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Ph.D. Programme in Biology and Applied Biotechnologies

A Cross-disciplinary Approach to Enhance the Conservation of Two Leaf-eating Monkeys (*Rhinopithecus brelichi* and *Trachypithecus françoisi*) in China

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Therefore, my Ph.D. project attempted to study and enhance the conservation of two endangered Leaf-eating Monkeys (*Rhinopithecus brelichi* and *Trachypithecus françoisi*) in China using a cross-disciplinary approach. As a trial ofan interdisciplinary approach to primate conservation, this project would never have been achieved without the help and support of a lot of academic and non-academic professionals. Here, I would like to thank my professors and collaborators so much for your great kindness many times across different fields and disciplines. Prof. Cristina Giacoma, Dr. Marco Gamba, Dr. Rinodato Isidoro, Dr. Olivier Friard, and Prof. Peter Narins comprise the bioacoustics team who trained me in the diverse skills and statistical analysis of vocalization study. Prof. Yeqin Yang and Dr. Chia L. Tan trained me for behavioural studies and conservation practice of our two species. Dr. Hale

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Abstract

In the Anthropocene, humans have been identified as a substantial cause of wildlife extinction. As rapid economic and social development transforms the earth, human beings have caused many forms of wildlife, including non-human primates, to become endangered, and even brought them to the brink of extinction. Asian colobines are one of the most representative of these species. Understanding the ecology and behaviour of the species, the local people close to these animal habitats, and the interaction between the species and local people is of great importance for community-based conservation. The Guizhou snub-nosed monkey (*Rhinopithecus brelichi*) and the François' langur (*Trachypithecus françoisi*) are two endangered Asian leaf-eating monkeys in China and face the same predicament as many other endangered mammalian species. Globally, the Guizhou snub-nosed monkeyis only found in Fanjingshan National Nature Reserve, with a population of between 600 and 750 individuals, while the global population of François' langurs is about 1700 individuals, and Mayanghe National Nature Reserve is home to the largest portion of this population. My Ph.D. project attempts to apply an interdisciplinary approach to the study of numbers and distribution, behaviour, and human-monkey interactions, incorporating scientific data, literature and contributions from multiple disciplines to create a science-story model for an innovative and integrated conservation of species. First of all, my investigation in the field estimated that the population size of François' langurs in Mayanghe Nature Reserve is up to 554 individuals. The majority of our sightings (67 group records) fell within a 1 500 m radius of the nearest rivers or

tributaries. Second, using discriminant functions and artificial neural networks, I conducted the first quantitative study on the species' vocal communication. We confirmed that each species has nine vocal types that are distinguishable both spectrographically and by ear. Meanwhile, we recorded an unexpected high-frequency signal in *R. brelichi* and demonstrated the vocal repertoire and related context of François' langurs in the wild. Next, with several mixed analysis social science techniques, I conducted several surveys on attitudes and perceptions around the interaction between each species and local people. These studies revealed the common influence of the perceived "cost-benefit" of species on local people's attitude towards each species, while demographic factors have various effects on local attitudes in particular contexts. Finally, based on my research and other relevant scientific literatures, I created a novel virtual stories model based on conservation science to effectively communicate to the public and thereby enhance the connection between humans and animals. This model could be extended to any primate or wildlife species to bridge the communication gap between scientists and other stakeholders and promote the integrated conservation of endangered species. Overall, my study demonstrates how to use a cross-disciplinary approach to promote the collaborative conservation of endangered nonhuman primate species, which might be a positive and useful synthesis in developing a paradigm shift relating to the cultural challenge of the biodiversity crisis in "post-Christian" society in the future.

Chinese Summary

应用跨学科方法提高中国黔金丝猴（*Rhinopithecus brelichi*）和黑叶猴（*Trachypithecus françoisi*）的保护

牛克锋

意大利都灵大学，生物科学和系统生物学系

2018 年 1 月，提交意大利都灵大学的博士论文

摘要（中文）在人类世，人类已经成为了引起野生动物濒危和灭绝的主要力量。在全球范围内，人类经济社会的高速发展已将很多野生动物（含非人灵长类）推向了濒危的境地和灭绝的边缘。亚洲疣猴便是这些动物中最具代表性的一组。理解动物的生态与行为、动物栖息地附近的居民以及两者间的相互作用对做好基于社区的物种保护管理具有非常重要的意义。黔金丝猴(*Rhinopithecus brelichi*)和黑叶猴（*Trachypithecus françoisi*）是中国两种濒危的叶猴，面临着与其他大多数亚洲叶猴相似的生存窘况。黔金丝猴有 600-750 只，全部分布于梵净山国家级自然保护区；黑叶猴全球约有 1700 只，最大的野外种群分布在中国的麻阳河自然保护区。我的博士研究尝试采用跨学科的方法致力于提高对黔金丝猴和黑叶猴的保护。在这一研究中，我对物种的种群数量与分布、行为以及人猴关系进行了研究，同时并入

了其他科学数据以及其他学科如摄影、写作等的贡献创立了一个“科学—故事模型”,对物种实施了创新性的综合保护。首先，我的研究估计了麻阳河自然保护区内黑叶猴的种群数量，大约有 72 群 554 只，并发现了大部分黑叶猴（67 群）记录点集中于沿河流两岸（1500 米内）分布的模式。其次，利用判别函数分析和人工神经网络，我对两个物种的声音通讯行为进行了首次定量研究，结合声谱图等证实了每个物种具有 9 种声音模式，收集到了野生黑叶猴不同声音以及每种声音的发声背景，并首次记录到了一种黔金丝猴的高频发声。接着，用社会学调查和分析技术，我对各个物种与当地居民的相互作用进行了知识、感知和态度的定量研究。这些研究发现了当地居民对物种的“成本—收益”感知对人的态度均具有影响，而在不同条件下，不同社会人口因子对人的态度影响却有变动性。最后，基于我的研究以及其他相关的科学文献，我创立了一个新颖的基于保护科学的虚拟故事模型，去向公众高效地传达关于物种的知识和保护信息，从而提高人和动物之间的连接。这种“科学—故事模型”可以推广至任何灵长类或者其他野生动物物种，实现对物种的综合保护。总而言之，我的研究提供了一个如何采用跨学科的方法去提高濒危非人灵长类的综合保护案例，这将为“后基督”社会应对全球生物多样性保护危机的文化挑战以及重塑新的文化范式提供了一个积极而又有用的综合体范本。

Chapter 1 General Introduction

Biodiversity Crisis and Conservation

Human beings have become one of the best adapted species on Earth, with people able to adapt to almost all of the earth's terrestrial habitats. From the early seeds of civilisation to agricultural society to capitalist modernity, human beings have been gradually transformed from "biological human" to "economic man", and the natural environment has also been modified by human beings, in the "humanisation of nature" (Smith 1776; Marx 1927). The purpose of human activity is not only to meet the needs of instinct and survival, but also the pursuit of surplus value and the profits of production (Smith 1776; Marx 1927; Camerer and Fehr 2006). Human cooperation and production, coupled with science and technology, have vastly increased humanity's ability to transform nature (White 1967). As humans, we drastically change the living space around ourselves. The consequence for other wild animals is not only the direct threat of human activity, but also the damage to their ecosystem. Humans have been identified as a substantial cause of the sixth mass extinction in the Anthropocene (Ceballos *et al.* 2015; Corlett 2015).

After western scientists and scholars recognized the crisis of biodiversity in the 1980s, conservation biology emerged as a crisis-oriented field and was defined as "a new synthetic discipline [which] addresses the dynamics and problems of perturbed species, communities, and ecosystems" (Soulé 1985). Recently, a set of core principles of conservation biology was debated, and strategies for conservation simultaneously maximizing the preservation of biodiversity and the improvement of human well-being are highlighted in new conservation

science (Kareiva and Marvier 2012). It has been pointed out that “today's conservation science incorporates conservation biology into a broader interdisciplinary field that explicitly recognizes the tight coupling of social and natural systems” (Kareiva and Marvier 2012).

For conservation initiatives to succeed, it is necessary to understand species themselves as well as human-wildlife interactions, and then incorporate local stakeholders into the decision-making process through science-based management (Manfredo1989; Kareiva and Marvier 2012; Bennett *et al.* 2017; Treves *et al.* 2016). Under the circumstances, using coupled human and natural systems approaches to understand how people and wildlife are interlinked, together with the mechanisms that may weaken or strengthen those linkages, is of utmost importance (Liu *et al.* 2007a, b; Carter *et al.* 2014). However, so far this approach has only been applied for research on and conservation of high-profile species, such as the Chinese giant panda (*Ailuropoda melanoleuca*) in Wolong National Nature Reserve, China and the Bengal tiger (*Panthera tigris*) in Chitwan National Park in Nepal (Carter *et al.* 2014).

Nonhuman Primate Conservation in China

Nonhuman primates remain an essential component of biodiversity and their conservation has become one of the grand challenges we are facing in today’s increasingly human-influenced world (Fuentes and Hockings 2010; Setchell *et al.* 2017; Estrada *et al.* 2017). According to recent research, anthropogenic pressure on primates and their habitats has brought ~60% of 504 primate species to the edge of extinction and has caused population decline in ~75% (Estrada *et al.* 2017). These anthropogenic activities are associated with global and local market demands from humans, leading to extensive habitat loss through the

expansion of industrial agriculture, large-scale cattle ranching, logging, oil and gas drilling, mining, dam building, and the construction of new road networks in primate range regions (Estrada *et al.* 2017).

It is urgent and imperative to promote effective primate conservation, raise scientific and public awareness of the plight of the world's primates and change human behaviour toward these species, if there is to be any hope for a sustainable future for our closest relatives (Estrada *et al.* 2017). To encourage a shift in human activity, a cognitive hierarchy model of human behaviour can be productively applied to influence mental construction and decision making (Camerer *et al.* 2004). With a specific application of this model in wildlife conservation and management, local people's knowledge of species and awareness around interaction between humans and other species can influence patterns of human intentions and behaviour related to wildlife (Fulton *et al.* 1996; Whittaker *et al.* 2006; Manfredo *et al.* 2009). Thus, to study species and attitudes toward wildlife and then transmit this knowledge to stakeholders can positively influence humanity's awareness about these species and then improve the level of primate conservation (De Young *et al.* 1993a,b ; Carter *et al.* 2014; Fulton *et al.* 1996; Whittaker *et al.* 2006).

There are 28 species of non-human primate in China (Fan *et al.* 2017; Jiang *et al.*2017; Hu *et al.* 2017; Li *et al.* 2016). Although most of these primate species and their habitats have been protected by Chinese law since the 1980s (the Law of the People's Republic of China on the Protection of Wildlife 1988), one fifth of these species are still on the edge of extinction (CR) and another third are Endangered (EN) at present according to the IUCN Red List of Threatened Species (IUCN 2017). According to the latest evaluation of mammal

conservation, the primate order has the highest ratio of threatened to unthreatened species and the highest rate of over-exploitation by humans; habitat loss and human interference are the three leading threats to mammals in China (Jiang *et al.* 2016; 2017).

As is the case in many other countries, primates have been exploited and persecuted in China for thousands of years, right up until the present day. Primates are persecuted due to their being viewed as agricultural pests; they are also hunted for meat, and used in traditional medicine and as model organisms in biomedical research (e.g., Behie and Groves 2016; Huang *et al.* 2002; Zhang and Li 2004). Primates are also culturally significant and feature in paintings and literature; there is even a year named after them in the Chinese zodiac (Cui *et al.* 2012; Qin 2008; Zhang 2015; Ellwanger *et al.* 2015). The relationship between people and primates in China, both past and present, is often complex and contradictory.

Meanwhile, although modern science originated in the West, the positive and negative effects of the transformation of nature caused by human activities coupled with science and technology do not only appear in the developed western countries (White 1967). In the process of global industrialisation over recent centuries, the application of western science and technology to production has become an intrinsic driving force for developing countries. This has pushed developing countries to incorporate the western scientific cultural system and advanced technologies into their own cultural systems, and to eventually form their own unique fusion culture on the basis of their traditional cultures. In the Chinese case, after the Second World War, and as China underwent reform and opening, one important national policy was achieving an advanced level of science and technology under the influence of western methods (He 1992).

Today, a complex synthesis mingling traditional culture with western traditions of science and technology may be the primary barrier to current and future conservation of primates and wildlife in China and in most developing countries. This synthesis, which can shape human cultural attitudes and behaviours toward primates, has influenced conservation contribution efforts through conservation regulation, policy, and animal welfare, wildlife farming and playing, the wildlife trade, and so on. To avoid escalation of the problem, conservation education and communication targeting the next generation is perhaps our last hope (Zhang *et al.* 2014). Therefore, we should provide conservation education and communication about species and nature to prevent further conflict (De Young *et al.* 1993a,b; Redford *et al.* 2012; Kareiva and Marvier 2012). Since the current ecological (including biodiversity) crisis of our society has its historical roots in our traditional culture and religion in the "post-Christian" world (White 1967), there needs to be a paradigm shift in our cultural system; wildlife needs to be viewed as more than just a tangible resource to be exploited.

Figure 1.1 Case I: François' langurs (*Trachypithecus francoisi*)
by *Chen Xiaohua*

Figure 1.2 Case II: Guizhou snub-nosed monkeys (*Rhinopithecus brelichi*)
by *Chen Xiaohua*

Conservation Species and Approaches

Over the course of my Ph.D. research, I mainly focused on the integrated conservation of two endangered Leaf-eating Monkeys in China. Case I is that of the François' langur (Figure 1.1, *Trachypithecus françoisi*) and case II is that of the Guizhou snub-nosed monkey (Figure 1.2, *Rhinopithecus brelichi)*. The François' langur is a species of Asian Colobinae (Pousarges 1898, Groves 2001). It occurs in the limestone hills and river valleys of central China and northern Vietnam between 21°45' and 29°20' N (Insua-Cao *et al.* 2012, Han *et al.* 2013). The global population of this species consists of about 1700 individuals at about 30 isolations (Niu in prep.). It is considered an endangered species due to threats from human activities such as poaching, habitat loss and fragments (Bleisch *et al.* 2008). Mayanghe

National Nature Reserve is home to the largest wild population of François' langurs in the world (Niu *et al.* 2016).

The Guizhou snub-nosed monkey, also known as the gray snub-nosed monkey, was described by Thomas (1903) after the collection of a fur near Fanjingshan in Guizhou, China. It belongs to the genus *Rhinopithecus* of odd-nosed monkeys (Yang *et al.*, 2012). This genus comprises of five species: Guizhou snub-nosed monkey *R. brelichi*, Sichuan snub-nosed monkey *R. roxellana*, Yunnan snub-nosed monkey *R. bieti*, Tonkin snub-nosed monkey *R. avunculus* and Myanmar snub-nosed monkey *R. strykeri* (Kirkpatrick 1998; Yang *et al.*, 2002; Tan *et al.*, 2007; Geissmann *et al.*, 2011; Kirkpatrick and Grueter, 2010). Worldwide, the Guizhou snub-nosed monkey currently only occurs within Fanjingshan National Nature Reserve (FNNR) in China (27°49'–28°01' N, 108°45'–108°48'E, Yang *et al.*, 2002; Niu *et al.* 2010). Currently, the population of Guizhou snub-nosed monkeys is about 600-750 individuals in the wild (Yang *et al.*, 2002; Xiang *et al.*, 2009; Guo *et al.* 2017). It is considered ~~as~~ one of most endangered primate species in the world and was also categorized as a National class I protected animal in China (Yang *et al.*, 2002; IUCN, 2013). In two cases in the 1980s, local hunters faced strict legal punishment, and since then this species has rarely been threatened with direct harm (Data from FNNR). However, habitat loss and limitation, decreased genetic diversity and human disruption to habitat continue to threaten the survival of this species (Yang *et al.*, 2002; Yang *et al.*, 2012).

According to a coupled human and natural systems approach (Carter *et al.* 2014), on the one hand, I conducted a biological study of the species' population size, distribution and behaviour; on the other hand, it was necessary to also explore the various dynamics and factors

affecting the relationship between people and animals. Thus, I also conducted a survey on human-nonhuman primate interactions to better understand the effect of the human dimension in animal conservation (Manfredo 1989).

