



A qualitative study of zoonotic risk factors among rural communities in southern China

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Background: Strategies are urgently needed to mitigate the risk of zoonotic disease emergence in southern China, where pathogens with zoonotic potential are known to circulate in wild animal populations. However, the risk factors leading to emergence are poorly understood, which presents a challenge in developing appropriate mitigation strategies for local communities.

Methods: Residents in rural communities of Yunnan, Guangxi and Guangdong provinces were recruited and enrolled in this study. Data were collected through ethnographic interviews and field observations, and thematically coded and analysed to identify both risk and protective factors for zoonotic disease emergence at the individual, community and policy levels.

Results: Eighty-eight ethnographic interviews and 55 field observations were conducted at nine selected sites. Frequent human–animal interactions and low levels of environmental biosecurity in local communities were identified as risks for zoonotic disease emergence. Policies and programmes existing in the communities provide opportunities for zoonotic risk mitigation.

Conclusions: This study explored the relationship among zoonotic risk and human behaviour, environment and policies in rural communities in southern China. It identifies key behavioural risk factors that can be targeted for development of tailored risk-mitigation strategies to reduce the threat of novel zoonoses.

Keywords: ethnographic, qualitative, rural communities, southern China, Zoonotic Risk, 2019-nCoV, coronavirus, SARS

Introduction

Emerging and re-emerging zoonotic diseases are key contributors to morbidity and mortality in southern China.^{1,2} This region, considered a 'hotspot' for emerging zoonotic diseases, harbours abundant wildlife while also undergoing land use change and natural resource overexploitation leading to intensified human–animal interactions that favour the emergence of zoonotic diseases.³ People living in the rural areas of southern China primarily cultivate rice and fruits, raise swine and poultry in households or on small farms,⁴ but also traditionally hunt wild animals as an alternative income source.⁵ The mixed landscape has abundant crops, which attracts wild animals into the communities, and livestock rearing is common.⁶ This brings humans and animals into

close contact in dense populations, creating a wildlife–livestock–human interface for zoonotic disease emergence.⁷

In recognition of the challenges of emerging infectious diseases after the severe acute respiratory syndrome (SARS) outbreak in 2002 caused by a bat-origin coronavirus, the Chinese government established a national real-time hospital-based infectious disease reporting system.¹ Likewise, live poultry market interventions were initiated in response to highly pathogenic avian influenza (HPAI) in southern China in 2001.⁸ In December 2019 (after the completion of the current study), a novel coronavirus (2019-nCoV) emerged in Wuhan, China and spread rapidly across China and the world.^{9,10} This virus is a group 2b coronavirus, which includes SARS-CoV and bat SARSr-CoVs, and

its closest relative is a virus identified in a *Rhinolophus affinis* bat from Yunnan.^{10,11} Environmental samples positive for 2019-nCoV were found in an urban market in Wuhan where some of the earliest known human cases originated.^{12,13} This likely index site sold predominantly seafood, but is also thought to sell live wildlife at the market, and a temporary ban on the wildlife trade for food has been put in place across China. These efforts in response to SARS, HPAI and 2019-nCoV represent a reaction-driven response to zoonotic disease outbreaks, whereas, apart from the new temporary ban on wildlife trade, only limited preventative measures are currently being enacted in the region to reduce the risk of future zoonotic disease outbreaks.¹⁴

However, detailed knowledge of the social and ecological mechanisms of zoonotic disease emergence in the region is limited, and therefore cannot yet inform evidence-based policies and practices for targeted surveillance programmes.¹⁵ Using a qualitative approach through ethnographic interviews and field observations, this study aimed to understand interactions among humans, animals and ecosystems, to shed light on the zoonotic risks in these presumed high-risk communities and to develop an evidence base for identifying appropriate strategies for zoonotic risk mitigation.

