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ABSTRACT

Bat species and their populations are declining globally due to a variety of anthropogenic activities. Human activities, motivated by negative attitudes toward, perceptions of, and poor knowledge and appreciation of these animals, have a major effect on their conservation. Thus, it is important to improve our understanding of bat–human interactions to help design appropriate bat conservation measures. We investigated human–bat interactions in a sample (n = 423) of people living around the Omo Forest Reserve and the International Institute of Tropical Agriculture in Southwestern Nigeria. People who considered themselves more vulnerable to disease transmission from bats held more negative perceptions of and beliefs about bats. A major finding in this study suggests that respondents' perceived vulnerability to diseases from bats did not correlate with destructive behaviors toward bats. Participants with a low level of education intentionally killed more bats than those with a higher level of education. The majority of the participants did not appreciate the role of bats in ecosystems and had a poor understanding of bats' niche in nature and the resulting benefits for humans. We suggest that positive messages that neutralize superstition and myths and highlight the role of bats in ecosystems are *urgently* needed. They could lead to behavioral changes that benefit bats.

KEYWORDS

Chiroptera; conservation; disease risk; human–animal interaction; myths; wildlife

Certain wildlife species are the target of human hostility due to the proliferation of myths and beliefs that convey negative emotions and attitudes toward them. These interactions in turn result in low tolerance and intentional killing of animals (Alves et al., 2012; Aziz et al., 2017; Ceríaco, 2012; Ferreira et al., 2013; Tarrant et al., 2016). Many beliefs, myths, and oral traditions are passed down through generations; they carry positive and negative

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messages that impact bats and many other wildlife species (Musila et al., 2018; Prokop et al., 2009a, b; Remmele & Lindemann-Matthies, 2018). Alarmingly, people seem unwilling to modify their controversial views of animals such as bats (de Oliveira et al., 2019).

Historically, myths, beliefs, and superstitions have been created and practiced as a mechanism to understand and counteract human ailments (Halla et al., 2019). For example, in some African nations, there is widespread belief that witchcraft is both the cause and cure of diseases (Ackoff, 1953). Bats are notoriously shrouded in myths and beliefs (Kingston, 2016; Musila et al., 2018; Prokop et al., 2009) and are widely used in traditional medicine practices that involve the use of meat or blood (Mildenstein et al., 2016; Suwannarong et al., 2020a). Beliefs in magical powers may function as part of a disease-avoidance mechanism (Prokop & Kubiatko, 2014; Toth, 2019), and having these beliefs may motivate individuals to act aversively to avoid contamination in the presence of environmental cues of disease transmission.

Some research indicates that humans are responsible for a global decline in bat populations due to habitat loss, climate change, diseases, and bush meat hunting and consumption (Frick et al., 2020; Ripple et al., 2016). For instance, it has been determined that overhunting caused the extinction of at least three Old World fruit bat species (Mildenstein et al., 2016). Bushmeat consumption, however, is perceived as a risky practice in terms of zoonotic disease transmission (Baudel et al., 2019; Kamins et al., 2011; Leroy et al., 2009; Mickleburgh et al., 2009). It is suggested that a perceived risk of disease transmission could reduce the hunting of wild animals (Duonamou et al., 2020; Evans et al., 2020). Nevertheless, the misunderstanding of bats as reservoirs of zoonotic diseases has led to their persecution worldwide. This misconception continues to occur despite that notable human pathogens such as SARS-CoV-1 and SARS-CoV-2 have not been detected in bats (Shapiro et al., 2021). Hence, the relationship between perceived vulnerability and myths and beliefs about bats is still not clear. By looking at the existing myths and beliefs about bats, we find that there is a scarcity of evidence associating bat meat consumption and hunting with disease transmission.

Attitudes and behaviors toward wild animals are influenced by gender differences (Kellert & Berry, 1987; Prokop & Randler, 2018). For instance, it has been suggested that men and individuals with low educational levels eat bush meat more often than women and highly educated individuals (Akem & Pemunta, 2020; Friant et al., 2015; Suwannarong et al., 2020b; but see Luiselli et al., 2019). From another perspective, it is proposed that women have lower preferences for unpopular animals because they may pose a disease transmission risk or are predatory (Prokop & Randler, 2018). Women typically prefer cute and harmless animals, while men have preferences for unpopular animals, such as spiders, mice, or large carnivores (Lindemann-Matthies, 2005; Prokop & Tunnicliffe, 2010). Ultimately, women are expected to be more cautious than men because of the role they play in child rearing in the community; therefore, they must protect not only themselves but also their offspring (Curtis et al., 2004). In fact, women are significantly more opposed than men to keeping bats in their homes (Lim & Wilson, 2019; Lundberg et al., 2021). There is, however, a scarcity of research on the vulnerability of women to disease transmission from bats.

