

Improving Conservation and Recreation in Environments
Shared by Humans and Bats

A Thesis Presented for the
Master of Science
Degree

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ABSTRACT

White-nose syndrome (WNS) has drastically changed how caves are managed in the United States. This disease has killed millions of bats throughout eastern North America and continues to spread westward. Since the discovery of WNS, The U.S. National Park Service (NPS) has acted to slow the spread of the disease through the development of educational programs and the deployment of decontamination measures. Despite the vast array of research on the biological and ecological aspects of bats and WNS, few studies focus on how visitor attitudes and knowledge of management strategies implemented in response to WNS impact the effectiveness of these programs. To better inform management decisions, I examined national park visitor attitudes towards bats and common cave management actions.

To better understand the context surrounding WNS management in U.S. national parks, I conducted in-depth qualitative interviews with 15 key informants that worked for or closely with the National Park Service. Common themes emerged from these interviews, including the diversity of cave management programs in national parks, the use of context-specific management plans, the similar challenges national parks face when managing for bats and WNS, and the difference in cave management perceptions between the general public and cavers.

Using this information, I created a visitor survey assessing their attitudes towards bats, knowledge of WNS, and perceptions of common WNS preventive measures. I surveyed 1365 visitors at eight national parks throughout the country during the summer of 2019. Overall, respondents expressed positive attitudes towards bats, moderate to high knowledge of bat ecology, and a high recognition of WNS. Visitor recognition of WNS varied greatly between the parks, with visitors at Jewel Cave National Monument (South Dakota) having the highest recognition of WNS (87%) and visitors at El Malpais National Monument (New Mexico) having the lowest recognition of WNS (63%). Using the Theory of Planned Behavior as a framework, we also found that visitors would likely follow WNS preventive actions, with structural equation models showing that attitudes and subjective norms had the greatest influence over visitor behavioral intent.

Using these results, I present the implications of this research and management actions that may be implemented to meet multiple conservation objectives. It will be crucial to continue to integrate biological and social science research to achieve management goals focused on enhancing recreation and conservation in environments shared by humans and bats.

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CHAPTER 1: INTRODUCTION

Bats in the U.S. provide critical ecosystem services; most notably, they eat an incredible number of insects and save farmers billions of dollars each year in pest suppression alone. However, these services are under threat, as numerous anthropogenic conservation risks to bats have developed, including habitat loss, wind energy development, roost and hibernacula disturbances by people, climate change, and disease. In recent years, the most severe threat to cave-hibernating bat species is white-nose syndrome (WNS). The arrival of WNS to North America in 2006 created new considerations and priorities for how caves and cave-roosting bats are managed across the U.S. White-nose syndrome is a disease caused by the fungus *Pseudogymnoascus destructans* (*Pd*). The fungus infiltrates the skin tissues of bats during hibernation, and manifests with a variety of associated effects, including dehydration, interrupted metabolic activities, winter emergence and exposure, starvation, and often death (Reeder et al. 2012; Cryan et al. 2013; Verant et al. 2014).

White-nose syndrome has killed at least 5.7 million bats since its arrival (U.S. Fish and Wildlife Service 2012) and continues to rapidly spread westward (U.S. Geological Survey 2019). Currently, WNS has spread to 35 states and 7 Canadian provinces, and *Pd* has been documented in four additional states (Fig. 1). The spread of WNS has been primarily attributed to bat-to-cave-to-bat or bat-to-bat transmission; however, there is evidence that the fungus can persist within cave environments for years (Lorch et al. 2013) and fungal spores can be spread to different locations by humans on gear or clothing (Puechmaille et al. 2010; Lindner et al. 2011; Langwig et al. 2012; Knudsen et al., 2013; Frick et al. 2016). The fungus is presumed to have been first introduced into caves near Albany, New York from Europe via anthropogenic activities (Leopardi et al. 2015). Additionally, the more recent detection of *Pd* and WNS in Washington in 2016, approximately 1,900 km from the closest known occurrence of the disease, is thought to have been anthropogenically spread (Lorch et al. 2016).

To reduce the risk of people spreading *Pd* to new areas and reduce other anthropogenic disturbances to bats, the White-nose Syndrome Disease Management Working Group, which is a national interagency working group led by the U.S. Fish and Wildlife Service, developed recommended practices for caves that have been made accessible to the public. Using the best available scientific data and universal precautions, this guide gives cave managers information on how to select and implement management actions that minimize the risk of visitors disturbing bats and spreading the fungus to other areas based on the *Pd*/WNS status of the cave and available

resources. The strategies in this guide include providing educational materials or programming to visitors and staff about bats and WNS, screening visitors before they enter the caves, cleaning clothes and gear before and/or after entering a cave, and restricting access to part of or the entire cave.

Despite the vast array of research on the impact of WNS on bats and the creation of WNS preventive strategies, there has been a lack of studies on people's attitudes towards bats or perceptions of these WNS preventive actions. Slowing the spread of WNS and preventing anthropogenic disturbances to bats requires participation and support from people. This issue is further complicated because of people's complex relationships with bats. Historically, bats have been disliked by the public for multiple reasons, including disease-related fears and associations with myths and folklore. In the U.S., rabies and histoplasmosis are the two most common public health risks associated with bats. Additionally, bats have been associated with unfavorable myths, like all bats drink blood and bats will fly into people's hair (Prokop and Tunncliffe 2008; Prokop et al. 2009). Despite these negative perceptions, recent studies have shown that people's attitudes towards bats has become more positive, with some studies showing that the public has become more knowledgeable of bats' importance to ecosystems (Sexton and Stewart 2007; George et al. 2016; Fagan et al. 2018).

It is crucial to understand people's perceptions towards bats to ensure the success of conservation actions regarding this group of species, including the implementation of a variety of WNS preventive actions. Government agencies and non-governmental organizations have put forth significant efforts to educate the public about the importance of bats and the danger that WNS poses to their survival. As studies indicate that the public has more positive attitudes towards bats and support bat conservation efforts, cave managers want to ensure that the actions they take to minimize anthropogenic threats to bats do not sour the public's relationship with bats or the managing agencies making the decisions. With this in mind, the goal of this thesis is to provide natural and cultural resource managers with the information needed to make informed decisions that balance bat and cave conservation with human safety and recreational interests. In particular, WNS preventive efforts by the U.S. National Park Service (NPS) were the target of this study, as the NPS manages extensive cave resources and has a close relationship with the public through its recreational and educational opportunities focusing on bats and the caves they inhabit.

Charged with the preservation of natural and cultural features for the enjoyment of current and future generations, parks have integrated WNS educational messaging into their cave interpretive programming to give visitors information on how this disease is impacting bat populations and what they can do to help. Additionally, parks have implemented varying WNS preventive measures based on the disease status, cave and park layout, and resources availability of the park. However, to our knowledge, there has only been one study evaluating visitor attitudes towards bats and support for bat conservation efforts, and there have been no empirical studies evaluating visitor perceptions of commonly used WNS preventive actions. This thesis will address three understudied topics at eight national park units (Figure 1) to inform resource management regarding bats roosting in caves:

- 1) Key informant perceptions of bat and cave management in national parks
- 2) Visitor attitudes towards bats and knowledge of bats and WNS
- 3) Predictive factors that explain visitors' willingness to participate in WNS preventive strategies.

CHAPTER 2: KEY INFORMANT PERCEPTIONS OF BAT AND CAVE MANAGEMENT IN U.S. NATIONAL PARKS

This chapter is modified from a paper in review:

Shapiro, H.G., A.S. Willcox, E.V. Willcox, and M. Verant. *In review in Wildlife Society Bulletin*. Perceptions of Bat and Cave Management in U.S. National Parks.

My use of “we” throughout this chapter is in reference to my co-authors and myself. I was the primary contributor to this work, which involved developing the project design and survey instrument, statistical analysis, and all writing. A.S. Willcox advised on study design and assisted with editing. E.V. Willcox advised on question design and assisted with editing. M. Verant aided in participant identification and assisted with editing.

ABSTRACT

White-nose syndrome (WNS) has killed more than 5.7 million bats across eastern North America and is considered one of the deadliest wildlife diseases of the modern era. The U.S. National Park Service (NPS) manages over 4,700 caves and is tasked with balancing the conservation of natural resources with the public’s recreational experiences. Despite the close connection the NPS has with the public, few studies have focused on the social consequences of rapidly changing cave management plans in response to WNS expansion. We explored key stakeholders’ perceptions of bat and cave management at caves managed by the NPS through 15 semi-structured key informant interviews. Common themes that emerged from these interviews were the diversity of current cave management programs, the use of context-specific management plans in NPS-managed caves, the similar challenges national parks face when managing for bats and WNS, and the difference in cave management perceptions between the general public and cavers. While informants agreed upon the challenges the NPS faces in managing its bats and caves, caver and government respondents were divided on their attitudes towards how federal agencies have handled the spread of WNS. Understanding the social context of how WNS has shaped cave management in national parks is crucial for enhancing park visitor experiences and support for bat conservation.

INTRODUCTION

Caves are unique ecosystems that contain a variety of cultural, natural, and paleontological resources (Albers et al. 2003, Widga and Colburn 2015, Medellin et al. 2017). Across the United States, caves are owned and managed by a diversity of federal and state agencies, conservation organizations, and private landowners. The U.S. National Park Service (NPS) manages over 4,700 caves, including two UNESCO-recognized caverns: Carlsbad Caverns and Mammoth Cave. There are multiple laws that define the NPS’s authority to manage and conserve cave resources, most

notably the Federal Cave Resources Protection Act of 1988. This law directs the Department of Interior “to secure and protect significant caves on federal land for the benefit and enjoyment of all people while fostering increased cooperation and information exchange among those who use caves for scientific, educational, or recreational purposes” (National Park Service 2016). While the primary objective of the NPS is to preserve cave systems for future generations, these cave systems are popular tourist attractions that provide valuable educational opportunities, as the NPS utilizes self-guided and ranger-led tours to educate the public about unique geologic features, cave-dwelling wildlife, and the importance of protecting these valuable ecosystems. Additionally, caves have provided the NPS opportunity to teach the public about the importance of bats and current threats to bats.

The arrival of white-nose syndrome (WNS) to North America in 2006 created new considerations and priorities for how caves and other underground ecosystems used by bats are managed across the U.S. White-nose syndrome is a disease caused by the fungus *Pseudogymnoascus destructans* (*Pd*). As the fungus infiltrates the skin tissues of bats during hibernation, WNS manifests with a variety of associated effects, including dehydration, interrupted metabolic activities, winter emergence and exposure, starvation, and often death (Reeder et al. 2012, Cryan et al. 2013, Verant et al. 2014). White-nose syndrome has killed millions of bats throughout eastern North America (U.S. Fish and Wildlife Service 2012) and continues to spread westward (U.S. Geological Survey 2019). To date, WNS spread has been primarily attributed to bat-to-cave-to-bat or bat-to-bat transmission; however, there is evidence that the fungus can persist within cave environments for years (Lorch et al. 2013) and fungal spores can be spread to different locations by humans on gear or clothing (Puechmaille et al. 2010; Lindner et al. 2011; Langwig et al. 2012; Knudsen et al., 2013; Frick et al. 2016). The fungus is presumed to have been first introduced into caves near Albany, New York from Europe via anthropogenic activities (Leopardi et al. 2015). Additionally, the more recent detection of *Pd* and WNS in Washington in 2016, approximately 1,900 km from the closest known occurrence of the disease, is thought to have been anthropogenically spread (Lorch et al. 2016). In response to this devastating epidemic, a national interagency plan and recommendations for cave access and decontamination (White-nose Syndrome Response Team 2018a, 2018b) based on universal precautions (U.S. Geological Service 2011) and the best available scientific evidence have been developed to reduce disturbance of bats

within caves and other underground sites and to minimize the risk of human-assisted spread of *Pd* (U.S. Fish and Wildlife Service 2011).

The NPS has been instrumental in the national response to WNS, as it manages extensive cave resources, has close relationships with the public, and provides opportunities for recreation, education, and scientific exploration of cave ecosystems. Parks across the U.S. implement varying measures to prevent the spread of WNS, including providing educational materials and interpretive programs about WNS, screening visitors before cave tours, cleaning and decontaminating footwear and gear that has been in contact with bats or their habitats, providing dedicated gear for researchers or educational groups, and restricting access to caves where necessary to protect bats, other cave resources, and human safety (National Park Service 2017, National Park Service 2018a, National Park Service 2019a).

Although the NPS and other partners in the national WNS response have quickly acted to implement these management interventions and have funded multiple biological and ecological studies on the impacts of WNS on bat populations (U.S. Fish and Wildlife Service 2011; National Park Service 2018b), there have been no studies on the impacts of these new cave management practices on stakeholder groups. The effectiveness of current and future conservation actions often depends on the support and participation of stakeholders (Schwartz 2006). Using qualitative interviews with people who worked for or closely with NPS, we investigated how bat and cave management practices in the U.S., with a focus on NPS-managed caves, have changed since the discovery of WNS and key stakeholder perceptions of these changes. Understanding the perspectives of land managers and stakeholders is crucial for effective conservation and management of caves and bats. The results of this study will allow for stakeholders in NPS-managed caves to better understand the context surrounding bat and cave management since the discovery of WNS, allowing for the NPS to improve bat conservation actions and enhance visitor experiences.

Background

To reduce the risk of people spreading *Pd* to areas without the fungus and reduce anthropogenic disturbances to bats, the White-nose Syndrome Disease Management Working Group (2019) developed guidance on recommended practices for show caves, which are caves that have been made accessible to the public, based on universal precautions and best available scientific data. This guide gives show cave managers information on how to select and implement

management actions to minimize risks of visitors spreading the fungus or disturbing bats through assessing the likelihood and consequence of the risks in context of the status of *Pd* and WNS in the area, and considering operational goals and resources of the show cave(s).

