Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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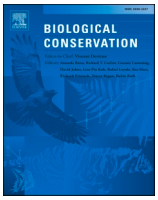

Does public fear that bats spread COVID-19 jeopardize bat conservation?

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ABSTRACT

With >1 400 species, bats comprise the second-largest order of mammals and provide critical ecological services as insect consumers, pollinators, and seed dispersers. Yet, bats are frequently associated with infectious human diseases such as SARS, MERS, and Ebola. As early as the end of January 2020, several virological studies have suggested bats as a probable origin for SARS-CoV-2, the causative agent of COVID-19. How does the public view the role of bats in COVID-19? Here we report pilot data collected shortly after the outbreak of COVID-19 using two online surveys, combined with a conservation intervention experiment, primarily on people who are receiving or have received higher education in China. We found that 84% of the participants of an online survey (n = 13 589) have misunderstood the relationship between bats and COVID-19, which strengthened negative attitudes towards bats. Knowledge of bats, gender, and education level of the participants affected their attitudes towards bats. Participants who indicated a better knowledge of bats had a more positive attitude towards bats. The proportion of female participants who had negative attitudes towards bats was higher than that of male participants. Participants with a higher education level indicated a more positive attitude towards bats after the outbreak of COVID-19. A specially prepared bat conservation lecture improved peoples' knowledge of bats and the positive attitudes, but failed to correct the misconception that bats transmit SARS-CoV-2 to humans directly. We suggest that the way virologists frame the association of bats with diseases, the countless frequently inaccurate media coverages, and the natural perceptual bias of bats carrying and transmitting diseases to humans contributed to the misunderstandings. This probably led to a rise in the events of evicting bats from dwellings and structures by humans and the legislative proposal for culling disease-relevant wildlife in China. A better understanding of the relationship between disease, wildlife and human health could help guide the public and policymakers in an improved program for bat conservation.

1. Introduction

The ongoing COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, is among the greatest disasters to human society. Likewise, this pandemic is impacting biodiversity at a global level (Corlett et al., 2020; Evans et al., 2020). One critical question that scientists have been working hard to answer is the origin of SARS-CoV-2. Shortly after the outbreak of COVID-19, several studies suggested bats as a probable animal origin for SARS-COV-2 (Xu et al., 2020; Lu et al., 2020; Zhou et al., 2020; Wu et al., 2020; Zhu et al., 2020). In particular, the coronavirus RaTG13, isolated from a horseshoe bat (*Rhinolophus affinis*), is 96% identical to SARS-CoV-2 at the whole genome level (Zhou et al., 2020). These studies are of paramount importance because they provide direct evidence that SARS-COV-2 has a natural animal origin, raising the hope for explaining how COVID-19 might have begun in the first place. The World Health Organization referenced these studies in several reports (World Health Organization, 2020a, 2020b), stressing their significance. However, such scientific evidence, often misinterpreted by the media and the general public due to a range of psychological mechanisms, can pose potential threats to bats (López-Baucells et al., 2018; MacFarlane and Rocha, 2020).

Bats are a highly diverse order of mammals, with >1400 species

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recognized to date (Burgin et al., 2018). Apart from the long-recognized role in improving human sonar and radar systems, bats play critical ecological roles as insect controllers, pollinators, and seed dispersers (Fenton and Simmons, 2014; Kunz et al., 2011). Yet, bats are vulnerable to a range of human threats, ranging from well-documented habitat loss and human hunting to newly-identified white-nose syndrome and wind energy production (Frick et al., 2020, 2010; Luo et al., 2013, 2015; Vincenot et al., 2017; Voigt and Kingston, 2016; Stone et al., 2012; Lewanzik and Voigt, 2014). As a consequence, close to 1000 species of bats require conservation or research attention (Frick et al., 2020).

Coinciding with the suggestion that bats are a probable origin for SARS-COV-2, there was a surge of reported events that citizens across China evict bats from dwellings and structures, some of which led to direct bat deaths (Zhao, 2020). Additionally, legislation to cull disease-relevant wildlife, including bats, was proposed by a team of lawmaking scholars and named this proposal "Ecological Culling" (Ma, 2020). Worse still, several regions other than China, such as Indonesia, have used bat culling as a strategy to combat COVID-19 (CMS, 2020; Tuttle, 2020). The close association between the scientific advances linking bats to COVID-19, followed by the bat repelling and culling behavior of people, suggests that the public and policy managers might have directly or indirectly related bats to COVID-19. As highlighted by several scholars, such misunderstandings may drive new threats to bats (MacFarlane and Rocha, 2020; Tuttle, 2020; Zhao, 2020).

Data on peoples' knowledge, attitudes, and practices (KAP) are frequently incorporated in infectious disease control (Claude et al., 2018; Dhimal et al., 2014). In the case of COVID-19, a few dozen KAP studies have been conducted, primarily concerning the successful implementation of the control measures of COVID-19 (Abdelhafiz et al., 2020; Azlan et al., 2020; Zhong et al., 2020). Several attributes of the participants (e.g., gender, education level, and knowledge) can affect humans' attitudes towards bats (Bjerke and Østdahl, 2004; Davey, 1994; Prokop and Tunnicliffe, 2008), which again can affect their attitudes towards human actions on bats (Hoffmaster et al., 2016). Because external events such as the outbreak of COVID-19 can affect peoples' attitudes towards bats, changes in human actions towards bats are likely. Previous studies have suggested that better knowledge of bats is positively related to improved attitudes towards bats (Musila et al., 2018). Improving peoples' knowledge of bats through education may help to counter the negative effects of the COVID-19 pandemic on bat conservation. In this study, we aimed to understand the links between the COVID-19 pandemic, attitudes towards bats, and bat conservation. To do so, we first made a conceptual model of connections (Fig. 1). To examine our model, we then collected pilot data using two online surveys. Finally, we conducted a conservation intervention experiment to identify outreach strategies that may improve peoples' attitudes towards bats and improve bat conservation.

2. Materials and methods

2.1. Questionnaire design

We constructed an online questionnaire (https://wj.qq.com/s2/5519189/24f5/) to assess the effect of the COVID-19 outbreak on peoples' attitudes towards bats, based on previous KAP surveys (Claude et al., 2018; Dhimal et al., 2014; Musila et al., 2018; Serebe et al., 2014). This questionnaire was written in Mandarin Chinese and was mainly targeted at people who are receiving or have received higher education in China, a group of people who might have a more objective view on the relationship between bats and disease. The questionnaire consisted of 31 items, including five demographic questions such as age and gender, and took a median of 230 s to complete. Whenever possible, we measured participants' attitudes with a 5-point Likert scale ranging from (1) strongly agree, (2) slightly agree, (3) neutral, (4) slightly disagree, (5) strongly disagree, for example (Likert, 1932). All attitudes were measured after the outbreak of COVID-19, including the attitudes towards bats before the COVID-19 pandemic. Thus, it is likely that the pre-pandemic attitudes towards bats were affected by the outbreak of COVID-19.

