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Factors Influencing Support for Bat Management and Conservation in the Wildland-Urban Interface

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Abstract

Knowledge, attitudes, and beliefs about bats often underlie social support for bat management and intentions to conserve bats. Effective bat conservation and management hinges on understanding these drivers across contexts. Lands classified as wildland-urban interface (WUI) are rapidly expanding in the USA, increasing the likelihood of human-bat interactions from management practices and encroachment on forested landscapes. We surveyed 410 households in one Arizona WUI community to assess residents' knowledge, attitudes, beliefs, and emotions toward bats, and differences among these variables associated with demographic traits, past encounters with bats, support for bat management, and willingness to place artificial bat roosts on their properties. Greater knowledge and positive attitudes, beliefs, and emotions positively predicted willingness to place roosts 59% to 85% of the time, varying across demographic groups; they did not predict support for bat management. Our findings demonstrated that contexts and demographic traits are important considerations for bat conservation and management.

Keywords: Artificial roosts, public attitudes, bats, beliefs, Chiroptera, human-wildlife interactions, wildlife management, wildland-urban interface

Introduction

Public perceptions and attitudes towards bats (Order: *Chiroptera*) vary widely in the Americas. Bats are consistently ranked among the most disliked and feared animals (Arrindell, 2000; Davey et al., 1998) because of their association with negative aesthetics, threatening information and representations, diseases, and human-wildlife conflicts (Boëte & Morand, 2016; Greving & Kimmerle, 2020; Knight, 2008; Kretser et al., 2009; López-Baucells et al., 2018). Yet agency personnel are tasked with managing bats and public opinions to pursue effective management in the face of critical issues affecting bat populations in North America (e.g., habitat loss, White-nose syndrome, assumptions that bats contract COVID-19; Frick et al., 2020; Sasse & Gramza, 2020). Management approaches also vary widely among state wildlife management agencies. They range from categorizing bats as nuisances (e.g., Ohio; ODNR, 2021) to developing sophisticated interagency plans for maintaining bat populations (e.g., Arizona; AZGFD 2012, 2021), including the use of artificial roosts (i.e., anthropogenic structures designed to attract and house bats) to protect bats, garner public awareness, and even attract tourists (e.g., Hinman & Snow, 2003; Pennisi et al., 2004). Given this diversity, the term "bat management" in this study refers to the variety of management strategies that agencies deploy to address the biological, ecological, and human dimensions of bat conservation.

Current management strategies and messaging campaigns often minimize adverse associations with bats because of negative public perceptions (Hoffmaster et al., 2016; Lu et al., 2016; MacFarlane & Rocha, 2020). However, a growing body of research indicates that public attitudes towards bats are improving in the US (George et al., 2016; Fagan et al., 2018; Pennisi et al., 2004; Sexton & Stewart, 2007). This shift towards positive characterization has been associated with perceived ecosystem benefits and services (e.g., Great Smoky Mountains

National Park, Tennessee, Fagan et al., 2018; Fort Collins, Colorado, Sexton & Stewart, 2007) and corresponds with an increase in knowledge of these benefits (Kasso & Balakrishnan, 2013), often communicated through public education programs. Establishing drivers of positive and negative public perceptions of bats presents an opportunity to develop tailored messaging and outreach strategies that can garner public support for bat conservation, foster behavioral change to strengthen or extend efforts put forward by existing programs, and ultimately elevate public acceptance and support for bat management (Kingston, 2016; MacFarlane & Rocha, 2020; Siemer et al., 2020).

Human perceptions of bats across diverse social, ecological, and economic contexts are variable, which complicates public messaging to support bat management as one-size-fits-all approaches are unlikely to be effective. Research conducted at national parks and outreach events in the United States demonstrates that broader awareness of threats to bat populations and knowledge of ecological roles of bats can increase public support for bat management actions and behaviors (Fagan et al., 2018; Hoffmaster et al., 2016; Lu et al., 2016). Increased knowledge and affinity towards bats have also been linked to proximity to urban bat tourism sites such as Congress Avenue Bridge in Austin, Texas (Pennisi et al., 2004; Taylor & Butler, 2007), which yield significant returns for local economies and educational opportunities (Bagstad & Wiederholt, 2013). Recent research documented that local intentions to conserve bats were also strengthened by New York State residents' positive attitudes and their moral belief that they were responsible for bat conservation, even when they believed that managers and conservationists should bear more responsibility than residents as a whole (Siemer et al., 2020). Effectiveness of public outreach and bat management strategies at the community level therefore relies on translating variations in context-specific relationships between knowledge, attitudes,

beliefs, behaviors, and support for bat management into place-based action (Fagan et al., 2018; Kingston, 2016; Reid, 2016).