Depending on the risk level and status of WNS at the site, the guide recommends a variety of management actions and offers examples of how to put these actions into practice. Education of staff and visitors about bats and WNS and avoiding areas with roosting bats are actions recommended for all show caves. The guide recommends utilizing visitor screening at caves where *Pd*/WNS has not been detected or where the status of the fungus and disease are unknown. The goal of this procedure is to identify items (e.g. shoes, clothes) of incoming visitors that may have been contaminated with *Pd* in another cave. For caves with moderate to high risk of *Pd*/WNS, cleaning gear and equipment and use of dedicated equipment is recommended. Lastly, closure and access restrictions are recommended for high risk caves where other management actions cannot be carried out. The NPS utilizes these strategies in park areas that have show caves, with each park area utilizing a unique approach to managing visitors based on the layout, resources, and *Pd*/WNS status of the park. Many caves under the management of the NPS have remained open to public access and scientific research as long as risks to bats, other cave-related resources, and human safety can be mitigated.

METHODS

We initially used purposive sampling, which is a nonprobability sampling technique where the researcher selects the sample based on their own judgment, to recruit key informants (Babbie 2015). Respondent groups included NPS staff, state wildlife agency workers, and private citizens actively involved in caving groups with formalized relationships with the NPS. We chose these three respondent groups to obtain different perspectives regarding cave management across the U.S., with a focus on cave management in national parks. In particular, we attempted to interview state wildlife agency workers because we wanted a historical perspective of WNS-response in the U.S., and caves in the northeast are managed by state agencies or private cave owners. We initially identified a list of key informants based on their involvement with caves in national parks. After everyone from the initial list was contacted, we expanded our methods to include snowball sampling, where key informants were asked to suggest additional people for interviewing (Babbie 2015). Efforts were made to include differing opinions on cave management by asking respondents to recommend others who held contrasting viewpoints. We stopped interviewing people once we

reached data saturation, or the point when no new information or themes were observed in the data (Faulkner and Trotter 2017).

We used semi-structured interviews with key informants to understand the social context of bat and cave management practices within NPS units. We applied qualitative methods because this methodology allows respondents to provide data that elucidates nuances and themes, as our research questions have limited data in the literature (Babbie 2015). We created an open-ended interview guide (Appendix 1) with input from NPS staff who were familiar with WNS management throughout the parks. The questions examined respondents' involvement with national parks, their knowledge of current cave management practices, their opinions on the challenges facing national parks, visitor perceptions of cave management protocols, and their ideas for future park management initiatives. If a respondent's answer was unclear or incomplete, we used a probe, or an interviewing technique to request a more complete answer to a question (Babbie 2015). Interview duration ranged from 25 minutes to an hour-and-a-half. Interviews were conducted using Zoom video conferencing software (Zoom Video Communications Inc., San Jose, CA), recorded, and transcribed (GoTranscript, Edinburgh, UK). All methods for this project were approved by the University of Tennessee's IRB office (UTKIRB-18-04697-XP).

We used qualitative analyses to find commonalities in the key informant interviews. We used QSR Nvivo12 (QSR International, Melbourne, Australia) to first identify the range of responses to each question and to consolidate these responses into common patterns (Babbie 2015). We then looked to determine if these patterns transcended the specific questions where they emerged, and we organized these patterns into broader themes. Additionally, we selected quotes that best exemplified these patterns to provide a more in-depth understanding of the topics discussed in these interviews.

RESULTS

We interviewed 15 key informants during the fall of 2018 and spring of 2019 about their involvement with cave management and perceptions of current and future cave management practices. We interviewed key informants from the NPS (n = 9), caving groups (n = 5), and state wildlife agencies (n = 1). From these interviews, the following five themes emerged.

Current Cave and Bat Management Programs

National parks have adopted the practices outlined by the White-nose Syndrome Show Cave Guidance document (White-nose Syndrome Response Team 2019). These management

actions include education, screening visitors, cleaning and decontamination of gear or dedicated equipment, and cave closures. Key informants mentioned that national parks have adapted their passive communication materials (i.e. signage, websites) and active educational programs (i.e. tours, campfire talks) to include information about WNS. Additionally, informants noted that screening visitors was a common practice for parks that do not currently have WNS. Before entering the cave, visitors are asked questions by park staff about where and when they have gone into a cave. One of the challenges of this practice is reaching every visitor. In many parks, visitors must go through the visitor center to enter the cave; however, in others, there are multiple caves visitors can explore without going to the visitor center. To address this issue, one informant noted that “We reach a lot of visitors and we have done some preliminary studies to see how many people actually go to the visitor center before entering the caves.”

National Park Service key informants also mentioned cleaning or decontaminating footwear as their primary preventive measure. Many of the parks have installed walk-over mats before and/or after visitors enter the cave. One informant noted that the procedures surrounding these mats have changed as WNS has spread, stating “Now there’s a lot of debate in the caving community, the bat community, [and] the National Parks now that [WNS] is here, whether or not you need to [decontaminate] when you’re going in [to the cave].” Many informants noted that these mats are a relatively non-invasive way to clean or decontaminate visitors’ shoes. The last cave management practice the parks use is cave closures. Some parks apply cave closures that last part of the year (e.g. to reduce disturbance as bats are forming maternity colonies), some parks apply cave closures that last the entire year, and some parks restrict visitor access to parts of the cave to protect sensitive areas. However, cave closures are used as a last resort, as caves in national parks have remained open to public access and scientific research as long as risks to bats, other cave-related resources, and human safety can be mitigated.

Changes in Cave Management since the Discovery of WNS

Informants indicated that the most notable change in cave management practices associated with WNS was the implementation of additional cave management protocols and restrictions. More specifically, informants discussed early conversations between federal agencies to keep caves open, as informants strongly advocated for adaptive management practices rather than complete cave closures. For example, one informant stated, “when white-nose syndrome first came out, it was extremely challenging due to the fact that we did not even know [if] we were going

to...maintain and do any cave tours.” The main attraction for cave national parks is the caves, so cave closures could lead to a drastic drop in the educational and recreational opportunities that caves provide. Additionally, informants noted that complete cave closures would be detrimental to the diverse array of research occurring within the parks. Caves provide multiple opportunities for biological, geological, hydrological, and paleontological research. One informant noted that “We don’t want to sacrifice this large history of research from continuing if there are ways we can intervene with our researchers.” Both cavers and NPS staff agreed that across-the-board cave closures would do more harm than good and that context-specific management actions would better serve all stakeholders.

Cave Management Challenges

Informants identified three primary challenges for managing caves in national parks. The first was a lack of knowledge about existing bat populations and the impact of WNS on bats and cave ecosystems. For example, parks with multiple cave systems are focused on determining the species of bats that use the caves, the seasonality and purpose of use (i.e. winter hibernaculum, maternity roost in spring or summer, or intermittent day roosts), the population size of those species, and the potential impact WNS will have. One informant noted that “[Bat surveys] were something that should have been started when white-nose first hit or even before that to inventory or do a census of our bat population,” and another informant stated with “The catastrophic population decline in four of our species due to white-nose syndrome....we’re still trying to understand the ramifications of that in the cave and in the surface ecosystem.”

The second challenge informants mentioned was reaching all visitors with information on bats, WNS, and decontamination protocols at the park. The ways in which each park has responded to WNS varies because the natural resources, infrastructure, and layout of each park is different. For example, some parks have self-guided tours and others only have guided tours. Levels of visitation and the types of visitors also varies across parks and throughout the year. Additionally, some parks have only one central cave, whereas other parks have multiple dispersed caves. It is much easier to screen visitors and talk to them about decontamination protocols if there are limited entrances or exits to the cave and visitors are accompanied by park staff. One informant remarked that “the biggest challenge is just reaching people and getting outreach information out to them so that they’re prepared and that our risk of disease transfer is as low as possible,” with another

informant noting that “once you’re contacted, we’re pretty certain that people volunteer the [screening] information.”

The last challenge informants expressed was limited resources hindering research efforts and the implementation of decontamination measures. Informants recognized that the parks had the expertise and experience to slow the spread of the fungus, but they lacked the resources to fully implement their protocols. One caver who works closely with the NPS noted that the biggest challenge was “Money. The parks don’t have the resources and they need it. They simply need more money to do what they do best.” Additionally, an informant detailed the lack of staff on management in the parks by stating that “Even when we do deploy [decontamination mats], we don’t have enough staff to service them.” Lastly, the lack of monetary resources has impacted park knowledge of WNS and bats, as one informant detailed “I’ll go back to wishing we had more funding to do more research on bats specifically...having the research to be able to take a look at [summer bat behavior] and be prepared for making decisions.”

Public Perceptions of Management Actions

National Park Service informants noted that there were few reported incidents between park staff and visitors over the implementation of new management practices related to WNS. Most informants believed that once NPS staff explained the reasoning behind certain practices (e.g. decontamination mats) to visitors, they were more than willing to comply. However, respondents noted that the lack of reported incidences did not mean visitors were complying with park rules. One informant noted that, regarding cave closures, “We only have limited law enforcement to actually enforce those rules, so there’s potential for people to not comply. There’s nothing physically denying them from entering caves.” Another informant stated that “There have been violations of these closures and many if not most of them intentionally disregard the closures...almost never does anyone express objections to the closures publicly.”

Caver Perceptions of Cave Management on Federal Lands

Despite the lack of dispute from the general public, caver perceptions of how government agencies, not specifically the NPS, have handled the spread of WNS is more critical. Each of the five caver informants expressed concern for the bats and their willingness to help slow the spread of the disease. One informant expressed that “organized cavers...have made a deliberate effort to come down on the side of bats.” However, despite evidence that fungal spores can be transported between sites on gear and clothing and the circumstantial evidence that some of the longer-distance

movements of *Pd* (i.e. Europe to North America, eastern U.S. to Washington state) were most likely related to human activities (Lorch et al. 2013, Lorch et al. 2016), some respondents expressed concerns over the spread of information that humans may share the responsibility for spreading the fungus. An NPS informant noted “Some cavers do definitely feel like it’s bad to spread news [that humans/cavers are responsible for spreading the fungus], [they think] it is not us, why are you making us go through this?” and a caver informant expressed “There is no proof that people have spread [WNS] and we’re 13, 14 years into this phenomenon, then why are we doing something so intrusive?”

Caver informants noted that in addition to decontaminating their clothes and shoes, they are often required to decontaminate their gear or have separate sets of equipment for caves with and without WNS. Some of the caver informants stated that the decontamination protocols were too time-consuming in some areas, specifically when they were required to decontaminate their gear between caves in the same geographical area. One respondent noted that “In places where the disease has not arrived and you’re cleaning gear, whether it’s your researchers’ gear or your cave gear, you’re cleaning gear of nothing to prevent nothing.” However, these informants noted that they themselves, and many of the people they cave with, follow the decontamination protocols put in place by the managing agency. Caver respondents noted that heavy-handed approaches, like decontaminating gear between caves with the same WNS-status and blanket cave closures, are ineffective and place an undue burden on those who frequently visit the caves for research and recreation. One respondent expressed that “Even I, as a research scientist, can’t really buy off on everything some of these agencies are doing, like blanket cave closures and things like that.”

DISCUSSION

Responding to the threat of WNS to bat species in North America is a difficult and complex process. There is a vast array of management actions that federal and state agencies, land managers, and other conservation organizations have employed to try to disrupt the rapid advance of this disease and minimize impacts to vulnerable bat populations. Effective management of caves and bats susceptible to WNS requires multiple levels of intervention, including finding a treatment for infected bats, minimizing other stressors to vulnerable bat populations, decontaminating infected cave systems, and limiting human-mediated spread (Frick et al. 2016). Balancing the objectives of multiple agencies, non-profit organizations, and private citizens that are working together to combat this disease further complicates the issue.

This study focused on evaluating key stakeholder perceptions of NPS cave management practices concentrated on limiting human-mediated spread of WNS and reducing disturbances to bats. Our results show that informants support the management actions the NPS has implemented. In particular, informants supported the NPS's use of context-specific cave management plans that consider the WNS risks, operational goals, park resources, and the feasibility of the different management approaches. Additionally, informants were supportive of the NPS's decision to not implement blanket cave closures. Informants made it clear that while recreation is an important part of the NPS, their mission of conserving environments for future generations takes precedence. In relation to WNS and bats, respondents indicated that the health of bat populations within the parks supersedes visitation into the caves; however, in many cases, the NPS has had the resources and infrastructure to keep show caves open for recreation, research, and exploration.

In considering which interventions might effectively mitigate the human spread of WNS, visitor and staff educational efforts are considered one of the most important things cave managers can do to increase public support for bat conservation and reduce the risk of *Pd* spread by people (White-nose Syndrome Disease Management Working Group 2019). The NPS has invested resources into adapting their written educational materials (e.g. websites, pamphlets, junior ranger programs) and active programming (e.g. guided tours) to include information about WNS. Informants noted that based on their experiences, visitors have responded positively towards these educational efforts and were more likely to comply with new cave management practices once they were told about the reasoning behind these actions. These observations are supported by Fagan et al. (2018), which found that visitors to the Great Smoky Mountains National Park had positive attitudes towards bats and supported management actions to protect bats in historic buildings during peak visitation months. This study also emphasized the importance of educational efforts related to bats in national parks, as knowledge of bats, including ecosystem services provided by bats and severity of conservation threats to bats, had positive effects on support for bat management (Fagan et al., 2018).

It is unreasonable to expect government agencies to effectively manage the WNS risk without the support of cavers, policymakers, and the general public. Informants agreed that managing the WNS risk is a complex issue that requires communication and coordination among these different groups; however, it also opens up opportunities to create more effective and sustainable solutions. Informants noted that cavers play an essential role in cave management in

national parks, as they provide mapping services, aid in cave-rescue operations, and conduct scientific studies on these unique ecosystems. However, despite the mutualistic relationship between cavers and the NPS, there is still room for improvement. The two most notable differences between these groups was the spread of information that people are somewhat responsible for the spread of WNS and what cave management actions are appropriate. Both the NPS and caver informants recognized that there are some cavers who believe that bats are the only organism responsible for the spread of WNS. The management practices the NPS use are based on universal precautions and scientific evidence. Comments by caver informants that rule out human transmission of *Pd* or argue some of the decontamination and cave restriction protocols are too extreme ignore three important facts: 1) the NPS (and other government agencies) do not have perfect knowledge of where the fungus is and where it is not, 2) the fungus has been detected approximately 1,900 km from the known advancing front of the disease, as demonstrated by the jump to Washington in 2016, and 3) many caves function as unique ecosystems (like islands), and scientists do not know and cannot predict what the effects are of introducing new organisms into these sites. As the NPS has been actively engaging key stakeholders over the past decade, there are existing networks among cave visitors, caving groups, and the NPS. These groups should be encouraged to discuss the disease and its spread to understand contentious aspects and continue consensus-driven approaches to conserve and sustainably experience park cave resources.