In the questionnaire, we examined the effectiveness of two conservation messages on changing participants' attitudes towards bats (Table 1). In the first message, we described some of the scientific and ecological values of bats. In the second message, we described the bat-virus relationships based on the best available scientific evidence and warned the potential ecological consequences associated with "Ecological Culling". We sampled the same participants twice with the same

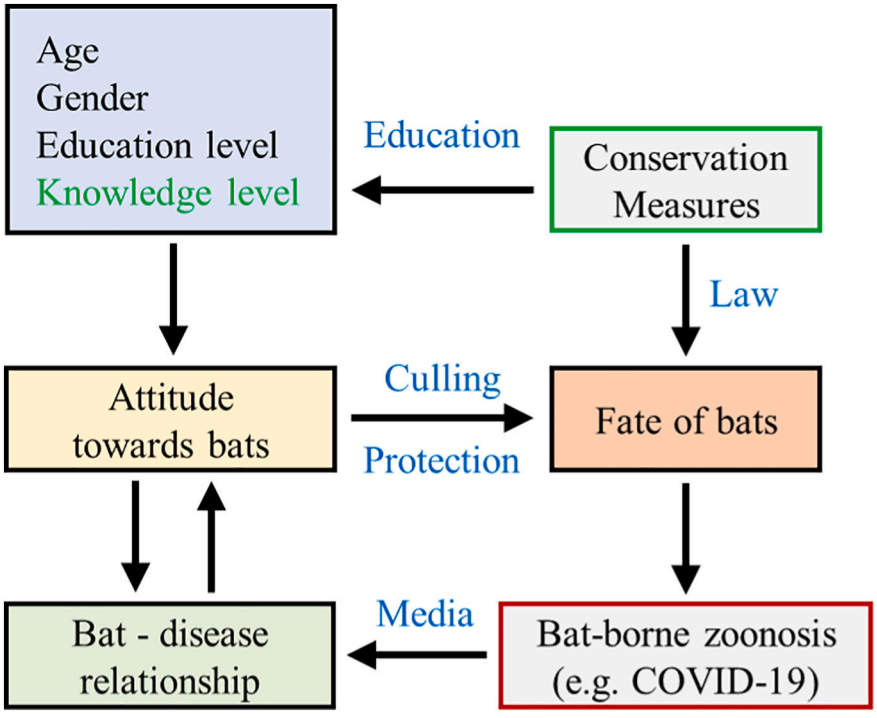

Fig. 1. A framework that may link COVID-19 to the fate of bats. Humans' attitudes towards bats are potentially influenced by several factors, among which the knowledge level of people represents a flexible one and can be changed through education. Humans' attitude towards bats is also affected by their attitudes towards the bat-disease relationship that depends critically on how the media report scientific advances. Specifically, the misinterpreted role of bats in zoonosis can lead to misunderstandings of the relationships between bats and disease.

Table 1
A summary of conservation methods for influencing peoples' attitudes towards bats.

Form	Message Content	Parameter	Effects	Source
Message 1: One sentence message explaining the scientific and ecological values of the bats.	"Scientific research indicates that although bats carry many viruses, they are an important reference for bio-inspired radar systems and play critical ecological roles in pest control, seed transmission, and plant pollination."	Attitude to Ecological Culling of bats	Yes a max. 2% change in participants' attitude	Question 21, Survey 1
Message 2: One paragraph message explaining the bat-virus relationship and potential serious consequence of "Ecological Culling".	"Current research shows that the probability is rather low for bats to transmit their viruses to humans directly. As an essential animal group for a stable ecosystem, the 'Ecological Culling' of bats will probably cause a series of serious ecological consequences. Thus, we should live in harmony with bats."	Attitude to bats	Yes a max. 30% change in participants' attitude	Between Question 25 and 26, Survey 1
Conservation lecture: A 40-minute prerecorded bat conservation lecture that was prepared by a group of bat experts.	This lecture covered the values of bats, the bat-virus relationship, the conservation status of bats, and some extraordinary features of bats. It aimed to maximize the appreciation of the values and to minimize the misconceptions of bats.	Attitude to bats; Attitude to bat-virus relationship; Attitude to bat culling proposals	Yes 5%–22% change in participants' attitude	Survey 2

question item: first in the early section and then in the late section after presenting the conservation messages. Moreover, we included two questionnaire items to collect participants' attitudes towards "Ecological Culling" and "Scientific Culling" proposals for bats. "Ecological Culling" of bats and other disease-relevant wildlife was proposed by a group of lawmaking scholars after the outbreak of COVID-19 (Ma, 2020), while "Scientific Culling" of bats was a hypothetical question created by us. "Scientific Culling" described the hypothetical scenario "if scientists found a way to remove bats from our surroundings".

We sent the surveys to our friends, colleagues, and university administrative staff (primarily the three universities of the authors) and asked them to post on WeChat Moments (similar to Twitter posts) and Chat Groups of QQ and WeChat, two popular internet chat-source tools in China. Before we distributed the questionnaire to the public, a test version was sent to a group of 17 graduate students who were asked to comment on the clarity and objectiveness of the question items, in addition to any other problems. Their feedback was incorporated into the final version that was distributed to the public on March 4th, 2020.

2.2. Bat conservation lecture

To explore conservation methods that might help to correct the misconception of the bat-virus relationship, we tested the effects of a specially prepared bat conservation lecture of approximately 40-minute duration in raising the positive attitudes towards bats. In this bat lecture, we covered the values of bats, the bat-virus relationship, the conservation status of bats, as well as some extraordinary features of bats such as echolocation (Table 1). One data figure from the first questionnaire showing attitude changes (Similar to Fig. 2B) was incorporated into the lecture slides. This lecture was prepared by a group of 13 bat experts, to maximize peoples' appreciation of the values of bats while minimizing their misconceptions of bats. The lecture was prerecorded as a video course and opened to registered students and university staff from Jilin Agricultural University and Northeast Normal University via an online platform (https://app.chaoxing.com/). The lecture was opened to approximately 22 000 participants at 13:30 on March 18, 2020. The video is now publicly available at https://zhibo.chaoxing.com/6067220.

To assess the effect of a bat conservation lecture on peoples' attitudes towards bats, we constructed a second online questionnaire containing some of the question items from the first survey and additionally four bat fact questions related to the lecture. This questionnaire consisted of 18 items and took a median of 111 s to complete. We were aware that some of the participants might have participated in the first survey and this experience can influence their responses to the second survey. In the second questionnaire, we added a question item and asked the participants to indicate the participation history of bat surveys (Item 5 of the second question, SI Appendix). We distributed this questionnaire as either a pre-lecture test (https://wj.qq.com/s2/5681687/067a/) or a post-lecture test (https://wj.qq.com/s2/5682028/e6c4/) to an approximately equal number of lecture attendants around 10 am on March 18th, 2020. The pre-lecture test participants were asked to finish the test by 13:30 when the lecture began. The post-lecture test participants were asked to start the test only after the lecture (around 14:10) and to finish it by 18:00. In total, we received valid data from 5954 and 915 participants for the pre-lecture and post-lecture tests, respectively. Each student in the lecture either participated in the pre-lecture test or the post-lecture test, but not both. Translated English versions of both questionnaires can be found in SI Appendix.

2.3. Data analysis

Data analysis was performed in MATLAB R2018b (MathWorks, Massachusetts, USA). The original survey data after English translation can be found as supplementary data (SI Datasets 1–3). The MATLAB script for data analysis, from data cleaning to data plotting, and statistical analysis, can be found in SI Dataset 4. Data cleaning procedures were applied to remove potentially unreliable data for both surveys. Specially, we limited the age of the participants between 12 and 80 years old, set the minimum age for the education level of middle school, high school, college, and graduate participants as 12, 14, 17, and 20 years old, and set the age range for current students of middle school, high school, college, and graduate school as 12 to 17, 14 to 20, 17 to 25, and 20 to 35 years old. Additionally, we excluded data from participants who took less than 1/4th or more than 4 times the median survey time. Nevertheless, with all the above data exclusion criteria, only data from 356 participants (2.6%) were excluded for survey 1. For survey 2, we limited the analysis to undergraduate, graduate, and post-graduate