Education level is another important predictor of human attitudes toward animals (Kellert, 1993; Røskaft et al., 2003). Low educational attainment is often associated with

negative attitudes toward animals and with the harboring of beliefs, myths, and superstitions (Alves et al., 2014; Hassan et al., 2020; Moura et al., 2010; Pinheiro et al., 2016; Tarrant et al., 2016), as well as with the tolerance of unpopular animal species (Onyishi et al., 2021) and with their direct persecution (Ceríaco, 2012). The role of education in the formation of attitudes toward bats is somewhat mixed. While some studies show a positive relationship with education (e.g., Boso et al., 2021; Liordos et al., 2021; Musila et al., 2018), others do not (Lu et al., 2021; Lundberg et al., 2021; Shapiro et al., 2020). Nonetheless, it is unclear whether less-educated individuals manifest more mythological beliefs about bats than people with high educational attainment.

Experiences with animals and exposure to nature may have a considerable influence on attitude formation in favor of or against animals (Kendall et al., 2006). As compared with urban areas, rural communities generally lack good hygiene and its residents have a low awareness about zoonoses (Duonamou et al., 2020; Xiang et al., 2010). Concurrently, there are lower formal educational levels and little or no access to media (Pinheiro et al., 2016; Zhang et al., 2014). Some studies suggest that people in urban communities tend to have more positive perceptions of wild animals than their counterparts in rural settings (Bandara & Tisdell, 2003; Bjerke et al., 1998; Randler et al., 2020; but see de Oliveira et al., 2019).

Research on the aforementioned is location-specific because reports on disease-mediated (Ebola, COVID-19) pandemics contribute to the generation of negative attitudes toward and persecutions of bats that can spread rapidly across the globe (Guyton & Brook, 2015; Lu et al., 2021; MacFarlane & Rocha, 2020; Rocha et al., 2021a). Likewise, local folklore and myths and beliefs about bats can negatively affect their conservation (da Costa Rego et al., 2015; Kingston, 2016; Lu et al., 2021). However, it is unclear what exactly is the perception of these animals among residents of rural and urban areas. Therefore, this study aimed at investigating human–bat interactions and exploring the knowledge that people in rural and urban communities possess about bats and the reactions they have toward bat conservation measures. We formulated specific objectives to determine:

(1) The association between level of perceived vulnerability to disease (PVD) and myths and beliefs about bats. Given that bats seem to raise disease transmissibility concerns (e.g., Shapiro et al., 2021), we predicted a positive relationship between PVD as an indicator of myths and beliefs about bats among study participants in rural and urban areas.
(2) The prevalence of bat meat consumption and hunting in relation to gender and formal education. We predicted that men hunt and eat more bat meat than women.
(3) The relationship between women feeling vulnerable to disease transmission from bats and the myths and beliefs they profess. We predicted that women feeling more vulnerable to disease transmission from bats and avoiding them is based on their beliefs about these animals.
(4) The relationship between levels of education and mythological beliefs about bats. We predicted it would be negative.
(5) The behaviors (positive or negative) toward bats in rural and urban communities. We predicted that respondents from rural areas would perform more negative behaviors toward bats than their urban counterparts.

Methods

The questionnaire and methods used in this study were submitted to and approved by the Department of Wildlife and Ecotourism Management, University of Ibadan, and the Forestry Research Institute of Nigeria.

Study Area

This study was conducted in different communities of the Omo Biosphere Reserve (OBR) and around the International Institute of Tropical Agriculture Forest Reserve (IITAFR) in the metropolitan area of Ibadan city. The OBR covers about 130,500 hectares and is in South-western Nigeria. It is a UNESCO Biosphere Reserve, a biodiversity hotspot, and a Key Biodiversity Area (KBA). The vegetation type in the reserve broadly includes mixed, moist, semi-evergreen rainforest zones, but massive logging of the indigenous rainforest that has occurred over the years has created extensive monoculture plantations and farmlands (Chima & Ihuma, 2014). There are over 300 agricultural settlements within the reserve. Likewise, there are three major land uses within the reserve: the Strict Nature Reserve (SNR), arable farming areas initially established for taungya farming with an enclave (AF), and monoculture plantations which consist of Cocoa plantations, *Pinus caribaea* plantation, *Tectona grandis* plantation, *Gmelina arborea* plantation, and *Nauclear diderichii* plantation.

The IITAFR is located within the Institute of Tropical Agriculture campus (IITA), north of the Ibadan metropolitan area. It covers about 1000 hectares. The reserve is a relic of secondary, dry, semi-deciduous rainforest covering about 360 hectares (Adeyanju et al., 2014) surrounded by research plots. There are both modern housing as well as ancient housing in villages and farmlands belonging to the original settlers (Osunsina et al., 2012).

Selection of Study Sites

According to IUCN, the straw-colored fruit bat (*Eidolon helvum*) is a species approaching threatened status. This species prefers to congregate in roosting places close to human settlements, with colonies of varying sizes, during the dry season for about six months (Adeyanju, pers. comm.). By the end of this period, the annual migration begins, which occurs at the beginning of the wet season (Fahr et al., 2015; Thomas, 1983). Eight communities were purposely chosen for the study in the two study sites. This decision was based on the proximity to a forest reserve with visible bat roosting places and within a distance of at least 3–5 km. At OBR, questionnaires were administered to residents living around the nature reserve sections (Figure 1). At Ibadan, the questionnaires were administered to residents living around the IITAFR (Figure 2).