Place-based management efforts are important as bat habitat and human development increasingly overlap across North America. The wildland urban interface (WUI) – areas where developed and wildland habitats intermingle – is rapidly expanding in the United States, becoming the focus of a growing body of research on public attitudes towards natural resources management, and in particular, wildfire risk and impacts (McCaffrey et al., 2013). Although existing research on behaviors toward bats and social drivers of support for bat management may have been conducted in the WUI or analogous areas (e.g., Sexton & Stewart, 2007), no scholars explicitly use this term to characterize the social-ecological context in which data are being collected. Forest thinning and prescribed burning in the western US are increasingly implemented in or adjacent to WUI areas to reduce wildfire risk to life and property (Kolden, 2019; Toman et al., 2011). These mitigation practices and other techniques such as timber production may unintentionally remove natural roosts (e.g., snags) and reduce habitat quality (Frick et al., 2020), leading to increased use of human structures (e.g., barns, sheds, and houses) by some bat species (e.g., those exhibiting roost plasticity and affinity to humans; Kunz & Reynolds, 2003) and a higher likelihood of negative human-bat interactions. Investigating public support for bat management in a WUI context has the potential to offer new insights into attitudes and perceptions at a localized level from a more holistic perspective that also takes forest and fire management into consideration. Understanding whether the WUI lens provides insights into support or opposition for bat management can provide pathways for better integration, applicability, and transferability of public perceptions of bats with broader social science literature and its role in North American wildlife management (e.g., Manfredo et al., 2019).

A deeper understanding of public knowledge, attitudes, beliefs, behaviors, and support for bat management of WUI residents will contribute to managing bats in several ways. This study will expand on the limited literature surrounding likelihood and potential outcomes of human-bat interactions in the WUI (e.g., McCollum et al., 2012). WUI-focused research can inform managers of the relationships among demographics (e.g., gender and age), attitudes, beliefs, and encounters with bats – indicated as foundational factors in crafting effective bat management, outreach, messaging, and strategies for behavioral change (Kingston, 2016; Reid, 2016; Sexton & Stewart, 2007). Knowledge of demographic differences in attitudes and beliefs can also help managers navigate the social diversity within the WUI (e.g., Paveglio et al., 2009), allowing them to proactively leverage residents' perceptions of management agencies to build support and minimize conflict for bat conservation (e.g., Sasse & Gramza, 2020; Sexton & Stewart, 2007; Siemer et al., 2020). Importantly, these data can forge opportunities for bottom-up behavioral change and household- or community-level action to reduce dependence on wildlife management professionals. Thus, collaborative efforts to conserve bats in WUI areas have the potential to be more ecologically and socially sustainable for bat populations, human residents, and management agencies alike.

The WUI and its residents in the state of Arizona are examples of social and ecological studies about both wildfire and bat management (e.g., Edgeley & Burnett, 2020; Johnson & Chambers, 2017; Mering & Chambers, 2012). To pursue bat management efforts, the Arizona Game and Fish Department (AZGFD, 2021) worked with agencies, researchers, and private citizens on research, inventory and monitoring, management, and education (Hinman & Snow, 2003; AZGFD, 2021). Developing cohesion at the intersection of social and biophysical components of human-bat interactions can inform effective place-based management approaches that are actionable for both managers and residents. Our objectives were to examine the

knowledge, attitudes, beliefs, and behavioral intentions toward bats, types of encounters with bats, and support for bat management. We studied one WUI community to (1) assess how the above variables vary among demographic groups, (2) evaluate support for bat management reported by respondents, (3) determine how the variables vary according to human-bat encounters in and outside the WUI, and (4) report the implications of our findings to facilitate relationships between knowledge, attitudes, beliefs, and demographics to support management efforts, conservation messaging, and human-bat interactions in the WUI.

Methods

Study Area

Kachina Village (KV), Arizona is a 4000-ha census-designated WUI community (population 2,932) located south of Flagstaff, AZ and bordered by Coconino National Forest (United States Census Bureau, 2019). Most properties are dominated by a mixture of ponderosa pine (*Pinus ponderosa*) and Gambel oak (*Quercus gambelii*). Thinning treatments and prescribed burns were conducted as part of the Flagstaff Community Wildfire Protection Plan between 2004 and 2005 (GFFP & PFAC, 2004). The area includes 52 ha of wetland and stream habitat that supports a diverse wildlife community, including foraging sites and flyways for 15 species of insectivorous bats. Big brown bats (*Eptesicus fuscus*) and Arizona occult myotis (*Myotis occultus*), known to use human structures in the area, are commonly captured species (Chambers, unpublished data; Mering & Chambers, 2012).

Survey Design and Administration

Surveys are an effective method for collecting rapid quantitative data among large human populations. As part of a larger study, we developed a 14-page survey instrument (see supplementary materials) that augmented existing research to examine public perceptions of bat

management using a combination of Likert, binary, and open-ended questions. The questions were divided into four sections focusing on each respondent's: 1) knowledge of bats, 2) experiences with bats and emotions associated with them, 3) perceptions, beliefs, and attitudes regarding bats and their management by AZGFD, and 4) demographic information. The survey instrument was pre-tested by students and faculty at Northern Arizona University (NAU) to ensure that questions were clear and interpreted consistently. The NAU Institutional Review Board approved this study (#10-0126).

