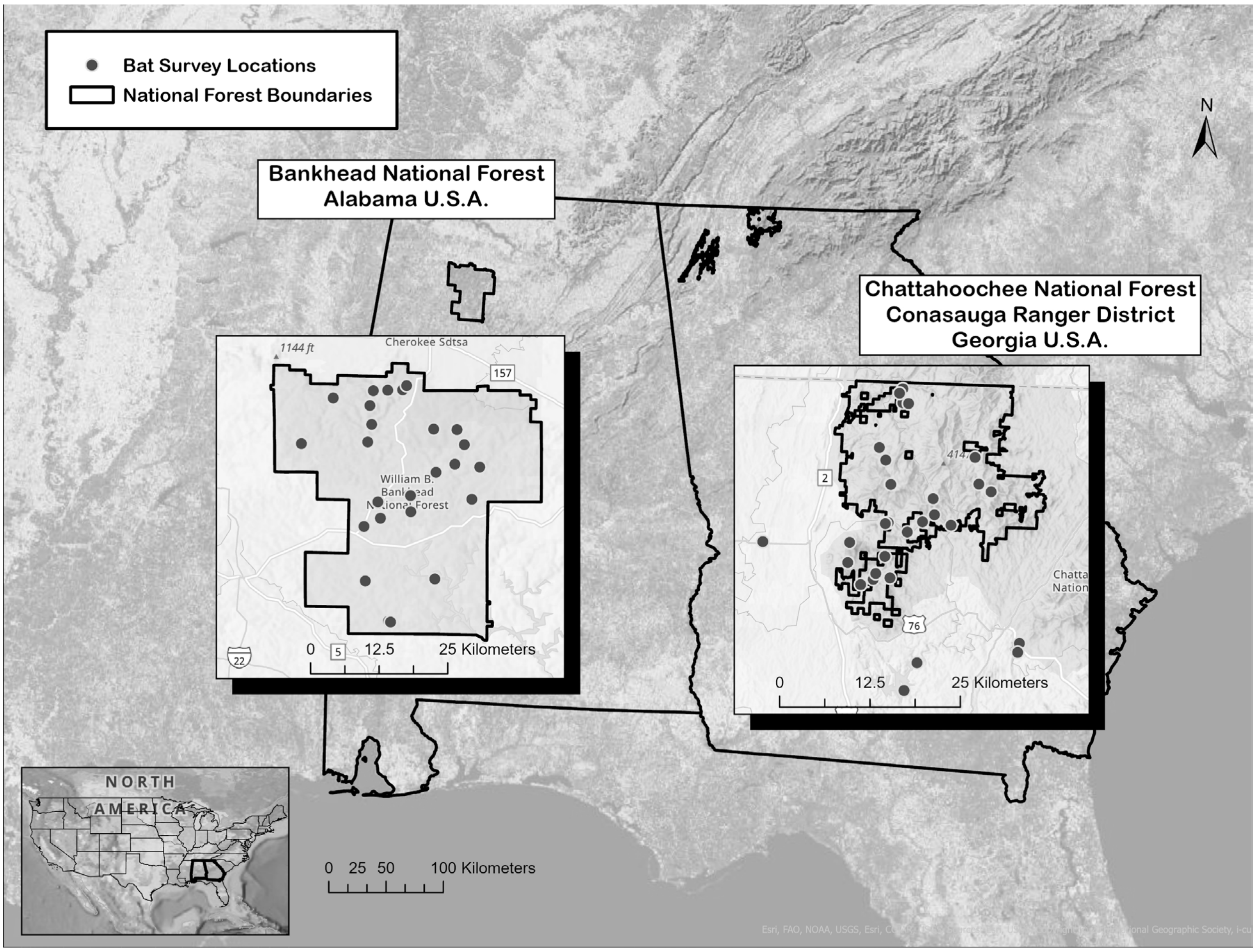

Fig. 1 - Locations of study sites in Bankhead National Forest Alabama, USA, and Chattahoochee National Forest Georgia, USA, where Bat Blitz events were conducted pre-WNS (2008 and 2010), and post-WNS (2022 and 2023). Trapping sites are indicated by circles.

Data collection

To ensure surveys were comparable, the same sites were sampled using similar net placement, to the extent possible, pre-WNS and post-WNS. We used single, double, and triple high mist-nets (Avinet Inc., Dryden, NY, USA; mesh diameter: 75/2, 2,6 m high, 4-shelves, 4–18 m wide) and occasionally harp traps, as appropriate for the sampling site. Sampling sites were monitored continuously for 3-5 hours after sunset, contingent on weather or other field conditions. Prior to WNS detection, we surveyed BNF (n = 24 sites) from August 11-13, 2008, and CNF (n = 35) from July 26-28, 2010. We resurveyed BNF (n = 28 sites) from August 2-4, 2022, and CNF (n = 33 sites) from August 7-9, 2023, 8 and 10 years following the detection of WNS in Alabama and Georgia, respectively.