Meanwhile, applying my findings relating to conservation status of species and the interaction between species and stakeholders, it was apparent that the knowledge might form a cognitive improvement (De Young *et al.* 1993a, b). Such improvements would help communities and the public to make more positive judgments on the value of species, further affecting one's ultimate attitude and behaviour toward primates (Fulton *et al.* 1996; Manfredo *et al.* 2009). Thus, I created a science story model to incorporate scientific knowledge and other emotional (Jacobs *et al.* 2012) and conservation messages into interesting stories to bridge a communication gap between human and species. The reason why we choose to use scientific stories to conduct scientific communication is because people have an innate affinity with stories at the psychological level (Sarbin 1986; Harari 2011). The potential of story in conservation communication has come to be recognized by conservation scholars (De Young *et al.* 1993a, b; Leslie 2013; Redford *et al.* 2012; Fernández-Llamazares and Cabeza 2017).

Aim and Overview of Thesis

With the framework mentioned above, the aims of my study are to build a science story model to promote integrated conservation of *R. brelichi* and *T. françoisi* in China. The project is entitled "A cross-disciplinary approach to enhance the conservation of two leaf-eating monkeys (*R. brelichi* and *T. françoisi*) in China". Here I will outline the chapter structure of the work and the contribution of each chapter to the goal of species conservation. These chapters

contain specific studies and discussions on species conservation at both the natural sub-system and social sub-system level.

First of all, I surveyed the population size and distribution of the François' langur (*Trachypithecus françoisi*) in Mayanghe National Nature Reserve, China (Chapter 2). This information is vital for species conservation because this reserve has always been considered as home to the largest wild population size in the world, but a scientific investigation of the whole reserve has never been conducted before.

Niu K., Xiao Z, Wang B., Yang D., Tan Chia L., Zhang P., Yan X., Wang H., Yu B., Yang T., Fan J., Cui D., Zou Q., Wu A., Wei L., Zou H., Gamba M., Giacoma C., Yang Y. (2016) Population Estimates and Distribution of François' Langurs (*Trachypithecus francoisi*) in Mayanghe National Nature Reserve, China. Chinese Journal of Zoology, 51(6):925-938.

Followed by the research above, I continued to study the behaviour, and in particular the vocal repertoires, of François' langurs (*Trachypithecus françoisi*) in Mayanghe National Nature Reserve, China (**Chapter 3**). The aims of this study are to further understanding of their vocal communication, in order to facilitate species conservation. It demonstrates that there are nine vocal types and related contexts for each call type in François' langurs in the wild, which is also important for understanding the vocal adaption of this species.

Niu K., Gamba M., Riondato I., Friard O., Xiao Z., Wu A., Yang T., Tan C. L., Yang Y., Giacoma C. A quantitative analysis of the vocal behaviour of the François' langur (*Trachypithecus francoisi*) at Mayanghe National Nature Reserve, China. American Journal of Primatology, in submission.

Meanwhile, I also worked with my colleagues to describe the vocal repertoire of the Guizhou snub-nosed monkeys (*R. brelichi*) (**Chapter 4**). In this study, we used a supervised machine learning to distinguish call types by measuring the acoustic elements of each call in *R. brelichi*. Our result identified nine major vocal types in the vocal repertoire of *R. brelichi*. Significantly, we also found a presence of high fundamental frequency call, whose harmonics are in the ultrasound domain. This result provided a better understanding of the vocalization of *R. brelichi* which might be helpful in promoting the conservation of this species.

Riondato I, Niu K, Tan C, Yang Y, Gamba C, Giacoma C. First quantitative description of *Rhinopithecus brelichi* vocal repertoire. In preparation, Primates

In terms of the social subsystem, to further involve the local community in conservation, I also studied human-langur interaction in a human-dominated area of MNNR (**Chapter 5**). Local people tend to have slightly negative responses for household impacts of the existence of langurs, while they had very positive perceptions for community impact. The impact of four variables, including age and gender, on perceptions at both household and community level caused significant variation in respondents' attitudes towards langurs. We recommended that local authorities and conservationists develop management strategies using these main explanatory trends and key perception predictors as priorities to promote co-existence between François' langurs and local people in MNNR.

Niu K., Liu W., Xiao Z., Wu A., Yang T., Riondato I., Ellwanger A.L, Ang A., Gamba M., Yang Y., Giacoma C. Exploring Local Attitudes and Perception Toward Endangered François' langurs in Mayanghe National Nature Reserve, China. International Journal of Primatology, in submission.

In next chapter, I also collaborated with my colleagues to survey local knowledge of and attitudes toward the Guizhou snub-nosed monkeys in Fanjingshan National Nature Reserve, China (**Chapter 6**). Our results indicated that respondents' attitudes toward the monkey and efforts to conserve it are generally positive and supportive. However, men are significantly more knowledgeable about the reserve than women and women are significantly more knowledgeable about the monkey than men. Based on our conclusion, we recommend improving communication between reserve officials and local communities, appreciating the role local folklore can play in conservation, incorporating villagers' perspectives into conservation planning, and implementing educational programs that target a wide demographic, with a particular emphasis on women.

Ellwanger AL, Riley EP., Niu K., Tan CL. (2015). Local People's Knowledge and Attitudes Matter for the Future Conservation of the Endangered Guizhou Snub-Nosed Monkey (*Rhinopithecus brelichi*) in Fanjingshan National Nature Reserve, China. International Journal of Primatology 36 (1), 33-54.

In the **Chapter 7**, I attempted to use the data obtained from this study, as well as other previous studies, to create a scientific story on the species to communicate with people

in a funny way. Science-Story models as a conservation tool provide a powerful opportunity to bridge the gap between conservation science and practice in both these cases (see Niu *et al.* 2015; Niu 2016). This science-story model might be a positive way to bring about a paradigm shift in the traditional cultural challenge of wildlife exploitation through the embedding of positive conservation messages. It is a key method to effectively communicate with the general public and educate local residents to discard an old-fashioned and negative traditional culture about wildlife and develop a new nature-culture system for a sustainable future in China.

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In the final chapter (**Chapter 8)**, I had a general summary for my thesis findings and discussed on the implication for future conservation research and practice of both species and other species.

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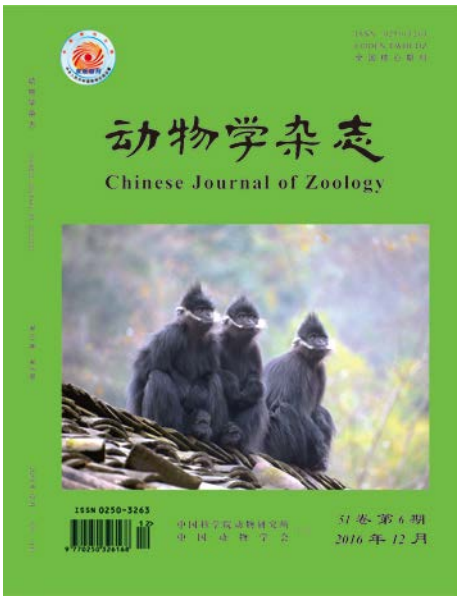

Chapter 2 Population Estimates and Distribution of François´ langurs (*Trachypithecus francoisi*) in Mayanghe National Nature Reserve，China

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Abstract

From October 2012 to May 2015, we surveyed the population of François´ langurs (*Trachypithecus francoisi*) in and nearby Mayanghe National Nature Reserve in Guizhou Province, China. Our methodologies included direct counting of langur groups and individuals along rivers and roads and at their sleeping sites, survey of local people through questionnaires and interviews, as well as the incorporation of published and unpublished data. We located a total of 72 langur groups (including 2 groups outside of the nature reserve) including 47 groups confirmed by direct counts, 8 groups by sleeping sites observations, 9 groups by questionnaires and interviews of local people with sleeping sites observations, and 8 groups incorporatedfrom published and unpublished data. Based on a mean group size of 7.7 ± 2.9 individuals (N = 25), we estimated the langur population at Mayanghe Reserve to be approximately 554 individuals. Specifically, 41 groups (315 individuals) were found in Liangqiao area, 16 groups (123 individuals) in Gongxikou area and 15 groups (116 individuals) in Wuchuan area. The François´ langurs were recorded at the mid to downstream of the Mayanghe River area, Juchishan area, Lanzihe area, Hongduhe in Gongxikou area, north Wuchuan area, south Wuchuan area and a few places such as Chanxihe, Anxi, Liangqiao, and Yintongzi. Comparing this current study to the previous one (1988 ~ 1989), the number of groups varied from 12 to 14 ~ 18 at the mid to downstream of Mayanghe River area, 10 to 9 ~ 13 at Lanzihe area, and 16 to 8 ~ 11 at Juchishan area. The main distribution area of François´ langurs was along three major rivers: Mayanghe River, Hongduhe River and Lanzihe River; especially along river banks and on cliffs where vegetation occurred. Furthermore, the majority of our sightings (67 group records or 93.1%) fell within a 1500 m radius from the center of the nearest rivers or tributaries. Thus, to ensure the species survival in Mayanghe Reserve and to reduce human-langur conflict, we recommend improved protection and restoration of natural vegetation along river banks, especially in areas densely populated by humans.

Key words

François´ langurs; *Trachypithecus francoisi*; Population estimate; Distribution; Mayanghe National Nature Reserve

Introduction

François´ langurs (*Trachypithecus francoisi*) are one of the “limestone” primate species (refer to those primates living in limestone habitats) of the genus Cymopithecidae (Colobinae) (Pousarges 1898; Roos et al. 2007). This species inhabits the karst hills and valleys of southern China and northern Vietnam (21 ° 45 '~ 29 ° 20') (Insua-Cao *et al.* 2012; Han *et al.* 2013). Due to the threat of hunting and habitat loss and fragmentation, François´ langur global population size was estimated to be only 2,000 individuals in 2008 (Bleisch *et al.* 2008). In 2014, the International Union for Conservation of Nature (IUCN) classified these langurs as an “Endangered (En)” species (IUCN 2014).

François´ langur subpopulation sizes and distributions are not well established. François´ langurs are distributed sporadically in at least 10 areas of northern Vietnam, and there is only one reported area in which more than 50 individuals are living (Dine *et al.* 2012; Insua-Cao *et al.* 2012). Due to hunting and other threats such as habitat fragmentation, the latest survey showed that the total population size of Vietnamese langurs has plummeted from 300 individuals down to about 160 individuals during the last decades (Nadler *et al.* 2007; Insua-Cao *et al.* 2012). In China, François´ langurs are found in Guangxi, Chongqing, and Guizhou, with a total population size estimated at 1 500 ~ 1 700 individuals. Worsening habitat fragmentation and degradation threatens the langur populations in all of these areas (Hu *et al.* 2011). In Guangxi, the langur population is estimated to be 350 individuals that inhabit 13 different areas (Li *et al.* 2007a; Wang *et al.* 2014). The Guangxi langur population is threatened by the local traditional medicine harvesting of all the body for "black ape wine" (Huang *et al.* 2002; Hu *et al.* 2004). In Chongqing, the langur population is estimated to be 200 individuals

(Su *et al.* 2002; Han *et al.* 2013). François´ langurs were first reported in Chongqing's Jinfoshan National Nature Reserve (Zhang *et al.* 1992) and later also reported in two areas outside of the Nature Reserve. In Guizhou Province, langur population estimates have grown from ~1000 individuals in the early 1990s to ~1200 individuals in 2011 (Li 1995), and the number of langur groups has increased from 132 to 137 (Hu *et al.* 2011). However, the current distribution of the langurs in Guizhou province is limited to the Mayanghe National Nature Reserve (MNNR), Kuankuoshui National Nature Reserve, Dashahe National Nature Resevre, Baiqing Nature Reserve and Yezhong Nature Reserve. This distribution is half of the original langur distribution in Guizhou. Notably, the original survey from the 1990s may have overestimated langur population size in Guizhou due to the fact that some of the data was derived from non-direct surveys (Hu *et al.* 2011).

Mayanghe National Nature Reserve (hereafter referred to as "MNNR") is located in the north of Guizhou Province, China, across the Yanhe County in Tongren City and Wuchuan County in Zunyi City. It is the largest protected area for François´ langurs in Guizhou Province. From 1988-1989, the population size of wild langurs in the south of MNNR was investigated for the first time. At least 395 individuals in 38 groups were confirmed at the area (Li *et al.* 1989, 1994). Since then, MNNR has undergone many ecological and social changes that potentially impact species conservation and management. As such, we undertook this study to investigate population size and distribution of François´ langurs throughout the reserve in order to develop a more effective management plan to protect this species.

Method

Study site

MNNR (Figure 2.3) was established in 1987 and is located at 28° 37'33 "~ 28° 54'27"N, 108 ° 3 '39 "~ 108° 20'25"E. It was approved as a national nature reserve in 2003 with a total area of 31,113 hm^2 and a core area of 10 543 hm^2. MNNR is at the juncture of Wuchuan County and Yanhe County in Guizhou, China. In this reserve live 22, 816 people

(5, 040 households) in 40 administrative villages of seven towns. Most of these households are located in the experimental area and buffer zone (provided by the MNNR). In order to facilitate management and coordination, the protected area authority set up three management stations at Liangqiao, Gongxikou and Wuchuan in charge of MNNR management (Figure 2.3).

The landscape of MNNR is dominated by limestone hills and valleys (Wang 1994). The highest peak in MNNR is Daxiyakou with an elevation 1 538 m. Annual average relative humidity is 78.7%; and the average annual temperature is 16.7 ℃ with a range of -6 ℃ to 41 ℃. Average annual rainfall is 1 158.7 mm, which qualifies as mid-subtropical humid climate (Zhu *et al.* 1991).

The vegetation in MNNR is dominated by coniferous forest, broad-leaved forest, bamboo forest and shrubs. Other types of vegetation historically found in MNNR include evergreen broad-leaf forest, coniferous and broad-leaf forest and deciduous broad-leaf mixed forest; although, many of these vegetation types have declined over time due to human activity like agricultural land use (Sun 1994). The vegetation is secondary forest (Tang and other unpublished data). Broad-leaf forest and shrubs are the preferred habitat of langurs (Niu personal observation). Both of these vegetation types are distributed in the steep cliffs and valleys area along the rivers of the Mayanghe National Nature Reserve (provided by the Guizhou Forestry Investigation and Planning Institute 2002).

Figure 2.1 The Habitat of François´ langurs in MNNR

There are two major rivers in MNNR: the river in the south is the Mayanghe River, the river in the north is the Hongduhe River with its tributaries including the Lanzihe and Chanxihe. Steep cliffs line both sides of the rivers but are relatively flat outside of the valley. Generally, the bed rock in the river valley is exposed, and the cliff faces are not easily navigable to humans (Figure 2.1). The elevation of the valley is 260 ~ 740 m, and valleys are lined with natural vegetation that is langur habitat (Wang *et al.* 1994, Zeng *et al.* 2013). However, due to construction of the Pengshui hydropower station in 2005, water level of the northern Hongduhe River has risen in recent years covering part of the vegetation and resulting in habitat loss for the langurs (Jiang *et al.* 2006). The river banks beyond the valley are wide and flat, and human activities in these areas such as construction, road building, and farming (Wang 1994) have destroyed the natural vegetation and thus langur habitat. In the downstream areas of the Mayannghe River, the François´ langurs are habituated to human presence and routinely raid fields and feed on agricultural crops. François´ langurs in the Xiangguba area have also inflicted structural damage to homes, creating an intense conflict with local residents (Niu *et al.* 2015, Niu unpublished data).

Survey subjects

François´ langurs are not sexually dimorphic in size. The fur color of adult males and females is primarily black. Adult females also have white patches of fur on their cheeks and buttocks. Adult female genitals are also white. Usually, infants are born in spring and winter each year; the color of the infant is golden yellow from birth to 6 months (Figure 2.2, Wu *et al.* 2006). The social organization of François´ langurs is typically polygamous (Yang 1994).

Everyday François´ langurs have two feeding periods which vary across seasons (Luo *et al.* 2005). Spring foraging peak periods are13:00 ~ 14:00 and 16:00 ~ 17:00 respectively while the foraging peak periods in autumn are8:00 ~ 9:00 and 16:00 ~ 17:00 (Luo *et al.* 2005). Langurs often break branches loudly when they are feeding and moving. François´ langurs are typically "food generalists" and, in MNNR, they consume at least 164 different plant species (Luo *et al.* 2000; Zhou *et al.* 2006; Hu 2011). The langur diet is mainly comprised of leaves, fruits, flowers, and buds. In some areas, they also fed crops including corn (*Zea mays*) or other crops in summer and autumn (Luo *et al.* 2000; Chen *et al.* 2001; Hu 2011).