Procedure

The study was conducted in 2019, between the months of May and December. We used a convenience sampling method (Taherdoost, 2016) and targeted individuals aged 18 years and older. A pilot study was carried out in Ibadan, where we randomly chose 20

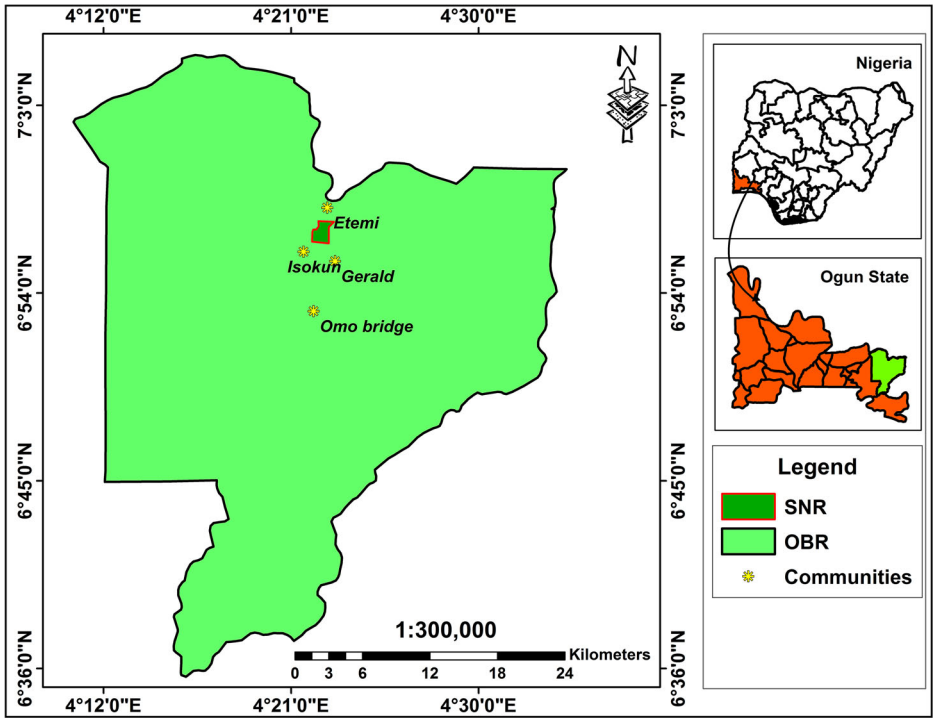

Figure 1. Map showing the communities where the study was carried out in Omo Biosphere Reserve, Ogun State, Nigeria. SNR = Strict Nature Reserve.

participants, to test the validity of the questionnaire and ensure that the questions were understandable. We wanted participants to be able to clearly report on their attitudes and behaviors toward, and traditions regarding, bats. The questionnaire was improved based on the comments made by the participants. Items from the questionnaire can be found in Table 1 and in the online supplemental file.

This study aimed at a sample size based on similar research in this field (e.g., Musila et al., 2018). The elders and community leader of OBR authorized the research team to administer the questionnaires and interview participants. Study participants were approached in their homes, offices, and farms by the researchers, and those who accepted to be involved in the study were given the questionnaire to complete, while other members of the research team helped the older participants and those who were unable to read or write. We explained to each participant the purpose of the survey and they were assured about the confidentiality of their responses. An interpreter assisted participants who could not read or write in English, especially those who spoke Yoruba and Hausa languages, and then filled the responses to each question on their behalf.

Questionnaire Design

The questionnaire contained four sections: respondent's demographic information (age, gender, place of residence [urban or rural], and number of children in the family) and