Materials and methods

Study sites and participants

The Yunnan, Guangxi and Guangdong provinces in southern China were selected for this study because of their historical importance in the origin of emerging infectious diseases,¹⁶ diverse wildlife population within protected forests¹⁷ and intensive wildlife farming and trade activities.¹⁸ Three sites in rural areas were identified in each province where our previous research had found numerous bat and rodent populations harbouring viruses with pathogenic potential for humans, at sites close to human communities.¹⁹⁻²¹

Enrolment criteria for participation in an ethnographic interview in this study included: individuals were residents of the target community, aged ≥ 18 y, with prior contact with live animals directly (e.g. by raising, hunting, trading or slaughtering live animals) or indirectly (e.g. through animals living in or entering dwellings/crops, bat roosts within roofs, animals invading stored food or crops). We targeted a gender breakdown of 35% of participants being female and aimed to have a diverse sample of participants from different age groups and levels of power and influence in the community.

Recruitment and sampling

In each province, project investigators provided a two-day training workshop for study staff from local provincial and city-level Centres for Disease Control and Prevention who spoke the local language and were familiar with the local community. This included a unit on the ethical conduct of human subject research, an in-depth review of the study design and objectives, and comprehensive information on the implementation of observational research, semistructured interviews and notetaking within the context of this study.

Participants were identified through key informants and the snowball sampling method because the population size at selected sites and the people who had high-risk contacts with live animals were difficult to elucidate.²² Starting with the key informants, we asked each participant to suggest people who met the inclusion criteria and who might be interested in participating in this study; we then contacted the referrals for potential participation in our study. Local study staff visited potential participants and provided these individuals with the participant information sheet to introduce them to the study. We aimed to obtain a minimum sample size of 20 participants from each of the three provinces, for a total sample size of over 60 participants. At least two field observations of local markets and household environments were conducted at each study site, for a total of 18 observations at a minimum.

Participation in the study was strictly voluntary. Study staff reviewed the information sheet with potential participants and explained the details of the study. This included the voluntary nature of participation, inclusion and exclusion criteria, study implementation processes (e.g. that the interview would be audio-recorded), potential risks and benefits of participation, results sharing and that they could withdraw their participation at any time. It was also explained that an item as a token would be given as appreciation for their participation, which was identified by the study team and appropriate for the context of the study sites.

Data collection and management

After completion of the informed consent process, one-on-one semistructured interviews were conducted focusing on the five core themes outlined in the interview guide related to zoonotic disease emergence: human movement, socioeconomics, biosecurity in human environments, human-animal contact and illness, and medical care/treatment and death (Supplementary Data I). All interviews were conducted in the local language and audio-recorded without any identifying information. Confidentiality was maintained by conducting the interviews in a private and secure environment. At the end of the interview, each study participant received a bottle of cooking oil or laundry detergent valued at no more than US\$10 as a token of appreciation.

Field observations were conducted by study staff at each study site concurrently. Observations were general and implemented in three settings: (1) local markets where live animals were traded, (2) in and/or around the dwellings of study participants and, if applicable, (3) community centres, to obtain an overview of the study site and the communities, and supplementary data on human-animal interactions and environmental biosecurity. The observed information was narrated by study staff and audio-recorded on site.²³

To enhance saturation, efforts were made to include a large variety of people with different backgrounds, to conduct a maximized number of interviews during the 8 wk study period in each province and to cover as many themes and subthemes from the interview guide as possible in each interview.²⁴ All data generated, including notes, audio files, digital transcripts and the interviewer checklist, were coded with an alphanumeric ID to preserve the confidentiality of participants. Paper files were