Figure 2.2 Adult female and infant of François´ langurs

In Guangxi, the home range of the langurs ranged up to 28.75 hm^2.Average monthly activity range was 8.35 hm^2, and average daily activity range was about 661m (Zhou *et al.* 2007). The longest daily distance travelled by a François´ langur group was 726m; the shortest was 354 m, and the average daily distance travelled was 566 m in a human-modified habitat of MNNR (Xiao *et al.* unpublished information). Most langur activity occurred in the daytime occurred on slopes ranging from 33~56 ° with high quality vegetation. In the evening, langurs were often observed on steep slopes or cliffs or caves near the river (Xiao *et al.* unpublished information). There were six to ten sleeping sites for each langur group in the MNNR; areas directly below each sleeping site were easily identified by the presence of large collections of langur urine and stool deposited over time (Huang *et al.* 2002; Wang *et al.* 2011; Zeng *et al.* 2013). Each group of François´ langurs occupied a relatively fixed area of activity typically within and on both sides of a river valley (Li *et al.* 1989; Li *et al.* 2007a; Zeng *et al.* 2013). When different groups encounter each other, a clear long loud call would be uttered by adult males (Li 1994; Yang 1994).

Survey Methods

In this study, langur populations were surveyed and estimated in MNNR through four methods including direct observation of langurs groups, sleeping site identification and quantification, questionnaires and interviews, and the use of unpublished data and literature. These methods have previously been used alone or in combination in primate population surveys (Hu *et al.* 2004; Wang *et al.* 2005; Li *et al.* 2007b; Tang *et al.* 2007; Hai 2011; Han *et al.* 2013; Salmona *et al.* 2014). Direct observation and quantification of langur groups was accomplished through line sample surveys and small area methods (Hu *et al.* 2004; Wang *et al.* 2005; Li *et al.* 2007b; Tang *et al.* 2007; Hai 2011; Han *et al.* 2013; Salmona *et al.* 2014). We

followed the path along the river and recorded the locations in which we observed langurs from April to May 2013 and in November 2013 in the Yanhe county area (Gongxikou and Liangqiao area). In the Wuchuan area, we mainly obtained population data through a questionnaire survey in November 2013 and by counting sleeping sites. In addition, data supplement is also from direct observations in this area. The altitudinal range of the survey area was 300 ~ 1 260 m a.s.l. Survey area vegetation included coniferous forest, coniferous and broad-leaf mixed forest, evergreen broad-leaf forest, evergreen and deciduous broad-leaf mixed forest, bamboo forest, shrub grass and farmland.

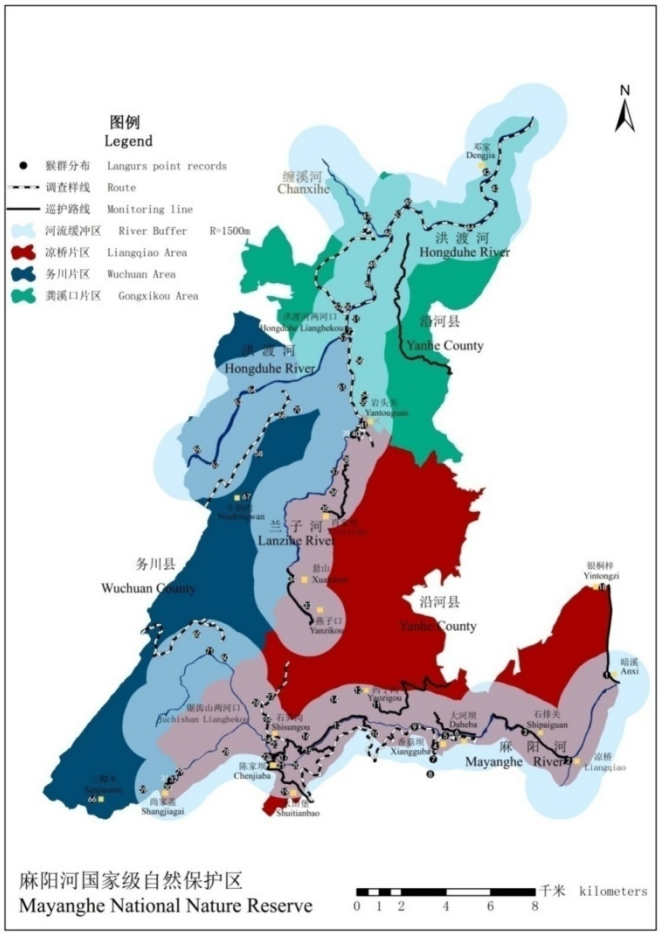

Figure 2.3 Distribution of François´ langurs along the rivers in and nearby Mayanghe National Nature Reserve (radius of buffer distance, R= 1500 m)

Direct observation

The survey lines were mainly along the existing roads or trails in the MNNR. Based on previous research in which langurs were observed on both sides of the rivers (Li *et al.* 1989;

Zeng *et al.* 2013), most of survey lines were selected along the Hongduhe River, Lanzihe River and Mayanghe River (Figure 2.3). For Hongduhe River in the north of MNNR, we implemented a boat survey; the other survey lines were investigated by walking. The safety of the investigators and difficulty of the terrain were also taken into account during the survey. The survey period was April to May and November (45 d) in 2013. April to May was selected due to the ease of spotting the bright fur color of the langur infant in this period (Wu *et al.* 2006). November was selected due to the improved visibility for spotting langurs in deciduous trees that have shed their leaves. Based on a previous study of langur activity patterns (Luo *et al.*2005), we opted to conduct our daily survey from 8:00 am to 17:00 pm.

In each survey, we recorded direct observations of monkey groups and sleeping sites along the survey line (Figure 2.3). Investigators were grouped into one or two groups, with each group containing three to eight persons and traveling along an assigned route (Figure 2.3) with binoculars (10 x 42, Bushnell FOV340FT). Once we encountered the langurs or their sleeping sites, we measured the coordinates of the location by GPS (Garmin 60CSx), and later pinpointed and recorded this information using geographic information system ArcGIS 10.2 associated with 1: 10 000 topographic map of MNNR and the Spot 5 satellite remote sensing image (2011). After identifying the coordinate of the langurs, then we named the group by location. If possible, we also recorded the size and composition of langur group. One group was defined as one record (Figure 2.3). In order to avoid repeated counting of monkeys, the investigators proceeded unidirectionally along the route (Hu *et al.* 2004).

To improve the accuracy of the survey, we also carried out district observations on group size, composition, and activity for at least 5 d at each of the following locations: Aitouguan, Xiangguba, and Shisungou (Figure 2.3). Once the langurs were observed in these areas, they were followed, and group size, composition and activity were recorded. During our study period, we also monitored and recorded the habitat terrain and vegetation. To analyze group size, we marked the langur group on a 1: 10 000 map and identified the group as an

independent group through the AcrGIS10.2 databases. From October 2012 to May 2015, survey lines were monitored daily by investigators and rangers for langur presence. Langur group data was added into our investigation and records to expand the comprehensiveness of the survey.

Combined with the observation points of the monkeys using the ArcGIS10.2, 1: 10 000 topographic maps and the Spot 5 satellite remote sensing images (2011), we identified and analyzed langurs records directly through our observation (See **Appendix I**). To avoid repeated counting of adjacent monkeys, the following principles were followed in the course of removal, retention, and consolidation of monkey observations. First, the groups were considered to be different if they have been found by the same investigator at different locations along the same line survey in the same day (times). Second, group size, composition and activity range were used to judge the identification of langur groups. If the group size and composition of two groups were different, they were considered to be different groups. Third, a river or village barrier between the two groups was also considered to determine whether adjacent monkeys belong to the same group. If the river contained exposed rocks that facilitated river crossing, adjacent monkeys were considered as one group; otherwise, if monkeys could not readily cross the river, the adjacent groups were regarded as different groups. The barrier of a village was based on whether there was a continuous habitat corridor between adjacent groups. If there was, the adjacent langurs were considered as one group.

Sleeping sites

Sleeping sites were also used to identify and analyze the number of adjacent langur groups (See **Appendix I**). The presence of fresh excreta on the cliffs helped determine if a sleeping site was in active use. During the survey, we recorded sleeping site locations via GPS then identified the coordinates on 1：10 000 topographic map and Spot 5 satellite remote sensing image (2011) using the geographic information system ArcGIS10.2. The data on

sleeping sites were used to help estimate group number. Independent sleeping sites helped identify single langur groups. To confirm a sleeping site as independent, we determined if the sleeping site was isolated from adjacent langur groups or separated from other groups due to a village or river barrier. If the above criteria did not work, we developed an additional rule based on average langur home range to identify the langur groups: If one sleeping site was <1km from an observed langur group or an adjacent sleeping site, that site was considered as the same langur group as the latter (Zhou *et al.* 2007). If a sleeping site was > 1 km from an observed langur group or an adjacent sleeping site, that site was considered to represent a second independent langur group.

Interview and Questionnaire survey

There is no previous information available on population size of François´ langurs in Wuchuan area in Zunyi City. Therefore, from November 6 to 12, 2013, we interviewed 78 villagers with a questionnaire in Maqing Village, Shawan Village, Shangba Village and Yueliang Village. Interviewees were all adults and no interviewee came from the same household. The survey question included personal information of the respondents, whether they were aware of the langurs, whether they had seen the langurs in the past three years, and if so, the date, location, group size and activity of the langurs. In order to reduce bias, three volunteer investigators from Tongren University were trained before the survey. Respondents were randomly selected from the name list of the village that MNNR provided. If the selected respondents were not available, we sought available neighbours instead. The locations of langur groups were recorded and named based on their location. After the interview, all the groups were marked on the 1: 10 000 topographic map and Spot 5 satellite remote sensing images using ArcGIS10.2 (2011). Then, investigators and rangers confirmed the existence of langur groups through daily monitoring at these locations. If langur sleeping sites were found in these areas, groups were confirmed. Finally, the numbers of langurs group were estimated and

judged according to the Sleeping Site section described above (See **Appendix I**).

Unpublished data and literature

In areas where langurs had been previously observed, but in which the survey could not be conducted, we used unpublished data and literature to supplement our population survey (See **Appendix I**). We incorporated data on langur group distribution based on reports (2003-2004) from Fauna and Flora International (FFI) and MNNR staff. In 2008 and 2011, MNNR reserve staff and rangers observed 1 langur group in Shuitianbao (Group No.: 19) and one group in Sanjiaomu (Group No.: 66); these two groups were incorporated into the final results. A survey conducted by Li et al. (1994) also reported on one group of langurs in Yaozigou (Group No.: 12); this group was also included in the results of the present survey.

Population size and distribution

To assess total population size, we counted and classified the number of langur groups based on multiple methods outlined above (Table 2.1). In order to accurately calculate the average size of the langur groups, we only use the groups that were found in open environments. The population size of langurs in and nearby the reserve was calculated according to the following formula:

Population size = Average langur group size × Group number

For conservation management purposes, we explored the spatial relationship between langur group locations and rivers. We used the geographic information system ArcGIS10.2 to carry out a river-line target buffer (B) analysis (Buffer Analysis) on langur distribution (Mu, et al. 2012). Finally, we analysed the distribution of monkeys in a buffer distance (R) following the formula below.

$$B = \{ x \mid d(x, \ O) \leq R \}$$

Where “x” is the observed langur location, “d” is the distance between the observed langur location and the river line target O, and R is the buffer distance.

Results

Population size and distribution in and near MNNR

A total of 72 groups of langurs were found in and nearMayanghe National Nature Reserve. Seventy groups were located inside the MNNR and two groups were in the periphery (Figure 2.3 and Table 2.1). Among them, we directly observed47 groups of langurs (65%) (Table 2.1). The average group size was 7.7 ± 2.9 individuals (mean ± standard deviation, range 2-13, n = 25). Total population size (about 554 ± 209 individuals) was estimated by the number of langur groups and the average group size in the area. The survey found that the langurswere most commonly found (Figure 2.3) on the cliffs lining river valleys and innearby area with good quality vegetation, including Mayanghe River area, the Hongduhe River area and Lanzihe River area. The majority of our langur sightings (67 group records or 93.1%) fell within a 1500 m radius from the centre of the nearest rivers or tributaries (Figure 2.3).

Table 2.1 Distribution, number of groups and group sizes of François´ langurs groups in and nearby Mayanghe National Nature Reserve based on different methods

Area	No. of groups				
	Direct count	Sleeping sites observations	Sleeping sites observations& questionnaire surveys / interview of local people	Published and unpublished data	Total
Liangqiao Area	31 (9,10,10,12,11,7,8,7,7, 11,6,8,13,8,8,2,8,2,2)	4	0	6	41
Wuchuan Area	6 (11)	0	9	0	15
Gongxikou Area	10 (5,6,7,8,7)	4	0	2	16
Total no. of groups	47	8	9	8	72

Numbers in bracket are group sizes of langurs.

There were 41 groups (315 monkeys; Group No.: 1 to 41) in the Liangqiao area, accounting for 56.9% of the total number of groups (Table 2.1 and Figure 2.3). Among them, 31 groups were identified through direct observation while 4 groups were identified by their sleeping sites. In addition, there were six groups of langurs identified through unpublished data

or previously published reports.

In the Wuchuan areas, 6 groups of monkeys were identified through field investigation. The locations of these group included Guanjiankou (group No.: 59), Fengbeiyan (group No.: 60), Longqingtou (group No.: 62), Zhongzhaigou (group No.: 58), Gelaozhai (group No.: 61), andChanshutang (group No.: 63). A total of 73 valid questionnaires from the Wuchuan area indicated that the langurs occurred at 25 locations in the survey area from November 2010 to November 2013. Investigators and rangers were able to confirm 9 independent sleeping sites (9 groups) in this area. In total 15 groups (116 individuals; Group No.: 58 ~ 72) were identified in the Wuchuan area (Figure 2.3 and Table 2.1).

Table 2.2 Changes in the population size and distribution of François´ langurs at different localities in and nearby Mayanghe National Nature Reserve

Locality	Surveyed area	No. of groups found in the 1988 and 1989 survey*	No. of groups found in this survey**
Mid to downstream of Mayanghe River area	From Shipaiguan to Daheba to Chenjiaba	12	14/18
Juchanshan area	From Chenjiaba to Lianghekou to Shangjiagai	16	8/11
Lanzihe area	From Lianghekou (Hongduhe) to Yantouguan to Yangzikou	10	9/13
Hongduhe in Gongxikou area	From Lianghekou (Hongduhe) along Hongduhe main river to Dengjia	No survey data	8/11
North Wuchuan area	North of Niudongwan at Wuchuan area	No survey data	4/10
South Wuchuan area	South of Niudongwan at Wuchuan area	No survey data	2/5
Others	Chanxihe, Yintongzi, Anxi, Liangqiao	No survey data	2/4
Total no. of groups		38	47/72

* Data in this column from Li et al. (1989, 1994) ; ** The number on the leftis the confirmed group No.: by direct counting while the number on the right is the number of groups using all methods.

A total of 16 langur groups (123 individuals; Group No.: 42 ~ 57) were identified in Gongxikou Area (Table 2.1 and Figure 2.3). Among them, ten groups were found through the direct observation while four groups were identified by their sleeping sites. In addition, there weretwo groups of langurs identified through unpublished data or previously published reports.

Dynamic variation of population

Similar to the first survey conducted from 1988 to 1989, we observedand identified langursin the mid to downstream areas of the Mayanghe River, Lanzihe Riverand in the Juchishan mountains. In addition, we located langur groups in Gongxikou, Northern and SouthernWuchuan, Liangqiao, Anxi, and Yintongzi (Figure 2.3 and Table 2.2). The number of langurgroups around the Mayanghe River increased from 12 to14 ~18, whilethe number of langur groups in the Lanzihe River Area remained about the same (historically: 10, currently: 9 ~ 13); The number of langur groups in Juchishan mountains decreased from 16 to 8 ~ 11.

Discussion

Population size

Due of the elusiveness of the François´ langur and the inaccessibility of their habitat, a systematic investigation of their population size is challenging. In this situation, researchers often combine different survey methods to reduce the disadvantage of a single method (Hu *et al.* 2004; Wang *et al.* 2005; Li *et al.* 2007b; Haus *et al.* 2009; Han *et al.* 2013; Wang *et al.* 2014). Here, the population of the langurs in MNNR was investigated by means of a comprehensive survey. Direct observations were made on 47 groups (362 langurs); this can be seen as minimum langur population size in MNNR. Using other methods to estimate langur group numbers, a total of 72 groups (554 individuals) were identified including 70 groups within the MNNR and two groups outside of MNNR (Table 2.1).