We administered the mail survey to all residential addresses (n = 1,230) in Kachina Village in April and May of 2010. Because 254 questionnaires were returned as undeliverable, the survey resulted in 976 valid addresses. Of those, 526 households responded for a 53.9% response rate. This resulted in a data set with a ±3% margin of error (Dillman, 2000). Reported responses to socio-demographic questions in our dataset aligned with the 2010 census data for this area, indicating that responses are likely representative of this population.

Data collection adhered to the Total Design Method, which optimizes the quality and quantity of responses to mail survey administration (Dillman, 2000). Addresses in our sample frame received a pre-survey postcard notifying them of the study, a technique widely recognized as improving response rates (Dillman et al., 2014). Each address then received a survey packet, which included a cover letter explaining our study, the questionnaire booklet, and a pre-paid return envelope. We requested that the person in the household ≥18 years of age with the most recent birthday answer the questionnaire to remove potential sample bias within households. Non-respondents received one final replacement survey packet via mail two weeks later.

Analyses

We summed the number of bat dietary items selected by respondents out of 11 options as a proxy for knowledge of bats (Table 1) following studies that used and demonstrated that

dietary knowledge is an important component of knowledge of, and attitudes toward, bats (Prokop & Tunnicliffe, 2008; Prokop et al., 2009; Sexton & Stewart, 2007). Seeds and fruit were listed separately to test whether respondents felt bats intentionally sought out seeds for consumption rather than as byproducts from consuming fruit. We created attitude and belief indices by summing coded values of responses to six five-point Likert-type questions. Attitude questions focused on respondents' feelings towards their own, their children's, and their pets' safety around bats in different contexts. Belief questions centered on respondents' perceived ecological importance of bats and the effects of bats on respondents' quality of life (Table 1). Attitude index values ranged from 6 (solely negative attitudes) to 30 (solely positive attitudes) and belief index values ranged from 7 (strong disagreement) to 35 (strong agreement). To ensure that the indices effectively measured attitude and belief constructs, we tested their reliability using Cronbach's alpha (McClendon, 2004). We used Shapiro-Wilk and Levene's tests to determine normality and homogeneity of variance among data (Ott & Longnecker, 2008). Questionnaires with incomplete responses to questions on knowledge, attitudes, and beliefs about bats were removed prior to these calculations to ensure composite measures and analysis were not skewed by missing data, leaving a data set of 410 valid responses.

We measured relationships between knowledge, attitudes, and beliefs using Pearson's correlations (r). We used binary logistic regression with Wald statistics and Receiver Operating Characteristic (ROC) curves to test whether knowledge, attitudes, and beliefs predicted two dependent variables: 1) desire to engage in behavior intended to conserve bats (i.e., place an artificial bat roost on one's property) and 2) support for bat management. The Wald statistic measures the significance of predictor variable coefficients (Hosmer & Lemeshow 2000) and the ROC curve plots the probability of predicting a true positive response (Pearce & Ferrier, 2000; Marzban, 2004). ROC values range from .5 to 1.0; values ranging from .7 to .8 are considered

moderately accurate, and values >.8 are considered highly accurate. Hosmer-Lemeshow (H-L GOF) tests were used to measure the goodness-of-fit for logistic regression models (Hosmer & Lemeshow, 2000). Because of the complexity of bat management followed by AZGFD (AZGFD, 2021; Hinman & Snow, 2003), we focused on the general concept of bat management (see Table 2) to assess respondents' broad support for management efforts AZGFD might carry out and gain insights into the values and beliefs respondents ascribed to their conception of bat management by AZGFD.

We assessed demographic differences in knowledge, attitudes, and beliefs about bats with a multivariate analysis of variance (MANOVA) (McClendon, 2004). We measured demographic differences in support for bat management using binary logistic regression. The independent effects of the variables included in the demographic group on attitude, knowledge, and beliefs index scores were tested using 1-way ANOVA followed by post-hoc Tukey-Kramer (HSD) tests (Ott & Longnecker, 2008) for differences between age and education levels. We asked respondents if they had encounters with bats within and outside of KV. The type of encounter was recorded according to encounter proximity, as either: 1) direct encounters (having physical contact with or presence of a bat within one's household); or 2) indirect encounters (observing bats from a distance but without physical contact). Additionally, respondents indicated whether they had positive, negative, or neutral emotions during the encounter. We tested for differences and correlations between attitudes, beliefs, and past encounters (locations, proximity, and emotion) with bats using 1-way ANOVA. We used binary logistic regression and ROC curves to determine if past encounters predicted desire to place an artificial bat roost on one's property. We tested goodness-of-fit for each encounter model (regression models: artificial roost = encounter location; artificial roost = encounter emotion; artificial roost = encounter proximity) using H-L GOF tests. We set $p \leq .05$ for all analyses and used SPSS version 26.