For all captured bats, we recorded species, reproductive status, sex, age, and body condition. During post-WNS surveys, field researchers followed United States Fish and Wildlife Services (USFWS) WNS Decontamination guidelines (WNSD Team 2018) and COVID-19 recommended strategies (Kingston et al. 2021). All capture and handling techniques were approved by the USFWS, Alabama Department of Conservation and Natural Resources (ALDCNR) and Georgia Department of Natural Resources (GADNR) and were consistent with the guidelines published by the American Society of Mammalogists (Sikes & Animal Care 2016). We conducted all work under the supervision of state biologists, operating under existing agreements with USFWS.

Analysis

We used the stats package in R version 4.1.1 (R Core Team 2020) to compare changes in bat species captures before and after WNS detection. Generalized linear models (GLMs) were applied, with the mean captures per site per night (mean capture rate) as the response variable. We excluded species captured at <10% of total sites from analyses. We performed a Shapiro-Wilks test for normality and found that the response variables were not normally distributed. Therefore, we used Poisson or negative binomial distributions when the response variables were over-dispersed. For each species, we examined changes in mean captures before and after WNS detection by comparing a model with a trend term (year) as a predictor variable to a null intercept model with no trend term, in which support for the null model would indicate stable relative abundance. Additionally, we compared these models to models including daily temperature and precipitation obtained from the closest weather stations to test whether changes in mean captures could be due to nightly weather conditions during surveys. We compared models for each species using Akaike's Information Criterion corrected for small sample sizes (AICc), considering models with ΔAIC < 2 from the null model as plausible. Lastly, we evaluated plausible models for goodness of fit and over- and under-dispersion using the DHARMa package (Hartig 2020).

Table 1 - Total number of bats captured, mean capture rates (number of captures/site), standard deviation (sd), and percent change in mean capture rates from pre- to post-white-nose syndrome (WNS) for 11 bat species captured at Bankhead National Forest in northern Alabama, USA, and the Chattahoochee National Forest in northern Georgia, USA. Percent change calculated as PC = (post-WNS – pre-WNS value / pre-WNS value) * 100.

Species	Pre-WNS (n = 59 sites)				Post-WNS (n = 61 sites)				Percent change
	2008	2010	mean	sd	2022	2023	mean	sd	
Eastern red bat	138	74	3,59	7,02	105	39	2,32	4,03	-35,38
Northern long-eared bat	101	87	3,19	10,58	0	1	0,02	0,13	-99,37
Tricolored bat	74	65	2,36	5,93	17	1	0,29	0,98	-87,71
Big brown bat	46	42	1,49	2,78	47	53	1,61	3,71	8,05
Evening bat	8	7	0,25	0,63	15	3	0,29	0,80	16,00
Indiana bat	16	0	0,27	2,08	0	0	0,00	0,00	-100,00
Little brown bat	0	9	0,15	0,61	0	0	0,00	0,00	-100,00
Eastern small-footed bat	0	5	0,09	0,47	0	1	0,02	0,13	-77,78
Gray bat	1	2	0,05	0,29	0	0	0,00	0,00	-100,00
Hoary bat	0	1	0,02	0,13	0	0	0,00	0,00	-100,00
Seminole bat	0	0	0,00	0,00	1	0	0,02	0,13	100,00
Total	384	292	11,46	21,82	185	98	4,55	6,05	-60,30

Table 2 - Parameters with estimates, standard errors (SE), and 95% confidence intervals (CI) for top northern long-eared and tricolored bat models from data collected at Bankhead National Forest in northern Alabama, USA, and the Chattahoochee Forest in northern Georgia, USA, pre-WNS (2008, 2010) and post-WNS (2022, 2023).

Parameter	Mean	SE	95% CI lower	95% CI upper
Northern long-eared bat				
Intercept	-1,60	1,41	-4,89	-0,11
Year	-2,79	1,43	-6,19	-1,25
Tricolored bat				
Intercept	-0,72	0,60	-2,05	0,06
Year	-1,49	0,61	-2,82	-0,69

RESULTS

We captured 676 bats of 11 species pre-WNS and 283 bats of seven species post-WNS detection combining BioBlitz events (Table 1). Prior to WNS, eastern red (*Lasiurus borealis*), northern long-eared, and tricolored bats were the most common species captured; however, capture rates changed post-WNS, with eastern red and big brown (*Eptesicus fuscus*) bats being the most common species captured. While we observed decreases in capture rates for northern long-eared (-99,4%), tricolored (-87,7%), and eastern red bats (-35,4%), evening (16,0%) and big brown (8,0%) bat capture rates increased post-WNS. Other myotis species captured were the eastern small-footed (*Myotis leibii*), gray (*Myotis grisescens*), Indiana, and little brown bats. The latter three species exhibited capture declines > 99%. Finally, we captured one hoary bat (*Lasiurus cinereus*) in 2010 and one Seminole bat (*Lasiurus seminolus*) in 2022 (Table 1).