Compared with the 1988-1989 survey results (Li *et al.* 1989, 1994), this survey yielded a greater number of langur groups and an increased population size. The reasons for this

may be: (1) an optimization of the survey methods; (2) a more systematic and thorough investigation. In this investigation, for the first time, François´ langur populations were surveyed in the Gongxikou along the Hongduhe River, in the southern and northern part of Wuchuan, and around the Chuanxi, Liangqiao, Anxi, and Yintongzi rivers. Furthermore, MNNR rangers provided much useful langur records during the 32-month investigation, enhancing the quality and thoroughness of the survey. (3) MNNR management strategies: In particular, the implementation of management policies and actions such as returning farmland to forest, vegetation restoration, and popularization of laws and regulations that promote langur conservation have had a positive impact on habitat protection and langur population size; (4) Changes in the feeding habits of the langurs: their adaptability to agricultural environments including feeding on readily available, energy rich crops may also be one of the reasons for the increased number of monkeys (Chen *et al.* 2001).

However, the number of langurs in different sub-regions varied (Table 2.2). In the survey conducted in 1988-1989 around the Mayanghe River and the Lanzihe River (formerly known as the "Red River"), langurs were mainly distributed in the jagged hills of the Mayanghe River Basin (16 groups), the middle and lower reaches of the Mayanghe River (12 groups) and the Lanzihe River (a Hongduhe River tributary) (10 groups) (Li *et al.* 1989).

The reasons for the changing number of François´ langur groups over time in the three sub-areas varied. The main reason for an increase in the number of langurs in the mid to downstream areas of the Mayanghe River is: (1) food trees for the langurs, such as *Prunus persica* and *Prunus sp.* (Niu et al. unpublished data) were planted in these areas in 2008; (2) over the past 30 years, langurs have increased the frequency and scale of the crop feeding in this region. Crops provide a readily available food source of the langurs and support population expansion and increased number of langur groups (Chen *et al.* 2001). For instance, only four groups of langurs (Li *et al.* 1989) were recorded at Xiangguba in 1989, while the current survey identified 6 groups of langurs in the same area. The area is one of the areas in which food trees for langurs were planted in the reserve. This area also has crop feeding by langurs, and one of the langur groups is additionally provisioned by local keeper.

The number of monkey groups in the midstream area of the Lanzihe River Basin was relatively unchanged since the previous surveys. Similar to Li and his colleagues (1989, 1994), the distribution of the monkeys was found from Xuanshan to Xiaojiaba, and Aitouguan, and Hongduhe Lianghekou in this survey (Li *et al.* 1989, 1994). This survey found a large area of relatively well-preserved broad-leaf forest at the base of the steep mountains. At the same time, farmland near the river has gradually been converted back to forest and these features have helped sustain a stable number of langur groups in this area. The number of monkey groups in the core area of Juchishan decreased since the previous surveys (Li *et al.* 1989, 1994), which could be attributed to overestimates in the previous surveys due to ineffective surveying methods (Table 2.2). However, this area is large with good quality vegetation, and could feasibly support more monkey groups; thus, in the future, further surveys of this area should be conducted.

Distribution of Langurs

There are two points worth noting on the distribution of langurs: (1) The survey found that there are still langurs distributed along the Hongduhe River at the Wuchuan Area. The results of this survey show that these areas still have considerable habitat suitable for the survival of langurs, and these areas should be protected; (2) François´ langurs were mainly distributed along three major rivers: Mayanghe River, Hongduhe River and Lanzihe River, and they were particularly observed in the cliffs where vegetation occurred along river banks. Furthermore, the majority of our sightings (67 group records or 93.1%) fell within a 1500 m radius from the centre of the nearest rivers or tributaries. This conclusion on the distribution of François´ langurs is consistent with the previous investigation on langurs in MNNR (Li *et al.* 1994; Yang 1994) and is also consistent with the distribution of the most suitable habitat along the valley (Zeng *et al.* 2013). Although the distribution pattern of the langurs has not been studied in depth, the distribution pattern of the langurs in the MNNR appears to be similar to the other subpopulations in Guizhou and Chongqing. Su and his colleagues (2000) found that the langurs were concentrated in the area near the Furong River at the junction of Wulong County

and Pengshui County in Chongqing. Tian *et al.* (2012) conducted an investigation of the langurs in the Yezhong protected area in Guizhou, and they found that the langurs there were distributed along the Beipanhe River.

The monkeys are concentrated along the rivers, probably due to the lack of human disturbance in these areas. Meanwhile, these areas are covered by the broad-leaf forests and shrubs, and thus there are adequate food resources for the langurs. The terrain is steep and the langurs can avoid predators while remaining close to a water source - thus providing good quality microhabitat for the survival of the langurs (Luo *et al.* 2000; Wang *et al.* 2011; Hu 2011; Zeng *et al.* 2013). Zeng *et al.* (2013) recently discovered that suitable habitat for langurs in the MNNR is mostly distributed near the river. Langur distribution can also be affected by human activities including the development of farmland, artificial forests, and the construction of roads and housing across MNNR. These developments limit langur distribution and travel. Therefore, MNNR managers should actively carry out species conservation research in the socio-ecological systems or Coupled Human and Natural Systems (CHANS) to explore species management strategies for the future (Liu *et al.* 2007).

Conservation implication and recommendations

Understanding population size and distribution of a primate species is essential for the effective protection of endangered primates (van Schaik *et al.* 1995; Mishra *et al.* 1998; Lammertink *et al.* 2003; Ha 2007). Over the past few decades, 6 to 7 species of limestone langurs that inhabit the karst environment have been forced to the edge of extinction due to the loss, fragmentation, and degradation of habitat as well as hunting (Yang 1990; Huang *et al.* 2002, 2008; Wojciechowski *et al.* 2013; Schwitzer *et al.* 2015). For example, two langurs species including the Cat Ba Langur (*T. poliocephalus poliocephalu*s) and Delacour's langur (*T. delacouri*) were included in the 2014-2016 world's 25 most endangered primates list (Schwitzer *et al.* 2015).

Meanwhile, the conservation of the limestone langur has attracted global attention. In 2011, the Endangered Primates Rescue Centre (EPRC) reintroduced a captive Delacour's

langur to the wild in hopes that this would aid in the conservation of this extremely small population (Nadler 2015). In 2012, the Cat Ba Langur Conservation Project successfully translocated a female Cat Ba langur into an all-male group in order to accelerate the recovery of wild langur populations (Raffel *et al.* 2014). In Guangxi, China, conservationists effectively reduced the conflict between the natural environment and economic development, increasing the number of *T. poliocephalus* from 165 to 245 through a wide cooperation between scientists, companies, governments and the community (Yin *et al.* 2010). The valuable experience gained from these cases is worth the attention of the François´ langur conservation managers; although local research and context is necessary for effective species management.

MNNR in China is home to the largest wild langur population in the world. In the Liangqiao area of MNNR, there are 315 individuals in 41 groups, which represent 56.9% of the total population in the reserve. In the Wuchuan area, there are 123 individuals in 16 groups and in the Gongxikou area, there are 116 individuals in 15 groups. Based on the results of this survey plus the major determinants of the primate extinction (Michalski *et al.* 2005), management authorities should focus on strengthening management along the Mayanghe, Hongduhe, and Lanzihe Rivers. Specifically, areas within 1, 500m of the river should be protected to promote habitat conservation and limit of human activities. Prohibiting deforestation and protecting the natural vegetation will ensure good quality langur habitat. Managers should also continue to promote the policy of "returning farmland to forest" and encourage local farmers give up farmland and allow vegetation restoration in areas < 1, 500 m from the rivers.

Meanwhile, local authorities should identify the main threats to langur conservation in each area of reserve and develop appropriate strategies to mitigate these threats.

In Liangqiao, we identified a total of 41 langur groups. Notably, the human population in this area is also dense (1,750 households). To ensure the success of langur conservation in Lianngqiao, the biggest challenge is to promote a positive relationship between humans and langurs. Recently, local villagers have begun breeding goats (*Capra aegagrushircus*), which will directly compete for food resources with the langurs. Habitat

sharing between langurs and livestock could also increase the incidence of disease transfer between species (Hu *et al.* 2011; Chen *et al.* 2012). Land use including houses, roads, and electricity infrastructure can negatively impact the dispersal and migration of langurs (Pan *et al.* 2013; data from MNNR). Finally, crop feeding by the langurs also leads to a conflict between humans and langurs (Niu *et al.* 2015). In order to protect crops, dogs (*Canis lupus familiaris*) are used to scare off langurs. Unfortunately, the langurs can also be killed by the dogs (data from MNNR). Given these challenges, several protection strategies should be given priority in this area: (1) strengthen management of the MNNR core area and reduce livestock to decrease the conflict in food resources and habitat use between goats and langurs; (2) carry out scientific research on crop damage caused by langurs and explore long-term compensation mechanisms to counter langur crop feeding; (3) implement community nature education (such as Little Green Guards Programme) (Niu 2012; Tan *et al.* 2014); (4) study experiences, successes and pitfalls of other similar conservation cases to improve langur conservation management. For instance, conservation efforts developed around white-headed langurs in Chongzuo, Guangxi involved cooperation from many stakeholders in order to promote species conservation and local community development (Yin *et al.* 2010).

In Gongxikou, langur habitat along the Hongduhe River has been altered due to construction of the Pengshui Hydropower Station (Jiang *et al.* 2006). This survey found that 9-10 langur groups lived in the hydropower station area. Jiang *et al.* (2006) reported 6-7 langur groups near the Pengshui Hydropower Station. The rise in water level not only changed langur activity range, but it also limited population exchange between langur groups living on opposite banks of the Hongduhe River (Jiang *et al.* 2006). Future work should assess langur distribution on both sides of the Hongduhe River and facilitate the construction of a monkey bridge over the river for langur use in order to promote migration and gene exchange between langur populations on either side of the river.

Good quality vegetation in the core area of Wuchuan area provides ideal François´ langur habitat. However, the difficult terrain makes adequate field surveys in this area challenging (Figure 2.3). For instance, in order to estimate langur group numbers in the

Juchishan at the juncture of Liangqiao and Wuchuan areas, we had to rely on unpublished data and reports. In the future, it will be necessary to increase the investigation and research on François´ langurs in order to obtain more accurate population size and distribution information in this area. This will not only provide accurate background information for the management and protection of langurs in Mayanghe River Basin, but it will also provide a scientific basis for IUCN to assess the global conservation status of François´ langurs.

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Cover Story

François´ langurs (*Trachypithecus francoisi*), the photo was taken by Kefeng Niu at 15:26 on December 15, 2015 at Daheba in MNNR.

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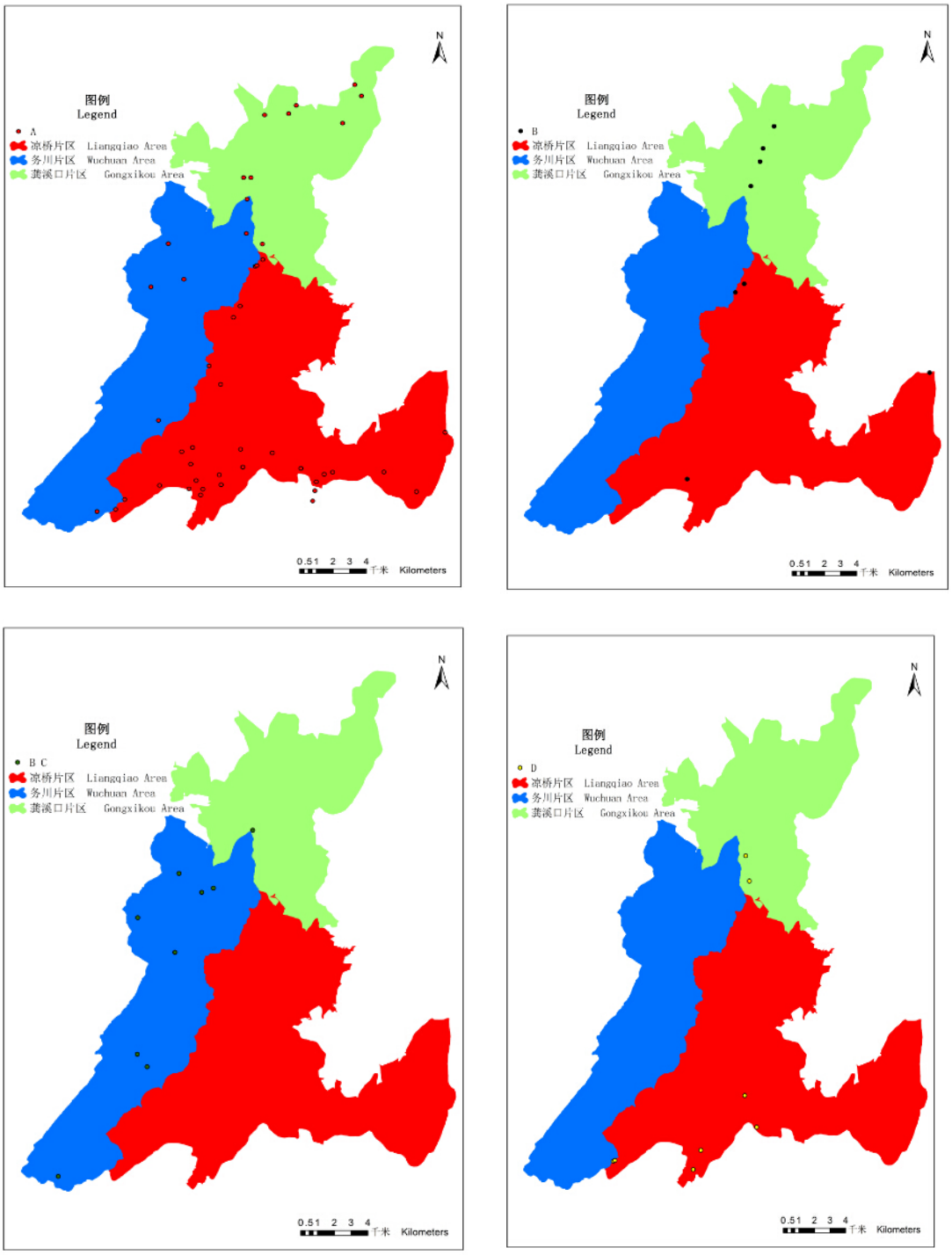
Appendix I



Groups number and localities identified by each method: A, Direct count (47 Groups); B, Sleeping sites observations (8 Groups); B & C, Sleeping sites observations & questionnaire surveys / interview of local people (9 Groups) ; D, Published and unpublished data (8 Groups)

Chapter 3 A Quantitative Analysis of the Vocal Behaviour of the François' langur (*Trachypitecus francoisi*) at the Mayanghe National Nature Reserve, China

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Abstract

Bioacoustics provided researchers with useful information for understanding social interaction and cognition of nonhuman primates. It also showed that the knowledge of acoustic communication sounds could have applications in the conservation of endangered species. In this study, we recorded 649 vocalizations emitted by free-ranging endangered François' langurs (*Trachypithecus francoisi*) at Mayanghe National Nature Reserve, China, from December 2014 to August 2015, and in November and December 2015. We considered the context in which each call was emitted and extracted acoustic features using two different methodologies. We collected a set of acoustic parameters using a semi-automatic procedure and used a fully automated extraction of spectral coefficients. We identified at least nine different vocal types (greet call, short loud call, contact call, threat call, scream, aerial predator alarm call, long loud call, terrestrial predator alarm call and high-frequency call) that are distinguishable both spectrographically and by ear. We performed a quantitative classification using Artificial Neural Networks and stepwise discriminant function analysis. These analyses showed that spectral coefficients obtained higher correct classification rates than the temporal and frequency acoustic parameters. We concluded that this first quantitative description of the free-ranging François' langurs vocal repertoire showed differences with what was observed in captive langurs and opened new perspective in the comparative investigation of the Asian colobines'

communication.

Key words

Communication; Acoustic analysis; Artificial Neural Networks; Multivariate analysis

Introduction

Knowledge of the vocal behavior is a key passage for the understanding of the evolution of communicative systems and social organization (Maynard & Harper, 2003; McComb & Semple, 2005). The study of vocal behavior can provide conservationists with new tools for surveying populations (Dacier, de Luna, Fernandez-Duque, & Di Fiore, 2011), long-term population monitoring (Andreassen, Surlykke, & Hallam, 2014), and allow understanding the effects of the anthropic impact on animal communication (Papale, Gamba, Perez-Gil, Martin, & Giacoma, 2015). Developing new acoustic monitoring tools will provide more information for planning management and reduce the negative impact of environmental changes on endangered species conservation (Laiolo, 2010).