Results

Demographic Summary

Respondents ranged from 18 to 82 years of age (M = 47, SD = 1), and more than half (55%) were female. Tenure as a KV resident ranged from .2 to 47 years (M = 11, SD = 1). Most respondents owned the property (85%); 15% were renters. Twenty-three percent of households had children under the age of 12. Eighty-two percent owned either dogs (78%), cats, (46%), or both (29%). Over half (56%) had earned a Bachelor's degree or higher, 28% had either vocational training or some college experience, 12% had a high school degree, and 1.5% did not graduate high school. Age and education levels were unrelated ($F_{7, 327}$ = 1.1, p = .3)

Knowledge, Attitudes, Beliefs, Behavioral Intention, and Support for Bat Management

Overall, respondents had low knowledge of bat diet, held positive attitudes towards bats, and showed moderate to strong agreement with beliefs about bats (Table 1). Insects were the most common food item correctly identified (98%), followed by fruit (72%), nectar (59%), and blood (35%). Four percent of respondents incorrectly believed that bats intentionally consumed seeds, leaves, and bark. In terms of attitudes, 60% of respondents would feel very safe if they encountered a bat in their neighborhood or in the wild; however, fewer respondents (32%) would feel very safe if their children or pets encountered bats. Over half of respondents (54%) strongly or somewhat agreed that "bat presence near my home increases my overall quality of life," and 75% strongly disagreed with the statement "bats are an unacceptable threat to my family's and personal well-being." Knowledge of bats weakly correlated with positive attitudes toward bats (r = .098, p = .047) and beliefs about bats (r = .18, p < .001). Positive attitudes towards bats increased with agreement with beliefs about bats (r = .65, p < .001)

Over 50% of respondents indicated willingness to install artificial roosts for bats on their property. Knowledge of bats predicted behavioral intention (one's desire to place an artificial

roost on one's property) 59% of the time (Wald = 5.86, $df = 1$, ROC = .59, $p < .001$). Attitudes toward bats predicted behavioral intention 79% of the time (Wald = 71.5, $df = 1$, ROC = .79, $p < .001$). Beliefs about bats predicted behavioral intention 85% of the time (Wald = 75.9, $df = 1$, ROC = .85, $p < .001$). These models met the H-L GOF test ($p \geq .2$).

Respondents were ambivalent about whether KV bats should be managed by local management agencies (e.g., AZGFD): 36% said yes, 24% reported no, and 40% were unsure. Common reasons for support towards bat management were opportunities for population monitoring and protection, preserving habitat, and controlling rabies. Respondents noted uncertainty in the term 'managed,' commenting that they did not know what bat management involved and expressed doubt or reluctance in government or AZGFD management (Table 2). Knowledge, attitudes, and beliefs did not predict support for or opposition to bat management (Wald ≤ 2.3, $df = 1$, ROC $\leq .55$, $p \geq .13$).

Demographic Influences on Knowledge, Attitudes, Beliefs, and Support for Bat Management

We identified a difference in knowledge, attitudes, and beliefs about bats across demographic groups (Wilks' Lambda = .78, $F_{26, 622} = 3.2$, $p < .001$), which were explained by one difference in knowledge and several differences in attitudes and beliefs among demographics (Table 3). Younger respondents (18 – 31 years) demonstrated a higher knowledge of bats than other age groups. Thirty-two- to 45-year-old respondents held more positive attitudes and stronger agreement with beliefs about bats, whereas these attitudes and beliefs were lowest among respondents >74 years of age. Male respondents' attitudes and beliefs were more positive toward bats and respondents with advanced academic degrees more strongly agreed with belief statements about bats (Table 3). We found no evidence that demographic variables predicted support for bat management (Wald ≤ 4.6, $p \geq .07$).

Encounters with Bats Within and Beyond the WUI

More respondents had encounters with bats both inside and outside KV (50%) than solely outside (32%) or inside KV (7%). Twelve percent had no encounters with bats. Most encounters (>70%) were indirect and positively received, which was reflected in written comments (e.g., "We've seen them flying around. We felt grateful and rewarded"). Ten percent of all respondents reported that bats had entered their homes and 6% found bats roosting on their property.

Overall, knowledge ($F_{3, 406} = 4.6$, $p = .004$), attitudes ($F_{3, 406} = 16.7$, $p < .001$), and beliefs ($F_{3, 406} = 22.9$, $p < .001$) varied across at least one component of previous encounters with bats (i.e., location, proximity, or emotion) (Table 4). Knowledge, attitudes, and beliefs were higher for those with bat encounters both inside and outside KV compared to encounters in one location or no encounters at all, and were highest for emotionally positive encounters with bats (Table 4). Knowledge was not associated with encounter proximity in KV yet was lower for those with no direct or indirect encounters outside of KV. Higher attitude and belief scores were associated with indirect encounters with bats regardless of location (Table 4). Positive emotions associated with past encounters predicted behavioral intention (Inside KV: Wald = 10.4, $df = 1$, ROC = .70, $p = .001$; outside KV: Wald = 7.1, $df = 1$, ROC = .69, $p = .008$). However, emotions did not predict support for bat management (ROC ≤ .48), and the location (ROC = .50) and proximity (ROC ≤ .56) of past encounters did not predict behavioral intentions or management support.