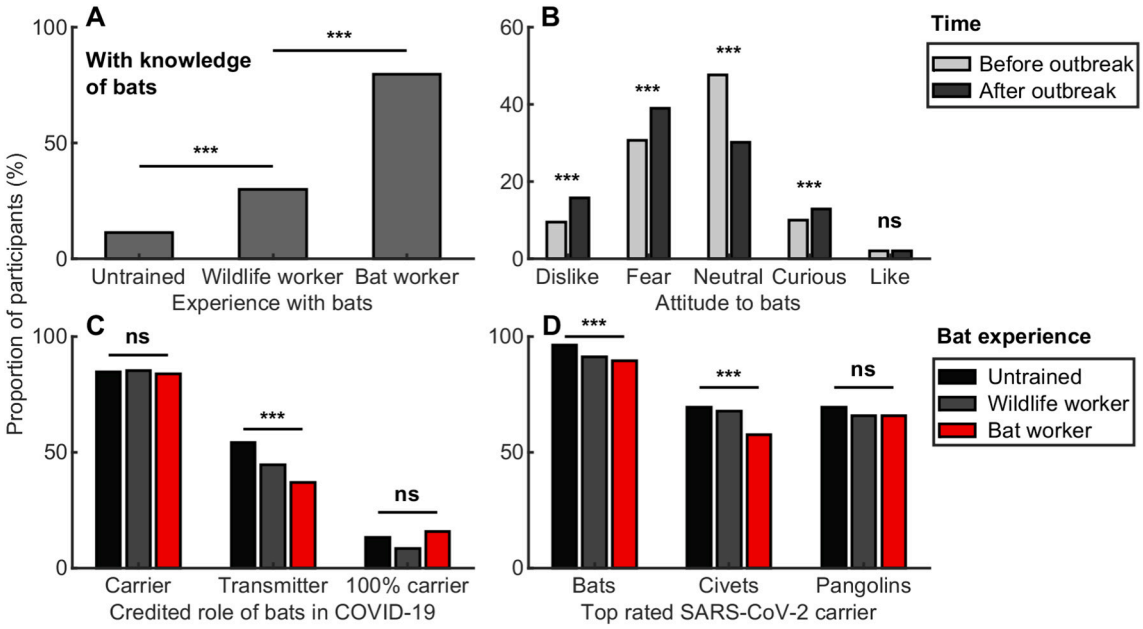

Fig. 2. Perceptions of bats with COVID-19 by the public. (A) The proportion of participants who indicated some or plenty of knowledge of bats among the wildlife untrained, wildlife workers, and bat workers. (B) Attitude towards bats before and after the COVID-19 outbreak. (C) The proportion of participants who misbelieved that bats carry SARS-CoV-2 ('Carrier'), bats transmit SARS-CoV-2 directly to humans ('Transmitter'), and every individual of bat carries SARS-CoV-2 (100% carrier). (D) Among 10 groups of animals mentioned by media, bats, civets, and pangolins are the three top-rated ones believed to carry SARS-CoV-2. Statistical significance between groups is indicated by asterisks: *** ($P < 0.001$) and ns ($P > 0.05$). The minimum sample size across all statistical analyses was 36 (number of bat workers of the "100% carrier" group in panel C).

students only, which accounted for 99.2% of the total data. Subsequently, we applied the same data exclusion criteria used above and excluded data from 445 participants (4%) in total.

We used Chi-square tests to compare the proportion of the participants between the two groups. When multiple explanatory variables or factors potentially affect the response variable, we built multinomial Proportional Odds Models (POM) to assess the effect of a particular factor (MATLAB function 'mnrfit.m') (McCullagh, 1980). Then, we reported the effect of this target factor on the response variable after controlling for other factors (function 'mnrval.m'). For the first survey, we examined five explanatory variables of the participants: gender, age, education level, knowledge level of bats, and the main residence region during the pandemic. For the second survey, we did not sample the main residence region of the participants during the pandemic, as it was not found to be statistically important for explaining the participants' attitudes. Instead, we sampled the participation history of bat surveys and incorporated this factor into the analyses. Statistical inferences were based on a 95% confidence interval. All the details of statistical analyses and results such as the intercepts for POMs and P values can be returned by running the data analysis MATLAB script (SI Dataset 4).

3. Results

3.1. Knowledge of and attitude towards bats

In the first survey, we collected data from 13589 participants, of which 93.4% were receiving or have received higher education, with 64.2% of the participants being female. We found that 87% of the participants indicated that they lack knowledge of bats and the knowledge of bats varied among wildlife untrained (non-professionals), wildlife workers, and bat workers (Fig. 2A; Chi-squared test, smallest $\chi^2 = 136$, $d.f. = 1$, all $P < 0.001$). 80% of the bat workers and 30% of the wildlife workers (after excluding bat workers) indicated having some or plenty of knowledge of bats. A lack of knowledge of bats is also reflected in the fact that 60.8% of the participants misbelieved that bats do not occur in the outdoor environment where they live or work, 44.5% would repel bats from such outdoor environment, and 20.5% of the participants misbelieved that bats deliberately attack humans.

We found that participants with a negative attitude towards bats outnumbered those with a positive attitude (Fig. 2B). Before the outbreak of COVID-19, merely 12.1% of the participants indicated a positive attitude (like or curious), whereas 40.2% indicated a negative (fear or dislike) attitude. After the outbreak of COVID-19, the percentage of participants who indicated a neutral attitude decreased by 17.4% (Chi-squared test, $\chi^2 = 867$, $d.f. = 1$, $P < 0.001$), which resulted in a 14.7% increase of the negative attitude participants (Chi-squared test, $\chi^2 = 587$, $d.f. = 1$, $P < 0.001$) and 2.8% increase of the curious attitude participants (Chi-squared test, $\chi^2 = 53$, $d.f. = 1$, $P < 0.001$). There was no significant change in the number of participants who liked bats (Chi-squared test, $\chi^2 = 0.2$, $d.f. = 1$, $P = 0.7$).

Using multinomial Proportional Odds Models (POM), we found that gender and knowledge of bats affected the participants' attitudes towards bats (Fig. 3). The proportion of female participants who had negative attitudes towards bats was higher than that of male participants (Fig. 3AB; POM, before COVID-19, $t = -17.5$, $P < 0.001$; after COVID-19, $t = -12.2$, $P < 0.001$). Participants who indicated a better knowledge of bats had a more positive attitude towards bats (Fig. 3CD; POM, before COVID-19, $t = -18.8$, $P < 0.001$; after COVID-19, $t = -14.7$, $P < 0.001$). However, education level correlated with the attitude of participants towards bats only after, but not before the COVID-19 outbreak (Fig. 3EF; POM, before COVID-19, $t = -1.1$, $P = 0.29$; after COVID-19, $t = -8.2$, $P < 0.001$). There was no evidence that age or residential region of the participants was related to peoples' attitudes towards bats (POM, all $P > 0.12$).

3.2. Misconceptions of the relationship between COVID-19 and bats

Misunderstandings of the relationship between COVID-19 and bats were prevalent among the participants (Fig. 2CD). Overall, 84.6% of the participants misbelieved that it is (highly) likely that bats carry SARS-CoV-2 ('Carrier'), 53.4% misbelieved that it is (highly) likely that bats transmit SARS-CoV-2 directly to humans ('Transmitter'), and 13.2%