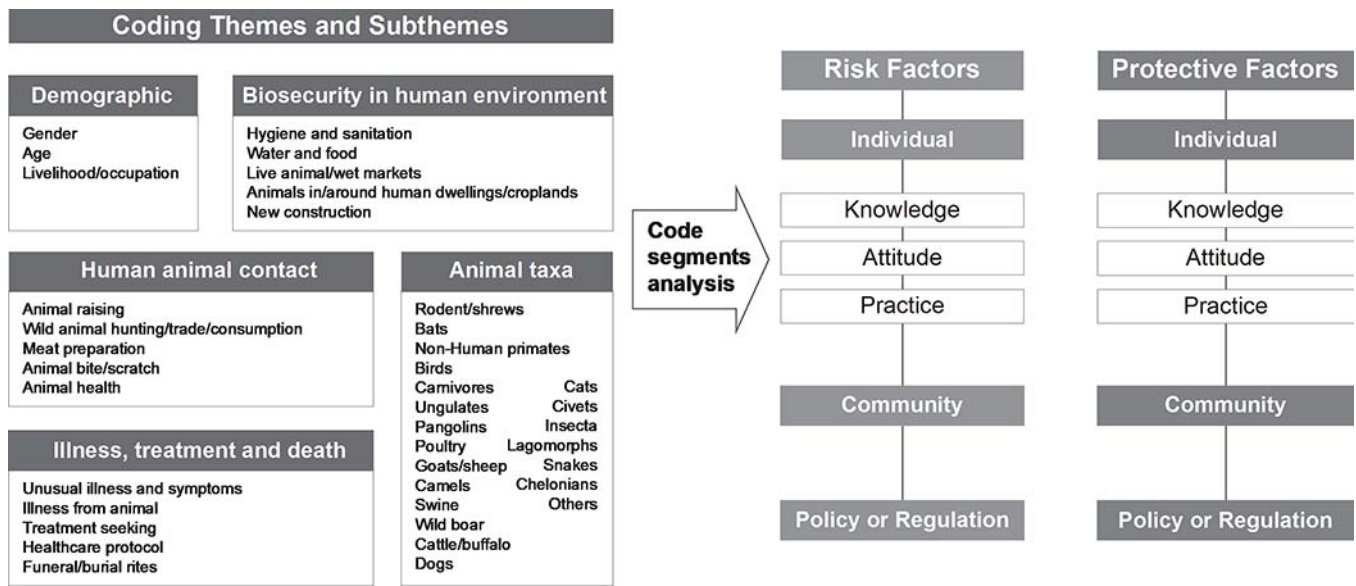


Figure 1. Coding themes, subthemes and analysis framework

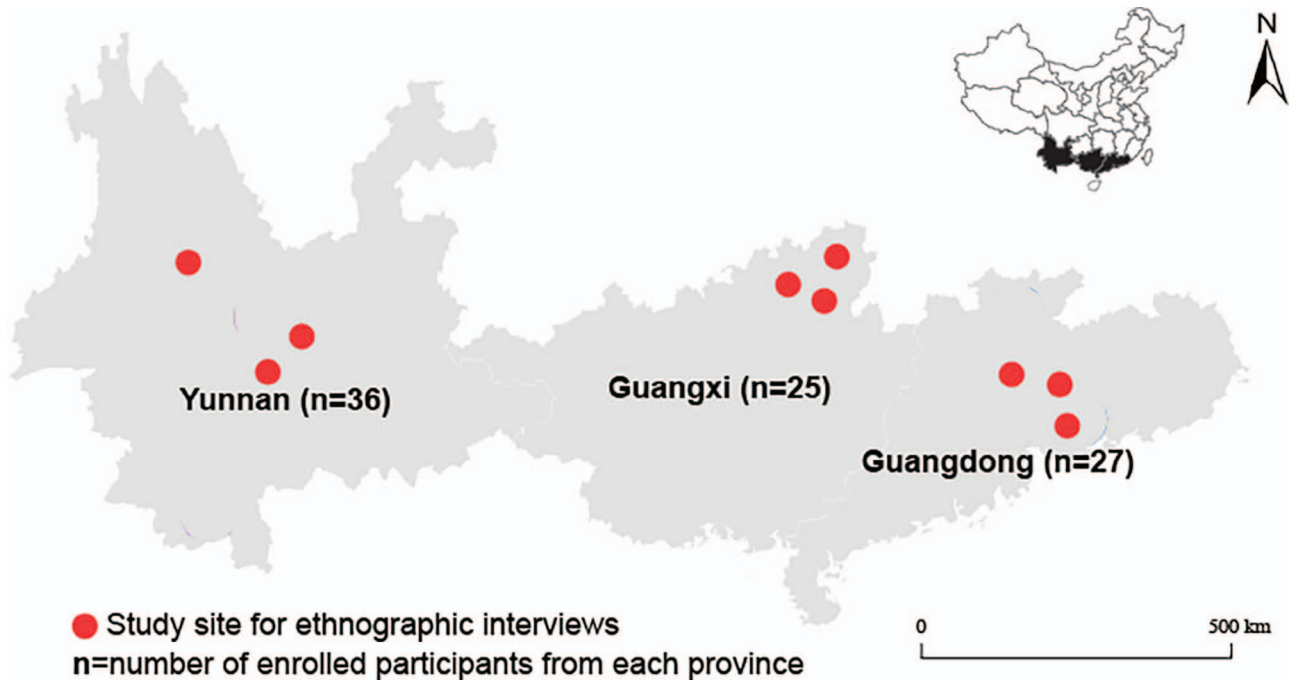


Figure 2. Nine study sites in the Yunnan, Guangxi and Guangdong Provinces, Southern China