This study provides information on how WNS has impacted the NPS management of cave systems, however there are limitations to this study. This study is exploratory in nature, as we interviewed a small group of key informants who work for the NPS or have worked closely with the NPS. As such, we caution against generalizing these results to all cave managers and cavers. Future research should continue to gauge support and perceptions of cave management actions among personnel in land management agencies, caving groups, and visitors to show caves to improve the effectiveness of bat conservation programming.

Management Implications

In considering how to best manage caves and bats, it is important to consider stakeholder experiences and opinions. There is a possibility that park resource and interpretation officers may have misperceptions of what cavers think about cave management within park boundaries. We found that NPS and caver informants agreed on the importance of bat conservation, the use of context-specific cave management plans, and the challenges parks face in slowing the spread of

WNS. However, obstacles to partnerships between cavers and national parks emerged in this study. At a basic level, it appears that some cavers support the idea that there is no evidence that humans spread WNS, thus cave closures and strenuous decontamination measures are unnecessary. On the other hand, the NPS follows the consensus of the interagency WNS response group, which utilizes national guidelines based on best available scientific evidence and universal precautions, as studies have shown the fungus can remain in clothes, shoes, and gear for long periods (White-nose Syndrome Response Team 2016). The continued use of context-specific management plans that utilize adaptive management practices paired with transparent and participatory decision making are likely needed for addressing WNS risk and could help achieve shared goals of bat conservation and public enjoyment of caves in national parks.

CHAPTER 3: VISITOR ATTITUDES TOWARDS AND KNOWLEDGE OF BATS AND WHITE-NOSE SYNDROME

This chapter is modified from a paper in preparation:

Shapiro, H.G., A.S. Willcox, E.W. Willcox, and M. Verant. *In prep.* U.S. National Park Visitor Attitudes and Knowledge of Bats and White-Nose Syndrome.

My use of “we” throughout this chapter is in reference to my co-authors and myself. I was the primary contributor to this work, which involved developing the project design and survey instrument, statistical analysis, and all writing. A.S. Willcox advised on study design, management implications, and assisted with editing. E.V. Willcox advised on question design and assisted with editing. M. Verant advised on study design, participant identification, and assisted with editing.

ABSTRACT

Stakeholder perceptions are essential to creating effective conservation plans, especially when these efforts focus on taxa that have a history of negative preconceptions, like bats. In the U.S., one organization that has worked to change people’s perceptions of bats is The U.S. National Park Service (NPS). The NPS offers a variety of educational programming on bats, including written educational material and ranger interpretive programs. These efforts to educate the public about bats have only increased with the discovery and spread of white-nose syndrome (WNS), an invasive fungus that has killed millions of bats in North America. Despite the NPS’s extensive efforts to educate the public, managers lack information on visitor perceptions and knowledge of bats. This study examined U.S. national park visitor attitudes towards bats, knowledge of bat ecology, and knowledge of WNS to determine which of these factors influenced visitor support of bat conservation efforts in national parks. During the summer of 2019, we collected 1365 surveys from visitors in eight protected areas managed by the NPS: Oregon Caves, Lava Beds, Carlsbad Caverns, El Malpais, Wind Cave, Jewel Cave, Mammoth Cave, and Cumberland Gap. Quantitative analysis revealed that visitors’ support for bat conservation in national parks was influenced by their positive attitudes towards bats, perceptions of ecosystem services bats provide, and recognition of WNS. However, park differences in visitor WNS recognition revealed that there are still gaps in the parks’ educational efforts. As bat management changes over the coming decade, understanding visitor perceptions of bats and integrating this information into cave management plans will be critical for the NPS to achieve its management goals focused on enhancing recreation and conservation in environments shared by humans and bats.

INTRODUCTION

Interactions between humans and wildlife has increased, as the conversion of natural areas to anthropogenic land uses has brought humans and wildlife closer together (Treves et al. 2006; White and Ward 2011). In the U.S., multiple government agencies are tasked with balancing wildlife conservation efforts with human interests. Thus, their ability to successfully manage wildlife is often influenced by public support and concern for the target species (Teel et al. 2010). Management efforts and funding often focuses on charismatic wildlife, as they tend to be more recognized and visually appealing (Kellert 1985; Vrij et al. 2003; Bellon 2019). Conversely, species that are misunderstood or do not have charismatic qualities, including bats, often garner less public support (Knight 2008).

Historically, bats have been disliked by the public for multiple reasons, including the risk of disease transmission and common misconceptions about the taxon. In the U.S., rabies is the only known zoonotic disease that can be transmitted from bats to people. Despite only one to three human rabies cases being reported annually (Center for Disease Control 2020), one study showed that risk perception associated with rabies was the greatest when compared with other zoonotic diseases (Hanisch-Kirkbride et al., 2013). Additionally, human rabies cases have become associated with exposure to bats, despite the fact that other wildlife species (e.g. raccoons, skunks) have historically or currently shared similar reported rabies case numbers (Ma et al. 2020). Studies have also shown that bats are viewed negatively by the public because of their aesthetics, as the public generally prefers animals that are behaviorally or phylogenetically similar to themselves (Kellert 1993; Kellert 1996; Batt 2009), and associations with unfavorable myths (e.g. all bats drink blood, bats fly into people's hair; Prokop and Tunncliffe 2008, Prokop et al., 2009). However, in recent years, public attitudes of bats have become more positive, with some studies showing that the public has become more knowledgeable of bats' importance to ecosystems (Sexton and Stewart, 2007; George et al., 2016; Fagan et al. 2018).

The recent shift in attitudes may be due in part to increased educational campaigns by government agencies (e.g. Fish and Wildlife Service, National Park Service, U.S. Department of Agriculture) and non-governmental organizations (i.e. National Wildlife Federation, Bat Conservation International), which have put forth significant efforts to improve the public's perception of bats (Moore 2019; NPS 2019b). These efforts often focus on educating the public on the ecosystem services bats provide, including their importance to suppressing agricultural pest

populations, and dispelling misinformation on bat ecology and disease transmission. The arrival of white-nose syndrome (WNS) to North America in 2006 only increased these efforts, as this disease killed at least 5.7 million bats and created new considerations and priorities for how caves and other underground ecosystems used by bats were managed across the U.S (U.S. Fish and Wildlife Service 2012).

In particular, the National Park Service has played a key role in conserving bat populations and improving the public's perceptions of this taxon, as it manages extensive cave resources and has a close relationship with the public by providing opportunities for recreation, education, and scientific exploration of cave systems. Parks across the U.S. integrated new educational messaging into their bat interpretive programming to give visitors information on how this disease is impacting bat populations and what they can do to help. However, to our knowledge, the impacts of these educational efforts on bats and WNS are unknown. One study on visitor perceptions of building-roosting bats in Great Smoky Mountain National Park found that visitors to Cades Cove, a popular driving loop with historic buildings, had positive attitudes towards bats and supported actions to protect bats in buildings (Fagan et al. 2018).

Despite the historically negative perceptions towards this taxon and the dire conservation status of many species of bats in the U.S., efforts to assess public perceptions of bats are limited. It is crucial to understand people's perceptions towards bats to ensure the success of conservation actions regarding this taxon. People's attitudes towards wildlife are a well-studied topic in the human dimensions of wildlife field, as they are important predictors of behavior (Vaske and Donnelly 2007; Vaske 2008). Conversely, ignoring the public's perception of a species can cause conservation plans to fail because of unanticipated public resistance or a lack of public support (Kaltenborn et al. 2006). Additionally, outreach programs can be tailored to promote support for conservation actions if they incorporate the public's perceptions and attitudes towards wildlife (Ajzen 1988; Ajzen and Fishbein 2005; Fishbein and Ajzen 2011).

The overall goal of this paper was to examine visitor perceptions of bats at eight national park areas, with the goal of providing the NPS with suggestions for their outreach strategies that may benefit bat conservation. The first objective was to survey visitors on their: 1) attitudes towards bats, 2) knowledge of bat ecology and ecosystem services, 3) belief in common bat myths and health risks 4) knowledge of WNS, and 5) attitudes towards bat conservation. The second

objective was to model attitudes towards bats and knowledge of bats and WNS as predictors of visitor support for bat conservation efforts in national parks.

METHODS

Study Area

We conducted our study at eight national park areas throughout the U.S., including Oregon Caves National Monument and Preserve (OR), Lava Beds National Monument (CA), Carlsbad Caverns National Park (NM), El Malpais National Monument (NM), Wind Cave National Park (SD), Jewel Cave National Monument (SD), Mammoth Cave National Park (KY), and Cumberland Gap National Historic Park (KY; Fig. 1). These areas were chosen because they are spread across a wide geographical area, represent a diversity of cave ecosystems, and have varying strategies to combat WNS.

Sampling Design

In June – August 2019, we surveyed adult visitors (18 years of age or older) at the eight protected areas managed by the NPS. We chose to survey visitors at the visitor center of each park based on the recommendations of park staff. Depending on the size of the visitor center at the park, we were either stationed inside the visitor center or directly outside of the entrance. We utilized intercept sampling to recruit voluntary participants for a tablet-based, self-administered survey at the visitor center for each park. We collected response data through the program iSurvey (www.harvestmydata.com). When an iPad was available, visitors were approached by the researchers, given a description of the study, and asked if they would like to participate. Every adult park visitor had an equal chance of being approached and recruited for participation in the study. After visitors completed the survey, they were given a unique patch designed for the study as a reward for their time. On average, it took visitors 10 to 15 minutes to complete the survey. All research materials and methods were reviewed and approved by the University of Tennessee's Institutional Review Board (UTK IRB-19-05081-XM) and the National Park Service's Programmatic Review and Clearance Process (OMB Control No. 1024-0024).

Survey Design

We conducted qualitative interviews with 15 key informants who work closely with or for the NPS to determine what aspects of visitor attitudes towards and knowledge of bats would be the most useful (Shapiro et al. *in review*). These interviews were recorded, transcribed, and coded for potential items to include in the survey. Using these interviews, we developed questions

examining visitor knowledge of bat ecology, belief in common bat myths, perceptions of likelihood of health risks associated with bats, and WNS recognition. Questions about visitor attitudes towards bats, knowledge of ecosystem services bats provide, and support for bat conservation efforts were developed using Fagan et al.'s (2018) survey as a template. Fifteen cognitive interviews were conducted with people within and outside of the wildlife science field to ensure that the survey items were easy to understand and conveyed the meaning the researchers intended (Vaske 2008).

Visitor attitudes towards bats were measured using a variety of 5-point Likert-type scale questions (harmful/beneficial, unpleasant/pleasant, scary/fascinating, worthless/useful, dislike/like). Visitor knowledge of bats was assessed using questions that focused on bat diets (yes/no/I don't know), hibernation habits (yes/no/I don't know), ecosystem services (Likert scale – not important/very important), and the likelihood of common myths/risks associated with bats (Likert scale – very unlikely/very likely). Visitor knowledge of WNS was examined using questions that focused on recognition of WNS (yes/no/I don't know), threat perception of WNS in the park they were visiting (Likert scale – not a threat at all/extreme threat), and knowledge of who or what was primarily responsible for the spread. Visitor support of bat conservation efforts were measured using a 5-point Likert scale (very unlikely to support bat conservation/very likely to support bat conservation). The survey was available in both English and Spanish.

Statistical Analysis

We assessed non-response error by comparing sociodemographic data from our survey with frequencies available from a National Park Service report titled “Linking the 2010 Census to National Park Visitors” (Vaske and Lyon, 2014). We initially used descriptive statistics to calculate measures of frequency for every question and measures of central tendency and variation for questions with interval or scale measurement levels. We also used Pearson-r correlations to measure the linear association between (1) visitors' belief in common bat myths or health risks associated with bats and (2) visitors' attitudes towards bats and perceptions of bat ecosystem services. Additionally, we used univariate between-subjects ANOVA tests to determine if there were any attitude or knowledge differences based on sociodemographic information (i.e. gender, education level) and visitor characteristics (i.e. intent to tour the cave).

Lastly, we conducted exploratory factor analysis using principal components analysis with a direct oblimin rotation to categorize visitor attitudes towards bats, knowledge of ecosystem

services, and belief in myths and health risks. We used Cronbach's alpha to assess extracted factor reliability. For explanatory variables, we used the factor scores for items that factored together and the raw scores (recognition of WNS). Visitor responses to the question "How likely are you to support bat conservation efforts in national parks?" were used as the response variable in the regression models.

We used multiple linear regression to examine relationships between support for bat conservation (response variable) and the explanatory variables. We assessed normality and homoscedasticity of residuals and checked multicollinearity with variance inflation factor. We evaluated standardized coefficients and 95% confidence intervals to estimate the relative importance of explanatory variables and to determine if a parameter's effect differed significantly from zero. We concluded statistical significance at $p = 0.05$. All analyses were conducted in SPSS Statistics 25 (IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY: IBM Corp.).

RESULTS

Response, Demographics, and Visitor Characteristics

We collected 1365 completed surveys. Response rates varied between parks, and overall, non-compliance averaged around 49%. We defined non-compliance as visitors who refused to take the survey after being spoken to by the researchers. We reached our survey goal at every park except El Malpais. Additionally, we inadvertently surveyed 15 additional people at Mammoth Cave. We compared sociodemographics (i.e. age, ethnicity, maximum education) with data available from a National Park Service report titled "Linking the 2010 Census to National Park Visitors" (Vaske and Lyon, 2014). We found no evidence of non-response error from available data, suggesting that the data collected in this study may accurately reflect visitors to U.S. national parks in general.

Respondents were 58% female, 86% white, and averaged 45 ± 14 (Mean $\pm$ SD) years old. Most respondents had earned a bachelor's degree (30%) or more than a bachelor's degree (35%). Most respondents were planning on touring the caves in the national park they were visiting (48%) or had already toured the caves (31%). Most respondents (58%) indicated that it was their first time visiting the national park they took the survey in, and roughly half (53%) of the respondents noted that they have visited caves in other national parks.