Discussion

Our findings highlight the importance of local context, social demographics, and experiences for identifying, tailoring, and implementing effective bat conservation and management approaches. We distill the findings of our study into three key implications regarding public knowledge, attitudes, beliefs, behavioral intentions toward bats, and support for bat management in the American WUI.

First, demographic variables (sex, age, education) and types of encounters between respondents and bats were associated with knowledge, attitudes, and beliefs. However, these variables were unrelated to behavioral intention whereas attitudes and beliefs were related to behavioral intention, aligning with other studies (Knight, 2008; Reid 2016; Sexton & Stewart, 2007). Although bats are often categorized as 'fear-relevant' animals regardless of demographics (e.g., Arrindell, 2000), we found that men reported more positive attitudes towards bats than women, coinciding with a large body of interdisciplinary literature that has documented similar gendered attitudinal trends towards bats (Davey, 1994; Kirkpatrick, 1984; Prokop et al., 2009). We also documented a reverse age-attitude trend as observed in previous studies (Bjerke & Østdahl, 2004; Davey, 1994). These gender and age differences could be related to multiple sources of variation, including social upbringing, anti-hunting support, fewer females in natural resource jobs, cultural gender-role stereotypes, gender sensitivity to animal cruelty, animal appearances, and nearly four decades of bat outreach (Kellert & Berry, 1987; Kirkpatrick, 1984; Knight, 2008; Medellín 2003; Tuttle, 1984). The number of potential sources of variations related to age, gender, and education level suggests there is a complexity to resident attitudes and beliefs towards bats that cannot be fully explained by quantitative surveys alone. For example, male Costa Rican farmers held more negative attitudes and beliefs towards bats than women (Reid, 2016), contrasting with our results. Yet similar to our results, Reid (2016) found that attitudes and beliefs correlated and predicted (negative) behaviors towards bats, suggesting that the context and relationship between attitudes and beliefs may more accurately predict behavioral intentions towards bats than gender and other demographic variables. Future studies may benefit from collection of qualitative data and methods that can extend quantitative interpretations, such as participant observation and complimentary ethnographic approaches (e.g., Castilla et al., 2020). As such, we recommend that individual demographic traits should not

be used as a primary basis for forming public bat outreach goals and behavior change campaigns, instead being used in concert with more contextual cues such as a community's recent history with human-wildlife interactions to avoid oversimplifying communication and messaging.

Second, demographic traits, knowledge, attitudes, and beliefs had little influence on respondents' support for bat management, which was highly varied in our dataset (Table 2). Public support for management is a complex process influenced by multiple factors, including social norms, individual species characteristics, and wildlife value orientations (Manfredo et al., 1998; Zinn et al., 2000). Our results contrast with others that found that support for bat management, either by agencies or individuals, was influenced by attitudes and beliefs (Fagan et al., 2018; Shapiro et al., 2020; Siemer et al. 2020). This may have resulted from respondents' uncertainty about what bat management might entail, and how it might affect them or their community. For example, Morzillo et al. (2010) similarly found that a lack of knowledge was the main reason for public uncertainty about black bear (*Ursus americanus*) management. Our focus on the general concept of bat management rather than a specific strategy provides insights into the values, beliefs, and conceptions respondents ascribed to wildlife management more broadly, "bat management" in particular (e.g., Shapiro et al., 2020), and even to the AZGFD. WUI residents' uncertainty suggests that there may be distinct differences in worldviews and value orientations towards bats and their management, which Knight (2008) and Siemer et al. (2020) found to be predictive of attitudes towards, and intentions to conserve, bats. However, the perceived trustworthiness, reliability, and responsibilities of AZGFD appeared to influence support for bat management in our study despite many respondents citing current strategies (e.g., habitat management, public education; AZGFD, 2021) in support of bat management. We suggest that future efforts to communicate with the public about bat management should be situated in an awareness of stakeholders' perceptions and knowledge of management agencies

coupled with direct examples and place-specific detail or contextualization. These approaches could allow residents in WUI and other developed areas to become more familiar with agencies and potential bat management approaches.