scanned electronically and then shredded. All electronic data were encrypted and password-protected, and access was limited to the study staff conducting analyses.

Data analysis

All interviews and observations were transcribed from the local language into Mandarin and translated into English. All transcripts were imported into MAXQDA release 12 statistical soft-

ware (VERBI Software, Berlin, Germany) for data management and analysis. The analysis process incorporated both deductive and inductive approaches, and followed a process of initial coding, identification of new themes, primary coding and identification and analysis of emerging themes.²⁵ An initial codebook associated with the five core themes of the interview guide was developed a priori. After a close reading of the transcripts, two authors used the initial codebook to independently code two transcripts in their entirety, making notes on emerging themes and specified

subthemes. Subsequently, the two authors adapted the codebook and used the modified codebook to code all of the transcripts. During the coding process, the two authors met when any major new themes or concepts emerged to decide on any necessary revisions to the codebook, until no new themes emerged and no new information was obtained from the coding. The final codebook was restructured with five sections: (1) demographics, (2) biosecurity in human environments, (3) human–animal contact, (4) illness, treatment and death and (5) animal taxa; subthemes were defined under each section.

After completion of the coding, a code report was generated from MAXQDA. Internal reliability was assessed by comparing the coded segments from two authors on the same two transcripts to reach a minimum code interaction rate of 80%.²⁶ A saturation grid was built using the ‘Segment Retrieval’ function in MAXQDA to ensure saturation was reached.²⁷ Coded segments were categorized into protective factors and risk factors based on their known associations with disease transmission, and the analysis was stratified at the individual, community and policy or regulation level.²⁸ At the individual level, both risk and protective factors were analysed in terms of the individuals’ knowledge, attitudes and practices to better understand the risk factors for identifying context-based strategies.²⁹ (Figure 1).

Results

Eighty-eight individuals from community sites were enrolled in the study from nine sites in the Yunnan (n=36), Guangxi (n=25) and Guangdong (n=27) provinces from March to December 2015. All study sites were rural locations with permanent housing structures for family dwelling or community use. Family-owned cropland for small-scale vegetable, fruit and rice production was distributed around human dwellings, extending to nearby mountains. New buildings and roads were under construction and live animals were sold at local wet markets. Few wild animals were seen during our visits to all of the sites during the daytime. (Figure 2).

I am on the way to interview a potential participant, currently going through a small local market, here they sell fresh vegetables, fruits, pork and live poultry on both sides of the street. Live chickens, ducks and geese are mixed and kept in cages, I can smell the faeces. A vendor (female) is slaughtering a chicken for her customer who just selected one from the cage, she seems very proficient, only wears an apron but no gloves, the ground is covered by blood and feathers. Not far away, there is a woman wearing an orange uniform who is cleaning the street. After 5 minutes, I turn my way into a cropland, surrounded by Karst mountains, there are mostly rice and some vegetables planted, small birds are flying, two cattle are eating grass. I see a house across the cropland, which is the home of our potential participant, I hear a dog barking when I approach the house (observation made in Xiaolou County, Guangzhou, Guangdong province, 25 September 2015).