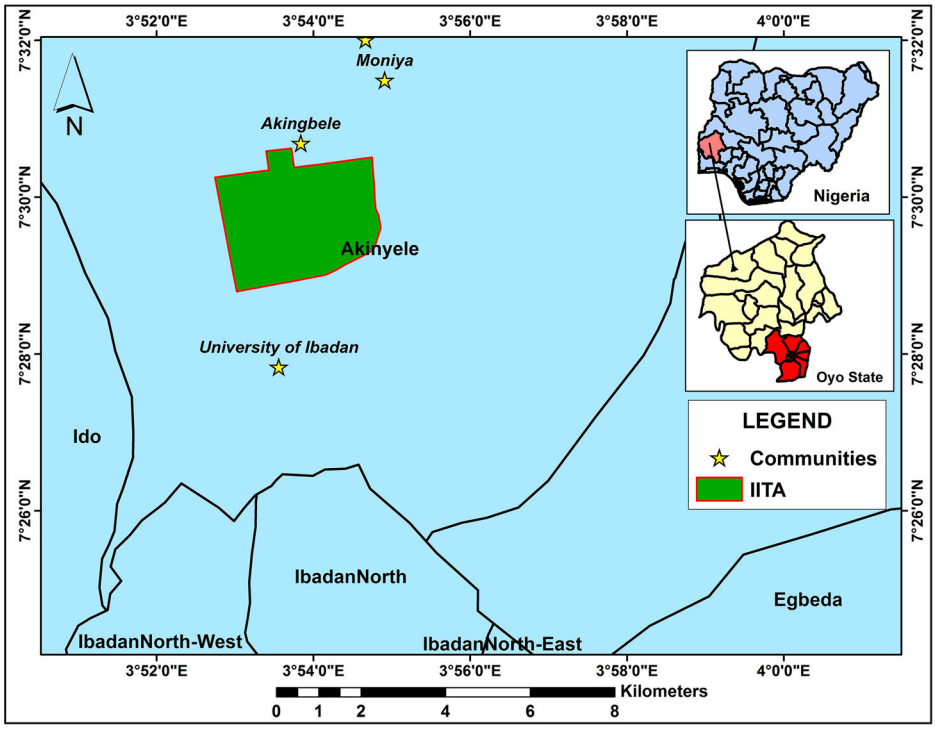

Figure 2. Map showing the communities where the study was carried out in Ibadan metropolis with reference to the International Institute of Tropical Agriculture Forest Reserve (IITAFR), Oyo State, Nigeria.

general knowledge; specific knowledge of basic facts about bats and their biology; cultural beliefs and superstitions; and perceived vulnerability to diseases. Several questions assessed experiences with bats.

Bat–Human Encounters

Bat–human encounters were examined with one item: How often do you see bats around your community? We were also interested in the places where bats were found most frequently and the benefits bats have for people. Participants also reported on whether they were aware of any traditional beliefs about bats in their communities, of bats used as a food source, or of bats as resources from the forest.

Myths and Beliefs About Bats

Myths about animals differ between countries (e.g., Herzog & Burghardt, 1988; Prokop et al., 2009). We developed a questionnaire consisting of nine items reflecting perceptions of bats in some parts of Nigeria (e.g., "Bats are ghosts," see Table 1 for more details). Participants indicated their level of agreement with each item on a 1 (strongly disagree) to 5 (strongly agree) scale. High scores indicate stronger beliefs about bats. We conducted a factor analysis to determine whether beliefs constituted a single or multiple factor structure. We extracted factors based on an Eigenvalue > 1 criterion and applied a Varimax

Table 1. Results of factor analyses of items measuring mythological beliefs and perceived vulnerability to diseases from bats.

		Factor loadings	
		1	2
	Mythological Beliefs		
Factor 1 Bats as ghosts	Bats as ghosts	0.68	0.01
	Bats brings bad luck to people	0.82	0.002
	When you see a bat in your house, it was sent by your enemy to harm you	0.78	–0.007
	If a bat urinates on someone, he/she becomes powerless	0.57	0.2
	It is a bad omen if bats start living in your new house before you move in	0.56	0.16
Factor 2 Medical benefits from bats	Traditional doctors use bats to cast spells or for other traditional purposes	0.19	0.82
	Body parts of bats are used by witchdoctors to cast spells on people	0.19	0.79
	Eating bat meat helps in the treatment of fertility problems in men and women	–0.009	0.75
	The presence of bats in my area is a sign of peace	–0.03	0.67
	Perceived Vulnerability to Diseases from Bats		
Factor 1 Bat aversion	I would share a water bottle with someone handling bats with bare hands	0.79	0.02
	I would write with a pen used by someone handling bats with bare hands	0.76	0.17
	I do not think my hands are dirty after touching bats with bare hands	0.67	0.08
	I would never get sick even if I ate a bat bought from the market	0.64	0.03
Factor 2 Perceived disease transmissibility from bats	I would never go near a friend who suffers from a headache after touching a bat	0.04	0.96
	I would never go into the house of a friend who suffers from headaches after entering a cave with many bats	0.14	0.95

rotation. Two factors emerged that accounted for 30% and 18% of the total variance (Eigenvalues = 3.35, 1.94). Factor 1 was comprised of five items reflecting the belief that bats are ghosts (Table 1). These items demonstrated good reliability and were grouped to form a composite variable, which we named *Bats as Ghosts* ($\alpha = 0.77$). Factor 2 was comprised of four items reflecting the use of bats in traditional medicine (Table 1). These items showed good reliability and were grouped to form a composite variable named *Medicinal Benefits from Bats* ($\alpha = 0.76$).

Perceived Vulnerability to Diseases from Bats

This questionnaire section was based on the PVD Inventory developed by Duncan et al. (2009). The original PVD consists of 15 items grouped into two subscales: susceptibility to infectious diseases (Perceived Infectability [PI]; 7 items), and emotional discomfort in contexts that suggest an especially high potential for pathogen transmission (Germ Aversion [GA]; 8 items). We modified most of the original items to assess disease transmission from bats. High scores indicate a stronger perceived vulnerability to diseases. We extracted factors based on an Eigenvalue > 1 criterion and applied a Varimax rotation. Fifteen items were originally loaded on four factors. After deleting items which loaded on two or more factors simultaneously, a factor analysis was run again and two factors emerged accounting for 40% and 30% of the total variance (Eigenvalues = 2.37, 1.56). Factor 1 comprised four items, similar to those in the Germ aversion subscale (Table 1). These items showed

acceptable reliability and were grouped to form a composite variable, which we named *Bat Aversion* ($\alpha = 0.69$). Factor 2 consisted of two items reflecting susceptibility to infectious diseases (Table 1). These items showed good reliability and were grouped to form a composite variable named *Perceived Transmissibility from Bats* ($\alpha = 0.91$).