Third, knowledge, attitude and belief scores were higher among individuals who had indirect and positive affective encounters with bats (e.g., seeing bats) inside *and* outside of the WUI rather than in one location. This suggests that the WUI alone is an unlikely driver of positive views towards bats in this community. Instead, emotional learning that occurred during respondents' distanced encounters may have had a more profound impact on attitudes and beliefs toward bats than the physicality of encounters. Moreover, these findings may reflect the reported cognitive tendency for people to generalize their perceptions of birds to bats in order to fill in knowledge gaps about bats (Davis et al., 2013), which may have been reinforced by distanced encounters. There is also the equal possibility that individuals with more knowledge, positive attitudes, and beliefs about bats or higher education levels were more likely to recall positive experiences with bats, actively seek out opportunities for bat observation or interaction, or to respond to this survey. However, recent evidence from a sample of university students suggests that people recall more information about bats when it attached to negative portrayals, and most likely negative attitudes and beliefs, towards bats (Greving & Kimmerle, 2020). Millar and Millar (1996) noted that affective learning occurred more often in direct experiences with nature and cognitive learning occurred with indirect experience. This intuitively makes sense given that direct negative encounters with bats (e.g., unintended physical contact or property damage) often cause negative attitudes and human-bat conflicts (Conover, 1997; Kretser et al., 2009). However, direct encounters with bats are rare (e.g., Sexton & Stewart, 2007) and they did not influence the attitudes of the relatively few respondents in our study that had such encounters. These mismatches in the associations of knowledge, attitudes, and beliefs to encounters resulted from

two trends: 1) most respondents had real indirect encounters that were coupled with positive attitudes; and 2) respondents with more knowledge also reported more emotionally rewarding encounters with bats. This indicates that direct, real-life encounters with bats, facilitated by wildlife experts, could provide an untapped opportunity for respondents to use their knowledge to establish or enhance preexisting positive attitudes and beliefs toward bats. These results are consistent with the attitude-modifying qualities of direct experience (Millar & Millar, 1996; Duerden & Witt, 2010) and emphasize the importance of promoting positive affective associations with bats to foster positive views towards, and combat negative associations with, bats.

Management Implications for Human-Bat Interactions in the WUI and Beyond

The case study design of this survey effort means that there are limitations to the extent that we can generalize our findings. Residents in WUI communities experience circumstantial influences on attitudes toward wildlife that were not measured in this study. Residents may be more likely to interact with forest and wildlife management officials in WUI areas, particularly if there is an increased presence related to management activities (e.g., forest thinning). These unassessed interactions may have affected respondents' trust in wildlife management. The proximity of KV to a university (Northern Arizona University) and the higher percentage of Bachelor's degree recipients (56% compared to 29.5% in 2020; United States Census Bureau, 2020) also may have affected knowledge, attitudes, and beliefs about wildlife and increased access to wildlife expertise and scientific information, as observed in studies near Colorado State University (Sexton & Stewart, 2007), Texas State University (Taylor & Butler, 2007), and University of Florida (Pennisi et al., 2004).

KV is surrounded by public lands and national forests, like many WUI communities across the United States. Our work is particularly relevant to other WUI or exurban communities

in western North America in terms of community composition (distance to forested areas, wildfire severity levels; Theobald & Romme, 2007), attitudes toward bats (Gilbert, 1982; Sexton & Stewart, 2007) and potential rabies exposure (McCollum et al., 2012) – a conclusion that is also supported by potentially higher tolerance towards wildlife and bats among KV residents than communities in the eastern United States (Conover, 1997; Kretser et al., 2009; Sasse & Gramza, 2020; Siemer et al., 2020). We encourage further consideration of the role of unique or context-based factors on public perceptions and support for bat management in future studies; this could be explored through place-based scenarios or with questions that specifically address local vegetation, habitat, climate, or social conditions.

Conservation and wildlife management agencies will continue to conduct public bat education and outreach in the WUI as development into wildlands continues. Our results indicate that targeting conservation and management efforts towards younger residents could leverage preexisting positive attitudes and beliefs about bats while either activating or reinforcing latent intentions to conserve bats. These efforts should be designed to avoid the assumption that more knowledge alone will generate public support for management and conservation activities. Indeed, our results showed that knowledge levels were low and did not help predict management support or conservation intentions. This is important because efforts to engage the public and existing studies of perceptions about bats often conclude with a need for increased public education. However, there tends to be little exploration of how to adapt those approaches to address study findings; instead, education is applied as a panacea for low awareness or negative perceptions.

Given these considerations, fostering opportunities for residents to take action to support and learn about bat management can enable more sustainable long-term public involvement and support for bat protection. Public outreach efforts can expand on interactive techniques that build

on positive indirect experiences with bats such as agency-sponsored hikes in partnerships with local communities, theatrical and artistic activities (e.g., poetry and performances; Gómez-Ruiz et al., 2015), community-based monitoring initiatives (Robinson et al., 2010), and citizen science (e.g., online reports of house-roosting bats). These indirect experiences can translate into direct actions such as the construction of artificial roosts on participants' properties and the collection of data for bat conservation (e.g., Beeker et al., 2013). Moreover, inclusion or volunteerism in bat research (Taylor, 1999) allows nongame managers, such as the AZGFD, to demonstrate their expertise, clarify the meaning and intent of their bat management plans, establish greater public understandings of agency purpose and actions, and ground truth positive message framing to counteract negative information and perceptions of bats (Greving & Kimmerle, 2020; MacFarlane & Rocha, 2020; Siemer et al., 2020). These approaches can bolster public knowledge, confidence, and awareness of the social and ecological importance of local bat populations to support shared responsibility for their conservation.