Demographics

The majority of study participants were males (n=58, 68%), local residents aged 31–50 y (n=55, 63%) and making a living in

Table 1. Demographic characteristics of the study participants

Characteristic	Participants (n=88)		
	Frequency, n	%	
Gender	Male	58	66
	Female	30	34
Age (y)	18–30	8	9
	31–50	55	63
	>50	25	28
Province	Yunnan	36	41
	Guangxi	25	28
	Guangdong	27	31
Source of livelihood	Government employee	10	11
	Private company employee	7	8
	School teacher	5	6
	Cash crop production (e.g. fruit tree, bamboo)	23	26
	Grain crop production (e.g. corn, rice)	32	36
	Household animal raising for sale	13	15
	Domestic animal farmer	1	1
	Wild animal farmer	2	2
	Health worker	2	2
	Construction worker	10	11
Small business (e.g. restaurant, grocery store owner)	Nature reserve worker	8	9
	Student	16	18
Other casual or out-migrating work (non-specific)	Mineworker	1	1
	Other casual or out-migrating work (non-specific)	1	1
Has worked or work on multiple jobs to make a living	30	34	
	35	40	

grain and cash crop production. Small business (n=16, 18%), household livestock production (n=13, 15%) and other migrant and casual work (n=30, 34%) were the other main contributors to local incomes, and many participants reported multiple income sources (n=35, 40%). Without sharing detailed income or education information, participants who discussed socioeconomic status generally indicated low levels of education (e.g. ‘I didn’t go to school that much’) or a low economic status (e.g. ‘We are poor’) (Table 1).

Potential risks from frequent human–animal interactions

Most participants reported contact with domestic animals in their daily routine of animal raising, slaughtering and meat preparation for consumption, including cats, dogs, poultry, pigs, cattle and goats. The migrant work of some participants limited the amount of time individuals had for household level animal

Box 1. Illustrative quotes: individuals' knowledge, attitudes and practices regarding human–animal contact

- 'My family do not eat the sick animals, we will bury them. But some other people are not willing to throw them away, for example, they use the dead pigs to make preserved meat' (male worker at a local restaurant, 23-y-old, Yunnan).
- 'Two bats flew into our room, so we caught them to eat' (female peasant farmer, 60-y-old, Guangxi).
- 'I work at this restaurant, my daughter works in Guangdong, my husband also works outside, nobody has time to take care of the raised animals' (female worker at a local restaurant, 45-y-old, Guangxi).
- Interviewer: 'Why do people not catch wild animals now?' Interviewee: 'There are few wild animals now, you cannot make much money by catching them, so there are just a few people who are doing this for fun' (male peasant farmer, 40-y-old, Guangdong).
- 'I hurt my waist very seriously, it was painful, and I could not bear the air conditioner. One day, one of my friends made some snake soup and I had three bowls of it, and my waist obviously became better, otherwise, I cannot sit here for such a long time with you' (male peasant farmer, 67-y-old, Guangdong).
- 'I think if my chickens get sick, I will kill them before they die, and eat them' (male peasant farmer, 80-y-old, Guangxi).
- 'I found the chickens died, then I washed them to feed my dog' (female janitor at a local college, 50-y-old, Guangxi).
- 'The excrements of pig are used as fertilizer, much better than the chemical fertilizer' (female peasant farmer, 45-y-old, Yunnan).
- 'We usually buy live animals and kill them by ourselves at home' (female peasant farmer, 45-y-old, Guangxi).
- Interviewer: 'Do people take special protections when they handle wild animals?' Interviewee: 'No, they just handle them as raised animals' (male wild animal farmer, 56-y-old, Guangxi).
- Interviewer: 'Do you wear gloves when killing chicken?' Interviewee: 'No, that would be inconvenient' (female worker at a local restaurant, 50-y-old, Guangxi).
- 'My son wants to keep a dog, but I do not allow him. Because dogs are not clean and they will affect human health' (female peasant farmer, 23-y-old, Yunnan).
- Interviewer: 'Do you know what animals will infect human?' Interviewee: 'Dead animals.' Interviewer: 'Details?' Interviewee: 'Dogs and rats.' Interviewer: 'Do you know how they infect human?' Interviewee: 'Some contact, like bite' (female peasant farmer, 62-y-old, Yunnan).
- Interviewer: 'Many people would catch animals they find, you think different?' Interviewee: 'That's not good, I did not know anything when I was young, when there were many birds and animals in the forest, but now there are few, the only reason is people are destroying the ecosystem, and also many eucalyptus trees were planted, which affect the water, soils, and worms grow up in the trees that birds eat' (male peasant farmer, 40-y-old, Guangdong).
- 'Local people now pay more attentions to viruses carried by animals, they worry about it and they do not want to get infected, our government spend a lot of time on conservation' (policeman, 50-y-old, Guangdong).
- Interviewer: 'Local people catch bats to sell to the restaurants?' Interviewee: 'Yes. It's said bats can prevent cancer' (male peasant farmer, 40-y-old, Guangdong).
- Interviewer: 'Why do people like eating bats?' Interviewee: 'Nourishment for vitality' (male peasant farmer, 65-y-old, Guangdong).
- Interviewer: 'Will people get shot once bats bite them?' Interviewee: 'No. People only get injections for snake or dog bites' (male peasant farmer, 60-y-old, Guangdong).
- Interviewer: 'Do you know which illness can infect animal and human?' Interviewee: 'Rabies. Who was bitten by dogs needs to get an injection' (female peasant farmer, 43-y-old, Yunnan).