Models for northern long-eared and tricolored bats that included year had Akaike weights of 0,94 and 0,95, respectively, indicating associations between time periods and changes in captures (SM Table 1). Negative parameter estimates for both species had 95% confidence intervals that did not include zero (Table 2), indicating a significant decline in capture rates. For the other species analyzed (big brown, eastern red, and evening bats), the null models were within ΔAIC < 2 with no weather or temporal covariates explaining changes in capture rates (SM Table 1).

DISCUSSION

Our findings align with previously documented declining tricolored bat captures in WNS-positive regions (O'Keefe et al. 2019, Perry & Jordan 2022). The trends we observed are similar to those found during hibernation (Loeb & Winters 2022, Perea et al. 2024) and summer activity patterns obtained from acoustic monitoring (Perea et al. 2022) along the periphery of the WNS endemic region. These results provide crucial data needed to support the decision-making process regarding the listing of tricolored bats under the Endangered Species Act (ESA) (Kitchell 2022). The plight of the federally endangered northern long-eared bat, another species heavily impacted by WNS in the region, is evident in the significant declines between Bat Blitz events, indicating near disappearance in both forests, with a single capture for Georgia in 2023. Prior to WNS detection in northern Alabama and Georgia, the northern long-eared bat was a common species in the region, with consistent captures each summer (Grider 2020). Our findings mirror the severe declines observed in regions further north, emphasizing the urgency of conservation measures for these heavily impacted species (Cheng et al. 2021, Perry & Jordan 2022).

Although not significant, we documented changes in capture rates of the other species included in our analyses. The most common species captured, the eastern red bat, exhibited a decline in captures post-WNS compared to pre-WNS sampling periods. While this species is not believed to be negatively affected by WNS (Francl et al. 2011), it is impacted by wind energy development (Arnett et al. 2016, Choi et al. 2020). However, previous surveys in the southeastern United States suggest no apparent decline in eastern red bat populations in the region over time (O´Keefe et al. 2019, Evans et al. 2021). Although the null model was within ΔAIC < 2, our results may indicate variations due to temperature, an important covariate in our best model, as eastern red bats were captured more frequently on warmer nights. In contrast, our results indicate increased capture rates of big brown and evening bats. Several studies in northern regions suggest a potential link between big brown bat population increases and declines in little brown and northern long-eared bats due to competitive release dynamics after WNS (Hauer et al. 2019, Deeley et al. 2021, Johnson et al. 2021). However, other studies report marginal increases or no significant difference in captures following WNS (e.g., Francl et al. 2012, Moosman et al. 2013, Pettit & O'Keefe 2017, O'Keefe et al. 2019). Therefore, increases in captures of big brown and evening bats post-WNS may not necessarily indicate an increase in abundance in this region, but rather suggest reduced competition in foraging habitats, enabling access to previously suppressed areas. Further studies are needed to confirm or disprove this possibility.

Observed records of species captured in less than 10% of the sites and therefore not included in the analyses remain anecdotal yet informative. The federally endangered gray and Indiana bats, along with the rare eastern small-footed bat, exhibit summer ranges at the southern limits of their distribution within Georgia and Alabama, far from regions with higher densities (Best & Jennings 1997, Loeb & Winters 2013, Holliday et al. 2023). The little brown bat, once common in eastern North America, has suffered a drastic decline due to WNS (Cheng et al. 2021). The range of this species, however, was limited in Georgia and Alabama even before the detection of WNS (Beck & Morris 2017, Perea et al. 2024). Finally, we only captured one hoary bat and one Seminole bat. Hoary bats, known for their migratory nature in the southeastern United States during winter (Grider et al. 2016, Wieringa et al. 2021, Perea et al. 2023), are uncommon in summer (Bender et al. 2015, Grider et al. 2016) and difficult to capture through mist-netting surveys due to their open-space foraging characteristics. The case of low capture rates for the Seminole bat is likely explained by being at the edge of its distribution. Although there are records as far north as Arkansas (Perry 2018), the distribution of the Seminole bat is primarily in the coastal plain region of the southeastern United States.

The data collected through Bat Blitzes organized by SBDN offer a unique opportunity to monitor long-term changes in bat communities by resampling sites in a manner similar to previous Blitz efforts. Our study underscores the role of BioBlitz events as rapid field surveys at specific geographic locations as well as highlighting the impact of WNS on the bat community in the Bankhead National Forest in northern Alabama and the Chattahoochee National Forest in northwest Georgia. The impact of WNS is evidenced by significant and drastic declines in the federally endangered northern long-eared bat and the proposed endangered tricolored bat after the detection of WNS. Although planning these events is time-consuming and increasingly expensive, the opportunity to train emerging scientists and collect large amounts of data in a short period of time makes them a worthwhile effort. We encourage other states to consider replicating previous efforts to contribute to the growing body of evidence that many of North America's bat species are in need of conservation action. Finally, as a platform for scientific research and knowledge sharing on monitoring techniques, BioBlitz events offer unique opportunities to collect data and collaborate on threatened or endangered species, working with state biologists under existing permits.

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