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Table 1. Questions and values used to measure levels of knowledge, attitudes, and beliefs about bats to survey residents of Kachina Village, a northern Arizona wildland-urban interface community, in 2010.

Index questions	*M*	*SD*
Knowledge of bats		
Which of the following do you think bats eat? [a]	3.0	1.8
Attitudes toward bats (Cronbach's alpha = 0.94)	22.5	6.7
How safe or afraid would you feel if you encountered a bat in the wild? [b]	4.3	1.0
How safe or afraid would you feel if you encountered a bat in your neighborhood? [b]	4.3	1.0
If you have or had children, how safe or unsafe would you feel if your child or children came in close contact with a bat in the wild? [b]	3.5	1.4
If you have or had children, how safe or unsafe would you feel if your child or children came in close contact with a bat in your neighborhood? [b]	3.5	1.4
If you have or had pets, how safe or unsafe would you feel if your pet(s) came in close contact with a bat in the wild? [b]	3.4	1.4
If you have or had pets, how safe or unsafe would you feel if your pet(s) came in close contact with a bat in your neighborhood? [b]	3.4	1.4
Beliefs about bats (Cronbach's alpha = 0.78)	28.8	4.7
Bats are free to live wherever they occur naturally. [c]	4.5	0.9
Bats are important for a healthy ecosystem. [c]	4.7	0.6
I enjoy seeing bats near my home. [c]	4.2	1.1
It is best to avoid contact with a bat under all circumstances. [d]	2.5	1.3
Bat presence near my home increases my overall quality of life. [c]	3.8	1.2
Bats are an unacceptable threat to my family's and personal well-being. [d]	4.6	0.9
Knowing there are bats in my neighborhood reduces my overall quality of life. [d]	4.4	1.1

[a] Respondents chose from 11 bat dietary items: insects, fruit, nectar, leaves, bark, seeds, fruit, blood, birds, amphibians, reptiles, small mammals, and other bats; we deducted leaves, seeds, and bark from the final knowledge measure because they are not intentionally consumed by bats.
[b] Responses: 1 = very unsafe, 2 = somewhat unsafe, 3 = neither safe nor unsafe, 4 = somewhat safe, 5 = very safe.
[c] Responses: 1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree.
[d] Responses: 1 = strongly agree, 2 = somewhat agree, 3 = neither agree nor disagree, 4 = somewhat disagree, 5 = strongly disagree.

Table 2. Responses to questions about support for bat management in a northern Arizona wildland-urban interface, 2010.

Do you feel the bat population in Kachina Village should be managed by local wildlife organizations such as Arizona Game and Fish Department (AZGFD)?	
Responses (*n* = 406)	Justification (participant responses copied verbatim)
Yes (*n* = 155, 38%)	"Because they [bats] freak me out." "To keep ignorant people from killing them." "AZGFD is *supposed* to manage state wildlife." "To ensure safety and education for everyone and bats." "AZGFD can identify the suitable habitat and have expertise." "I don't want someone killing or poisoning them. Test for rabies. Due to white nose syndrome - watch their health."
No (*n* = 105, 26%)	"Leave nature alone!" "Budget monies should be spent elsewhere." They [AZGFD] are busy enough and doing a good job." "They're [bats] fine, government interference usually does more harm than good." "Only if it is meant to increase the population. Otherwise I don't care for how they [AZGFD] manage other species." "Unless the population is decreasing from unnatural causes I think they should be left alone or increased by offering them more places to roost."
Unsure (*n* = 146, 36%)	"How would they be managed?" "What do you mean by 'manage'?" "'Managed' as in 'killed off' or as in made to be over-populated for hunting?" "Not sure what 'managed' means with regards to bats or other wild creatures." "I think there are better groups. AZGFD seems more interested in game species than wildlife in general." "Depends on how they [bats] are managed and how it is handled. As long as there is no harm to them."

Table 3. Demographic associations with knowledge of bats (i.e., number of bat dietary items correctly selected by respondents), attitudes toward bats, and beliefs about bats in Kachina Village, a northern Arizona wildland-urban interface community, 2010*.