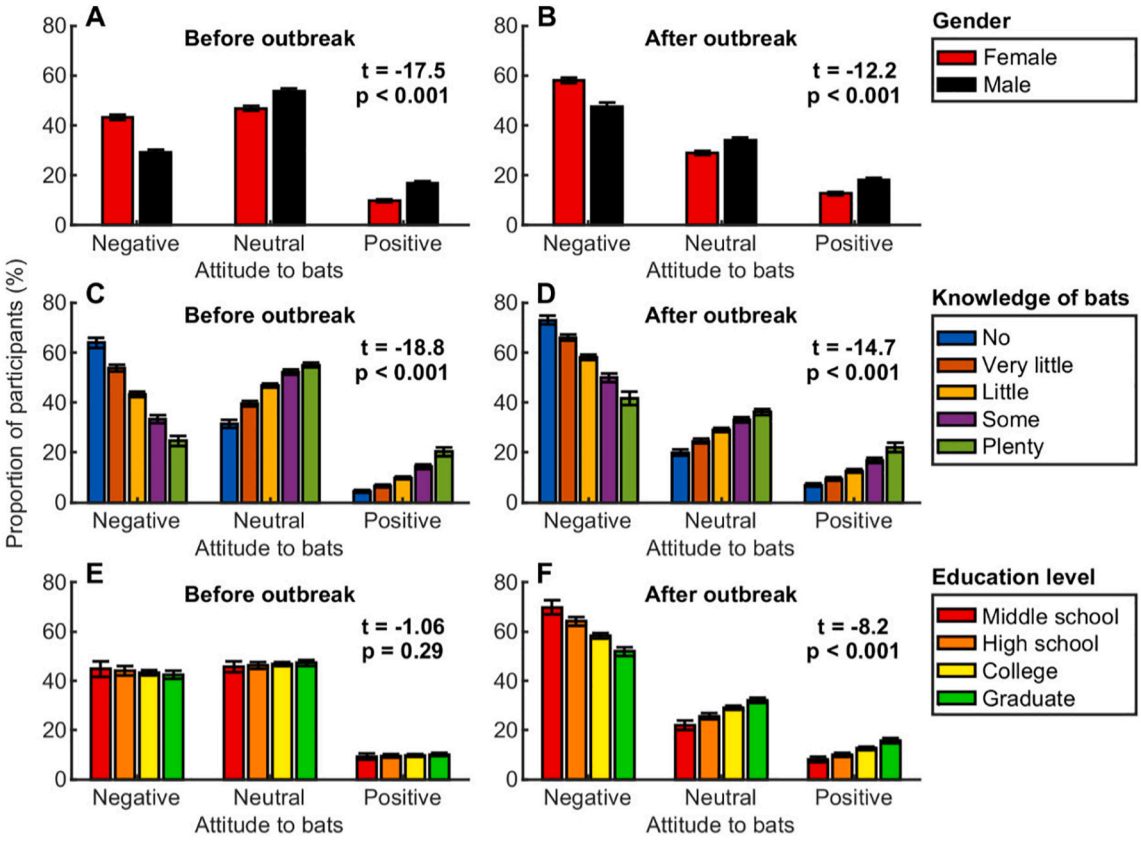

Fig. 3. Attributes of the participants explain the attitude differences to bats. (A, B) The attitude towards bats by female participants was more negative than that by male participants. (C, D) Participants with less knowledge of bats were more negative in attitudes towards bats. (E, F) After the outbreak of COVID-19, participants with more education were less negative in attitudes towards bats. The minimum sample size across all statistical analyses was 28 (number of participants who had no knowledge of bats and indicated a positive attitude in panel C).

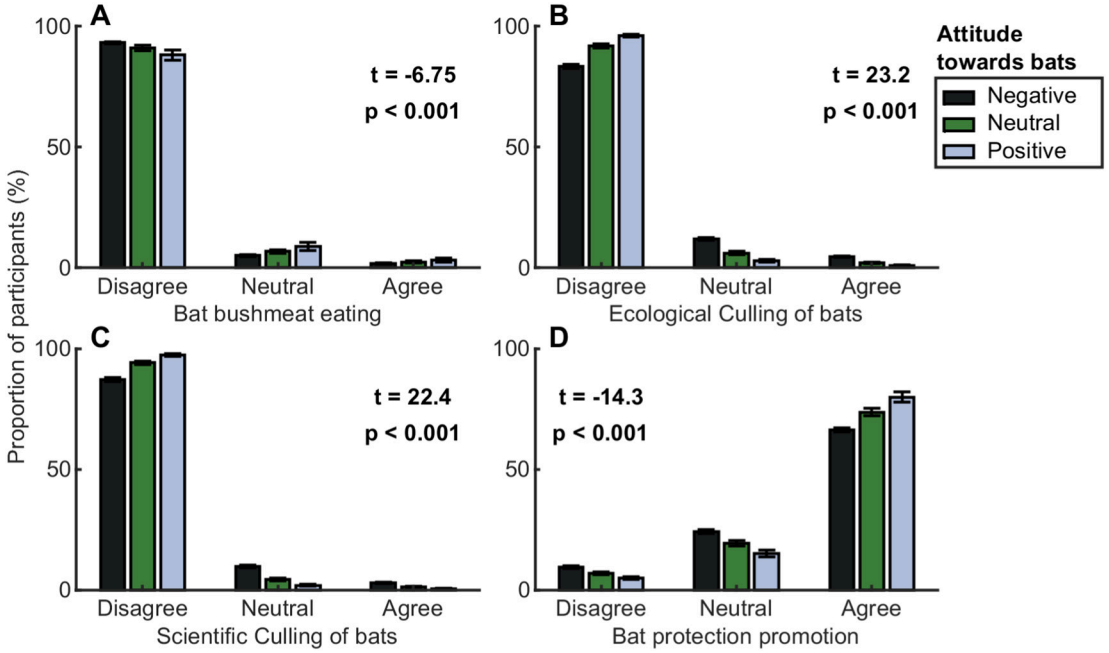

Fig. 4. Effects of attitudes towards bats on attitudes towards human actions on bats. Most participants disagreed with the bat bushmeat eating (A) and the bat culling proposals (B, C) and agreed with bat conservation (D). Participants who indicated a negative (fear or dislike) attitude towards bats were more likely to support the bat culling proposals, but less likely to support bat protection. Data were the predicted effect of the target factor (attitude to bats) with the multinomial proportional odds model. Error bars indicate the 95% confidence interval.

misbelieved that it is (highly) likely that all bats carry SARS-CoV-2 ('100% carrier'). Similarly, among the 10 groups of animals that were mentioned by the media with COVID-19, bats were top-rated as a possible SARS-CoV-2 carrier by 96% of the participants, followed by pangolins and civets by 69.3% participants each. Surprisingly, bat workers, who have the best knowledge of bats, only showed a slightly better understanding of the relationship between COVID-19 and bats. Specifically, a similarly high proportion of the bat and wildlife workers (~84%) misbelieved that it is (highly) likely that bats carry SARS-CoV-2 (Chi-square test, all $P > 0.6$).

3.3. Attitudes towards human actions on bats

In contrast to the largely negative attitudes towards bats, 93.8% of the participants (highly) opposed the human behavior of eating bat bushmeat (Fig. 4A), 81.2% of the participants (highly) opposed the proposal for "Ecological Culling" bats (Fig. 4B), and 77.1% of the participants (highly) opposed the proposal for "Scientific Culling" of bats (Fig. 4C). Moreover, 63% of the participants indicated that they are willing to participate in activities for promoting the importance of bats (Fig. 4D). Nevertheless, 4.9% (n = 664) and 6.9% (n = 936) of the participants (highly) supported the "Ecological Culling" and the "Scientific Culling" proposals for bats, respectively.

To test whether participants' attitudes towards bats affect their attitudes towards human actions, further statistical tests with POMs were performed. We found that the attitude towards bats, both before and after the COVID-19 outbreak, correlated with the attitude towards human actions on bats (Fig. 4). Participants who indicated a negative (fear or dislike) attitude towards bats were more likely to support the bat culling proposals, but less likely to support bat protection proposal, compared to participants with a neutral or positive (curiosity or like) attitude (POMs, |t| range: 14.3 to 23.2, all $P < 0.001$).

3.4. Conservation measures to improve attitudes towards bats

To improve peoples' attitudes towards bats, two distinct messages about bats were delivered in the survey (Table 1). Our data indicated that the first message emphasizing the values of bats alone only slightly (max. 2%) changed participants' attitudes towards the proposal for "Ecological Culling" of bats (Fig. 5A; POM, $t = -4.1$, $P < 0.001$). By contrast, the second message was effective at reducing participants' negative attitudes towards bats with a magnitude of up to 30% (Fig. 5B; POM, $t = -53.5$, $P < 0.001$). This finding suggests that the negative attitudes towards bats were partly driven by the misconception of the bat-virus relationship and that peoples' negative attitudes towards bats can be reduced with proper knowledge.