Colobines are a phyletic lineage showing unique peculiarities from morpho-physiological and behavioral points of view (Fleagle,2013; Borries, Lu, Ossi-Lupo, Larney, & Koenig, 2011; Wang, Zhang, & Yu, 2013). They can live in extreme environments and present peculiar anatomy (e.g., nose and stomach morphology, Jablonski, 1998). Despite their astonishing biological adaptation and even if they are one of the most diverse and endangered groups of primates (Roos et al., 2014;

Estrada et al., 2017), they are remarkably understudied compared to old world monkeys (Nadler, Rawson, &Thinh,2010). Langurs constitute a tribe of the subfamily Colobinae (Presbytini) and seven genera are currently recognized (Roos et al.,2014). In this tribe, the genus *Trachypithecus* is the most diverse and includes 20 different species (Roos et al., 2014).

The vocal communication of langurs has been rarely investigated. Studies on vocal communication have dedicated their attention to the species-specific features of single call types seeking for diagnostic cues for species identification (*Presbytis johnii*: Herzog & Hohmann, 1984; *Presbytis entellus* & *P. johnii*:Hohmann, 1988; *Presbytis potenziani*: Tilson & Tenaza, 1982). Further studies on langur communication clarified whether vocal signals could vary within- and between- individuals, populations, and contexts (*Simias concolor*: Tenaza, 1989; *Presbytis senex*: Hohmann, 1990; *Presbytis johnii*: Hohmann & Vogl, 1991; *Presbytis thomasi*: Steenbeek & Assink, 1998; Wich, Koski, de Vries, & van Schaik, 2003; Wich, Schel, & de Vries, 2008; Erb, Hodges, & Hammerschmidt, 2013; Erb, Ziegler, Lestari, & Hammerschmidt, 2016). Previous research also investigated calling patterns (*Trachypithecus vetulus nestor*: Eschmann, Moore, &Nekaris, 2008). However, previous studies have rarely provided a comprehensive description of the vocalizations emitted by the langurs. The pioneering studies of *P. johnii* (Poirier, 1970) and *Rhinopithecus r. roxellana* (Tenaza, Fitch, & Lindburg, 1988, Clarke, 1990) provided the first insights into the structure of the communicative system of langurs, and it was later developed using comparative

methodologies by Riondato and colleagues (Riondato, Giuntini, Gamba, & Giacoma, 2013; Riondato et al., 2017) on *Pygathrix nemaeus* and *P. cinerea*. Unfortunately, the descriptions mentioned above were mostly made on calls recorded from captive animals that may only partly inform about the complete potential of vocal behavior of langurs in nature (e.g., Poirier, 1970; Tenaza et al., 1988; Clarke, 1990; Riondato et al., 2013). At present, most of our knowledge on free-ranging langurs communication comes from only very limited publications on a few langur species (e.g., *P. johnii* & *P. entellus*: Hohmann, 1989; *Presbytis thomasi*: Wich et al., 2003 & 2008; *T. v. nestor*: Eschmann et al., 2008).

Furthermore, most of the previous studies are qualitative. Traditionally the study of vocal repertoires has been characterized by multiple approaches, which alternatively gave priority to the context in which the vocalization occurred, or to the qualitative description of the calls, or again to their acoustic parameters (e.g. Fischer & Hammerschmidt, 2002; Gamba & Giacoma, 2007; Bezerra, Souto, & Jones, 2010; Riondato et al., 2013; Röper et al., 2014; Sobroza, Cerqueda, Simões, & Gordo, 2017). Quantitative studies are necessary to understand the evolution of vocal communication via comparative studies (Bouchet, Blois-Heulin, & Lemasson, 2013) and phylogenetic reconstruction (McCracken & Sheldon, 1997).Recently, Artificial Neural Networks (or ANNs) have been indicated as a powerful tool for the classification of animal acoustic emissions (Zimmermann, 1995; Favaro, Briefer, & McElligott, 2014) and have been successfully applied to categorize the vocalizations of black lemurs *Eulemur macaco* with greater efficiency(Pozzi, Gamba, & Giacoma, 2010). Although this technique has

the advantage of dealing with incomplete and noisy data (Placer & Slobodchikoff, 2000), its application in primate vocal classification is still very limited. The reason for this is probably owing to the fact that most primatologists are not familiar with this technique (Pozzi et al., 2010). However, using this technique to further explore the primate sound classification can develop a more standardized approach to study primate vocal repertoire and compare results among species.

The vocal communication of endangered François' langur (*Trachypithecus francoisi*) was rarely investigated, and current evidence relies on dated recordings of captive individuals (Krishnamurthy, 1991&1994). Here we recorded vocalizations and associated contexts of free-ranging François' langurs in Mayanghe National Nature Reserve, China. We extracted vocalization features using two different methodologies. We collected acoustic parameters with a semi-automatic procedure and processed the files using an automated extraction of spectral coefficients. We then performed the first qualitative description of the vocal repertoire of *T. francoisi* recorded in nature and the first quantitative description of its vocal repertoire by applying Discriminant analysis and ANN. Lastly, based on previous references, we discussed similarity and differences between the vocal repertoire of this species when compared to other Asian colobines.

Methods

Study area, subjects and observations

We recorded the vocal behavior and related context of François' langur around Qinglong village (Figure 3.1) at the juncture between buffer and transition zone of Mayanghe National Nature Reserve, China from December 2014 to August 2015,

and then in November and December 2015 (Niu et al., 2016). We observed four groups of langurs (identified as groups TS, HWD, L, X) all inhabiting the areas close to the village, a human-modified habitat (Niu et al., 2016).

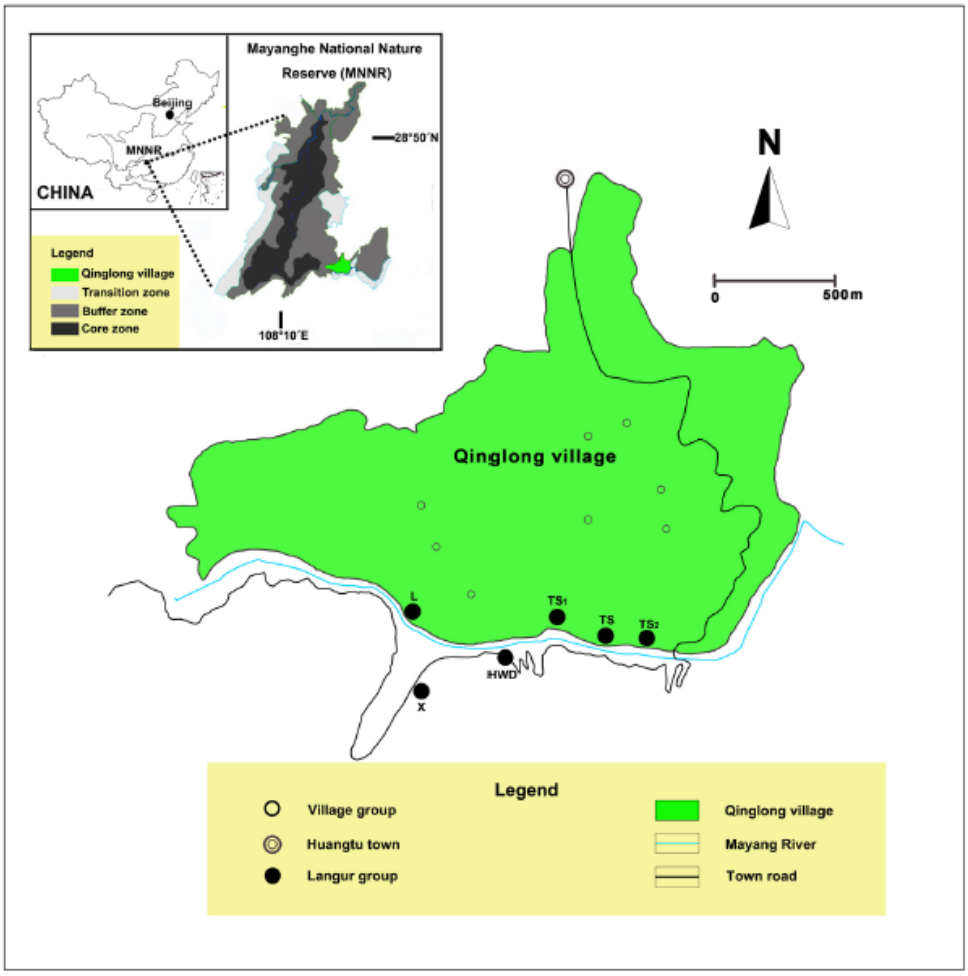

Figure3.1 Study site in Mayanghe National Nature Reserve (MNNR)

The age class and sex of the study individuals were used to understand the composition of each group (Table 3.1). We recognized adult males from adult females because of the visible presence of penis and testicles and the thick fur in the chest area (Yang, 1994; Wang et al., 2017). Females showed prominent black nipples and a white patch in the pubic area; a gradual decrease in the individuals' body size allowed recognizing subadults and juveniles; the infants aged within six months were easily

distinguishable by the orange fur (Wang et al., 2017). We described group composition for all the study groups (Table 1). Starting from 1997 group TS was provided food for 15 days per month (N=34 months, data from MNNR) within the Mayanghe National Natural Reserve long-term monitoring program.

Table 3.1 Group composition of the study langurs in the Mayanghe National Nature Reserve in 2015

Group Code	Group Size	AM	AF	SA	JUV	INF
TS	11	1	4	1	4	1
L	8	1	2	1	2	2
X	10	1	4	1	2	2
HWD	13	1	5	0	5	2
TS_1	7	1	2	0	3	1
TS_2	4	1	2	1	0	0

AM, adult males; AF, adult females; SA, subadults (both sexes); JUV, juveniles (both sexes); INF, infants (both sexes)

Observations of the langurs in Group TS were done at a distance of 10 m because the animals were fully habituated to humans. All the individuals in this group were recognized based on body size and particular body marks (e.g., an incomplete ear). During the study period, we also recorded the arrival of a solitary adult male. Following the arrival of this male, Group TS separated into two subgroups (Group TS_1 and TS_2, Table 1 and Figure1) following a takeover attempt by this new male. This event resulted in the split of Group TS. The resident adult male stayed in Group TS_1 and the invading adult male in group TS_2 (Niu, unpublished data). We also recorded the three neighbouring groups in the Laoyingyan area (HWD, L, and X), which were usually observed and recorded at a distance of 20 m. We observed three encounters that led to physical fights between the males of Groups TS, L, and HWD.

In this study, data were collected in accordance with the legal requirements of

People's Republic of China, and with the permission of Mayanghe National Nature Reserve Administration.

Recordings of the vocalizations and identification of the vocal types

Vocal signals were recorded by a Sound Devices 702 Recorder equipped with a Sennheiser ME67+K6 semi-directional microphone over 29 days of fruitful observations. We used additional audio, and video recordings were taken using a video camera recorder (Sony HDR-CX160). Audio from the video files was selected using BORIS (Friard & Gamba, 2016). We focused attention on a group member for 15 minutes using an all-occurrence sampling of the vocalizations (Altmann, 1974). We made all efforts to direct the microphone towards the mouth of the focal animal and tried our best to keep a distance of maximum 20 m from the subject. Vocalizations recorded in the presence of groups of tourists, noisy vehicles or close to the river, have been discarded because of the high levels of background noise. We discarded all the calls showing a partial overlap with other langur sounds or bird calls. We selected only call emitted by adults to quantify the vocal repertoire size because of the instability of acoustic parameters in the early life of nonhuman primates (Takahashi et al., 2015). We ended having 649 high-quality vocalizations recorded from adult individuals of both sexes which we positioned in single files (sample rate: 44,100 Hz, bit rate: 16 bit) and normalized using PRAAT 5.4.09 (*scale to peak function*, Boersma and Weenink, University of Amsterdam).We labelled the calls to a specific vocal type based on behavioral observation, integrating aural perception, visual inspection of the spectrograms and previously available descriptions(e.g., Hohmann, 1989;

Krishnamurthy, 1991). While paying particular attention to frequency and duration characteristics, KN, MG, and IR performed a visual inspection of the printed spectrograms of each call in the sample. Because one of the call types was readily distinguishable from the others but recorded only twice, it was considered for the qualitative evaluation of repertoire size but not for quantitative analysis.

Feature extraction and selection

We collected acoustic parameters with a semi-automatic procedure and also processed the files using an automated extraction of spectral coefficients. The semi-automatic collection of acoustic parameters (hereafter, ACP) consisted of measuring, for each call, regardless of the vocal category to which it was assigned, 16 acoustic properties using Praat. We measured average fundamental frequency (F0mean), minimum fundamental frequency (F0min), maximum fundamental frequency (F0max), and fundamental frequency at the beginning (F0start) and the end (F0end) of the utterance. We also measured the standard deviation of the F0 during the call (F0stdev), its cumulative variation (F0var, Favaro, Ozella, & Pessani, 2014b), and the absolute slope (F0absslope, Favaro et al.,2014b). To detect these source-related features, Fast Fourier transforms were generated for all calls (frequency range: 0–10,000 Hz; dynamic range: 30 dB). The actual variation of the fundamental frequency (F0) was measured using the autocorrelation method (‘Sound: To pitch (ac). . .’) after adjusting the analysis parameters according to the range of variation for each vocalization (Gamba & Giacoma, 2007; Nadhurou, Gamba, Andriaholinirina, Ouledi, & Giacoma, 2015). To verify the F0 estimation, we investigated the waveform

indicating the time between occurrences of a particular feature and calculating the period of the signal. We also collected the overall duration of the signal (Duration), the number of complete cycles of F0 modulation per second (Fm_Rate, Favaro et al., 2014b), the frequency values at the upper limits of the first (Q25%), second (Q50%), and third quartiles (Q75%) of energy, the percentage of time required to reach the F0min (Pt2min), and the percentage of time required to reach the F0max (Pt2max, Gamba et al., 2016). Because of the background noise and the distance between the animals and the microphone, we could not measure vocal tract-related acoustic features (e.g., formants). We used a Praat script to automate file opening, editing, and saving of the measurements (Gamba, Colombo, & Giacoma, 2012). All the acoustic parameters we measured were then submitted to Principal Component Analysis. The PCA identified six principal components. The six axes accounted for 92.33% of the cumulative variance.

The automated extraction of spectral coefficients (Linear Frequency Bins, hereafter, LFB) was performed processing all vocal signals using an FFT-based approach on the OCCAM computer (Aldinucci, Bagnasco, Lusso, Pasteris, &Rabellino,2016). A custom-made script in Praat first calculated the overall duration of the sound and then split the vocalization into ten portions of equal length. For each portion, the program extracted a set of 14 spectral coefficients, which relate to the energy of different acoustic frequencies between 450 Hz and 7000 Hz. The script would automatically collect the total duration of the vocalization, and the amplitudes of the resulting spectra by sequentially select the frequency bins between 500 and 7000 Hz

(e.g., 501–1000 Hz, 1001–1500, 6501–7000 Hz). Because extracting amplitudes at very low frequencies might result in detecting only additive noise, we set the first frequency bin between 50 Hz and 500 Hz. We obtained a set of 141 measurements that we submitted to Principal Component Analysis. The PCA identified 15 principal components. The 15 axes accounted for 82.99% of the cumulative variance.

Call classification via a Multi-layer perceptron and Discriminant analysis

We used Neural Networks (Multi-layer perceptron, Weka 3.8) and Discriminant analysis to perform class prediction analyses on the two datasets we obtained (ACP and LFB). Neural Networks (or ANNs) are computational models inspired by biological neural networks. They consist of an interconnected network of elements or units (also called neurons), usually organized in different layers. Each connection has particular weights and biases that can be adjusted over time to create a mapping between an input matrix and an output space (Pozzi et al., 2010). ANNs do not require a linear distribution of the acoustic features and therefore may be more effective than traditional class-prediction statistical approaches (Mercado, Green, &Schneider, 2008). The neural network procedure has two phases. During the first phase, usually called training (or learning phase), the network adjusts weights and biases to recognize specific output targets that are provided by an external operator. The adjustment is achieved during successive iterations (or epochs) and is applied only to part of the dataset, called training set. The two crucial parameters of the different runs were learning rate (hereafter, L) and momentum (hereafter, M). Each network was trained for 500 iterations. In the second step, the classification phase (or generalization), a

previously unseen set of inputs (the remaining part of the dataset) has been classified in the predefined output categories, according to the classification scheme elaborated during the training phase. The network performance was evaluated using Cohen's K and ROC area (see Pozzi et al., 2010).