Attitudes towards Bats

Overall, respondents liked bats (Mean $\pm$ SD; 4.16 ± 0.93). Respondents also thought that bats were beneficial (4.54 ± 0.69), pleasant (4.12 ± 1.00), fascinating (4.27 ± 1.00), and useful (4.66 ± 0.62). We found statistically significant differences in respondent attitudes towards bats between respondents who explore caves recreationally (4.31 ± 0.84) vs. those that do not (4.07 ± 0.97), respondents who are members of a caving group (4.41 ± 0.76) vs. those that are not (4.14 ± 0.94), and between respondents who had gone into the cave/were planning on going into the cave (4.22 ± 0.89) vs. respondents who were not planning on going into the cave (3.93 ± 1.04). However, these statistical differences have little real-world applications, as visitor attitudes towards bats remained positive across all parks/regions and the effect size was small (partial eta-squared ranged from 0.01 - 0.02).

Knowledge of Bat Ecology

Most respondents thought that bats in the US hibernate (74%). Most respondents also reported that bats hibernate in caves (86.7%), under bridges (56.1%), in mines (78.5%), and in houses/buildings (68.7%). Fewer respondents reported that bats hibernate in trees (40.4%). Respondents were also asked about the diet of bats in the U.S. Most respondents indicated that bats in the U.S. eat insects (98.4%), fruit (77.7%), and nectar (61.6%). Fewer visitors indicated bats in the US eat blood (20.7%), pollen (36.0%), and fish/wild animals (17.6%). There were no statistically significant differences between groups of respondents in terms of knowledge of bat hibernation or diets.

Belief in Common Myths and Health Risks

Respondents thought it was neither likely nor unlikely for a bat to be blind (Mean $\pm$ SD; 3.07 ± 1.42) or for a bat to have rabies (2.87 ± 1.15). Respondents answered it was unlikely for bats to fly into a person's hair (1.85 ± 1.01), for a person to be bitten by a bat (1.60 ± 0.82), or for a person to get rabies from a bat (2.10 ± 1.11). There were no differences based on demographics (e.g. gender, age) or caving behaviors in respondents' belief in common bat myths or perceptions of health risks.

We found positive significant correlations between the respondents' answers for all the bat myths and perceptions of health risks. Most notably, there was a substantial positive correlation between the likelihood for a bat to fly into your hair and the likelihood for you to be bitten by a bat ($r = 0.48$, $p < 0.001$, $r^2 = 0.23$). Additionally, there was a weak positive correlation between

the likelihood for you to be bitten by a bat and for a bat to have rabies ($r = 0.29$; $p < 0.01$; $r^2 = 0.08$), and a substantial positive correlation between the likelihood for you to be bitten by a bat and for a you to get rabies from a bat ($r = 0.44$; $p < 0.01$; $r^2 = 0.19$). There was a substantial positive correlation between the likelihood for a bat to have rabies and for you to get rabies from a bat ($r = 0.58$; $p < 0.01$; $r^2 = 0.34$). There were also weak significant correlations between people's overall attitudes towards bats and the likelihood for bats to be blind ($r = -0.17$; $p < 0.01$; $r^2 = 0.03$), for bats to fly into your hair ($r = -0.24$; $p < 0.01$; $r^2 = 0.06$), for you to be bitten by a bat ($r = -0.22$; $p < 0.01$; $r^2 = 0.05$), for a bat to have rabies ($r = -0.20$; $p < 0.01$; $r^2 = 0.04$), and for you to get rabies from a bat ($r = -0.21$; $p < 0.01$; $r^2 = 0.04$).

Knowledge of Ecosystem Services

Respondents reported that bats are very important for controlling biting insects (Mean $\pm$ SD; 4.70 ± 0.68) and eating agricultural pests (4.59 ± 0.78). Additionally, respondents thought that bats were somewhat important for pollinating plants (3.70 ± 1.41). The most notable relationship was substantial positive correlation between controlling biting insects and controlling agricultural pests ($r = 0.65$; $p < 0.01$; $r^2 = 0.42$), as respondents who thought bats were important for controlling biting insects thought bats were important for controlling agricultural pests. Additionally, there were weak, positive correlations between respondent's overall attitude towards bats and the importance of bats for controlling biting insects ($r = 0.26$; $p < 0.01$; $r^2 = 0.07$), controlling agricultural pests ($r = 0.27$; $p < 0.01$; $r^2 = 0.07$), and pollinating plants ($r = 0.23$; $p < 0.01$; $r^2 = 0.05$).

Knowledge of White-nose Syndrome

Most respondents had heard of WNS before taking the survey (78.8%). There were differences in recognition of WNS between the parks, with approximately 87% of respondents at Jewel Cave recognizing WNS vs. 63% of visitors at El Malpais recognizing the disease. Additionally, the greatest number of respondents believed humans were primarily responsible for the spread (44.0%), followed by both humans and bats being responsible for the spread (26.7%), and not knowing who or what was responsible (24.8%). Only 3% of respondents thought bats were primarily responsible for the spread of WNS. Respondents also thought WNS was an extreme threat in the park they were currently visiting (42.0%). A majority of visitors from all the parks, with the exception of El Malpais (where 60% of respondents indicated they did not know), thought that WNS was a moderate to extreme threat in the park they were currently visiting.

Data Reduction with Principal Components Analysis

Support for bat conservation was measured using a single statement that asked how likely it was for the respondent to support bat conservation efforts in national parks. Respondents indicated that they would be very likely to support bat conservation efforts (Mean $\pm$ SD; 4.24 $\pm$ 0.92)

Attitudes towards bats were measured using five statements encompassing general attitudes and emotions towards bats. Most respondents reported that bats were beneficial (94.6%), pleasant (73.8%), fascinating (87.1%), and useful (95.8%). Additionally, most respondents liked bats (79.2%). All five items factored together, explaining 59.76% of the variance with a Cronbach's $\alpha = 0.83$. This suggests that the items are unidimensional and have high internal consistency (Table 1).

Beliefs about the importance of ecosystem services provided by bats were measured with three statements regarding insect control and pollination services by bats in the U.S. Respondents thought bats were important to very important for suppressing biting insect populations (94.3%), suppressing agricultural insect pests populations (91.5%), and pollination (61.5%). Although these items factored together, the pollination item was removed to improve internal consistency to an acceptable level (Cronbach's $\alpha \geq 0.70$; UCLA 2020). The remaining two items explained 82.49% of the variance with a Cronbach's $\alpha = 0.78$. This suggests that the items are unidimensional and have high internal consistency (Table 1).

Beliefs about the likelihood of common bat myths or health risks were measured using five statements. Respondents were relatively split on the likelihood for bats to be blind (39.9% thought it was unlikely) and how likely it was for a bat to have rabies (40.6% thought it was unlikely). Respondents thought it was unlikely for a bat to fly into a person's hair (80.5%), for a person to be bitten by a bat (90%), and for you to get rabies from a bat (70.3%). Although these items factored together, the likelihood of bats being blind item was removed to improve internal consistency to an acceptable level (Cronbach's $\alpha \geq 0.70$; UCLA 2020). The remaining four items explained 54.89% of the variance with a Cronbach's $\alpha = 0.72$. This suggests that the items are unidimensional and have high internal consistency (Table 1).

Multiple Regression

When we regressed support for bat conservation efforts on the explanatory variables (attitudes towards bats, likelihood of myths/health risks, importance of ecosystem services, and

recognition of WNS), the resulting model explained 19% of the variance. Attitudes towards bats ($\beta = 0.39, p < 0.001$), perceived importance of services from bats ($\beta = 0.05, p = 0.04$), and recognition of WNS ($\beta = 0.06, p = 0.03$) were significant in explaining how likely visitors were to support bat conservation efforts. These variables had confidence intervals that did not overlap zero (Table 2).

When we regressed support for bat conservation on the explanatory variables for visitors who had toured the cave(s) or were going to tour the cave(s) and for visitors who were not touring the cave(s), the resulting models explain 20% and 22% of the variance respectively. Attitudes towards bats ($\beta = 0.38, p < 0.001$), perceived importance of services from bats ($\beta = 0.10, p = 0.04$), and recognition of WNS ($\beta = 0.06, p = 0.04$) were significant in explaining how likely visitors were to support bat conservation efforts for people who had or were planning on touring the caves. These variables had confidence intervals that did not overlap zero (Table 3). Attitudes towards bats ($\beta = 0.40, p < 0.001$) and perceived likelihood of common bat myths and health risks ($\beta = -0.13, p = 0.03$) were significant in explaining how likely visitors were to support bat conservation efforts for people who were not intending to tour the caves. These variables had confidence intervals that did not overlap zero (Table 3).

When we regressed support for bat conservation on the explanatory variables for visitors who had previously visited national parks with caves versus those who had not, the resulting models explain 20% of the variance. Attitudes towards bats ($\beta = 0.35, p < 0.001$) and recognition of WNS ($\beta = 0.09, p = 0.01$) were significant in explaining how likely visitors were to support bat conservation efforts for people who had previously visited a national park with caves. These variables had confidence intervals that did not overlap zero (Table 4). Attitudes towards bats ($\beta = 0.42, p < 0.001$) was significant in explaining how likely visitors were to support bat conservation efforts for people who had not visited other national parks with caves. This variable had confidence intervals that did not overlap zero (Table 4).

When we regressed support for bat conservation on the explanatory variables for visitors who had previously visited the national park they took the survey in and for visitors visiting the park they took the survey in for the first time, the resulting models explain 20% and 19% of the variance, respectively. Attitudes towards bats ($\beta = 0.41, p < 0.001$) was significant in explaining how likely visitors were to support bat conservation efforts for people who had previously visited the park. This variable had confidence intervals that did not overlap zero (Table 5). Attitudes

towards bats ($\beta = 0.42$, $p < 0.001$) and perceived importance of services from bats ($\beta = 0.08$, $p = 0.03$) were significant in explaining how likely visitors were to support bat conservation efforts for people who were visiting the park for the first time. These variables had confidence intervals that did not overlap zero (Table 5).

DISCUSSION

Examining people's attitudes towards historically unpopular species and assessing public support for management actions is essential for achieving conservation goals. This study examined national park visitor attitudes toward bats and knowledge of bats and WNS with the goal of improving NPS educational efforts and outreach programs. We found that visitors had positive attitudes towards bats, were relatively knowledgeable of bat ecology, recognized the importance of bats to ecosystems, and had a high recognition of WNS. Additionally, we found that attitudes towards bats, perceived importance of ecosystem services, and recognition of WNS were important factors influencing support for bat conservation efforts.

The positive attitudes displayed towards bats and the large influence of attitudes on support for bat management actions are not unique to this study. A recent study conducted in Great Smoky Mountain National Park found that visitors to Cades Cove, a popular driving loop used for wildlife viewing and visiting historic buildings, had positive attitudes towards hypothetical bat encounters (e.g. level of fear or fascination of seeing bats in historic buildings), which heavily influenced their support for bat management in historic buildings (Fagan et al. 2018). Outside of the national park system, some studies have shown that the U.S. public has expressed positive attitudes towards bats (Sexton and Stewart 2007; George et al. 2016). However, studies on undergraduate student perceptions of endangered species (Knight 2008) and children's perceptions of bats and spiders (Prokop and Tunncliffe 2008) revealed that bats are often grouped with other wildlife as a source of animal phobias, showing that bats historic negative connotations still persist to this day.

Educational efforts about bats appear to be effective at increasing visitor knowledge of bats, as respondents rejected common myths about bats, did not feel threatened by bats, and were somewhat knowledgeable about bat hibernation habitats, diets, and ecosystem services. In particular, perceptions about the importance of bats for suppressing insect populations and pollination had positive effects on attitudes towards bats and support for bat conservation. Previous research has indicated that increased knowledge of bats can be associated with more positive attitudes toward bats (Sexton and Stewart, 2007; Prokop and Tunncliffe 2008; Prokop et al. 2009).

Conversely, other research suggests that there is no correlation between knowledge and attitudes of wildlife that pose a risk of physical attack or disease transmission (Özel et al. 2009). Despite this positive relationship between knowledge of ecosystem services and attitudes towards bats, visitors overestimated the importance of bats for controlling biting insect populations. This result is consistent with studies in the Great Smoky Mountains National Park and Fort Collins, Colorado, which found that people believed bats were most important for controlling mosquito populations (Fagan et al., 2018; Sexton and Stewart, 2007). Bats in the U.S. are incredibly important for suppressing insect pest populations, and they save farmers billions of dollars each year in pest suppression alone (Boyles et al., 2011). Dietary studies indicate that mosquitoes consist of a small proportion of bats overall diet when compared to moths and beetles (Jones et al., 2009; Gonsalves et al., 2013). While the misconception of bats controlling mosquito populations appeared to positively influence people's attitude towards bat, educators should emphasize bats' actual diet and their critical role in suppressing insect pests that target important crop species.

In addition to being knowledgeable of bat ecology, visitors also had a high recognition of WNS, as nearly 80% of visitors had heard of WNS before taking the survey. However, there were park-based differences in knowledge of WNS, with visitors to Cumberland Gap (74% heard of WNS), Carlsbad Caverns (71% heard of WNS), and El Malpais (63% heard of WNS) having the lowest recognition of WNS. While these numbers show that a majority of visitors have heard of WNS, they represent the lowest recognition of all the parks. One explanation for the lower percentages in Cumberland Gap and El Malpais is that caves are not the primary attraction of the protected area, as a majority of visitor respondents were not planning on touring the caves. This result is supported by Fagan et al.'s (2018) study, which found visitors to Cades Cove, who are primarily there to view the historic buildings and wildlife, had low knowledge of WNS. In these parks, there are less educational materials available in the park about bats and WNS. Additionally, as visitors were not looking to enter the caves, there is a chance that they were not exposed to caving guidelines for the parks, which often include messages about WNS. Thus, when considering the application of these results and how to best educate visitors about bats and WNS, it is important to incorporate visitor's recreational intentions. However, these reasons do not explain why the percentage of people who have heard about WNS at Carlsbad Caverns was low compared to the other parks that focus on caves. One explanation may be the lack of management practices focusing on WNS in the park at the time of this survey. Personal observations by the

researchers in July 2019 indicated that Carlsbad Caverns had limited resources on WNS in the park, compared to the other parks included in the sample. At the time of this study, there were no screening procedures, decontamination mats, or handouts that visitors could take and read about the disease. However, during the winter of 2019/2020, Carlsbad Caverns installed walk-over decontamination mats at the entrances and exits to the cave, so it would be helpful to determine if the presence of these mats increases visitors' awareness of WNS.