husbandry, leading to reduced household animal raising. However, many participants kept dogs or cats for companionship, home protection or preventing rat infestations. Poultry, pigs and cattle were commonly raised for meat consumption and the animal waste was further used as crop fertilizer. Few participants took protective measures when handling or slaughtering domestic animals, or sought medical treatment from a nearby clinic after getting bitten or scratched. Vaccinating domestic animals was not widely implemented among study participants. Sick and dead animals were usually buried, but some participants discussed consuming sick animals or feeding the carcasses to other domestic animals.

On the whole, many participants reported that wild animal hunting, trading or consumption activities have decreased in recent years; however, local communities were still reporting hunting or consumption of some wild animals (e.g. rodents, bats, civets, frogs, snakes and birds) for recreation or additional income. Some participants indicated a preference for wild over

domestic animals for consumption; many also held a belief in the purported curative power of wild animals or their by-products. Most participants were fully informed about rabies and the link to dog bites, as well as the postexposure treatment; however, few were aware of other zoonotic diseases and their origin in animals (Box 1).

Environmental biosecurity concerns in local communities

Recent infrastructural development promoted by local governments was observed and reported around all study sites. Participants reported that this has contributed to improved hygiene and sanitation conditions in local communities. Local wet markets provided safe pork, the most consumed meat among study communities, which had undergone inspection from designated slaughtering houses. However, some participants were concerned about sanitation in local markets,

Box 2. Illustrative quotes: concerns about the community environment

- Interviewer: 'Do they wash hands with soap?' Interviewee: 'No. The places to kill chickens and ducks are usually dirty and smelly, especially during the summer' (male chef at a local restaurant, 24-y-old, Guangdong).
- Interviewer: 'Are there toilets in your house?' Interviewee: 'Yes, but they are all squat-style toilets which we need to transfer the faeces out of the house' (male handyman, 51-y-old, Yunnan).
- 'Once a person died, his or her children will clean the body, put on the cloth, and put the body into a coffin to stay at home. Then they inform relatives and friends to have a meeting to select a date for the burial, when there will be cemetery ritual activities and dinner. When my father-in law and mother-in law died, their bodies stay at home for 3 days' (female peasant farmer, 43-y-old, Yunnan).
- 'There is a cave behind our house, there are always some people going inside the cave and catching bats for food' (female peasant farmer, 60-y-old, Guangxi).
- 'We almost see deer every winter when its snowing around this village, so our dogs pursued deer' (male staff member of local nature reserve, 45-y-old, Guangxi).
- Interviewer: 'What kind of animals live in this area?' Interviewee: 'Weasels. People often see weasels stealing chicken from their houses' (male staff member at local forestry department, 40-y-old, Guangdong).
- Interviewer: 'When you see rats or dead rats, would you call the infection sanitary department for help?' Interviewee: 'There are too many rats in the village, we only call the infection sanitary department for help when someone is infected' (male worker at a local restaurant, 23-y-old, Yunnan).
- Interviewer: 'How do you deal with the wastes, like the organs you do not eat from the chicken?' Interviewee: 'Throw them away.' Interviewer: 'Where do you throw? A certain place?' Interviewee: 'Anywhere is OK like at the roadside' (female owner of a local grocery store, 54-y-old, Yunnan).
- Interviewer: 'Do people worry about the well water quality?' Interviewee: 'Yes, so many people are buying water for drinking, but I am old, I do not care, and I feel the well water is better, sweet, and I drink well water' (male peasant farmer, 80-y-old, Guangxi).

particularly in areas where live poultry were sold and slaughtered. Sterilized tap water was reported to be available in local communities, but anxiety was expressed by some participants regarding water sources shared with animals or polluted by animal waste.