We used Discriminant analysis to identify linear combinations of the principal components that maximize differences among vocal types. During the stepwise procedures, we set F-value thresholds for acceptance or rejection of independent variables at F = 3.84 and F = 2.71 respectively. The probability of group membership was selected as equal regardless of differences in group size. This criterion allowed us to check for large differences in group sizes between vocal types. The stepwise discriminant function analysis (sDFA, IBM SPSS Statistics 23; Lehner, 1996; Nadhurouet al., 2015; Gamba et al., 2015) allowed the identification of the weight of the different principal components in discriminating the call types and then we used the leave-one-out cross-validation to exclude that particular cases may over-influence call classification. We plotted the first two Discriminant functions of ACP and LFB using R 3.4.1 (R core team, 2013: package *ggplot2*).

The percentage of correctly classified instances (hereafter, CCI) represented the number of cases that were correctly assigned to the *a priori* vocal type we indicated. CCI was used as the indicator to establish the performance of each classification process for each dataset.

Results

A priori identification of the vocal types

We were able to recognize nine call types across the vocalizations of free-ranging François' langurs, all of which were distinguishable by ear and visual inspection of the spectrograms. They were the greet call, short loud call, contact call, threat call, scream, aerial predator alarm call, long loud call, terrestrial predator alarm call and high-frequency call (Table 3.2). In general, we were able to record males that emitted the long loud call together with short loud calls during groups encounter or during male fights. In the same context, adult females emitted high-frequency calls, very long high frequency and frequency modulated vocalizations (see spectrogram in Figure 3.2). Contact call and threat call were two common calls recorded from both females and males. We found that François' langurs emitted acoustically different alarm calls which varied apparently according to different classes of predators. The emissions of the aerial predator alarm call were associated with the presence of large raptors, whereas we observed the langurs emitting terrestrial predator alarm calls only when domestic dogs were nearby. The scream, another long high-frequency vocalization, was emitted only by females when physically injured by male or another female. Greet calls were emitted exclusively by females. These calls were repeatedly given when they were exchanging hugs after aggression. We reported more details on the spectrograms and the context of each call type in Table 3.2 and Figure3.2. We have also reported in Table 3.2 whether we could see a spectrographic similarity in between our calls and those described by other studies.

Table 3.2 Definition of the vocal types and whether they were described in previous works, proposed contexts of emission, sex of the emitters, and description of the call characteristics

Call types	Proposed Context	No. of vocalizations	Gender	Acoustic Structure of Vocalizations	Similar call (or unit) in captive *T. francoisi*[a]	Similar call (or unit) in other langur species[b]
Aerial predator alarm call	WG:in presence of a potential aerial predator (e.g., eagle)	10	AM, AF	Low frequency, intense, and short vocalization with clear pulsed structure.		
Terrestrial predator alarm call	WG:in presence of a potential terrestrial predator (e.g., domestic dogs)	15	AM, AF	Short and loud low-pitched call, with clear pulsed structure and visible formants pattern.	Different acoustic structure of alarm call	
Threat call	WG:competing for food. Can also be directed to humans or dogs.	121	AM, AF	Short duration, intense call with visible pulsed structure and clear formants pattern.	Threat cough	
Greet call	WG:occurred after aggressions, possibly mediates reconciliation	41	AF	Very short and low frequency call	Contact greet	
Contact call	WG:feeding, resting, travelling	105	AM, AF	Low frequency, low intensity pulsed vocalization.	Whoop call	
Short loud call	BG:group encounter, fighting an invading male, interaction with humans	153	AM	Short duration and low-pitched harsh vocalization with pulsed structure.	Alarm bark	harsh bark or long loud call (harsh bark unit), *P. johnii; T. v. nestor*
Long loud call	BG:group encounter, fight between a resident male and an invading male, other unknown	189	AM	Long and intense low pitched pulsed vocalization with clear formants pattern		an exhalation unit in the midsection of loud call, *P. entellus and P. johnii*
Scream	WG:food competition, aggression with bites by other male or females	13	AF	Loud and long, tonal high frequency call, with clear modulated structure	Threat scream	
High frequency call	BG:emitted during inter-group fights by non-fighting females	2	AF	Long duration, intense, high frequency modulated vocalization	Higher average fundamental frequency than PSV-3	

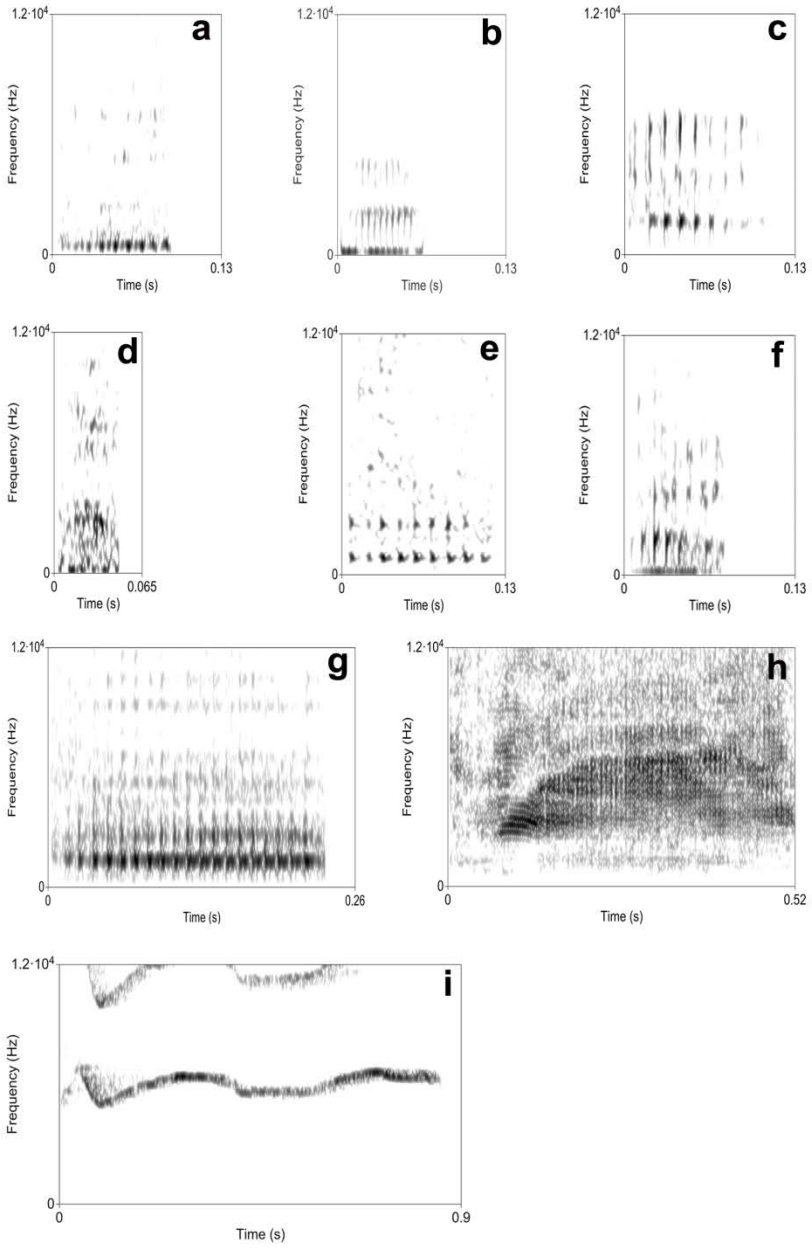

Figure 3.2 Spectrogram of a typical vocalization representative for each vocal type in *T. francoisi*: (a) Aerial predator alarm call, (b) Terrestrial predator alarm call, (c)Threat call, (d) Greet call, (e) Contact call, (f) Short loud call, (g) Long loud call, (h) Scream, (i) High frequency call

Quantitative description of the call types

Overall, the vocal emissions of wild François' langurs could be assigned to the call types we indicated *a priori* (Figure 3.2) by both MLP and sDFA (Figure 3.3a-d). Both MLP and sDFA using the PCA factors (see Appendix II) calculated on LFB showed a higher percentage of CCI when compared to those obtained using the factors computed on ACP (Table 3.3).

We selected a 15 units network (one hidden layer network), which yield the best performance for LFB (learning rate =0.1; momentum = 0.1, CCI = 84.6 %). The average kappa and AUC values of top 5 best neural network models were 0.806±0.003 and 0.963±0.000, respectively (Table 3.3).The corresponding models based on the acoustic parameters showed the highest CCI at 66.8% (learning rate =0.1; momentum = 0.3, Table 3.3).The sDFA model based on LFB was highly significant and correctly classified 81.1% of cases according to the vocal type 78.8% cross-validated; Figure 3.3)against a CCI of 50.7% of the model built on the PCA factors derived from ACP (49.6% cross-validated). The sDFA model (for LFB) correctly categorized 86.7% Terrestrial predator alarm call, 100%Aerial predator alarm call, 80.0% Contact call, 73.2 % Greet call, 72.5% Long loud call, 100% Scream, and 90.2% Short loud call, 82.6% Threat call (Figure 3 and 4). We also observed that 14.3 % of Long loud calls were classified as Aerial predator alarm call; 13.3% of Terrestrial predator alarm calls classified as Greet call; 14.2% of Greet calls classified as Threat call (Figure 3.3). The canonical correlations for the first two dimensions were 0.83 and 0.87, respectively (Wilks' Lambda= 0.021, F (7, 639) = 66.161, P<0.001) in the full data set.

The sDFA models (for ACP) correctly categorized 53.3% Terrestrial predator

alarm call, 40% Aerial predator alarm call, 44.2 % Contact call, 75.6 % Greet call, 46.3% Long loud call, 84.6% Scream, and 36.6 % Short loud call, 69.4% Threat call (Figure3 and 4). Meanwhile, we observed that 20.0 % of Terrestrial predator alarm calls were classified as Short loud call; 20.0% of Aerial predator alarm calls were classified as Contact call and another 20.0% were classified as Short loud call; 29.8% of Contact calls were classified as Long loud call. 22.3% and 19.1% of Long loud call were classified as Aerial predator alarm calls and Contact calls respectively. 18.3% and 20.3% of Short loud call were classified as Terrestrial predator alarm calls and Threat calls respectively (Figure 3.3). The canonical correlations for the first two dimensions were 0.78 and 0.74, respectively (Wilks' Lambda= 0.120, F (7, 637) = 97.868, P<0.001) in the full data set.

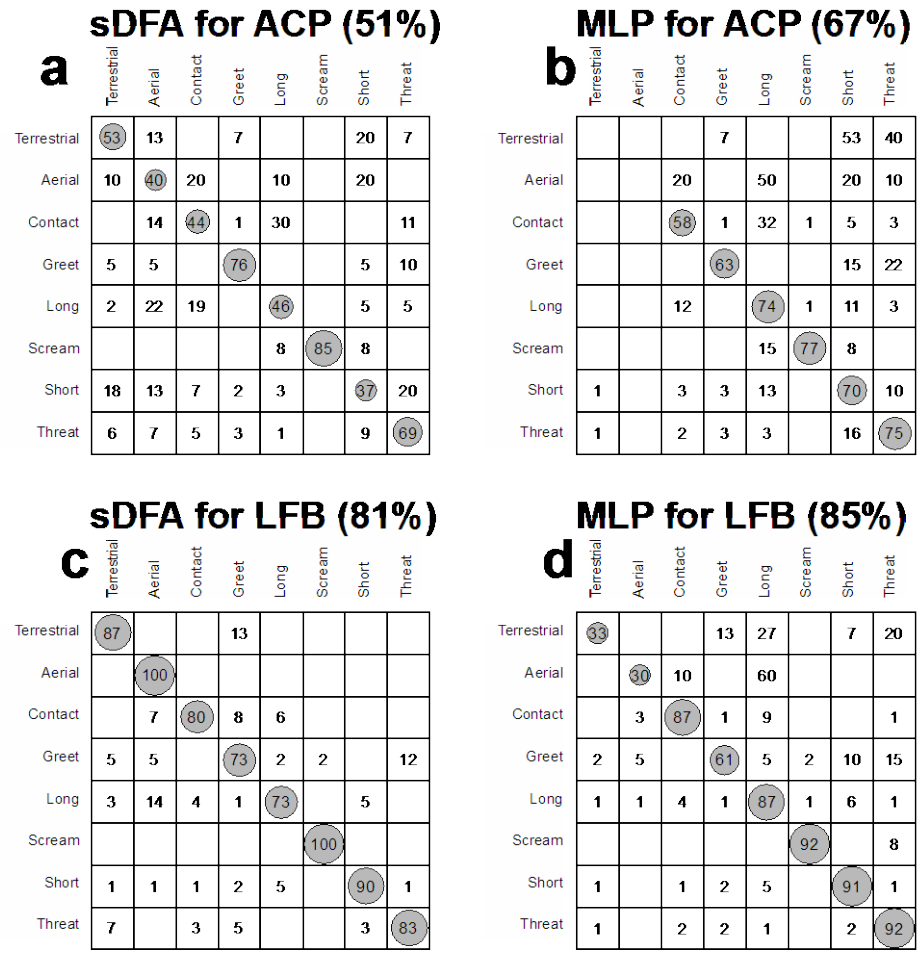

Figure3.3 Plots showing the percentage of correctly classified instances (CCI) showed by stepwise Discriminant analysis (sDFA) and multi-layer perceptron (MLP)applied to the Principal Component axes calculated from the acoustic parameters (ACP) and the linear frequency bins (LFB). Each plot shows *a priori* call types in columns and classification in rows: (a) sDFA for ACP, (b) MLP for ACP, (c) sDFA for LFB, (d) MLP for LFB. Grey circles denote CCI. Size of the circles expands at the increase of CCI. Abbreviated call types: Greet, Greet call; Aerial, Aerial predator alarm call; Short,

Short loud call; Terrestrial, Terrestrial predator alarm call; Contact, Contact call; Threat, Threat call; Long, Long loud call; Scream, Scream

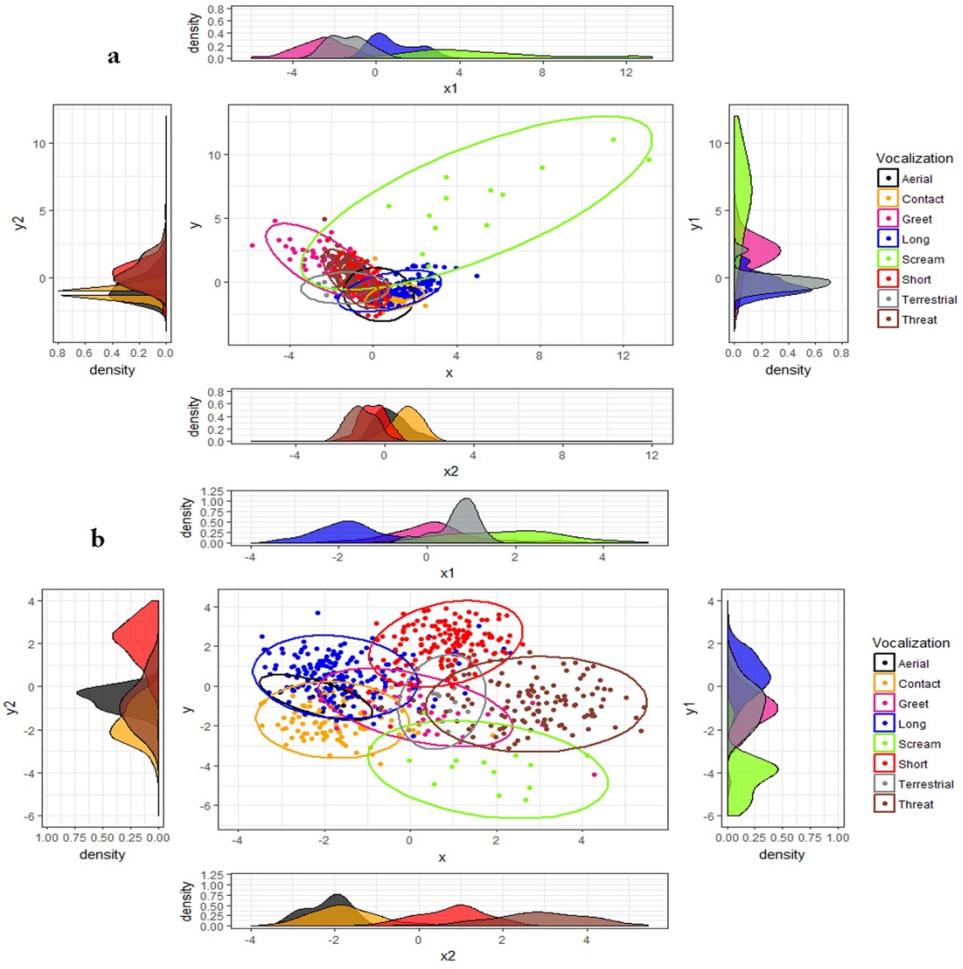

Figure3.4 Scatterplot of the first two Discriminant functions (sDFA) calculated using the Principal Component Analysis axes extracted from the acoustic parameters(a) and the linear frequency bins coefficients (LFB) (b)measured from the vocalizations of *Trachypithecus francoisi*. Each plot shows the first discriminant function on the X-axis and the second Discriminant function on the Y-axis. Abbreviated call types: Greet, Greet call; Aerial, Aerial predator alarm call; Short, Short loud call; Terrestrial,

Terrestrial predator alarm call; Contact, Contact call; Threat, Threat call; Long, Long loud call; Scream, Scream

Discussion

Our study provides the first quantitative description of the vocal repertoire of free-ranging François' langurs, where ANNs and sDFA validated the *a priori* classification of eight vocal types. We also found a ninth vocal type that we described qualitatively but could not be used in the statistical analysis because of the limited sample. Among these vocal types, we could indicate vocalizations used to maintain contact and to mediate affiliative contacts following a conflict, to interact with potential predators, threat calls exchanged when competing for food, and screams associated with bites. We also recorded a high-frequency call emitted by females when males were fighting and long and short loud calls given during group encounters and male conflicts.