Demographics	Categories		Knowledge of bats				Attitudes toward bats				Beliefs about bats			
		n	*M*	*SD*	*F*	*p*	*M*	*SD*	*F*	*p*	*M*	*SD*	*F*	*p*
Gender	Male	174	2.8	1.8	0.8	.37	23.8	6.3	13.5	< .001	29.5	4.2	7.9	.005
	Female	215	3.0	1.8			21.3	6.9			28.1	5.0		
Age*	18–31	59	3.6^{A}	1.9	5.2	< .001	21.8^{AB}	16.5	5.7	< .001	28.9^{A}	4.3	5.0	.001
	32–45	122	3.1^{A}	1.7			24.5^{A}	17.5			29.8^{A}	4.0		
	46–59	133	2.9^{AB}	1.8			21.9^{B}	22.0			28.5^{A}	5.1		
	60–73	62	2.3^{B}	1.5			21.2^{B}	21.2			28.1^{A}	5.0		
	≥ 74	10	2.1^{AB}	1.4			17.1^{AB}	19.1			23.6^{B}	5.2		
Education*	Elementary	2	4.0	0.0	1.1	.35	20.0	2.8	2.0	.053	21.0^{AB}	0.0	3.9	< .001
	Some high school	4	3.0	1.8			19.5	4.4			24.3^{AB}	5.0		
	High school degree	19	2.5	1.5			22.3	7.2			28.0^{AB}	4.9		
	Vocational/trade	16	2.2	1.4			19.4	7.5			26.0^{A}	5.7		
	Some college	97	3.0	1.7			21.3	7.1			28.0^{AB}	5.3		
	Associate	34	2.8	1.4			21.2	6.5			29.0^{AB}	4.5		
	Bachelor’s	114	2.9	2.0			23.1	6.5			29.1^{AB}	4.1		
	Master’s/Ph.D.	104	3.2	2.0			24.0	6.4			30.0^{B}	4.2		
Children < 12 years of age in household	Yes	89	2.8	1.8	4.1	.45	22	6.0	.002	0.96	29	3.7	2.0	.16
	No	300	3.3	1.8			22	7.0			29	5.0		
Pet owner	Yes	315	3.0	1.8	2.9	.09	22.5	6.0	.06	.80	29.0	3.7	2.2	.14
	No	67	2.6	1.8			22.4	7.0			28.0	5.0		

*Values not sharing the same letters are statistically different (Tukey-Kramer HSD, $p \leq 0.05$).

Table 4. Associations between past encounters with bats and knowledge, attitudes, and beliefs about bats held by residents of Kachina Village, a northern Arizona wildland-urban interface community, 2010*.

Encounter	Categories		Knowledge of bats				Attitudes toward bats				Beliefs about bats			
		n	*M*	*SD*	*F*	*p*	*M*	*SD*	*F*	*p*	*M*	*SD*	*F*	*p*
Location	Inside KV	27	2.4^{AB}	1.8	4.6	.004	20^{AB}	6.5	16.7	< .001	28^{A}	4.4	23.0	< .001
	Outside KV	129	2.9^{AB}	1.7			22^{B}	6.4			28^{A}	4.7		
	Both^	203	3.2^{A}	1.9			24^{C}	6.5			30^{A}	3.5		
	None	51	2.4^{B}	1.7			18^{A}	6.8			25^{B}	6.1		
Proximity	Inside KV													
	Direct	36	2.8^{A}	1.6	2.3	.11	22.4^{AB}	6.8	13.0	< .001	28.5^{AB}	4.6	20.2	< .001
	Indirect	187	3.2^{A}	1.8			24.1^{A}	6.1			30.2^{A}	3.4		
	None	187	2.8^{A}	1.8			20.7^{B}	6.9			27.3^{B}	5.3		
	Outside KV													
	Direct	87	3.1^{A}	1.9	3.7	.03	21.3^{A}	6.8	17.8	< .001	28.6^{A}	4.2	19.5	< .001
	Indirect	230	3.1^{A}	1.8			24.0^{B}	6.1			29.7^{A}	3.9		
	None	93	2.5^{B}	1.7			19.5^{A}	7.1			26.3^{B}	5.9		
Emotion	Inside KV													
	Positive	187	3.2^{A}	1.8	2.7	.04	24.9^{A}	5.6	21.3	< .001	30.7^{A}	3.0	33.7	< .001
	Negative	13	1.9^{A}	1.0			14.3^{B}	5.4			24.4^{BC}	4.0		
	Neutral	28	2.7^{A}	2.0			20.6^{C}	6.0			27.1^{B}	4.0		
	No opinion	6	2.7^{A}	3.1			16.2^{BC}	6.3			22.2^{C}	6.2		
	Outside KV													
	Positive	242	3.3^{A}	1.8	6.4	< .001	25.0^{A}	5.3	34.2	< .001	30.8^{A}	2.8	63.3	< .001
	Negative	41	2.1^{B}	1.2			17.2^{B}	6.9			24.9^{B}	4.9		
	Neutral	39	2.7^{AB}	1.7			19.0^{B}	6.4			25.9^{B}	4.4		
	No opinion	8	2.0^{AB}	2.3			16.6^{B}	5.4			21.5^{C}	6.1		

*Values not sharing the same letters are statistically different (Tukey-Kramer HSD, $p \leq 0.05$).

^Refers to respondents that experienced bat encounters inside and outside of KV