We found that the bat lecture was effective at improving the knowledge of bats, increasing positive attitudes towards bats, decreasing

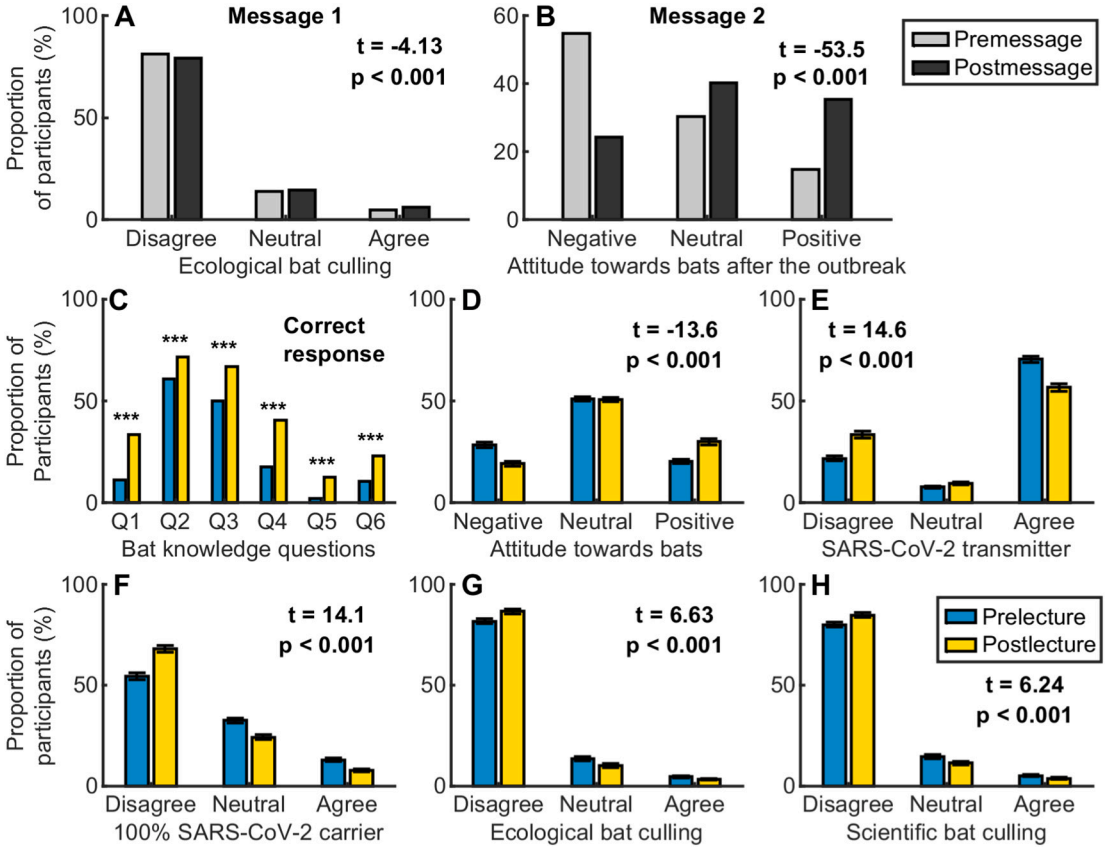

Fig. 5. Effects of conservation measure on peoples' attitudes towards bats. (A) Effects of Message 1, which highlighted the ecological values of bats, on peoples' attitudes towards the "Ecological Culling" proposal for bats. (B) Effects of Message 2 on peoples' attitudes after the pandemic towards bats. In Message 2, we explained the relationships between bats and viruses based on the best available scientific evidence and warned of potentially serious ecological consequences associated with the "Ecological Culling" of bats. (C) Effects of a bat conservation lecture on peoples' knowledge of bats. Q1, self-indicated some or plenty of knowledge of bats; Q2 to Q6 are bat fact questions that correspond to questions 7, 8, 9, 10, and 17 in questionnaire 2 (Appendix). (D–H) Effects of the bat conservation lecture on participants' attitudes towards bats, the bat-virus relationship, and bat culling proposals. Figure legends for panels C-H are shown in panel H. Statistical significance between two groups in panel C is indicated by asterisks: *** ($P < 0.001$). Data in panels D–H were the predicted effect of the target factor (bat lecture) with the multinomial proportional odds model, after controlling for the influences of other factors. Error bars indicate the 95% confidence interval. The minimum sample size across all statistical analyses was 118 (number of participants who made a correct response to question 5 (Q5) in the pre-lecture test in panel C).

misunderstandings of the bat-virus relationships, and reducing the willingness to support bat culling proposals (Fig. 5C–H). Compared to the pre-lecture group, there were 22.2% more participants from the post-lecture group who indicated a positive knowledge of bats (some or plenty of knowledge) (Fig. 5C; Chi-squared test, $\chi^2 = 747.1$, $d.f. = 1$, $P < 0.001$). An increase in the knowledge of bats was also reflected by the proportion of participants that provided correct responses to the five bat fact questions that were increased by a magnitude ranging from 10.4% to 22.8% (Fig. 5C; Chi-squared test, smallest $\chi^2 = 138.7$, $d.f. = 1$, all $P < 0.001$). After controlling for the effects of gender, education level, and the history of participation in bat knowledge tests or questionnaires, we found that there were 9.7% more participants who indicated a positive attitude towards bats, 13.7% and 5.3% fewer participants who misbelieved that it is (highly) likely that bats transmit SARS-COV-2 directly to humans and that all bats carry SARS-COV-2, and 4.8% and 4.8% more participants who opposed to the Ecological Culling and Scientific Culling proposals on bats (POM, $|t|$ range: 6.2 to 14.6, all $P < 0.001$). However, after the lecture, 56.7% of participants still misbelieved that it is (highly) likely that bats transmit SARS-COV-2 directly to humans, reflecting a deep-rooted misconception of the bat-virus relationship and the limitations of the bat conservation lecture.

4. Discussion

4.1. Attitudes towards bats are largely negative

Our survey revealed that there were almost four times more participants who indicated a negative attitude towards bats (fear or dislike) than those who indicated a positive attitude (curious or like) towards bats after the outbreak of COVID-19. One possible reason is that knowledge of bats is scarce among the participants. Specifically, our survey showed that 87% of the participants indicated a lack of knowledge of bats. Knowledge of bats is not only related to the attitudes towards bats, but also to the attitudes towards human actions on bats (Fig. 5). Participants who indicated a negative (fear or dislike) attitude towards bats were more likely to support the bat culling proposals, but less likely to support bat protection, compared to participants with a neutral or positive (curiosity or like) attitude. On the other hand, there has been no bat conservation organization and very limited conservation-driven bat research in mainland China (Feijó et al., 2019). Another explanation is that the outbreak of COVID-19 increased peoples' negative attitudes towards bats. Note, it is very likely that the 14.7% increase of negative attitude participants after the COVID-19 outbreak represents an underestimation, as the attitude towards bats before the pandemic was sampled in the same survey after the outbreak of COVID-19. It is likely that the pre-pandemic attitude towards bats reported in this study was also negatively affected by the outbreak of COVID-19. The high proportion of participants with a negative attitude towards bats contrasts with the widely-accepted view that China is one of the rare countries where bats are praised in culture (Kingston, 2016; Lunney and Moon, 2011). This finding suggests that a positive cultural image of bats does not guarantee a positive attitude of the public towards them.

4.2. Misunderstandings of the relationship between bats and COVID-19

Our data showed that people, including bat researchers and wildlife workers, misunderstand the relationship between bats and COVID-19. We suggest that misunderstandings of the bat-virus relationship via misleading media outlets represent a key factor in driving peoples' negative attitudes towards bats (López-Baucells et al., 2018; Tuttle, 2020). The coronaviruses of bats are approximately 87% to 96% genomically similar to SARS-CoV-2, but there is no evidence that bats carry SARS-CoV-2 or that bats transmit SARS-CoV-2 directly to humans, a statement shared by other international organizations including the World Health Organization (CMS, 2020; World Health Organization, 2020c). However, in media reports, the scientific message, such as "*bats may be a natural reservoir of SARS-CoV-2*", is often distorted into "*bats are responsible for COVID-19*", and circulates rapidly and widely (MacFarlane and Rocha, 2020). Of note, message distortion via media reports also occurs to other public-concerned events such as food safety (Todd et al., 2007).