Attitudes towards bats, perceptions about the importance of bats for suppressing insect populations, and recognition of WNS all had a positive influence on support for bat conservation efforts. However, the predictor variables that influenced support for bat conservation changed based on visitor recreational intentions and past behaviors. The most notable difference in predictors was for visitors who were intending on touring the caves (or had already toured the caves) versus those that were not intending on touring the caves. Belief in myths or health risks became a significant negative predictor of support for bat conservation for people who were not intending on touring the caves. In other words, we would expect visitors who believe in bat myths and health risks to have less support for bat conservation efforts. Belief in myths/health risks was not a significant predictor for people who were planning on (or had already) touring the cave. Other studies have shown that recreational intentions or behaviors can influence support for conservation actions (Tarrant and Green 1999; Daigle et al. 2002; Salz and Loomis 2005), thus, it is important for parks to consider visitor caving intentions when creating educational materials and outreach programs.

There were two primary limitations of this study. First, there was the potential for social desirability and acquiescence bias. Although the questions were not highly personal and we did not collect any identifiable information, there is a possibility that people felt the need to answer questions in ways they thought were socially acceptable because they were taking a survey in a protected area. Second, the sample at Wind and Jewel Cave may have not been characteristic of a typical summer. During our sampling time, the cave was closed at Wind Cave because of elevator repairs. People still visited the visitor center and park, but there was a drop in visitation compared to earlier weeks. Because of this closure, more people visited Jewel Cave, which is only 52 km from Wind Cave.

Management Implications

Public support for wildlife management is crucial for effective, long-lasting conservation impacts. Currently, the NPS offers many ways for visitors to learn about bats, including websites, signage, pamphlets/brochures, movies, junior ranger programs, ranger talks, and guided tours. Additionally, the parks in this study have updated their educational materials and tours to include information about WNS; however, there is still room for improvement.

Most notably, re-evaluating people's attitudes towards bats and perceptions of risk in light of COVID-19 will be crucial in developing effective conservation messaging. Even though the virus did not originate from the U.S., this pandemic has brought to light the dangers of zoonotic diseases and the potential of bats as reservoirs for multiple diseases. Debunking misinformation about COVID-19 and providing accurate and up-to-date information will be crucial for maintaining the positive attitudes that have been displayed towards bats in recent years (MacFarlane and Rocha 2020).

Additionally, parks should emphasize what actions visitors can take to help conserve bat populations. After completing the survey, many visitors wanted additional information on bats, WNS, and how they can help protect bat populations. There was an overall feeling of helplessness after learning about the disease, and many visitors wanted to do more than just follow cave management practices. Some parks have tried to address this need with adopt-a-bat programs or selling bat boxes in their bookstore to give visitors an actionable bat conservation behavior. We suggest that national parks with caves emphasize these programs and items within their bookstores and provide people with information on how they can help conserve bat populations. Additionally, we suggest that researchers conduct focus groups with park visitors to discuss how parks can better engage visitors in bat conservation efforts during and after their visit. As bat and cave management actions continue to change over the coming decade, it will be crucial to continue to integrate biological and social science research to achieve management goals focused on enhancing recreation and conservation in environments shared by humans and bats.

CHAPTER 4: VISITOR PERCEPTIONS OF WHITE-NOSE SYNDROME PREVENTIVE ACTIONS

This chapter is modified from a paper in preparation:

Shapiro, H.G., A.S. Willcox, E.W. Willcox, and M. Verant. *In prep for PlosOne*. U.S. National Park Visitor Intentions towards White-nose Syndrome Preventive Actions: An Application of the Theory of Planned Behavior

My use of “we” throughout this chapter is in reference to my co-authors and myself. I was the primary contributor to this work, which involved developing the project design and survey instrument, statistical analysis, and all writing. A.S. Willcox advised on study design, management implications, and assisted with editing. E.V. Willcox advised on question design and assisted with editing. M. Verant advised on study design, participant identification, and assisted with editing.

ABSTRACT

In the United States, the discovery and spread of white-nose syndrome (WNS) has drastically changed how bats and caves are managed. The U.S. National Park Service has been instrumental in the national response to WNS, as it manages extensive cave resources and has a close relationship with the public. However, managers lack information on visitor support for management actions designed to slow the spread of WNS. This study utilized the Theory of Planned Behavior to determine how visitor attitudes, subjective norms, and perceived behavioral controls impacted their behavioral intent on WNS preventive actions, including participation in educational programming on bats, wearing clothes or shoes that have not been exposed to the fungus, walking over decontamination mats, and complying with cave closures. During the summer of 2019, data were collected using an on-site survey of 1365 visitors to eight national park units: Oregon Caves, Lava Beds, Carlsbad Caverns, El Malpais, Wind Cave, Jewel Cave, Mammoth Cave, and Cumberland Gap. Visitors were willing to participate in all of the management actions addressed in the survey. Additionally, attitude was the strongest predictor of behavioral intentions, followed by subjective norms. Perceived behavioral control was not a significant predictor for behavioral intent, but it had a moderating influence on attitudes, subjective norms, and intention for multiple WNS preventive actions. With visitors expressing support towards WNS preventive actions, it is important for parks to continue to positively reinforce these attitudes with educational programming that justifies the reasoning and importance for these strategies. As WNS continues to spread across the U.S., understanding visitor behavioral intent and the factors that explain it will be crucial for the success of WNS preventive actions and the conservation of bat populations in national parks.

INTRODUCTION

Cave management has changed drastically over the past decade, as the arrival of white-nose syndrome (WNS) in North America created new considerations and priorities for how caves used by bats are operated. White-nose syndrome is a disease caused by the fungus *Pseudogymnoascus destructans* (*Pd*), which infiltrates the skin tissues of bats during hibernation. This infiltration causes a variety of effects, including dehydration, winter emergence and exposure, interrupted metabolic activities, starvation, and death (Reeder et al. 2012, Cryan et al. 2013; Verant et al. 2014). Currently, WNS has been confirmed in 13 bat species, including two endangered species and one threatened species, and *Pd* has been found on six additional species, including two endangered species (White-Nose Syndrome Response Team 2020). To date, the spread of WNS has primarily been attributed to bat-to-bat transmission or bat-to-cave-to-bat transmission; however, there is evidence that the fungus can persist within cave environments for years and can be spread to different locations by humans on gear or clothing (Puechmaille et al. 2011; Lidner et al. 2011; Langwig et al. 2012; Knudsen et al., 2013; Frick et al. 2016).

In response to the devastation caused by WNS, a national interagency group developed recommendations for cave access and decontamination (White-nose Syndrome Response Team 2018a, 2018b) using the best available science and universal precautions (U.S. Geological Service 2011) to reduce anthropogenic disturbance on bats and minimize the risk for human-mediated spread of *Pd* (U.S Fish and Wildlife Service 2011). One of the organizations that has been critical in the national response to WNS is the U.S. National Park Service (NPS), as it manages extensive cave resources and has direct contact with the public. Parks across the country have implemented varying measures to prevent the spread of WNS based on the current disease status of their park, including providing educational materials on WNS, expanding current bat interpretive programs to include information on WNS, screening visitors before cave tours, cleaning and decontaminating gear and clothing that has been in contact with bats or their habitats, and restricting access to caves when necessary to protect bats, other cave resources, and human safety (National Park Service 2017, National Park Service 2018, National Park Service 2019a).

Despite the fact that the effectiveness of WNS preventive strategies depends on the support and participation of visitors, there is little to no information on visitors' perceptions of or willingness to follow these actions aimed at slowing the spread of WNS. Our research objective was to determine underlying factors that explain national park visitors' willingness to participate

with WNS preventive strategies. We accomplished this task using the Theory of Planned Behavior (TPB; Fishbein & Ajzen 2011) to identify the attitudes, subjective norms, and perceived behavioral control following five common preventive strategies, including participating in educational programming on bats, wearing clothes or shoes that have not been contaminated by *Pd*, walking over decontamination mats, complying with cave closures that last part of the year, and complying with year-long cave closures.

Theoretical Framework

We used several variables related to the TPB model to understand what factors influence visitor intent to follow or participate in five common WNS preventive strategies. The TPB is a social psychology model that explains individuals' intentions to enact behaviors (Ajzen 1988). The TPB provides data that can be applied to develop behavior change programs (Fishbein & Ajzen 2010), thus providing a starting point for organizations and agencies to build wildlife conservation programs. The TPB has frequently been used in the human dimensions of wildlife field to explain behaviors related to hunting (Hrubes 2001; Shrestha et al. 2012), recreation (Martin & McCurdy 2009), and participation in conservation programs (Willcox et al. 2012; Sakurai et al. 2015; Kaeser & Willcox 2017). This theory assumes that behaviors are enacted after planned, conscious, and deliberative thought (Ajzen 1988). Because of this, we believed that the TPB would be an appropriate framework to explain what factors influence visitors to participate in WNS preventive strategies. We used direct measures to assess visitors' behavioral intentions, attitudes, subjective norms, and perceived behavioral controls towards five WNS preventive actions.

According to the TPB, behavioral intention, defined as the strength of a person's intention to perform a behavior, is the most important predictor of behavior. Behavioral intention is predicted by three principal factors: a person's attitude towards the behavior, subjective norms about the behavior, and perceived behavioral control regarding the performance of the behavior (Fishbein & Ajzen 2011). The first explanatory variable of behavioral intention is attitude towards a behavior, which is defined as the degree to which performance of the behavior is positively or negatively viewed (Ajzen 2019). The second explanatory variable of behavioral intention is subjective norms, which are defined as the perceived social pressure to engage or not to engage in behavior (Ajzen 2019). The final explanatory variable of behavioral intention is perceived behavior control, which is defined as a person's perception of their ability to perform a given behavior (Ajzen 2019). However, as this theory has evolved over the years, the conceptualization

of perceived behavioral control's influence on behavioral intent has shifted. One can expect that attitudes and subjective norms have independent, direct relationships with behavioral intention, as a behavior can be deemed undesirable but socially acceptable. However, PBC should influence attitudes and subjective norms (Martinez and Lewis 2016; Ajzen 2019). For example, attitudes and subjective norms become less relevant in shaping intention when PBC is low because the action is not thought to be possible (Dillard 2011). Thus, PBC may not just act as a concept that works parallel with attitudes and subjective norms, but also as a moderator variable that interacts with attitudes and subjective norms (Yzer 2007).

METHODS

Study Area

The study area was comprised of eight national park units throughout the U.S., including Oregon Caves National Monument and Preserve, Lava Beds National Monument, Carlsbad Caverns National Park, El Malpais National Monument, Wind Cave National Park, Jewel Cave National Monument, Mammoth Cave National Park, and Cumberland Gap National Historic Park (Figure 1). These areas were chosen because they are spread across a wide geographical area, represent a diversity of cave ecosystems, and have varying strategies to combat WNS.

Sampling Design

From June – August 2019, we surveyed adult visitors at the eight national park units. Our goal was to survey 175 visitors from each park. We utilized intercept sampling to recruit voluntary participants for a tablet-based, self-administered survey in or near the visitor center of each park based on the recommendations of park staff. When a tablet was available, visitors were approached by the researchers, given a description of the study, and asked if they would like to participate. Data were collected through the program iSurvey (www.harvestmydata.com; Wellington, New Zealand). Every adult park visitor had an equal chance of being approached and recruited for participation in the study. After visitors completed the survey, they were given a unique patch designed for the study as a reward for their time. On average, it took visitors 10 to 15 minutes to complete the survey. All research methods were reviewed and approved by the University of Tennessee's Institutional Review Board (UTK IRB-19-05081-XM) and the National Park Service's Programmatic Review and Clearance Process (OMB Control No. 1024-0024).

Survey Design

The results from the second chapter of this thesis were used to inform the creation of this part of the survey. To summarize, we interviewed 15 key informants from the NPS and organized caving groups to identify common WNS preventive strategies that the NPS utilizes. The interviews were recorded, transcribed, and coded for potential items to include in the survey. We constructed five behavioral intent statements based on the most frequent cave management techniques and paired statements for attitudes, subjective norms, and perceived behavioral controls following the theory of planned behavior research protocols (Fishbein & Ajzen 2011). Fifteen cognitive interviews were conducted with people within and outside of the fisheries and wildlife field to ensure that the questions were easy to understand and were conveyed the meaning that was intended.

We used direct measures for behavioral intent, attitude, subjective norm, and PBC. The five cave management practices addressed in this survey were 1) participating in educational programming on bat and cave conservation, 2) wearing clothes/shoes that have not been in a contaminated cave, 3) walking over decontamination mats before/after entering a cave, 4) complying with cave closures that last part of the year, and 5) complying with cave closures that last the entire year. For behavioral intent, visitors were asked on a scale of 1 (very unlikely) to 5 (very likely) how likely it was for them to participate in the WNS preventive strategies. For attitudes, we asked visitors, on a scale of 1 (very undesirable) to 5 (very desirable), what their attitude was towards a specific management practice or program. For subjective norm, we asked participants how their behavioral intent was influenced by rangers, the group they are traveling with, and other visitors (not including the group they are traveling with) on a scale of 1 (strongly disagree) to 5 (strongly agree). For PBC, we asked participants how their behavioral intent was influenced by their perceived level of control over the management action (was following the management action completely up to the participant?), their resources, and their knowledge of the management action on a scale of 1 (strongly disagree) to 5 (strongly agree).