A first indicator of the communication complexity of this species came from the analysis of the calls emitted in response to predators. In Mayanghe, previous studies showed that juvenile François' langurs could be killed by dogs (Niu et al., 2016) and adults reacted to the raptors flying over (Niu, pers. obs.). As expected considering previous findings by Hohmann (1989, *P. entellus*) and several other studies, including the paradigmatic work on vervet monkeys (*Chlorocebus pygerythrus*: Seyfarth, Cheney, & Marler, 1980), two different vocalizations were emitted in the presence of aerial and terrestrial predators.

Male langurs emitted long loud calls that can be easily detected as far as 100m (Hohmann, 1989; Wich & Nunn, 2002; Eschmann et al., 2008; Steenbeek & Assink, 1998). They consist of different units that we analysed separately in the current study. We found that a unit of long loud call is very similar to the units of the loud calls of *P. entellus* and *P. Johnii* emitted during intergroup encounters (Hohmann, 1989). The long loud call serves as territorial advertisement in a karst environment were visual contact can be impaired by ground irregularities. Further, they can play a territorial defence function as they were frequently emitted against the invading male. Further, in agreement with Wich and Nunn (2002)'s hypothesis and findings on *Presbytis thomasi* (Wich et al., 2003), we have observed that the long loud call may also mediate mate attraction during intergroup encounters.

We found that the occurrence of the long loud calls was associated with the emission of short loud calls, which were similar to the harsh bark of Nilgiri langurs (*P. johnii*: Hohmann, 1989) and the alarm bark of *T. francoisi* previously described by (Krishnamurthy, 1991). These calls are also similar to the unit that starts the long loud call of other Asian langurs (*P. johnii*: Hohmann, 1989; *Trachypithecus vetulus nestor*: Eschmann et al., 2008). Thus, it appeared that an alarm vocalization is associated to the vocalizations emitted during intergroup encounter and territorial conflict, in agreement with findings on other primates. For example, the long multiunit song emitted by *Indri indri* is normally preceded by the roar (Torti et al.,2013). These characteristics open the possibility that each separate unit may encode specific information related to different motivational state (Narins & Capranica, 1978).

We also recorded a high frequency call that was spectrographically similar to the PSV-3 call (“possible stress induced and stereotypic vocalizations” - type 3; Krishnamurthy, 1994). The contextual description of Krishnamurthy (1994) reported that the PSV-3 call was given by captive adult females and subadult female which were stressed. We observed that females, in the wild, emitted high frequency calls during male fights.

We recorded adult female emitting screams when bitten by adult male or female. The spectrograms of the scream are notably similar to the "threat scream" (Krishnamurthy, 1991), which were observed in captivity during severe attacks or male threats. The previous studies of Krishnamurthy (1991) on *T. francoisi* also offered other insights. We recorded a threat call that is very similar to the "threat cough" in Krishnamurthy (1991), in both acoustic structure and context. The contact call has a spectral energy distribution similar to the "whoop", which mediates group cohesion in captivity (Krishnamurthy, 1991). The spectrograms of the greet call are similar to the greet calls published by Krishnamurthy (1991). Greet calls occurred shortly and repeatedly before or during female hugging. The greet calls can be a form of conflict resolution or reconciliation after females competed for access to food.

Overall, we found that the spectrographic representation of vocalizations in *T. francoisi* is qualitatively more similar to those of *P. johnii* or *P. entellus* (Hohmann, 1989) than odd-nosed monkeys (*Pygathrix nemaeus*&*P. cinerea*: Riondato et al., 2013&2017; *N. larvatus*: Röper et al., 2014; *Rhinopithecus brelichi*: Riondato, 2016).This result is consistent with the previous analyses, which suggested that the

acoustic structure of calls may be consistent with molecular phylogeny of Asian colobines (Hohmann, 1989; Meyer et al., 2012). However, taking into account the number of vocal types, which may indicate phylogenetic proximity across different taxa (Gamba et al., 2012), we identified a vocal repertoire for *T. francoisi* that is smaller than previously described for captive *T. francoisi*(15, Krishnamurthy, 1991) and other wild langurs (*P. johnii*: 17 and *P. entellus*: 18, Hohmann, 1989) but similar to those reported for some odd-nosed monkeys (*N. larvatus*: 7, Röper et al., 2014; *P. cinerea*: 8, *P. nemaeus*: 8, Riondato et al.,2013; *R. brelichi*: 9, Riondato, 2016).Study conditions (e.g., habitat noise, difficulty to access the habitat, free-ranging animals or captive animals) may lead to differences in the assessment of vocal repertoire size. As Krishnamurthy (1991) pointed out, the number of vocalization of captive individuals may be overestimated because of continued human disturbance or potential stress (Krishnamurthy, 1994). Moreover, during our observations, the langurs may spend time on the cliffs where we are not able to record them or eventually flee in response to residents, thus potentially reducing our chance to record all of the vocal types. Differences in call classification methods are key factors in producing different results and prevent detailed comparisons. We suggest a new methodology, based on linear frequency bins, which can be reliable for the analysis of extensive collections of animal sounds. This is the main reasons why we adopt a quantitative approach and we tested two different methods. First we collected temporal and frequency parameters traditionally utilised to describe acoustic structure in previous studies and second we adopt a completely automatic feature extraction of frequency coefficients. We showed

that, while both methodologies and datasets allowed to achieve significant results, the automatic feature extraction submitted to an artificial neural network may indeed provide the highest percentage of correctly classified interests. These results are in agreement with previous findings of Pozzi and colleagues (Pozzi et al.2010; Pozzi, Gamba, Giacoma, 2013) and may provide researchers with a new method that may indeed unify the approach to the study of primate vocal repertoire. Of course, as in every automatic approach, background noise and its variability can be critical issues. Terrestrial and aerial calls that have most of their energy in the low frequency bands where ambient noise is higher were in fact characterised by a lower classification predictability when the analysis were based on Linear Frequency Bin than on traditional Acoustic Parameters. We are confident that future works may use the promising method presented in our paper to investigate the vocal repertoire of other colobines further.

Our results also possess an applied potential for the non-invasive monitoring of wild population of Francois' langurs. Long and short loud calls can be good predictors of the presence of males meanwhile screams can be a good indicator of the presence of females. Other frequent calls, as the threat calls, can be recorded as far as 30 m and may allow detecting the presence of a group. Future studies should aim to integrate this information with the use of passive acoustic recording to strengthen the ability to monitor population dynamics, the potential impact of human activities, and the effectiveness of conservation policies.

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CONFLICTS OF INTEREST

We declare no competing interests and no conflicts of interest.

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Appendix II

Principal Component Analysis based on Linear Frequency Bins (Initial Eigenvalues >1)

Component	Initial Eigenvalues	Extraction Sums of Squared Loadings				
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	
1	46.202	32.767	32.767	46.202	32.767	32.767
2	17.757	12.593	45.36	17.757	12.593	45.36
3	16.628	11.793	57.153	16.628	11.793	57.153
4	9.957	7.062	64.215	9.957	7.062	64.215
5	5.782	4.101	68.316	5.782	4.101	68.316
6	4.19	2.971	71.287	4.19	2.971	71.287
7	3.039	2.155	73.442	3.039	2.155	73.442
8	2.449	1.737	75.179	2.449	1.737	75.179
9	2.175	1.543	76.722	2.175	1.543	76.722
10	1.887	1.338	78.06	1.887	1.338	78.06
11	1.694	1.202	79.262	1.694	1.202	79.262
12	1.485	1.053	80.315	1.485	1.053	80.315
13	1.395	0.989	81.305	1.395	0.989	81.305
14	1.194	0.847	82.151	1.194	0.847	82.151
15	1.181	0.838	82.989	1.181	0.838	82.989
16	0.947	0.672	83.66			

17	**0.909**	**0.645**	**84.306**			
18	**0.885**	**0.628**	**84.933**			
19	**0.81**	**0.575**	**85.508**			
20	**0.777**	**0.551**	**86.059**			
21	**0.724**	**0.513**	**86.572**			
22	**0.679**	**0.482**	**87.054**			
23	**0.638**	**0.452**	**87.506**			
24	**0.594**	**0.421**	**87.928**			
25	**0.546**	**0.387**	**88.315**			
26	**0.501**	**0.355**	**88.67**			
27	**0.488**	**0.346**	**89.016**			
28	**0.444**	**0.315**	**89.331**			
29	**0.438**	**0.311**	**89.642**			
30	**0.41**	**0.291**	**89.933**			
31	**0.398**	**0.282**	**90.215**			
32	**0.365**	**0.259**	**90.474**			
33	**0.354**	**0.251**	**90.726**			
34	**0.347**	**0.246**	**90.971**			
35	**0.326**	**0.231**	**91.203**			
36	**0.321**	**0.227**	**91.43**			
37	**0.307**	**0.218**	**91.648**			
38	**0.29**	**0.206**	**91.854**			
39	**0.273**	**0.193**	**92.047**			
40	**0.267**	**0.19**	**92.237**			
41	**0.264**	**0.187**	**92.424**			

42	**0.249**	**0.176**	**92.6**			
43	**0.248**	**0.176**	**92.776**			
44	**0.244**	**0.173**	**92.949**			
45	**0.237**	**0.168**	**93.117**			
46	**0.233**	**0.165**	**93.282**			
47	**0.222**	**0.157**	**93.44**			
48	**0.213**	**0.151**	**93.59**			
49	**0.207**	**0.147**	**93.737**			
50	**0.202**	**0.143**	**93.88**			
51	**0.194**	**0.137**	**94.018**			
52	**0.189**	**0.134**	**94.152**			
53	**0.187**	**0.133**	**94.284**			
54	**0.182**	**0.129**	**94.413**			
55	**0.179**	**0.127**	**94.541**			
56	**0.176**	**0.125**	**94.666**			
57	**0.174**	**0.123**	**94.789**			
58	**0.17**	**0.121**	**94.91**			
59	**0.169**	**0.12**	**95.03**			
60	**0.166**	**0.118**	**95.147**			
61	**0.162**	**0.115**	**95.262**			
62	**0.16**	**0.113**	**95.375**			
63	**0.157**	**0.112**	**95.487**			
64	**0.152**	**0.108**	**95.595**			
65	**0.147**	**0.104**	**95.7**			
66	**0.145**	**0.103**	**95.803**			

67	**0.144**	**0.102**	**95.905**			
68	**0.14**	**0.099**	**96.004**			
69	**0.138**	**0.098**	**96.102**			
70	**0.136**	**0.096**	**96.199**			
71	**0.133**	**0.095**	**96.293**			
72	**0.13**	**0.092**	**96.385**			
73	**0.13**	**0.092**	**96.477**			
74	**0.126**	**0.089**	**96.567**			
75	**0.122**	**0.086**	**96.653**			
76	**0.121**	**0.086**	**96.739**			
77	**0.118**	**0.084**	**96.823**			
78	**0.117**	**0.083**	**96.906**			
79	**0.116**	**0.083**	**96.988**			
80	**0.115**	**0.081**	**97.07**			
81	**0.11**	**0.078**	**97.148**			
82	**0.109**	**0.078**	**97.225**			
83	**0.108**	**0.077**	**97.302**			
84	**0.105**	**0.075**	**97.377**			
85	**0.104**	**0.074**	**97.451**			
86	**0.102**	**0.072**	**97.523**			
87	**0.102**	**0.072**	**97.595**			
88	**0.099**	**0.07**	**97.665**			
89	**0.098**	**0.069**	**97.734**			
90	**0.096**	**0.068**	**97.803**			
91	**0.095**	**0.067**	**97.87**			

92	**0.094**	**0.066**	**97.937**			
93	**0.091**	**0.065**	**98.001**			
94	**0.09**	**0.064**	**98.065**			
95	**0.088**	**0.063**	**98.128**			
96	**0.086**	**0.061**	**98.189**			
97	**0.084**	**0.06**	**98.248**			
98	**0.082**	**0.058**	**98.307**			
99	**0.082**	**0.058**	**98.365**			
100	**0.08**	**0.057**	**98.422**			
101	**0.079**	**0.056**	**98.478**			
102	**0.078**	**0.056**	**98.534**			
103	**0.077**	**0.055**	**98.588**			
104	**0.075**	**0.053**	**98.642**			
105	**0.073**	**0.052**	**98.694**			
106	**0.073**	**0.052**	**98.745**			
107	**0.072**	**0.051**	**98.796**			
108	**0.069**	**0.049**	**98.845**			
109	**0.069**	**0.049**	**98.894**			
110	**0.067**	**0.048**	**98.942**			
111	**0.066**	**0.047**	**98.988**			
112	**0.065**	**0.046**	**99.034**			
113	**0.063**	**0.045**	**99.079**			
114	**0.062**	**0.044**	**99.123**			
115	**0.061**	**0.043**	**99.166**			
116	**0.06**	**0.042**	**99.209**			

117	**0.058**	**0.041**	**99.25**			
118	**0.058**	**0.041**	**99.291**			
119	**0.057**	**0.041**	**99.332**			
120	**0.057**	**0.04**	**99.372**			
121	**0.054**	**0.039**	**99.411**			
122	**0.053**	**0.038**	**99.448**			
123	**0.052**	**0.037**	**99.486**			
124	**0.051**	**0.036**	**99.522**			
125	**0.049**	**0.035**	**99.557**			
126	**0.049**	**0.035**	**99.592**			
127	**0.048**	**0.034**	**99.625**			
128	**0.046**	**0.033**	**99.658**			
129	**0.046**	**0.032**	**99.69**			
130	**0.044**	**0.031**	**99.722**			
131	**0.041**	**0.029**	**99.751**			
132	**0.04**	**0.028**	**99.779**			
133	**0.039**	**0.028**	**99.807**			
134	**0.038**	**0.027**	**99.834**			
135	**0.037**	**0.026**	**99.861**			
136	**0.037**	**0.026**	**99.887**			
137	**0.036**	**0.025**	**99.912**			
138	**0.034**	**0.024**	**99.936**			
139	**0.032**	**0.023**	**99.959**			
140	**0.031**	**0.022**	**99.981**			
141	**0.027**	**0.019**	**100**			