Misunderstandings of the relationship between COVID-19 and bats might be additionally fueled by the long-credited role of bats in causing human diseases. Bats are frequently associated with zoonotic diseases and have been suggested to carry more viruses than other mammalian groups (Drexler et al., 2012; Olival et al., 2017; Schneeberger and Voigt, 2016), although this common suggestion has begun to be challenged (Mollentze and Streicker, 2020). According to the disease-avoidance hypothesis, humans have evolved a set of psychological processes that promote aversions to disease-associated animals (Davey, 1994; Matchett and Davey, 1991; Prokop and Tunnicliffe, 2008; Ware et al., 1994). Thus, humans might be naturally biased to perceive bats as a potential threat of carrying or transmitting infective viruses such as SARS-CoV-2.

4.3. Potential harm of the misunderstood bat – disease relationship

We believe that there is an urgent need to correct the misunderstandings of the bat-virus relationship by the public. Apart from the unnecessary psychological stress associated with bats to the public, misunderstandings can cause direct harm to bat survival. Shortly after publications reporting high genomic similarity between bat-derived coronaviruses and SARS-CoV-2, repeated bat repelling events were reported across China (Zhao, 2020). Additionally, the "Ecological Culling" of bats and other disease-relevant animals under certain circumstances was proposed by lawmaking scholars, aiming to revise the Wildlife Protection Law of the Peoples' Republic of China (Ma, 2020). Similarly, the culling of bats was used as a strategy to combat COVID-19 in several other regions of the world such as Indonesia (CMS, 2020; MacFarlane and Rocha, 2020; Tuttle, 2020). These extreme reactions from the public and scholars illustrate some of the serious consequences associated with misinterpreted scientific evidence. In fact, the bat-derived coronavirus that was closest to SARS-CoV-2 (96% identical) lacks five of the six critical amino acid residues at the receptor-binding domain for invading human cells (Zhang and Holmes, 2020).

Furthermore, there is no evidence that culling bats is an effective measure to control bat-borne diseases (Hallam and Mccracken, 2011; Streicker et al., 2012). Even worse, culling bats can increase bat vulnerability and the spread of bat-borne viruses, and in turn increases the risk of infecting humans (Amman et al., 2014; Olival, 2016; Plowright et al., 2015, 2008). For example, extensive culling of common vampire bats in Latin America that was aimed to prevent rabies transmission failed to reduce, and instead, increased the prevalence of rabies within the bat populations (Plowright et al., 2008). Similarly, to control Marburgviruses, the opening of the roost housing a large colony of Egyptian fruit bats was sealed. This effectively reduced the colony to 1%–5% of its original size, but the prevalence of Marburgviruses in the surviving population was more than twice the prevalence before the culling measure (Amman et al., 2014).

Beyond the culling of a targeted bat species that is associated directly with the disease, the culling of bats during the COVID-19 pandemic was unfounded. On the one hand, to our best knowledge, there is no evidence that bats carry or spread SARS-CoV-2, despite thousands of papers discussing the relationships between bats and COVID-19, as reflected by the >7000 citations of the original paper based on Google Scholar (Zhou et al., 2020). On the other hand, in the reported cases of bat repelling or culling events (Tuttle, 2020; Zhao, 2020), no information exists to support that the victims were the Intermediate horseshoe bat or even a horseshoe bat species. It should be noted that bats are a highly diverse order of mammals with more than 1400 species. Unspecified culling of bats in the case of the COVID-19 pandemic is just one example showing the common mismatch between scientific evidence and human practices

(Beretti and Stuart, 2008).

4.4. Conservation measures to improve attitudes towards bats

In this study, we have tested the effects of two intervention measures, i.e., the conservation message and conservation lecture, on peoples' attitudes. Although our data suggested that both conservation measures are effective in reducing peoples' negative attitudes towards bats (Table 1), they differed in the effectiveness. Specifically, providing the scientific and ecological values of bats via a message alone only minimally (2%) increased participants' willingness to oppose the bat culling proposal, which agrees with earlier suggestions (Kidd et al., 2019b; Kingston, 2016). By contrast, the conservation lecture, which contained information on both the values of bats and the knowledge of the relationships between bats and diseases, had a stronger effect in increasing participants' willingness to oppose the bat culling proposals (4.8%). Nevertheless, it is alarming that after the conservation lecture, 56.7% of the participants still misbelieved that it is (highly) likely that bats transmit SARS-COV-2 directly to humans. This result stresses the limitations of the conservation lecture as an intervention method. It should also be noted that we evaluated the effects of the conservation lecture immediately after its presentation. The short-time nature of the evaluation makes it difficult to predict peoples' attitudes or the effect of conservation intervention measures across time. Thus, long-term studies monitoring peoples' attitudes towards bats and bats' role in disease need to be conducted.

5. Conclusion

This study provided some pilot data suggesting that there is an intrinsic network connecting disease-relevant animals, virological research, and the public. Scientific research on disease-relevant animals may have a strong psychological effect on humans directly and on the fate of these animals indirectly. We hope that this study can serve as a reference for the public and policymakers in guiding their responses to disease-relevant animals during COVID-19 and similar public-concerned events. Since misunderstandings originated from virological researches, we stress that the virological community should follow the well-established principles to frame the association of wildlife and disease (Kidd et al., 2019a, 2019b; López-Baucells et al., 2018; MacFarlane and Rocha, 2020). Nevertheless, the current study is limited by the focused participants (primarily university students) and thus would not reflect the general attitudes of people in China. Lastly, we hope that professional psychologists and social scientists can be interested in this ignored topic, and more objective and standardized questionnaires can be constructed to survey broader communities to reveal psychological mechanisms that can be leveraged to reduce the misunderstandings.

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CRediT authorship contribution statement

J.L. and J.F. conceived the study; J.L., M.L., X.W., H.Y., M.W., S.Q. constructed the questionnaires and conducted the survey, with help from H.Z and J.F.; J.L. analyzed the data and drafted the manuscript; Y. L. prepared and J.F. gave the bat conservation lecture; all authors discussed the data and edited the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abdelhafiz, A.S., Mohammed, Z., Ibrahim, M.E., Ziady, H.H., Alorabi, M., Ayyad, M., Sultan, E.A., 2020. Knowledge, perceptions, and attitude of Egyptians towards the novel coronavirus disease (COVID-19). J. Community Health. https://doi.org/10.1007/s10900-020-00827-7.

Amman, B.R., Nyakarahuka, L., McElroy, A.K., Dodd, K.A., Sealy, T.K., Schuh, A.J., Shoemaker, T.R., Balinandi, S., Atimnedi, P., Kaboyo, W., Nichol, S.T., Towner, J.S., 2014. Marburgvirus resurgence in Kitaka mine bat population after extermination attempts, Uganda. Emerg. Infect. Dis. 20, 1761–1764. https://doi.org/10.3201/eid2010.140696.

Azlan, A.A., Hamzah, M.R., Sern, T.J., Ayub, S.H., Mohamad, E., 2020. Public knowledge, attitudes and practices towards COVID-19: a cross-sectional study in Malaysia. PLoS One 15, e0233668. https://doi.org/10.1371/journal.pone.0233668.

Beretti, M., Stuart, D., 2008. Food safety and environmental quality impose conflicting demands on Central Coast growers. Calif. Agric. 62, 68–73. https://doi.org/10.3733/ca.v062n02p68.

Bjerke, T., Østdahl, T., 2004. Animal-related attitudes and activities in an urban population. Anthrozoös 17, 109–129. https://doi.org/10.2752/089279304786991783.

Burgin, C.J., Colella, J.P., Kahn, P.L., Upham, N.S., 2018. How many species of mammals are there? J. Mammal. 99, 1–14. https://doi.org/10.1093/jmammal/gyx147.