Statistical Analyses

We assessed non-response error by comparing sociodemographic data from our survey with frequencies available from a National Park Service report titled “Linking the 2010 Census to National Park Visitors” (Vaske and Lyon, 2014). Gender data were not available from this report and were not considered in this preliminary analysis. All analyses were conducted in SPSS 25 and

SPSS Amos 26 Graphics. We used principal component analysis with a Varimax rotation and the corresponding Cronbach's alpha to assess the reliability of the variables measuring the latent concepts. All independent variables were mean centered prior to analysis. Attitudes, subjective norms, and perceived behavioral control were calculated using TPB protocols (Ajzen, 1988). The mean-centered variables were used to generate interaction terms (Aiken et al. 1991) between attitudes and perceived behavioral control and between subjective norms and perceived behavioral control. We employed Structural Equation Modeling (SEM) with maximum likelihood estimation to determine the relationships between behavioral intent (response variable) and the calculated direct measures of attitude, subjective norm, PBC, and the interaction terms (explanatory variables) (Figure 2). We chose SEM because it is a more flexible tool than regression modeling. We excluded surveys that were not complete from this analysis.

RESULTS

Response, Demographics, and Visitor Characteristics

We collected 1365 completed surveys. Response rates varied between parks, and overall, non-compliance averaged around 49%. We defined non-compliance as visitors who refused to take the survey after being spoken to by the researchers. We reached our survey goal at every park except El Malpais ($n = 125$). Additionally, we inadvertently surveyed 15 additional people at Mammoth Cave ($n = 190$). We found no evidence of non-response error from available data, suggesting that the data collected in this study may accurately reflect visitors to U.S. national parks in general. Respondents were 58% female, 86% white, and averaged 45 ± 14 (Mean $\pm$ SD) years old. Most respondents had earned a bachelor's degree ($n = 409$; 30%) or more than a bachelor's degree ($n = 490$; 35%). Most respondents were planning on touring the caves in the national park they were visiting ($n = 659$; 48%) or had already toured the caves ($n = 31\%$). Most respondents ($n = 791$; 58%) indicated that it was their first time visiting the national park they took the survey in, and roughly half ($n = 636$; 53%) of the respondents noted that they have visited caves in other national parks.

Theory of Planned Behavior Analyses

Behavioral Intent

Behavioral intent was directly measured using a single statement for each of the five behavioral models (five-point scale from 1 = very unlikely to 5 = very likely). Respondents were likely to participate in guided or recorded educational programs or tours that focus on bat and cave

conservation; were very likely to wear clothes/shoes that were not exposed to WNS, even if it meant changing their clothes/shoes after they entered the park; were very likely to use decontamination mats before and/or after entering a cave; were very likely to comply with cave closures that last part of the year; and were very likely to comply with cave closures that last all year (Table 6).

Attitude

Attitude was directly measured using a single statement for each of the five behavioral models (five-point scale from 1 = very undesirable to 5 = very desirable). Respondents had positive attitudes towards guided or recorded educational programs or tours that focus on bat and cave conservation (Mean $\pm$ SD: 4.04 ± 0.91); wearing clothes/shoes that were not exposed to WNS, even if it meant changing their clothes/shoes after they entered the park (4.33 ± 0.91); using decontamination mats before and/or after entering a cave (4.53 ± 0.75); cave closures that last part of the year (4.45 ± 0.86); and cave closures that last all year (4.29 ± 1.01). For each of these management actions, only a small percentage felt they were undesirable (Percent ranging from 1.90% to 7.30%).

Subjective Norm

Subjective norm was measured using three statements. Visitors agreed that the actions of the group they were traveling with, other visitors, or national park staff influenced them to participate or comply with the cave management actions (Table 7). The actions of national park staff affected visitor behaviors the most and the actions of visitors outside of the respondent's group affected visitor behaviors the least. The three subjective norm statements factored together into one variable for each behavior, explaining between 70% and 73% of the total variance and having a Cronbach's α between 0.79 and 0.81, indicating adequate construct validity and reliability.

Perceived Behavioral Control

Perceived behavioral control was measured using three statements. Visitors agreed that their participation was influenced by their awareness of the cave management programs. Visitors also agreed that participation in educational programming and compliance in wearing clothes/shoes that have not been contaminated by WNS was completely up to them and was influenced by their resources. However, visitors neither agreed nor disagreed that walking over decontamination mats and complying with cave closures was completely up to them or influenced

by their resources (Table 8). The three perceived behavioral control statements factored into one variable for each behavior together into one variable for each behavior, explaining between 61% and 64% of the total variance and having a Cronbach's α between 0.69 and 0.70, indicating adequate construct validity and reliability.

Structural equation model analysis

The test for goodness-of-fit was acceptable for every model (Hooper et al. 2008), with an RMSEA ranging between 0.047 to 0.075, the CFI ranging between 0.956 – 0.978, and the SRMR ranging between 0.028 – 0.065. Behavioral intent for the five models had the following R^2 value: participating in educational programming = 0.29, wearing clean clothes/shoes = 0.31, using decontamination mats = 0.21, complying with cave closures that last part of the year = 0.28, and complying with cave closures that last the entire year = 0.35 (Table 9). These models explained 21% - 39% of the variance of the dependent variables. The SEM's standardized results show that the relationship between attitudes and behavioral intent had the largest effect size for all white-nose syndrome preventive behaviors. Subjective norms had the second largest effect on behavioral intent. Perceived behavioral controls only had a significant influence on behavioral intent for complying with year-long cave closures (Table 9). The interaction between attitudes and PBC had a significant influence on behavioral content for complying with partial and year-long closures. The interaction between subjective norms and PBC had a significant influence on behavioral intent for participating in educational programming, using decontamination mats, and complying with partial cave closures (Table 9).

DISCUSSION

White-nose syndrome preventive actions in national parks have changed drastically over the past decade, as the rapid spread of this disease has led to parks continuously adapting their disease preventive measures to minimize risks of visitors spreading the fungus or disturbing vulnerable bat populations. The success of these actions relies on the support and participation of visitors. The first step in increasing participation and compliance with these strategies is to understand what factors influence visitor participation. The NPS and other managing agencies and organizations can then improve their outreach programming to encourage higher participation, while maintaining the integrity of their WNS prevention strategies. By applying the TPB to explain visitor behavioral intent to common WNS preventive action, we can provide specific recommendations to address visitor participation based on key predictor factors.

The TPB provided significant models that explained a good proportion of the variance for behavioral intent to participate in educational programming about bats, wear clothes/shoes that have not been contaminated by the fungus, walk over decontamination mats before and/or after touring the cave, and complying with cave closures. Visitors indicated that they were very willing to follow or participate in all of these disease preventive actions, indicating that NPS efforts to slow the spread of the fungus have visitor support. Interviews with park staff and observations from the researchers revealed that most visitors support WNS preventive actions when paired with educational materials or efforts explaining the reasoning for these measures. This result is not unique to this study, as a study on visitor support for bat management in historic buildings in Great Smoky Mountain National Park found that visitors were very likely to support management actions that benefited bat conservation, even if these strategies restricted visitor access to certain historical sites (Fagan et al. 2018). Fagan et al. (2018) also found that accompanying any new management strategy with educational materials or outreach programming would likely increase the success of these plans. Thus, developing communication strategies that explain the dangers of WNS to bats and how visitors can support bat conservation by participating in these actions would likely keep visitor support and participation high.

Similar to other studies on people's participation with conservation or wildlife-related behaviors, our results indicated that attitudes and subjective norm components of the theory were important to predict behavioral intent (Hrubes et al. 2001; Martin & McCurdy 2009; Willcox et al. 2012). In particular, attitudes towards a behavior had the greatest effect on behavioral intent for all WNS preventive actions addressed in this study, a common result which has been expressed in previous studies (Fishbein and Ajzen 1975; Armitage and Conner 2001; Manfredo 2008). Improving the strength of visitors' positive attitudes towards WNS preventive actions would most likely not yield a significant behavior change since most visitors already approved of these actions. However, maintaining visitors' positive attitudes towards these strategies will be essential for continued visitor support and participation of these actions. This result, paired with visitors' positive attitudes towards bats indicates that the parks' current approach of framing these preventive strategies as essential for the conservation of bat populations has been effective.

Subjective norms were also an important predictor of behavioral intent for WNS preventive actions. Unsurprisingly, visitors were more likely to be influenced by park staff (i.e. rangers or guides) compared to the group they were traveling with or other visitors, as park staff are likely

viewed as having more authority and knowledge than fellow visitors. However, other visitors' actions, whether it was the group respondents were traveling with or people they did not know, still influenced visitor behavioral intent. In particular, it is important for park staff to communicate with visitors about WNS preventive measures found throughout the park, especially in parks with decentralized cave systems. For example, Lava Beds National Monument had over 20 caves visitors could explore on their own. It was not a guarantee that visitors would first stop at the visitors center and it was not possible for park staff to be located at every one of these caves. To address this issue, the park gave visitors information about WNS preventive actions at the fee booths at the entrance of the park, asked people to pick up a caving permit at the visitor center, and set out signs to remind visitors of these rules at the various cave sites (National Park Service 2020). Ensuring that at least one person in a traveling group is aware of these procedures, especially when it is not feasible for parks to have staff at the caves, is important for parks to increase the likelihood of visitors following WNS preventive strategies.

Perceived behavioral control was only a significant predictor of behavioral intent for complying with year-long cave closures, and it was the least influential component for this WNS preventive action. Previous studies have found that PBC often becomes a less influential factor when people's decisions are under volitional control, meaning outside factors do not limit their intent when considering whether or not to perform a behavior (Hrubes et al., 2001; Madden et al. 1992). Although the PBC described in the variable (i.e. ability, resources, knowledge) might be important to visitor participation in WNS preventive actions, visitors do not perceive that these factors limit them from fulfilling the tasks required to touring the caves. Despite the limited effect of PBC on behavioral intent, it is important for managers to consider it when developing or implementing new WNS preventive actions for multiple reasons. First, the interaction between PBC and attitudes or PBC and subjective norms were significant effects on behavioral intent for most of the preventive strategies. While the interaction terms had a minor influence on behavioral intent, this result provides support for the idea that PBC should be conceptualized differently than attitudes and subjective norms, as people likely consider PBC when reporting on their attitudes or subjective norms. Second, it is possible for PBC to influence behavioral intent depending on the location and resources of the park. Parks included in this sample had varying resources and strategies to ease the burden of some WNS preventive actions. For example, Oregon Caves loaned clothing to visitors who were unsure of whether their clothing had been in a *Pd*-positive cave. This

program allowed for visitors who were not aware of the requirements for touring the caves to remain on their tour without having to drive at least an hour back to their accommodations to get a new set of clothing.

There are several limitations and avenues for future research. First, given that managers of the park units included in the sample advocate for the use of WNS preventive actions, some respondents may have inaccurately stated their behavioral intent and attitudes towards participation in these strategies due to social desirability bias. Second, our sample at Wind and Jewel Cave were not representative of a typical summer. During the sampling time, the cave at Wind Cave was closed because of elevator repairs. There was a noticeable drop in visitation to the visitor center compared to earlier weeks. Because of this closure, more people visited Jewel Cave. Lastly, while the TPB provides the parks with useful information about what factors influence visitor behavioral intent towards WNS preventive actions, it is likely that there are other variables that influence visitors decisions. It will be important for parks to follow up this study by examining visitors actual participation in WNS preventive actions.

Implications

The NPS is one of many agencies that are working to conserve bat populations and slow the spread of WNS in the United States. As the fungus that causes WNS can be transported on people's clothing and shoes, visitors to national parks represent one avenue that can transmit the fungus over a large area. Thus, maximizing visitor participation in WNS preventive strategies, which include education and decontamination, will be critical to conserving vulnerable bat populations located within national parks. By better understanding what factors influence visitor behavioral intent, the NPS can improve their communication and outreach strategies to garner the most visitor support. Many visitors were inquisitive about how the fungus and WNS spread, the risks humans pose to bats, and how the WNS preventive measures protect vulnerable bat populations. Capitalizing on this interest by providing explanations on how specific WNS preventive actions were developed and what their intended effects will be important to maintaining positive attitudes towards these strategies. As cave management actions continue to change over the coming decade, especially in light of WNS and COVID-19, evaluating visitors' perceptions and participation in these disease preventive strategies will be crucial for achieving management goals focused on enhancing recreation and conservation in environments shared by humans and bats.

CHAPTER 5: CONSERVATION AND MANAGEMENT IMPLICATIONS

National Park Service managers of cave systems are often tasked with fulfilling multiple objectives, including balancing continued public access to caves with responsible stewardship to ensure sustainable public enjoyment and resource conservation. The arrival of WNS in 2006 created new considerations and priorities for how bats and the caves they inhabit are managed. However, nearly 15 years after the discovery of this fungus and drastic changes to cave management policies that followed, there is a lack of social science studies to gauge public support for bats and the management actions designed to protect them, which is crucial for lasting conservation impacts. National Park Service natural and cultural resource managers can use the results of this project to develop further support for bat management and identify gaps in their WNS educational programming. More specifically, managing agencies should continue to work with caving groups to create WNS preventive strategies that prevents the anthropogenic spread of *Pd* while not placing an undue burden on cavers who greatly contribute to the exploration and conservation of cave systems. Additionally, managers should ensure that their educational and outreach programs promote and maintain positive attitudes towards bats and WNS preventive strategies, as attitudes were the most important predictor of bat conservation support and visitor behavioral intent towards common WNS preventive actions.

Maintaining positive attitudes towards bats and WNS preventive actions will be essential for the success of bat conservation efforts in national parks. It will be important for parks to continue to use adaptive management to update their educational programming and use of different WNS preventive measures, as the resources, park layout, and cave systems in each national park area is unique. However, managers could model their educational and decontamination programs on the programs of the parks where visitors had the most complete knowledge of bats and WNS, like Jewel Cave and Mammoth Cave. Furthermore, outreach and public communication to maintain positive attitudes towards bats could emphasize bats' importance to U.S. agriculture and address perceptions of risk associated with bats, including the likelihood of a bat having rabies and what people should do if they encounter a bat. Lastly, management and conservation agencies should emphasize programs (e.g. adopt-a-bat programs, bat boxes) that provide visitors with an actionable bat conservation behavior. Caves that do not currently have these programs could conduct focus groups with visitors to determine how to better engage visitors with bat conservation efforts in a way that would preserve the safety and well-being of people and bats.