Some participants raised concerns about the environment around their households. In addition to wild animals (e.g. rats, bats and birds) observed entering or living inside human dwellings and contaminating stored food, bat caves or roosts were reported in the community close to human dwellings. Wild animals (e.g. bats, wild boars and deer) were also observed in croplands or orchards eating crops or fruits. Some participants reported that rearing domestic animals as free-range allowed interactions between domestic and wild animals (e.g. wild boars, chickens, dogs and wild birds) (Box 2).

Existing opportunities for mitigating the risks

Many participants indicated that the recent enforcement of wildlife protection laws, as well as gun control policies, has significantly reduced the wildlife hunting, trading or consumption activities. Free or low-priced vaccines for domestic animals were provided by the government, but a lack of access to vaccines in rural areas was reported as one of the main risks associated with raising animals in the household. Participants discussed community healthcare facilities and health insurance, including the national immunization programme for children, as providing accessible protection and preventative services to the local population. Public education about rabies was reported as an example of a zoonotic disease prevention programme that had improved local awareness of the need

for protective measures and postexposure treatment. However, the lack of management plans to address human animal conflicts in local communities as discussed by some participants brings potential zoonotic risks (Box 3) (Supplementary Data II).

Discussion

This study provided evidence of human–animal interactions in rural communities of southern China that increase the potential for zoonotic disease emergence and suggested opportunities for risk mitigation. Population migration from rural communities to urban areas for employment, as well as the wild animal protection policy changes in China in recent years, have led to a perceived overall reduction in activities such as household animal raising and wildlife trade.^{30,31} Protective attitudes, knowledge and a supportive social environment for disease prevention were reportedly being developed within the community.³¹ Existing local preliminary programmes and policies around human and animal health, community development and conservation are considered effective resources to begin or continue developing cost-effective strategies to mitigate zoonotic risks.

In spite of these positive changes over the long term, there is little understanding within enrolled participants of the transmission mechanisms and ecology of zoonotic pathogens that currently circulate in animal populations in the region. This is of particular concern in rural communities where close contact with bats and rodents was reported, and zoonotic pathogens have been detected in the widely distributed animal populations with