Claude, K.M., Underschultz, J., Hawkes, M.T., 2018. Ebola virus epidemic in war-torn eastern DR Congo. Lancet 392, 1399–1401. https://doi.org/10.1016/S0140-6736(18)32419-X.

CMS, 2020. 2020/005: facts about bats and COVID-19 (by Convention on the Conservation of Migratory Species of Wild Animals) [WWW document]. URL. https://www.cms.int/en/news/2020005-facts-about-bats-and-covid-19. (Accessed 7 June 2020).

Corlett, R.T., Primack, R.B., Devictor, V., Maas, B., Goswami, V.R., Bates, A.E., Koh, L.P., Regan, T.J., Loyola, R., Pakeman, R.J., Cumming, G.S., Pidgeon, A., Johns, D., Roth, R., 2020. Impacts of the coronavirus pandemic on biodiversity conservation. Biol. Conserv. 246, 108571. https://doi.org/10.1016/j.biocon.2020.108571.

Davey, G.C.L., 1994. Self-reported fears to common indigenous animals in an adult UK population: the role of disgust sensitivity. Br. J. Psychol. 85, 541–554. https://doi.org/10.1111/j.2044-8295.1994.tb02540.x.

Dhimal, M., Aryal, K.K., Dhimal, M.L., Gautam, I., Singh, S.P., Bhusal, C.L., Kuch, U., 2014. Knowledge, attitude and practice regarding dengue fever among the healthy population of highland and lowland communities in central Nepal. PLoS One 9, e102028. https://doi.org/10.1371/journal.pone.0102028.

Drexler, J.F., Corman, V.M., Muller, M.A., Maganga, G.D., Vallo, P., Binger, T., Gloza-Rausch, F., Rasche, A., Yordanov, S., Seebens, A., Oppong, S., Sarkodie, Y.A., Pongombo, C., Lukashev, A.N., Schmidt-Chanasit, J., Stocker, A., Carneiro, A.J.B., Erbar, S., Maisner, A., Fronhoffs, F., Buettner, R., Kalko, E.K.V., Kruppa, T., Franke, C.R., Kallies, R., Yandoko, E.R.N., Herrler, G., Reusken, C., Hassanin, A., Kruger, D.H., Matthee, S., Ulrich, R.G., Leroy, E.M., Drosten, C., 2012. Bats host major mammalian paramyxoviruses. Nat. Commun. 3, 796. https://doi.org/10.1038/ncomms1796.

Evans, K.L., Ewen, J.G., Guillera-Arroita, G., Johnson, J.A., Penteriani, V., Ryan, S.J., Sollmann, R., Gordon, I.J., 2020. Conservation in the maelstrom of Covid-19 – a call to action to solve the challenges, exploit opportunities and prepare for the next pandemic. Anim. Conserv. 23, 235–238. https://doi.org/10.1111/acv.12601.

Feijó, A., Wang, Y., Sun, J., Li, F., Wen, Z., Ge, D., Xia, L., Yang, Q., 2019. Research trends on bats in China: a twenty-first century review. Mammal. Biol. 98, 163–172. https://doi.org/10.1016/j.mambio.2019.09.002.

Fenton, M.B., Simmons, N., 2014. Bats: A World of Science and Mystery. University of Chicago Press, Brooklyn, New York.

Frick, W.F., Pollock, J.F., Hicks, A.C., Langwig, K.E., Reynolds, D.S., Turner, G.G., Butchkoski, C.M., Kunz, T.H., 2010. An emerging disease causes regional population collapse of a common North American bat species. Science 329, 679–682. https://doi.org/10.1126/science.1188594.

Frick, W.F., Kingston, T., Flanders, J., 2020. A review of the major threats and challenges to global bat conservation. Ann. N. Y. Acad. Sci. 1469, 5–25. https://doi.org/10.1111/nyas.14045.

Hallam, T.G., Mccracken, G.F., 2011. Management of the panzootic White-Nose Syndrome through culling of bats. Conserv. Biol. 25, 189–194. https://doi.org/10.1111/j.1523-1739.2010.01603.x.

Hoffmaster, E., Vonk, J., Mies, R., 2016. Education to action: improving public perception of bats. Animals 6, 6. https://doi.org/10.3390/ani6010006.

Kidd, L.R., Bekessy, S.A., Garrard, G.E., 2019a. Neither hope nor fear: empirical evidence should drive biodiversity conservation strategies. Trends Ecol. Evol. 34, 278–282. https://doi.org/10.1016/j.tree.2019.01.018.

Kidd, L.R., Garrard, G.E., Bekessy, S.A., Mills, M., Camilleri, A.R., Fidler, F., Fielding, K. S., Gordon, A., Gregg, E.A., Kusmanoff, A.M., Louis, W., Moon, K., Robinson, J.A., Selinske, M.J., Shanahan, D., Adams, V.M., 2019b. Messaging matters: a systematic review of the conservation messaging literature. Biol. Conserv. 236, 92–99. https://doi.org/10.1016/j.biocon.2019.05.020.

Kingston, T., 2016. Cute, creepy, or crispy—how values, attitudes, and norms shape human behavior toward bats. In: Voigt, C.C., Kingston, T. (Eds.), Bats in the Anthropocene: Conservation of Bats in a Changing World. Springer International Publishing, Cham, pp. 571–595. https://doi.org/10.1007/978-3-319-25220-9_18.

Kunz, T.H., de Torrez, E.B., Bauer, D., Lobova, T., Fleming, T.H., 2011. Ecosystem services provided by bats. Ann. N. Y. Acad. Sci. 1223, 1–38. https://doi.org/10.1111/j.1749-6632.2011.06004.x.

Lewanzik, D., Voigt, C.C., 2014. Artificial light puts ecosystem services of frugivorous bats at risk. J. Appl. Ecol. 51, 388–394. https://doi.org/10.1111/1365-2664.12206.

Likert, R., 1932. A technique for the measurement of attitudes. Arch. Psychol. 22, 55.

López-Baucells, A., Rocha, R., Fernández-Llamazares, Á., 2018. When bats go viral: negative framings in virological research imperil bat conservation. Mamm. Rev. 48, 62–66. https://doi.org/10.1111/mam.12110.

Lu, R., Zhao, X., Li, J., Niu, P., Yang, B., Wu, H., Wang, W., Song, H., Huang, B., Zhu, N., Bi, Y., Ma, X., Zhan, F., Wang, L., Hu, T., Zhou, H., Hu, Z., Zhou, W., Zhao, L., Chen, J., Meng, Y., Wang, J., Lin, Y., Yuan, J., Xie, Z., Ma, J., Liu, W.J., Wang, D., Xu, W., Holmes, E.C., Gao, G.F., Wu, G., Chen, W., Shi, W., Tan, W., 2020. Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet 395, 565–574. https://doi.org/10.1016/S0140-6736(20)30251-8.

Lunney, D., Moon, C., 2011. Blind to bats: Traditional prejudices and today's bad press render bats invisible to public consciousness. In: The Biology and Conservation of Australasian Bats. Royal Zoological Society of NSW, Mosman, NSW, Australia, pp. 44–63.

Luo, J., Jiang, T., Lu, G., Wang, L., Wang, J., Feng, J., 2013. Bat conservation in China: should protection of subterranean habitats be a priority? Oryx 47, 526–531. https://doi.org/10.1017/S0030605311001505.

Luo, J., Siemers, B.M., Koselj, K., 2015. How anthropogenic noise affects foraging. Glob. Chang. Biol. 29, 3278–3289. https://doi.org/10.1111/gcb.12997.

Ma, H., 2020. Nine Suggestions for Revising the Wildlife Protection Law From the Research Committee of Administrative Law of China Law Society (in Chinese). Official WeChat Account of the School of Law-based Government. URL. https://mp.weixin.qq.com/s/N6_1z62flopcXtlTm5HGXA.

MacFarlane, D., Rocha, R., 2020. Guidelines for communicating about bats to prevent persecution in the time of COVID-19. Biol. Conserv. 248, 108650. https://doi.org/10.1016/j.biocon.2020.108650.