DIRECTIONS FOR FUTURE RESEARCH

Future research should focus on gauging the public's attitudes towards bats and support for bat conservation. Comparing the public's and national park visitors' attitudes towards and knowledge of bats and WNS preventive strategies would give management and conservation agencies useful information on whether their educational outreach efforts extend beyond areas managed by the NPS. Additionally, in light of COVID-19, it will be important to re-evaluate people's attitudes towards bats and perceptions of risks. This pandemic has brought to light the dangers of zoonotic diseases and the potential of bats as reservoirs for disease, so it is likely that people's attitudes have shifted towards this group of species over the past several months. Lastly, it will be crucial to continue to integrate biological and social science research to achieve management goals focused on enhancing recreation and conservation in environments shared by humans and bats. Currently, many studies and funding opportunities focus on the biological and ecological aspects of bats and WNS. However, it will be crucial to incorporate the public's perception of bat management efforts to achieve long-term conservation success.

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APPENDICES

Table 1. Factors and associated measurement items assessed in an analysis of U.S. national park visitor perceptions of bats during June to August 2019. We present factor loadings, item means, standard deviations, and Cronbach's α .

Factor and associated measurement items	Factor loadings	$\bar{x}$	SD
Attitudes towards bats			
Cronbach's $\alpha = 0.83$			
Harmful/Beneficial ^a	0.69	4.54	0.69
Unpleasant/Pleasant ^b	0.80	4.12	1.00
Scary/Fascinating ^c	0.81	4.27	0.95
Worthless/Useful ^d	0.75	4.66	0.62
Dislike/Like ^e	0.81	4.16	0.93
Importance of ecosystem services from bats (USA)			
Cronbach's $\alpha = 0.78$			
Suppressing biting insects ^f	0.91	4.70	0.68
Suppressing agricultural insect pests ^f	0.91	4.59	0.78
Belief in Myths/Health Risks			
Cronbach's $\alpha = 0.72$			
Likelihood for bats to fly into hair ^g	0.68	1.85	1.01
Likelihood to be bitten by bats ^g	0.74	1.60	0.82
Likelihood for bats to have rabies ^g	0.72	2.87	1.15
Likelihood for you to get rabies from bats ^g	0.82	2.10	1.11

*Bats importance to pollination and the likelihood that bats are blind were removed from their respective categories to improve the internal reliability of the factor to an acceptable level.

^aOrdered responses: 1 = primarily harmful, 2 = more harmful than beneficial, 3 = neither harmful nor beneficial, 4 = more beneficial than harmful, 5 = primarily beneficial

^bOrdered responses: 1 = primarily unpleasant, 2 = more unpleasant than pleasant, 3 = neither unpleasant nor pleasant, 4 = more pleasant than unpleasant, 5 = primarily pleasant

^cOrdered responses: 1 = primarily scary, 2 = more scary than fascinating, 3 = neither scary nor fascinating, 4 = more fascinating than scary, 5 = primarily fascinating

^dOrdered responses: 1 = primarily worthless, 2 = more worthless than useful, 3 = neither worthless nor useful, 4 = more useful than worthless, 5 = primarily useful

^eOrdered responses: 1 = strongly dislike, 2 = dislike, 3 = neither dislike nor like, 4 = like, 5 = strongly like

^fOrdered responses: 1 = not important, 2 = slightly important, 3 = moderately important, 4 = important, 5 = very important

^gOrdered responses: 1 = very unlikely, 2 = unlikely, 3 = neither unlikely nor likely, 4 = likely, 5 = very likely

Table 2. Multiple regression model for support for bat conservation efforts by visitors to eight national park areas across the USA during June to August 2019 (n = 1365). We present standardized parameter estimates (β), standard errors (SE), lower and upper limits of the 95% confidence interval, and statistical significance. Adjusted $R^2 = 0.19$, $F = 81.74$, $p < 0.001$.

Variable	β	SE	Lower CL	Upper CL	$p(\beta)$
Attitudes towards bats	0.39	0.03	0.31	0.41	<0.001
Likelihood of bat myths or health risks	-0.02	0.03	-0.06	0.04	0.58
Importance of ecosystem services	0.05	0.02	0.002	0.10	0.04
Recognition of white-nose syndrome	0.06	0.06	0.01	0.24	0.03

Table 3. Multiple regression model for support for bat conservation efforts by visitors during June to August 2019 who were intending on touring the caves during their visit (n = 285) versus those that were not (n = 1080). We present standardized parameter estimates (β), standard errors (SE), lower and upper limits of the 95% confidence interval, and statistical significance. Those who were not intending on touring the caves had an adjusted $R^2 = 0.22$, $F = 20.04$, $p < 0.001$. Those who were intending on touring the caves or had already toured the caves had an adjusted $R^2 = 0.20$, $F = 66.04$, $p < 0.001$.

Variable	β	SE	Lower CL	Upper CL	$p(\beta)$
Attitudes towards bats					
No intention to tour caves	0.40	0.05	0.21	0.41	< 0.001
Intention to tour caves	0.38	0.03	0.31	0.43	< 0.001
Likelihood of bat myths or health risks					
No intention to tour caves	-0.13	0.05	-0.21	-0.01	0.03
Intention to tour caves	0.01	0.03	-0.05	0.07	0.72
Importance of ecosystem services					
No intention to tour caves	-0.11	0.04	-0.17	0.00	0.06
Intention to tour caves	0.10	0.03	0.04	0.15	0.04
Recognition of white-nose syndrome					
No intention to tour caves	0.05	0.11	-0.11	0.31	0.36
Intention to tour caves	0.06	0.07	0.01	0.28	0.04

Table 4. Multiple regression model for support for bat conservation efforts by visitors during June to August 2019 who had previously visited a national park with caves (n = 729) versus those who had not (n = 636). We present standardized parameter estimates (β), standard errors (SE), lower and upper limits of the 95% confidence interval, and statistical significance. Those who had not previously visited a national park with caves had an $R^2 = 0.20$, $F = 39.14$, $p < 0.001$. Those who were intending on touring the caves or had already toured the caves had an adjusted $R^2 = 0.20$, $F = 43.71$, $p < 0.001$.

Variable	β	SE	Lower CL	Upper CL	$p(\beta)$
Attitudes towards bats					
First visit to park with caves	0.42	0.04	0.30	0.44	< 0.001
Visited other parks with caves	0.35	0.04	0.27	0.43	< 0.001
Likelihood of bat myths or health risks					
First visit to park with caves	-0.003	0.04	-0.07	0.07	0.94
Visited other parks with caves	-0.03	0.04	-0.10	0.04	0.42
Importance of ecosystem services					
First visit to park with caves	0.04	0.04	-0.04	0.10	0.34
Visited other parks with caves	0.07	0.03	-0.004	0.13	0.07
Recognition of white-nose syndrome					
First visit to park with caves	0.03	0.04	-0.09	0.21	0.46
Visited other parks with caves	0.09	0.09	0.06	0.41	0.01

Table 5. Multiple regression model for support for bat conservation efforts by visitors during June to August 2019 who had visited the national park multiple times (n = 574) and those who were visiting the national park for the first time (n = 791). We present standardized parameter estimates (β), standard errors (SE), lower and upper limits of the 95% confidence interval, and statistical significance. Those who were visiting the national park for the first time had an adjusted $R^2 = 0.19$, $F = 32.47$, $p < 0.001$. Those had visited the park multiple times had an adjusted $R^2 = 0.20$, $F = 34.80$, $p < 0.001$.

Variable	β	SE	Lower CL	Upper CL	$p(\beta)$
Attitudes towards bats					
First visit	0.38	0.04	0.27	0.41	< 0.001
Multiple visits	0.41	0.04	0.30	0.47	< 0.001
Likelihood of bat myths or health risks					
First visit	-0.01	0.03	-0.08	0.05	0.70
Multiple visits	-0.02	0.04	-0.09	0.06	0.70
Importance of ecosystem services					
First visit	0.08	0.03	0.01	0.13	0.03
Multiple visits	0.03	0.04	-0.05	0.10	0.50
Recognition of white-nose syndrome					
First visit	0.06	0.08	-0.03	0.28	0.10
Multiple visits	0.06	0.09	-0.05	0.31	0.15

Table 6. Visitor behavioral intent questions about common cave management strategies used by the National Park Service to slow the spread of white-nose syndrome, 2019.

Statement	Mean	SD
If there are guided or recorded education programs or tours that focus on cave and bat conservation in national parks, how likely are you to participate?	4.00	0.95
If there are rules requiring visitors to wear clothes/shoes that have not been exposed to the fungus that causes white-nose syndrome, how likely are you to comply (even if it means changing clothes/shoes after entering the park)?	4.56	0.81
If there are rules requiring visitors to walk over decontamination mats before and/or after entering a cave in a national park, how likely are you to comply?	4.78	0.61
If there are cave closures that last part of the year in national parks to protect bats are, how likely are you to comply?	4.71	0.67
If there are year-long cave closures in a national park to protect bats, how likely are you to comply?	4.61	0.81

Table 7. Visitor subjective norm responses to the statement “I am more likely to do [management] action if [a ranger tells me to do it, the group I am traveling is doing it, other visitors are doing it],” 2019.

Management Practice	Mean	SD
Educational Programming		
A ranger tells me about it	4.15	0.86
Traveling group is doing it	4.00	0.95
Other visitors are doing it	3.65	1.08
Wearing clean clothes/shoes		
A ranger tells me about it	4.54	0.69
Traveling group is doing it	4.07	1.02
Other visitors are doing it	3.97	1.08
Walking over decontamination mats		
A ranger tells me about it	4.63	0.63
Traveling group is doing it	4.17	1.01
Other visitors are doing it	4.09	1.05
Complying with partial cave closures		
A ranger tells me about it	4.59	0.66
Traveling group is doing it	4.12	1.03
Other visitors are doing it	4.02	1.08
Complying with year-long cave closures		
A ranger tells me about it	4.56	0.73
Traveling group is doing it	4.06	1.07
Other visitors are doing it	3.97	1.11

Table 8. Visitor perceived behavioral control responses to the statement “Whether or not I participate/comply with [management action] is [completely up to me, influenced by my resources, influenced by my awareness],” 2019.

Management Practice	Mean	SD
Educational Programming		
Completely up to me	4.11	1.05
Influenced by resources	3.75	1.08
Influenced by knowledge	4.13	0.88
Wearing clean clothes/shoes		
Completely up to me	3.49	1.45
Influenced by resources	3.43	1.27
Influenced by knowledge	4.15	1.08
Walking over decontamination mats		
Completely up to me	3.19	1.57
Influenced by resources	2.84	1.45
Influenced by knowledge	3.95	1.25
Complying with partial cave closures		
Completely up to me	3.22	1.55
Influenced by resources	2.85	1.43
Influenced by knowledge	3.96	1.26
Complying with year-long cave closures		
Completely up to me	3.17	1.57
Influenced by resources	2.81	1.42
Influenced by knowledge	3.94	1.27

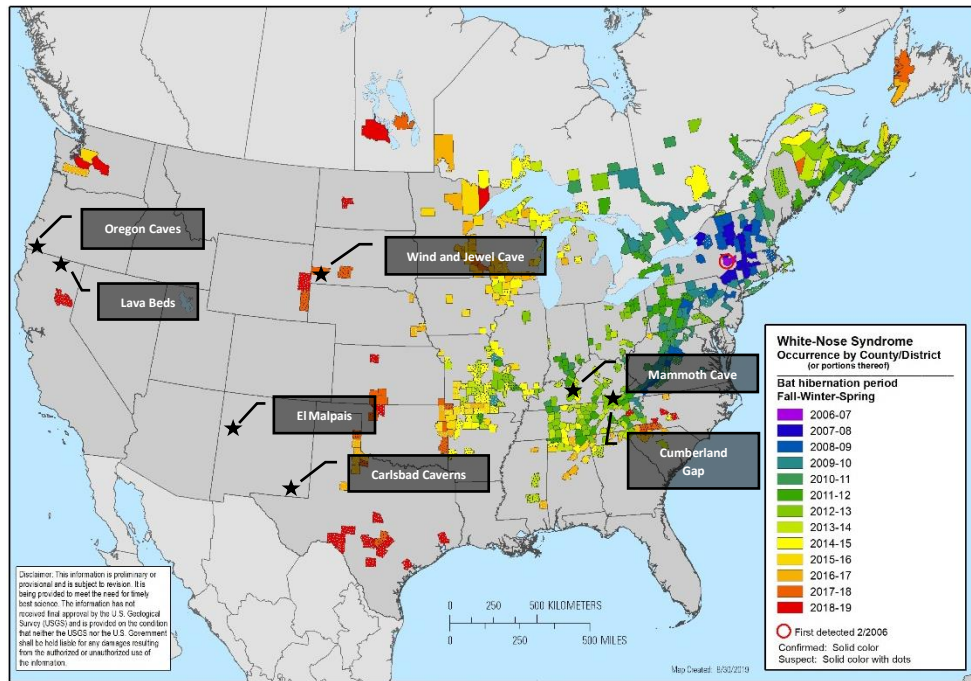
Table 9. Structural equation modeling outputs explaining how likely national park visitors were to participate or comply in white-nose syndrome preventive actions using the three components of the Theory of Planned Behavior (attitudes, subjective norms [SN], perceived behavioral control [PBC]) and two interaction terms (attitude*PBC; SN*PBC).

Predictor	Educational Programming ($r^2 = 0.39$)	Wearing Clean Clothes/Shoes ($r^2 = 0.31$)	Decontamination Mats ($r^2 = 0.21$)	Partial Closure ($r^2 = 0.28$)	Year-long Closure ($r^2 = 0.35$)
<i>Main Analyses</i>	β	β	β	β	β
Attitude	0.56***	0.48***	0.35***	0.38***	0.44***
SN	0.11***	0.16***	0.17***	0.26***	0.27***
PBC	0.04	-0.03	-0.03	-0.05	-0.09**
<i>Interaction</i>					
Attitude*PBC	-0.01	0.02	0.05	0.08**	0.11***
SN*PBC	-0.05*	-0.04	-0.09***	-0.07**	-0.03

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$



Citation: White-nose syndrome occurrence map - by year (2019). Data Last Updated: 8/30/2019. Available at: <https://www.whitenosesyndrome.org/static-page/wns-spread-maps>.