Data Analysis

We computed medians for ordinal variables and conducted frequency distribution analyses for categorical variables. The mythological beliefs and vulnerability to diseases data were categorized as interval and were not normally distributed. Thus, ordinal regression analyses (Jamieson, 2004) were conducted to examine predictors of mythological beliefs or vulnerability to diseases (ordinal outcome variable). We regressed simultaneously conservation mythological beliefs scores and perceived vulnerability to diseases scores onto the following variables: participant's age, education, frequency of encounters with bats, place of residence (urban/rural), and gender. Domains of perceived vulnerability to diseases were set as additional predictors of mythological beliefs and vice versa. Because the outcome variable had a binomial distribution (yes/no), binary logistic regression analyses were conducted to examine predictors of intentional killing of bats, hunting of bats, and eating of bat meat. Nagelkerke R^2 was used to examine the explained variance of the regression results. All statistical analyses were performed using STATISTICA Version 12.0 and R.

Results

A total of 423 respondents (310 men and 113 women) participated in the study, with 264 of them from OBR (rural group) and 159 from the metropolitan area of Ibadan city (urban group). Samples sizes were unequal because rural residents, unlike their urban counterparts, were more willing to participate in the study. The participants included students, farmers, hunters, traders, timber contractors, government employees, and private workers, and 95% lived in the southwestern region, while the rest were from the eastern and northern parts of the country. The mean number of children was 1.4 ($SE = 0.1$, $n = 423$). In terms of educational level, responses were coded as follows: 1 = none ($n = 62$), 2 = primary ($n = 51$, intended for 6–12 years old), 3 = secondary ($n = 124$, intended for 12–18 years old), 4 = college ($n = 41$), 5 = university ($n = 145$). In the context of this study, college education refers to polytechnic schools (OND and HND).

There were significant differences in educational attainment and mean age among the participants. Urban respondents were significantly more educated than the rural respondents (Chi-square test, $\chi^2 = 245.6$, $df = 1$, $p < 0.001$), and the mean age of urban respondents was significantly lower than the mean age of rural respondents (ANOVA, $F_{(1,\ 421)} = 219.24$, $p < 0.001$, Table 2).

Common Beliefs About Bats

Participants reported both positive and negative beliefs about bats. A significant number of respondents (77/423, 18%) shared that bats are used in traditional medicine. These

Table 2. Descriptive characteristics of the rural and urban respondents.

	Mean age (± 95% CI)	Gender		Educational level	Number of children	*n*
		Male	Female			
Rural	43 yrs (42–45)	221	43	2.6 (2.5–2.7)	2 (1.7–2.2)	264
Urban	25 yrs (23–27)	89	70	4.7 (4.5–4.8)	0.5 (0.2–0.8)	159

Note: For educational level, 1 = none, 2 = primary (6–12 years old), 3 = secondary (12–18 years old), 4 = college, 5 = university.

beliefs were common, especially among participants from urban communities (Table 3). Eight percent (34/423) of the participants reported that bats are used to treat human infertility. Interestingly, this belief was found exclusively among men and significantly more common in rural people (Table 3). Another 7% of participants (29/423) perceived bats as abnormal creatures (particularly men from rural areas, Table 3), and 2.3% (10/423) identified bats as a source of meat. For 5% of the participants (19/423), bats were sources of disease, poison, or destruction. Fourteen participants (3.3%) reported common misconceptions about bats, such as "bats are flying rats," "bats do not have an anus," and "bats are blind." About 10.4% of the respondents (44/423) shared positive beliefs, such as "bats cure diseases," "bats are good animals," and "signs of ushering peace." About half of the participants (196/423, 46%) did not report any beliefs about bats.

Benefits of Bats for People

We found that utilitarian views of bats prevailed. For instance, bats were mostly identified as sources of bushmeat and/or income when they are sold (148/423, 35%). These observations were more common among men from rural areas (Table 4). Bats were perceived as bushmeat and as resources in traditional medicine (44/423, 10.4%) by participants, regardless of place of residence or gender (Table 4). Only one participant (0.2%) reported that bats were beneficial for tourism; seven participants (1.7%) reported that bats destroy trees or cause disease. About 7.5% of the total sample (32/423) addressed ecological benefits from bats that included pollination, seed dispersal, and pest control. There were no differences in the perceived ecological value of bats between urban and rural residents or between men and women (Table 4). Responses from 11 participants (2.6%) were rather mixed (bats used as pets, sources of fat, used for security or alertness of danger or pollute air); the remaining 180 participants (42.6%) did not view bats as beneficial to people.

Table 3. Prevalence of common beliefs about bats by residence and gender. Values are sample sizes, with percentages (%) in parentheses.