Matchett, G., Davey, G.C.L., 1991. A test of a disease-avoidance model of animal phobias. Behav. Res. Ther. 29, 91–94. https://doi.org/10.1016/S0005-7967(09)80011-9.

McCullagh, P., 1980. Regression models for ordinal data. J. R. Stat. Soc. Series B 42, 109–127. https://doi.org/10.1111/j.2517-6161.1980.tb01109.x.

Mollentze, N., Streicker, D.G., 2020. Viral zoonotic risk is homogenous among taxonomic orders of mammalian and avian reservoir hosts. Proc. Natl. Acad. Sci. U. S. A. 117, 9423–9430. https://doi.org/10.1073/pnas.1919176117.

Musila, S., Prokop, P., Gichuki, N., 2018. Knowledge and perceptions of, and attitudes to, bats by people living around Arabuko-Sokoke Forest, Malindi-Kenya. Anthrozoös 31, 247–262. https://doi.org/10.1080/08927936.2018.1434065.

Olival, K.J., 2016. To cull, or not to cull, bat is the question. EcoHealth 13, 6–8. https://doi.org/10.1007/s10393-015-1075-7.

Olival, K.J., Hosseini, P.R., Zambrana-Torrelio, C., Ross, N., Bogich, T.L., Daszak, P., 2017. Host and viral traits predict zoonotic spillover from mammals. Nature 546, 646–650. https://doi.org/10.1038/nature22975.

Plowright, R.K., Sokolow, S.H., Gorman, M.E., Daszak, P., Foley, J.E., 2008. Causal inference in disease ecology: investigating ecological drivers of disease emergence. Front. Ecol. Environ. 6, 420–429. https://doi.org/10.1890/070086.

Plowright, R.K., Eby, P., Hudson, P.J., Smith, I.L., Westcott, D., Bryden, W.L., Middleton, D., Reid, P.A., McFarlane, R.A., Martin, G., Tabor, G.M., Skerratt, L.F., Anderson, D.L., Crameri, G., Quammen, D., Jordan, D., Freeman, P., Wang, L.-F., Epstein, J.H., Marsh, G.A., Kung, N.Y., McCallum, H., 2015. Ecological dynamics of emerging bat virus spillover. Proc. R. Soc. B 282, 20142124. https://doi.org/10.1098/rspb.2014.2124.

Prokop, P., Tunnicliffe, S.D., 2008. "Disgusting" animals: primary school children's attitudes and myths of bats and spiders. Eurasia J. Math Sci. Technol. Educ. 4, 87–97.

Schneeberger, K., Voigt, C.C., 2016. Zoonotic viruses and conservation of bats. In: Voigt, C.C., Kingston, T. (Eds.), Bats in the Anthropocene: Conservation of Bats in a Changing World. Springer International Publishing, Cham, pp. 263–292. https://doi.org/10.1007/978-3-319-25220-9_10.

Serebe, S.G., Tadesse, K.A., Yizengaw, H.A., Tamrat, S.M., 2014. Study on community knowledge, attitude and practice of rabies in and nearby Gondar town, North West Ethiopia. JPHE 6, 429–435. https://doi.org/10.5897/JPHE2014.0669.

Stone, E.L., Jones, G., Harris, S., 2012. Conserving energy at a cost to biodiversity? Impacts of LED lighting on bats. Glob. Chang. Biol. 18, 2458–2465. https://doi.org/10.1111/j.1365-2486.2012.02705.x.

Streicker, D.G., Recuenco, S., Valderrama, W., Gomez Benavides, J., Vargas, I., Pacheco, V., Condori Condori, R.E., Montgomery, J., Rupprecht, C.E., Rohani, P., Altizer, S., 2012. Ecological and anthropogenic drivers of rabies exposure in vampire bats: implications for transmission and control. Proc. R. Soc. B 279, 3384–3392. https://doi.org/10.1098/rspb.2012.0538.

Todd, E.C.D., Harris, C.K., Knight, A.J., Worosz, M.R., 2007. Spinach and the media: how we learn about a major outbreak. Food Prot. Trends 27, 314–321.

Tuttle, M.D., 2020. COVID-19 Impact: A Viral Witch Hunt.

Vincenot, C.E., Florens, F.B.V., Kingston, T., 2017. Can we protect island flying foxes? Science 355, 1368–1370. https://doi.org/10.1126/science.aam7582.

Voigt, C.C., Kingston, T. (Eds.), 2016. Bats in the Anthropocene: conservation of Bats in a Changing World. Springer.

Ware, J., Jain, K., Burgess, I., Davey, G.C.L., 1994. Disease-avoidance model: factor analysis of common animal fears. Behav. Res. Ther. 32, 57–63. https://doi.org/10.1016/0005-7967(94)90084-1.

World Health Organization, 2020a. 2019 Novel Coronavirus: overview of the state of the art and outline of key knowledge gaps/slides. Accessed on 12 February 2020 at. https://www.who.int/publications/m/item/2019-novel-coronavirus-overview-of-the-state-of-the-art-and-outline-of-key-knowledge-gaps-slides (World Health Organization).

World Health Organization, 2020b. Origin of SARS-CoV-2.

World Health Organization, 2020c. Q&A on coronaviruses (COVID-19). Accessed on April 17 2020 at. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub.

Wu, F., Zhao, S., Yu, B., Chen, Y.-M., Wang, W., Song, Z.-G., Hu, Y., Tao, Z.-W., Tian, J.-H., Pei, Y.-Y., Yuan, M.-L., Zhang, Y.-L., Dai, F.-H., Liu, Y., Wang, Q.-M., Zheng, J.-J., Xu, L., Holmes, E.C., Zhang, Y.-Z., 2020. A new coronavirus associated with human respiratory disease in China. Nature 579, 265–269. https://doi.org/10.1038/s41586-020-2008-3.

Xu, X., Chen, P., Wang, J., Feng, J., Zhou, H., Li, X., Zhong, W., Hao, P., 2020. Evolution of the novel coronavirus from the ongoing Wuhan outbreak and modeling of its spike protein for risk of human transmission. Sci. China Life Sci. 63, 457–460. https://doi.org/10.1007/s11427-020-1637-5.

Zhang, Y.-Z., Holmes, E.C., 2020. A genomic perspective on the origin and emergence of SARS-CoV-2. Cell 181, 223–227. https://doi.org/10.1016/j.cell.2020.03.035.

Zhao, H., 2020. COVID-19 drives new threat to bats in China. Science 367, 1436. https://doi.org/10.1126/science.abb3088.

Zhong, B.-L., Luo, W., Li, H.-M., Zhang, Q.-Q., Liu, X.-G., Li, W.-T., Li, Y., 2020. Knowledge, attitudes, and practices towards COVID-19 among Chinese residents during the rapid rise period of the COVID-19 outbreak: a quick online cross-sectional survey. Int. J. Biol. Sci. 16, 1745–1752. https://doi.org/10.7150/ijbs.45221.

Zhou, P., Yang, X.-L., Wang, X.-G., Hu, B., Zhang, L., Zhang, W., Si, H.-R., Zhu, Y., Li, B., Huang, C.-L., Chen, H.-D., Chen, J., Luo, Y., Guo, H., Jiang, R.-D., Liu, M.-Q., Chen, Y., Shen, X.-R., Wang, X., Zheng, X.-S., Zhao, K., Chen, Q.-J., Deng, F., Liu, L.-L., Yan, B., Zhan, F.-X., Wang, Y.-Y., Xiao, G.-F., Shi, Z.-L., 2020. A pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature 579, 270–273. https://doi.org/10.1038/s41586-020-2012-7.

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., Zhan, F., Ma, X., Wang, D., Xu, W., Wu, G., Gao, G.F., Tan, W., 2020. A novel coronavirus from patients with pneumonia in China, 2019. N. Engl. J. Med. 382, 727–733. https://doi.org/10.1056/NEJMoa2001017.