Figure 1. White-nose syndrome occurrence map with the locations of the 8 national park units included in our sample. Last updated August 30, 2019 by the United States Fish and Wildlife Service. Available at <https://www.whitenosesyndrome.org/where-is-wns>.

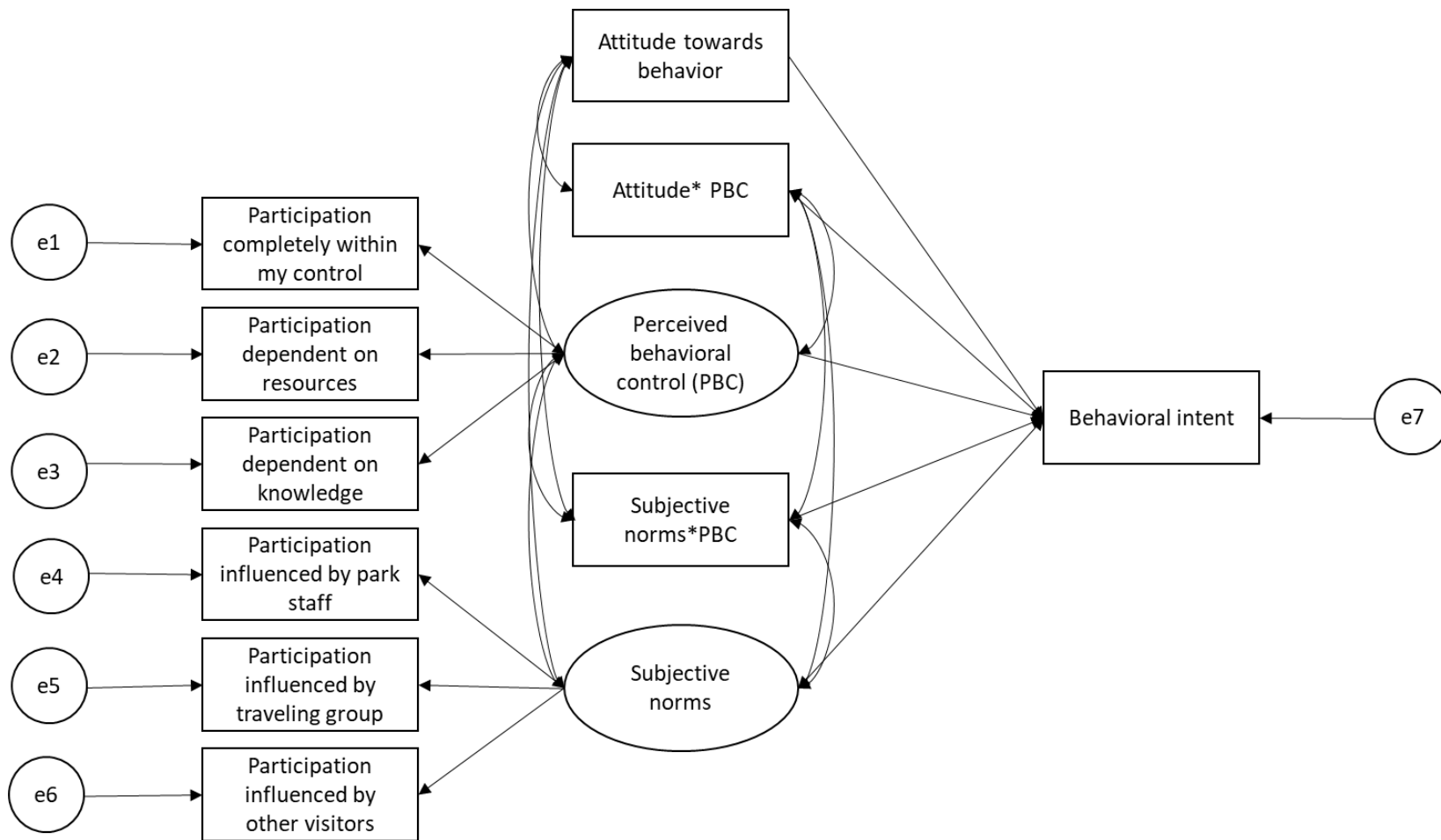


Figure 2. Example of the Theory of Planned Behavior template used for each of the five white-nose syndrome preventive strategies used in U.S. national parks.

**APPENDIX 1: QUESTION GUIDE USED TO INTERVIEW INFORMANTS ON
WHITE-NOSE SYNDROME MANAGEMENT STRATEGIES**

Questions

1. Briefly describe your involvement with show caves.
 2. What do you think are the biggest challenges facing [Insert NP or Show Caves] in relation to cave and bat management?
 3. What protocols or programs does [Insert National Park or Show Caves] currently have regarding caves and bats?
 4. Describe any individuals or groups who approve of current regulations and protocols related to bat conservation, cave management, and recreation.
 5. What strategies can [Insert National Park or Show Caves] implement to better manage bats, caves, and visitors?
 6. Describe any individuals or groups who would approve of additional regulations and protocols to improve bat and cave management.
 7. What types of visitors does [Insert National Park or Show Caves] attract?
 8. Are there other topics/information you would like to see included in this study?
 9. Who else should I talk to?
-

APPENDIX 2: SURVEY ITEMS USED TO ASSESS VISITOR PERCEPTIONS OF BATS AND WHITE-NOSE SYNDROME PREVENTIVE ACTIONS IN U.S. NATIONAL PARKS

1. Do you plan to tour the cave(s) during your visit?
 - a. Yes, I plan on touring the caves
 - b. No, I am not planning on touring the caves
 - c. I have already toured the caves

2. Bats in the United States are:

Primarily harmful	More harmful than beneficial	Neither harmful nor beneficial	More beneficial than harmful	Primarily beneficial
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3. Bats in the United States are:

Primarily unpleasant	More unpleasant than pleasant	Neither unpleasant nor pleasant	More pleasant than unpleasant	Primarily pleasant
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4. Bats in the United States are:

Primarily scary	More scary than fascinating	Neither scary nor fascinating	More fascinating than scary	Primarily fascinating
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5. Bats in the United States are:

Primarily worthless	More worthless than useful	Neither worthless nor useful	More useful than worthless	Primarily useful
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6. What is your attitude towards bats?

Strongly dislike	Dislike	Neither dislike nor like	Like	Strongly Like
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7. Do bats in the United States hibernate?

- a. Yes
- b. No
- c. I don't know

8. Do bats in the United States hibernate in:

	Yes	No	I don't know
Caves			
Trees			
Bridges			
Mines			
Houses/Buildings			
Other: (write in option)			

9. Do bats in the United States eat:

	Yes	No	I don't know
Fruit			
Insects			
Blood			
Pollen			
Nectar			
Wild animals/fish			
Other: (write in option)			

10. How likely is it:

	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
For a bat to be blind					
For a bat to fly into your hair					
For you to be bitten by a bat					
For a bat to have rabies					
For you to get rabies from a bat					

11. How important do you think bats in the United States are for:

	Not important	Slightly important	Moderately important	Important	Very important
Controlling biting insects (like mosquitoes)					
Controlling insect pests that destroy agricultural crops (like moths and beetles)					
Pollinating plants					

12. Have you heard of white-nose syndrome?

- a. Yes
- b. No

13. Is white-nose syndrome a threat to bats in the national park you are currently visiting?

Not a threat at all	Low threat	Somewhat of a threat	Moderate Threat	Extreme threat	I don't know
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14. Who/What do you think is responsible for the spread of white-nose syndrome?
- Humans are primarily responsible for the spread
 - Bats are primarily responsible for the spread
 - Both are responsible for the spread
 - Neither are responsible for the spread
 - Other (Write-in option)
 - I don't know

Please read the following message. You will use the information here to respond to the questions in the next section.

Bats provide natural pest control by eating insects that damage crops, saving the United States an estimated \$22.9 billion every year. They eat mosquitos too, but they are not a major component of their diet.

White-nose syndrome is caused by a fungus and has killed over 6 million bats in North America. Some species are more vulnerable to the disease than others and are now threatened with regional extinction.

Bats in the US can use caves throughout the year. In the summer, some bats roost together in maternity colonies where they give birth and raise their pups. In the winter, bats may use caves to hibernate and save energy until the spring. Bats can be found roosting in caves in national parks throughout the United States.

15. Please respond to the following questions about your behavioral intent towards the following management actions:

	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very Likely
How likely would you be to support bat conservation in national parks?					
If there are guided or recorded education programs or tours that focus on cave and bat conservation in national parks, how likely are you to participate?					
If there are rules requiring visitors to wear clothes/shoes that have not been exposed to the fungus that causes white-nose syndrome, how likely are you to comply (even if it means changing clothes/shoes after entering the park)?					

If there are rules requiring visitors to walk over decontamination mats before and/or after entering a cave in a national park, how likely are you to comply?					
If there are cave closures that last part of the year in national parks to protect bats are, how likely are you to comply?					
If there are year-long cave closures in a national park to protect bats, how likely are you to comply?					

16. Please respond to the following statements about your attitudes towards the following management actions:

For me:	Very undesirable	Undesirable	Neither undesirable nor desirable	Desirable	Very desirable
supporting the conservation of bats in national parks is:					
participating in live or recorded education programs and tours that focus on cave and bat conservation is:					
being required to wear clothes/shoes that have not been exposed to the fungus that causes white-nose syndrome when entering a cave in a national park (even if it means changing clothes/shoes after entering the park) is:					
being required to walk over decontamination mats that remove the fungus that causes white-nose syndrome from my shoes before and/or after					

entering a cave in a national park is:					
complying with cave closures that last part of the year in national parks to protect bats is:					
complying with cave closures that last all year in national parks to protect bats is:					

17. Whether or not I participate in guided tours of caves that focus on bat conservation in national parks:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Is completely up to me					
Is influenced by my resources (i.e. money, clothing available, time)					
Is influenced by my awareness of guided tours					

18. Whether or not I wear clothes/shoes that have not been exposed to the fungus that causes white-nose syndrome, even if it means changing my clothes/shoes after entering the park:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Is completely up to me					
Is influenced by my resources (i.e. money, clothing available, time)					
Is influenced by my awareness of the rules surrounding clothing items					

19. Whether or not I walk over decontamination mats before and/or after entering a cave to remove the fungus that causes white-nose syndrome in a national park:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Is completely up to me					
Is influenced by my resources (i.e. money, clothing available, time)					
Is influenced by my awareness of decontamination mats					

20. Whether or not I comply with cave closures that last part of the year in national parks to protect bats:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Is completely up to me					
Is influenced by my resources (i.e. money, clothing available, time)					
Is influenced by my awareness of the cave closures					

21. Whether or not I comply with year-long cave closures in national parks to protect bats:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Is completely up to me					
Is influenced by my resources (i.e. money, clothing available, time)					
Is influenced by my awareness of the cave closures					

22. I am more likely to participate in guided tours of caves that focus on bat conservation in national parks if: (Agree/disagree)

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Information about it is written on a sign					
A ranger suggests I do it					
The group I am traveling with is doing it					
Other visitors are doing it					

23. I am more likely to wear clothes/shoes that have not been exposed to the fungus that causes white-nose syndrome in a cave in national parks if, even if it means changing my clothes/shoes after entering the park:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The request is written on a sign					
A ranger tells me to do it					
The group I am traveling with is doing it					
Other visitors are doing it					

24. I am more likely to walk over decontamination mats before and/or after entering a cave in national parks if:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The request is written on a sign					
A ranger tells me to do it					
The group I am traveling with is doing it					
Other visitors are doing it					

25. I am more likely comply complying with cave closures that last part of the year in national parks if:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The request is written on a sign					
A ranger tells me to do it					
The group I am traveling with is doing it					
Other visitors are doing it					

26. I am more likely comply with year-long park cave closures in national parks if:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The request is written on a sign					
A ranger tells me to do it					
The group I am traveling with is doing it					
Other visitors are doing it					

27. How often do you visit this national park?

- First visit
- Every few years
- Weekly
- Once a year
- 2-5 times a year
- More than 5 times a year

28. Have you visited other national parks with caves?

- Yes
- No

29. If yes, which ones? (Write-in answer)

30. Which one of the following best describes the group you are traveling with? (Pick one)

- Traveling alone
- With Family
- With friends or relatives
- Club/organization/school
- Organized tour group
- Other

31. Have you (or do you) recreationally explore caves?
- Yes
 - No
32. If yes, how often?
- More than once a month
 - Once a month
 - Several times a year
 - Once a year
 - Other
33. Are you, or have you ever been, part of an organized caving group (grotto)?
- Yes
 - No
34. How far did you travel from your home to get to this national park? (Pick one)
- Not far at all, I can make day trips to this national park
 - Not too far, I live in the region (surrounding states)
 - Very far, I come from outside of the region (outside of surrounding states)
 - I'm visiting from another country
35. How would you describe your home community? (Pick one)
- Urban
 - Suburban
 - Rural
36. What is the highest level of formal education you have completed? (Pick one)
- Less than a high school diploma or equivalent
 - A high school diploma or equivalent
 - Some college
 - Associate degree
 - Bachelor's degree
 - More than a bachelor's degree
37. Which of these categories best indicates your race? (Pick one)
- American Indian or Alaska Native
 - Asian
 - Black/African American
 - Native Hawaiian or other Pacific Islander
 - White
 - Prefer not to answer
38. What is your age? _____

39. Are you?

- a. Female
- b. Male
- c. Other
- d. Prefer not to answer

VITA

Hannah G. Shapiro was born in Markham, Ontario, Canada. She moved to Raleigh, North Carolina in 2005 and went on to graduate from Raleigh Charter High School in 2014. She obtained her Bachelor of Science degree in Fisheries, Wildlife, and Conservation Biology at North Carolina State University in 2018. During her time as an undergraduate, she was selected as a NIFA Undergraduate Research and Extension Fellow in Belize, where she worked on interdisciplinary projects to improve sustainable agriculture practices and wildlife conservation in the Vaca Forest Reserve. In 2018, Hannah entered the Master of Science program in the Department of Forestry, Wildlife and Fisheries at the University of Tennessee to pursue research on U.S. national park visitor attitudes towards bats, knowledge of white-nose syndrome, and perceptions of white-nose syndrome preventive strategies.