	Residence		χ^2	Gender		χ^2
	Urban	Rural		Male	Female	
Traditional medicine	37 (23)	40 (15)	4.4*	50 (16)	27 (24)	3.4^{ns}
Human infertility	5 (3)	29 (11)	$p < 0.01$	34 (11)	0 (0)	$p < 0.001$
Abnormal animals	0 (0)	29 (11)	$p < 0.01$	28 (9)	1 (0.9)	$p < 0.01$

Note: The chi-square (χ^2) test was only used for "traditional medicine." For "human fertility" and "abnormal animals," owing to small sample sizes, the Fisher exact test was used. *$p < 0.05$, *ns* = not significant.

Table 4. The reported benefits of bats by residence and gender. Values are sample sizes, with percentages (%) in parentheses.

	Residence		χ^2	Gender		χ^2
	Urban	Rural		Male	Female	
Bushmeat and/or income	31 (19)	117 (44)	27***	116 (37)	32 (28)	21.5***
Bushmeat/traditional medicine	11 (7)	33 (13)	3.3^{ns}	35 (11)	9 (8)	1^{ns}
Ecological benefits	8 (5)	24 (9)	$p = 0.13$	28 (9)	4 (4)	$p = 0.06$

Note: Chi-square (χ^2) tests were done only for "bushmeat/income" and "bushmeat/traditional medicine." For "ecological benefits," owing to small sample sizes, the Fisher exact test was used. ***$p < 0.001$, *ns* = not significant.

Intentional Killing of Bats

About half of the participants (199 of 423, 47%) indicated that they had bats in their farms. These reports came significantly more frequently from participants in rural areas (60%) than from those in urban settlements (24%) (Chi-square test, $\chi^2 = 53.7$, $df = 1$, $p < 0.001$). This subsample of participants was included in subsequent statistical analyses. Hostile behavior toward bats was quite common: more than one-third of farm owners (36%) reported killing bats, and 22% reported destroying their resting places. About 40% of the respondents did not disturb bats and very few (1%) contacted responsible government agencies. When data on bat killing were compared with non-killing data (destroying resting places, no action, and contacting responsible government agencies), multiple logistic regression with all possible predictors (bats as ghosts, medicinal benefits from bats, bat aversion, perceived susceptibility to diseases from bats, participant's age, educational level, frequency of encounters with bats, residence and gender) showed that people with low levels of education killed bats more often than those with higher levels of education (Wald $\chi^2 = 4.14$, $p = 0.04$, Nagelkerke $R^2 = 0.1$). Intentional killing of bats was associated with hunting: 66 out of 73 people (90%) who reported killing bats on their farms also indicated that bats are hunted in their communities, but significantly fewer participants (86/124, 69%) of those who did not kill bats also reported that bats are hunted in their communities (Chi-square test, $\chi^2 = 9.01$, $df = 1$, $p = 0.003$). Similarly, 68 out of 75 respondents (91%) who reported killing bats on their farms also admitted to eating bat meat. However, a reduced number of respondents (93/127, 73%) of those who did not kill bats also reported that bats are used as a food source in their communities (Chi-square test, $\chi^2 = 7.42$, $df = 1$, $p = 0.001$, Figure 3).

Hunting and Eating of Bats

More than half of the respondents (249/423, 59%) acknowledged that bats are hunted in their communities, and 67% of them (283/423) reported that bats are used as a food source in their region. Both of these activities were more frequently reported by rural participants and by men as compared with women from urban settings (Table 5). There is an apparent inter-dependence between reported hunting and eating of bats: 239 out of 249 people (96%) who indicated hunting bats in their communities also reported using them as a food source; however, the reported eating of bats was rare (44/174, 25%) among people who did not admit to hunting bats. Bat hunting was more prevalent in men (204/310, 66%) than in women (45/113, 40%). Out of 283 participants reporting the

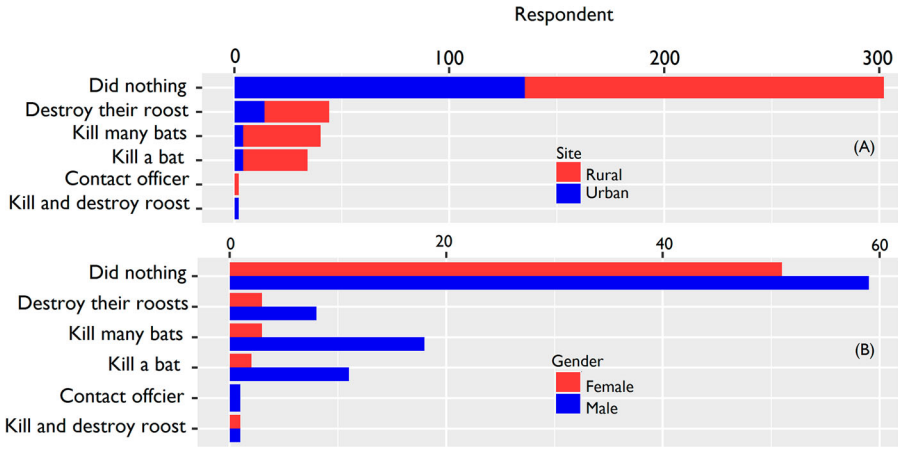

Figure 3. Reported behavior of respondents toward bats, by site and gender, in Omo Biosphere Reserve (rural) and Ibadan (urban).

consumption of bat meat, 33% (94/283) indicated that up to 20% of people in their communities engaged in this eating habit; 16% (45/283) said that this habit was common in 20–25% of the people in their communities; 23% suggested that the number was 50–70%; and 28% of the participants indicated that this practice occurred in >70% of the population in their communities.