Box 3. Illustrative quotes: policy/regulation level risk and protective factors

Healthcare	Interviewer: 'Is the town's hospital far away from you home?' Interviewee: 'About 100 meters.' Interviewer: 'How much do you pay one time?' Interviewee: '30 yuan for normal diseases.' Interviewer: 'Do you have any subsidies?' Interviewee: 'Yes, we have medical insurance' (female cook at a local restaurant, 46-y-old, Yunnan). Interviewer: 'How much you can get reimbursed for your treatment expense?' Interviewee: '75% of the expenses' (male peasant farmer, 36-y-old, Yunnan).
National immunization programme	Interviewer: 'Does your child get vaccine regularly?' Interviewee: 'Yes, some people will inform us.' Interviewer: 'Free charge of vaccine?' Interviewee: 'Almost free, only pay very small amount of injection fee' (male peasant farmer, 36-y-old, Yunnan).
Gun control policy	'There were many hunters, distributed in almost every village, but after the government announced it was illegal to have guns, there are no hunter anymore, but a few people still hunt secretly' (male staff member of local nature reserve, 30-y-old, Guangxi).
Animal health	'Vaccine for foot and mouth disease cost 1 RMB per shot, vaccine of sheep pox cost 2 RMB per shot' (female peasant farmer, 27-y-old, Yunnan). Interviewer: 'Did you give them vaccine?' Interviewee: 'No, of course not in this rural area, the epidemic prevention station staff go to villages to distribute vaccines, but here is not included in the village, that's why I did not get it' (male peasant farmer, 40-y-old, Guangdong). 'If these animals are sick, there is a vet in the villages. Averagely, there will be a good vet among 3 or 5 villages' (male wildlife researcher, 47-y-old, Yunnan).
Disease prevention	Interviewer: 'Does Yunnan CDC have systems to report the sudden death cases?' Interviewee: 'No, but we will investigate for young people's sudden death' (male staff member of local CDC, 42-y-old, Yunnan). Interviewer: 'How to control mouse at home?' Interviewee: 'The village committee give out rat poison each year and I also buy sticky rat board' (female peasant farmer, 43-y-old, Yunnan).
Rabies prevention	Interviewer: 'Are there many people who got sick after being bitten by dogs?' Interviewee: 'Not so many, since 2011, our state has monitored and treated more than 100 people. Treating regularly, they are never sick. But some people refused injection, as a result, they were dead.' Interviewer: 'Are there some policies that domestic dogs must be vaccinated?' Interviewee: 'Yes, but it's hard to implement' (male staff member of local CDC, 42-y-old, Yunnan).
Wildlife hunting and trading	'You know, catch, sell or eat wild animals is illegal. Government will punish you' (female peasant farmer, 40-y-old, Guangxi). Interviewer: 'Who is the main department to educate the public about animal conservation?' Interviewee: 'Mainly relies on the forest department and nature reserve. We go to village in a specific month every year to educate local people' (male staff member of local nature reserve, 30-y-old, Guangxi). 'They do not collect samples for transportation licence of farmed animals; for Inspection and quarantine certificate, they will sampling everything, including water, feeding stuff, oral, blood and rectal of animals regularly' (male bamboo rat farmer, 56-y-old, Guangxi).
Human animal conflict	Interviewer: 'Is there governmental compensation system if animals damage crops?' Interviewee: 'No, our winner bamboo shoots are eaten by wild boars. Nothing will be left once they come, and they run so fast. But there is no compensation, they sometimes run to the orchard to eat oranges and damage many trees. Even purple yams my mum planted are eaten' (male peasant farmer, 50-y-old, Guangdong).

the potential to spill over into the human population.^{20,32-35} In addition, rural residents may face a higher risk because of their limited access to quality healthcare facilities for proper diagnosis and treatment compared with urban residents.³⁶

Enforcement of current wildlife protection policy and continued community infrastructure development appears to significantly reduce high-risk contact between humans, wildlife and livestock. Closer collaboration between local animal and human health authorities within the current epidemic disease prevention programmes will provide educational and training opportunities to promote risk-mitigation knowledge, skills and best practice in local communities. For example, cave monitoring and management is a low-cost and efficient method to help restrict human activities (e.g. recreation and mining) that lead to contact

with bats in caves. This is of particular importance given the emergence of 2019-nCoV, which appears likely to be a bat-origin coronavirus.^{10,11}

As the first qualitative study in southern China to assess risk factors for zoonotic disease emergence, our scope was limited by current knowledge, only allowing us to focus on known presumed risk factors. With further urbanization, and subsequent increased interactions between human populations and the changing ecosystems, new risk factors for zoonotic disease transmission will likely emerge. This might include changes to the wildlife trade following the temporary ban put in place as a response to the emergence of 2019-nCoV.^{9,10} Further research to identify the risk factors among different populations will help develop more locally-relevant and fine-tuned risk

mitigation strategies and address the social and ecological bias to identifying recommendations for other community settings.

Conclusions

Using a qualitative approach, this study allowed us to explore a variety of risk factors at different individual, community and policy levels to contextualize the risks of zoonotic disease emergence in local communities. The findings provide guidance for future in-depth research on specific risk factors, as well as zoonotic disease control and prevention in southern China and potentially other regions with similar ecological and social contexts.

Supplementary Data

- I. Ethnographic Interview Guide
- II. Identified Risk and Protective Factors

Authors' contributions: All authors read and approved the final manuscript. MM, EH and AC designed the study, developed the research tools and implemented the pilot study; GZ, YZ and LZ made major contributions to study implementation; LF and SM developed the data analysis and interpretation plan; HT contributed to the initial analysis; HL contributed to the study implementation, data analysis and interpretation, and writing; PD edited and approved the final version.

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