Greater Vulnerability to Diseases from Bats Positively Correlates with Myths and Beliefs About Bats

The zero-order correlation (Spearman) between the *Bats as Ghosts* total score and the *Bat Aversion* total score was not significant ($r_s = 0.06$, $p = 0.19$, $n = 423$). However, the relationship with the *Perceived Transmissibility of Diseases from Bats* total score was significant ($r_s = 0.28$, $p < 0.0001$, $n = 423$). These results provide some evidence that mythological beliefs correlate with the perceived vulnerability to diseases from bats. Furthermore, we conducted an ordinal regression analysis to examine the relationship between the *Bats as Ghosts* total score and the possible predictors (Table 6). People more vulnerable to diseases (in both subscales) held more negative beliefs about bats. Myths perceiving *Bats as Ghosts* were more prevalent in women and in individuals with a low educational level. Age, frequency of encounters with bats and place of residence were not associated with the *Bats as Ghosts* subscale. The additional interaction term Gender × Bat Aversion

Table 5. Prevalence of hunting and eating of bats by residence and gender. Values are sample sizes, with percentages (%) in parentheses.

	Residence		X^2	Gender		X^2
	Urban	Rural		Male	Female	
Hunting	55 (34)	194 (73)	62***	204 (66)	45 (40)	23***
Eating	77 (48)	206 (78)	39***	224 (72)	59 (52)	26***

***$p < 0.001$.

Table 6. Ordinal regression analysis results and summarized scores for *Bats as Ghosts* and *Medicinal Benefits from Bats*.

	Bats as Ghosts				Medicinal Benefits from Bats			
Parameters	*df*	Wald χ^2	*p*	Estimate	*df*	Wald χ^2	*p*	Estimate
Intercept	20	564.5	< 0.0001	−1.36	16	577.8	< 0.0001	−2.71
Perceived disease transmissibility	1	26.7	< 0.0001	0.09	1	2.08	0.13	0.03
Bat aversion	1	5.12	0.016	0.03	1	9.02	0.002	−0.04
Age	1	0.27	0.60	−0.002	1	0.16	0.69	0.002
Encounters with bats	1	0.81	0.37	−0.03	1	25.57	< 0.0001	0.14
Education	1	39.1	< 0.0001	−0.32	1	13.17	< 0.001	−0.18
Residence (urban/rural)	1	0.38	0.54	0.05	1	29.32	< 0.0001	0.46
Gender	1	5.53	0.019	0.14	1	1.47	0.25	0.07

was not significant (Wald $\chi^2 = 1.14$, $p = 0.29$, estimate = –0.01); however, the interaction Gender × Perceived Transmissibility of Diseases from Bats was significant (Wald $\chi^2 = 9.44$, $p = 0.002$, estimate = 0.06). Further inspection of these results revealed that men who were more vulnerable to diseases from bats also scored higher in the *Bats as Ghosts* domain. Women's scores were not influenced by perceived transmissibility of diseases from bats.

The zero-order correlation (Spearman) between the *Medicinal Benefits from Bats* total score and the Bat *Aversion* total score was significant ($r_s = -0.34$, $p < 0.001$, $n = 423$). However, the relationship with *Perceived Susceptibility to Diseases from Bats* total score was not significant ($r_s = -0.04$, $p = 0.44$, $n = 423$). Next, we conducted an ordinal regression analysis to examine the relationship between the *Medicinal Benefits from Bats* total score and the possible predictors (Table 6). Individuals more vulnerable to diseases (in the *Bat Aversion* subscale) held fewer beliefs that bats had medicinal value. Those beliefs about bats were more prevalent in people with little or no formal education. Frequent encounters with bats showed a positive correlation with greater beliefs measured by the *Medicinal Benefits from Bats* subscale. Rural people held more beliefs in the *Medicinal Benefits from Bats* subscale than urban participants (Table 6). Age and gender were not associated with the *Medicinal Benefits from Bats* subscale; however, when the participant's place of residence was removed from the model, the effect of age became significant (estimate = 0.29, 95%CI [0.19–0.38], $p < 0.001$). Older people held more beliefs about the benefits of bats than younger people. The additional interaction terms Gender × Bat Aversion and Gender × Perceived Disease Transmissibility from Bats were not significant (Wald = 0.60 and 0.42, $p = 0.43$ and 0.51, estimate = –0.01 and –0.01, respectively).

Discussion

Our first hypothesis dealt with participants' PVD, which results from the myths and beliefs they have about bats. It is believed that bats bring bad luck, such as diseases or death (Boso et al., 2021; Lu et al., 2021; Lundberg et al., 2021; Prokop & Tunnicliffe, 2008). Perceived vulnerability to diseases has a positive correlation with disease cues in the environment (Faulkner et al., 2004; Prokop et al., 2010; Prokop & Kubiatko, 2014); however very few studies have investigated the association with mythological beliefs. From a conservation perspective, these associations seem plausible, especially when considering that

human behavior toward bats can be influenced by various myths and superstitions. We found support for our hypothesis: a significant positive correlation between *Bats as Ghosts* and the *Perceived Susceptibility to Diseases from Bats* domains. However, when the emotional discomfort from pathogen transmission from bats was high (*Bat Aversion* subscale), the *Beliefs About the Medicinal Value from Bats* were low. These results provide direct evidence that health concerns negatively affect public perception of wildlife (Buttke et al., 2015; Decker et al., 2011; Lundberg et al., 2021), which could potentially jeopardize public support for conservation of controversial animal species like bats (MacFarlane & Rocha, 2020; Rocha et al., 2021a, 2021b).

In this study, men had more postive perceptions about bats, which is in stark contrast with our original expectations. Our initial assumption was that because women are expected to be more sensitive to disease cues than men (Curtis et al., 2004), the influence of perceived vulnerability to diseases on mythological beliefs should be stronger in women than in men. Contrary to our expectation, we found that mythological beliefs in the *Bats as Ghosts* domain positively correlated with men's perceived susceptibility of infections from bats. This association was not found among women. One possible explanation is that men are in physical contact (hunting and intentional killing) more often than women (Baudel et al., 2019; Duonamou et al., 2020; Kamins et al., 2011; Musila et al., 2018; Shapiro et al., 2020). From a general perspective, this result questions a common assumption that higher disgust sensitivity in women is an adaptation to avoid disease and ultimately a strategy to protect their offspring.

Participants with low educational attainment were expected to have more mythological beliefs about bats than people with higher levels of education. In this study, participants with lower educational levels engaged in intentional killing of bats more often than people with higher educational levels, which corresponds with findings in other research studies on wildlife animals (Ceríaco, 2012; Onyishi et al., 2021). Findings in Cameroon's study showed that, despite acknowledging Ebola as a transmissable disease to humans through capturing, handling, or consumption of bushmeat (LeBreton et al., 2006; Van Vliet et al., 2017), the majority of the participants did not consider this practice as dangerous (Baudel et al., 2019). In this study, these activities were more common in men than in women, which is a finding reported in previous research (Akem & Pemunta, 2020; Suwannarong et al., 2020b). Deeper understanding of cultural practices that promote bushmeat consumption would be of interest for initiatives attempting to reduce bat hunting for meat consumption in traditional societies (Chausson et al., 2019) and to grant local and/or regional legal support to discourage and control bat hunting, especially of those species with a critical conservation status such as *E. helvum*.

Beliefs in relation to the cooking process of prey (bats), which Africans generally practice in their hunting, are founded on the assumption that this process eliminates any disease-causing pathogens present in the carcasses. Scientists are therefore developing ways to effectively mitigate disease transmission by message-framing strategies from human psychology (MacFarlane & Rocha, 2020), which is a crucial resource in this process. For instance, it is not clear whether bat hunters and/or consumers simply lack information about the risk of disease transmission from bats, or whether they ignore such information.

Lack of awareness of disease transmission risks is high particularly in rural areas (Duonamou et al., 2020), where bat hunting and bat meat consumption are more prevalent (Luiselli et al., 2019; Mildenstein et al., 2016). Rural participants in this study had lower levels of educational attainment, which is in agreement with the profile of participants in other research studies conducted in rural areas (e.g., Xiang et al., 2010) and with farm owners than with city dwellers. Therefore, it can be assumed that rural people have more opportunities to kill bats. Interestingly, however, we did not observe significant differences between urban and rural settlements in terms of mythological beliefs. This finding suggests that these beliefs are not exclusive predictors of bat hunting but are particularly important in rural contexts, where hunting is more common.

Limitations

Some people did not participate in this study because they were concerned that subsequent government actions would affect their bat-eating practices. In terms of sampling representation, we propose that future studies include, in addition to the Yoruba participants in Southwestern Nigeria, participants from other tribes (e.g., Hausa and Igbo), where attitudes and behaviors toward bats remain unexplored.

Conclusion

Negative views about bats are not disappearing; people continue to kill these animals for bush meat or destroy their resting places. These negative attitudes and practices increase the risk of extinction and the vulnerability of bats. Therefore, efforts should be made to change the perception and treatment of bats. There is an urgent need for the conservation of bats, particularly at this time when bat-associated diseases are rapidly influencing human health concerns, which in turn may decrease the public tolerance for wildlife protection. Utilitarian views of bats, such as them being a source of bush meat or medicines, are associated with the risk of disease transmission. People living around forest reserves in both sites (OBR and IITA in Ibadan environs) do not adequately recognize the role of bats in natural ecosystems and have a poor understanding of the benefits that bats have for people. Their knowledge is not that different from the knowledge possessed by people in the urban areas of the study. Positive messages neutralizing superstition and mythological beliefs and highlighting the role of bats in ecosystems through environmental activities and media campaigns are *urgently* needed to enhance awareness and possibly contribute to a behavioral change in humans in this rapidly changing world.

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Data Availability

Data for this paper are available on the personal web page of the corresponding author.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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