15 Principal Components based on Linear Frequency Bins

Component number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
% of Variance	46.202	17.757	16.628	9.957	5.782	4.19	3.039	2.449	2.175	1.887	1.694	1.485	1.395	1.194	1.181
Cumulative %	32.767	12.593	11.793	7.062	4.101	2.971	2.155	1.737	1.543	1.338	1.202	1.053	0.989	0.847	0.838
Total	32.767	45.36	57.153	64.215	68.316	71.287	73.442	75.179	76.722	78.06	79.262	80.315	81.305	82.151	82.989
	Loadings														
duration	0.365	0.307	-0.111	0.073	-0.046	0.013	-0.28	0.029	-0.081	0.096	-0.066	0.183	-0.086	0.196	-0.261
mb01_sl1	-0.095	0.258	-0.595	0.449	-0.029	0.365	0.168	0.037	0.027	0.073	0.063	0.005	0.04	0.15	0.004
mb02_sl1	0.253	0.459	-0.385	0.447	-0.334	0.057	0.031	0.165	-0.021	-0.087	0.085	-0.104	0.014	0.024	0.171
mb03_sl1	0.195	0.532	0.169	0.358	-0.452	-0.128	-0.058	0.216	-0.078	0.062	0.085	-0.086	0.04	0.244	0.029
mb04_sl1	0.305	0.23	0.391	0.321	-0.41	0.036	0.305	0.05	-0.144	-0.187	0.094	-0.021	-0.084	0.075	0.127
mb05_sl1	0.339	0.17	0.416	0.445	-0.207	0.197	0.166	-0.249	-0.193	-0.182	0.037	-0.123	-0.067	0.148	0.005
mb06_sl1	0.523	0.065	0.218	0.265	-0.397	0.355	-0.094	-0.085	-0.155	-0.206	-0.025	-0.071	-0.053	0.096	0.054
mb07_sl1	0.59	-0.112	0.165	0.2	-0.392	0.308	0.037	0.077	-0.196	-0.241	-0.038	-0.001	-0.111	0.103	0.053
mb08_sl1	0.557	-0.2	0.152	0.22	-0.423	0.173	0.233	0.174	-0.18	-0.095	-0.016	0.06	-0.099	0.106	-0.02
mb09_sl1	0.566	-0.212	-0.094	0.217	-0.46	0.094	0.266	0.207	-0.169	0.026	0.133	-0.072	-0.074	-0.027	-0.015
mb10_sl1	0.603	-0.097	-0.203	0.234	-0.472	0.061	0.122	0.181	-0.171	0.067	0.139	-0.162	-0.123	-0.047	0.011
mb11_sl1	0.629	-0.056	-0.249	0.251	-0.469	0.009	0.052	0.124	-0.208	0.097	0.125	0.043	-0.168	-0.009	0.018
mb12_sl1	0.629	-0.154	-0.228	0.292	-0.414	0	0.076	0.054	-0.211	0.07	0.1	0.174	-0.107	-0.048	0.02
mb13_sl1	0.633	-0.121	-0.255	0.289	-0.422	-0.011	0.052	0.06	-0.167	-0.027	0.152	0.087	0.031	-0.02	0.023
mb14_sl1	0.596	-0.167	-0.234	0.238	-0.453	-0.034	0.081	0.102	-0.15	-0.069	0.17	0.025	0.08	0.01	0.026
mb01_sl2	-0.117	0.187	-0.587	0.52	0.111	0.34	0.149	0.018	0.054	0.157	-0.011	0.065	0.099	0.057	-0.04
mb02_sl2	0.283	0.472	-0.212	0.575	-0.087	-0.059	-0.023	0.1	0.099	-0.113	-0.16	-0.044	0.12	-0.156	0.063
mb03_sl2	0.164	0.517	0.431	0.392	-0.241	-0.234	-0.096	0.101	0.056	0.117	-0.125	-0.026	0.109	0.105	-0.134
mb04_sl2	0.211	0.092	0.689	0.322	-0.055	0.012	0.325	-0.156	0.022	-0.099	-0.139	0.032	0.053	-0.082	-0.037

mb05_sl2	**0.292**	**0.107**	**0.606**	**0.38**	**0.051**	**0.211**	**0.15**	**-0.395**	**-0.067**	**-0.094**	**-0.138**	**-0.076**	**0.043**	**-0.027**	**-0.122**
mb06_sl2	**0.542**	**-0.017**	**0.484**	**0.213**	**-0.099**	**0.341**	**-0.12**	**-0.228**	**-0.003**	**-0.08**	**-0.21**	**-0.064**	**0.093**	**-0.128**	**-0.084**
mb07_sl2	**0.607**	**-0.197**	**0.409**	**0.146**	**-0.132**	**0.326**	**-0.003**	**-0.086**	**0**	**-0.1**	**-0.252**	**0.098**	**0.082**	**-0.135**	**-0.089**
mb08_sl2	**0.579**	**-0.329**	**0.408**	**0.174**	**-0.137**	**0.156**	**0.212**	**0.009**	**0.07**	**0.023**	**-0.248**	**0.106**	**0.105**	**-0.057**	**-0.145**
mb09_sl2	**0.673**	**-0.362**	**0.148**	**0.149**	**-0.183**	**0.058**	**0.167**	**0.098**	**0.089**	**0.191**	**-0.126**	**-0.12**	**0.119**	**-0.216**	**-0.15**
mb10_sl2	**0.695**	**-0.242**	**0.036**	**0.255**	**-0.235**	**-0.029**	**-0.025**	**0.03**	**0.078**	**0.241**	**-0.104**	**-0.199**	**0.07**	**-0.24**	**-0.115**
mb11_sl2	**0.716**	**-0.208**	**-0.022**	**0.267**	**-0.273**	**-0.082**	**-0.078**	**-0.026**	**-0.011**	**0.22**	**-0.129**	**0.1**	**-0.005**	**-0.191**	**-0.09**
mb12_sl2	**0.694**	**-0.297**	**-0.01**	**0.267**	**-0.234**	**-0.084**	**-0.042**	**-0.073**	**-0.004**	**0.222**	**-0.078**	**0.193**	**0.041**	**-0.221**	**-0.094**
mb13_sl2	**0.713**	**-0.311**	**-0.052**	**0.286**	**-0.209**	**-0.093**	**-0.009**	**-0.03**	**0.047**	**0.106**	**-0.051**	**0.128**	**0.242**	**-0.153**	**-0.064**
mb14_sl2	**0.688**	**-0.346**	**-0.057**	**0.284**	**-0.204**	**-0.112**	**-0.014**	**0.004**	**0.07**	**0.055**	**-0.082**	**0.034**	**0.266**	**-0.123**	**-0.075**
mb01_sl3	**-0.134**	**0.194**	**-0.577**	**0.498**	**0.264**	**0.296**	**0.089**	**0.005**	**0.05**	**0.167**	**-0.007**	**0.062**	**0.034**	**0.127**	**0.034**
mb02_sl3	**0.266**	**0.46**	**-0.123**	**0.637**	**0.112**	**-0.09**	**-0.073**	**0.054**	**0.13**	**-0.137**	**-0.136**	**-0.042**	**0.046**	**-0.048**	**0.194**
mb03_sl3	**0.13**	**0.527**	**0.455**	**0.417**	**-0.074**	**-0.262**	**-0.127**	**0.041**	**0.135**	**0.075**	**-0.106**	**-0.003**	**0.041**	**0.246**	**-0.053**
mb04_sl3	**0.176**	**0.066**	**0.729**	**0.277**	**0.115**	**-0.012**	**0.297**	**-0.186**	**0.067**	**-0.082**	**-0.097**	**0.041**	**-0.013**	**0.079**	**0.093**
mb05_sl3	**0.253**	**0.142**	**0.672**	**0.337**	**0.133**	**0.226**	**0.06**	**-0.367**	**-0.01**	**0.014**	**-0.048**	**-0.078**	**-0.001**	**0.1**	**0.002**
mb06_sl3	**0.52**	**-0.007**	**0.493**	**0.163**	**0.019**	**0.315**	**-0.299**	**-0.212**	**0.114**	**-0.064**	**-0.127**	**-0.076**	**-0.007**	**0.054**	**0.088**
mb07_sl3	**0.646**	**-0.186**	**0.421**	**0.071**	**-0.025**	**0.266**	**-0.157**	**0.019**	**0.181**	**-0.043**	**-0.147**	**0.111**	**-0.034**	**0.076**	**0.088**
mb08_sl3	**0.61**	**-0.317**	**0.377**	**0.103**	**0.009**	**0.14**	**0.121**	**0.069**	**0.228**	**0.092**	**-0.148**	**0.122**	**0.007**	**0.199**	**0.028**
mb09_sl3	**0.662**	**-0.393**	**0.164**	**0.158**	**0.009**	**0.038**	**0.094**	**0.111**	**0.248**	**0.221**	**-0.09**	**-0.138**	**0.008**	**0.032**	**0.076**
mb10_sl3	**0.71**	**-0.281**	**0.036**	**0.276**	**-0.016**	**-0.073**	**-0.104**	**0.077**	**0.162**	**0.245**	**-0.039**	**-0.223**	**-0.027**	**0.028**	**0.093**
mb11_sl3	**0.74**	**-0.219**	**0.017**	**0.269**	**-0.133**	**-0.118**	**-0.21**	**-0.018**	**0.098**	**0.22**	**-0.057**	**0.063**	**-0.079**	**0.032**	**0.07**
mb12_sl3	**0.734**	**-0.313**	**0.025**	**0.265**	**-0.083**	**-0.123**	**-0.129**	**-0.089**	**0.075**	**0.174**	**0.001**	**0.153**	**-0.049**	**0.001**	**0.065**
mb13_sl3	**0.711**	**-0.345**	**-0.027**	**0.283**	**-0.063**	**-0.127**	**-0.113**	**-0.082**	**0.124**	**0.027**	**0.08**	**0.142**	**0.165**	**0.046**	**0.112**
mb14_sl3	**0.688**	**-0.382**	**-0.02**	**0.276**	**-0.036**	**-0.132**	**-0.111**	**-0.064**	**0.174**	**-0.005**	**0.077**	**0.021**	**0.236**	**0.092**	**0.092**
mb01_sl4	**-0.128**	**0.211**	**-0.581**	**0.449**	**0.347**	**0.307**	**0.065**	**0.032**	**0.026**	**0.14**	**0.055**	**0.108**	**-0.021**	**0.066**	**0.027**

mb02_sl4	0.236	0.523	-0.135	0.541	0.23	-0.094	-0.071	0.085	0.114	-0.198	-0.044	-0.019	-0.105	-0.119	0.143
mb03_sl4	0.087	0.56	0.509	0.354	0.055	-0.248	-0.067	0.1	0.119	0.004	-0.011	0.02	-0.09	0.18	-0.053
mb04_sl4	0.156	0.127	0.747	0.15	0.195	0	0.335	-0.113	0.098	-0.078	0.045	0.098	-0.071	-0.061	0.114
mb05_sl4	0.284	0.246	0.678	0.197	0.182	0.249	0.036	-0.259	0.009	0.064	0.153	-0.039	-0.058	0.02	0.053
mb06_sl4	0.518	0.07	0.464	0.028	0.104	0.38	-0.306	-0.082	0.123	-0.079	0.071	-0.054	-0.088	-0.035	0.117
mb07_sl4	0.655	-0.092	0.363	-0.013	0.107	0.27	-0.164	0.151	0.215	-0.093	0.07	0.135	-0.146	-0.034	0.073
mb08_sl4	0.619	-0.292	0.346	0.004	0.166	0.095	0.165	0.178	0.27	0.027	0.048	0.135	-0.095	0.154	0.026
mb09_sl4	0.656	-0.423	0.087	0.053	0.201	0.005	0.143	0.117	0.264	0.107	0.082	-0.113	-0.09	0.03	0.068
mb10_sl4	0.714	-0.293	-0.007	0.193	0.155	-0.075	-0.061	0.062	0.206	0.143	0.111	-0.218	-0.139	0.018	0.116
mb11_sl4	0.747	-0.199	-0.006	0.214	0.09	-0.116	-0.194	-0.001	0.106	0.182	0.088	0.051	-0.205	-0.009	0.072
mb12_sl4	0.75	-0.302	0	0.189	0.133	-0.111	-0.088	-0.075	0.077	0.12	0.167	0.171	-0.113	-0.022	0.078
mb13_sl4	0.692	-0.332	-0.043	0.253	0.085	-0.163	-0.092	-0.081	0.124	-0.025	0.236	0.147	0.068	0.011	0.109
mb14_sl4	0.659	-0.388	-0.012	0.238	0.105	-0.19	-0.062	-0.038	0.178	-0.082	0.212	-0.01	0.157	0.066	0.123
mb01_sl5	-0.161	0.219	-0.611	0.384	0.37	0.295	0.074	0.029	-0.043	0.085	0.066	0.083	0.004	-0.001	-0.031
mb02_sl5	0.231	0.578	-0.182	0.48	0.29	-0.101	-0.054	0.089	0.003	-0.188	-0.001	-0.029	-0.077	-0.203	0.055
mb03_sl5	0.097	0.605	0.49	0.306	0.15	-0.26	-0.061	0.094	0.028	-0.014	0.014	0.004	-0.071	0.103	-0.133
mb04_sl5	0.151	0.275	0.684	0.056	0.284	-0.036	0.354	-0.029	-0.004	-0.048	0.134	0.091	-0.076	-0.138	0.013
mb05_sl5	0.312	0.387	0.606	0.092	0.227	0.195	0.033	-0.143	-0.125	0.151	0.222	-0.049	0.012	-0.038	-0.074
mb06_sl5	0.58	0.139	0.386	-0.084	0.17	0.34	-0.301	-0.004	-0.027	-0.057	0.155	-0.07	-0.048	-0.126	-0.001
mb07_sl5	0.695	-0.074	0.287	-0.151	0.134	0.262	-0.147	0.221	0.028	-0.143	0.13	0.131	-0.085	-0.085	-0.054
mb08_sl5	0.64	-0.25	0.282	-0.088	0.248	0.109	0.165	0.25	0.108	-0.088	0.075	0.135	-0.022	0.076	-0.143
mb09_sl5	0.69	-0.355	0.044	0.04	0.286	-0.001	0.179	0.215	0.107	-0.022	0.082	-0.12	-0.038	-0.029	-0.051
mb10_sl5	0.744	-0.253	-0.036	0.137	0.267	-0.071	-0.019	0.135	0.001	0.041	0.101	-0.246	-0.113	-0.049	-0.022
mb11_sl5	0.773	-0.155	-0.024	0.155	0.209	-0.102	-0.119	0.037	-0.085	0.054	0.114	0.04	-0.191	-0.042	-0.123
mb12_sl5	0.757	-0.283	-0.016	0.156	0.231	-0.129	-0.057	-0.052	-0.092	0.001	0.156	0.148	-0.145	-0.063	-0.068

mb13_sl5	0.726	-0.321	-0.04	0.241	0.212	-0.15	-0.056	-0.058	-0.058	-0.163	0.22	0.076	0.084	0.024	-0.018
mb14_sl5	0.695	-0.365	-0.039	0.173	0.209	-0.131	-0.058	-0.054	-0.012	-0.194	0.22	-0.066	0.194	0.003	-0.023
mb01_sl6	-0.116	0.269	-0.632	0.347	0.38	0.283	0.089	0.057	-0.093	0.101	0.003	0.089	0.059	-0.009	-0.067
mb02_sl6	0.271	0.635	-0.236	0.364	0.27	-0.109	-0.05	0.154	-0.09	-0.157	-0.061	-0.04	-0.034	-0.199	0.059
mb03_sl6	0.109	0.672	0.434	0.216	0.151	-0.277	-0.044	0.138	-0.034	-0.019	-0.043	0.037	-0.023	0.083	-0.168
mb04_sl6	0.17	0.382	0.633	-0.077	0.255	-0.061	0.341	0.06	-0.088	-0.013	0.107	0.061	0.004	-0.131	0.012
mb05_sl6	0.332	0.469	0.546	-0.034	0.198	0.156	-0.026	-0.035	-0.205	0.197	0.183	-0.072	0.087	-0.044	-0.076
mb06_sl6	0.584	0.218	0.307	-0.237	0.153	0.324	-0.294	0.089	-0.117	0.012	0.058	-0.073	0.074	-0.076	-0.021
mb07_sl6	0.695	0.033	0.218	-0.229	0.115	0.236	-0.166	0.31	-0.089	-0.136	-0.034	0.082	0.003	-0.041	-0.082
mb08_sl6	0.698	-0.171	0.213	-0.18	0.219	0.107	0.108	0.337	-0.008	-0.086	-0.032	0.064	0.108	0.08	-0.119
mb09_sl6	0.722	-0.295	0.031	-0.07	0.285	0.043	0.187	0.229	-0.004	-0.05	-0.061	-0.146	0.071	0.018	-0.109
mb10_sl6	0.787	-0.161	-0.046	0.055	0.261	-0.024	-0.001	0.111	-0.125	0.002	-0.059	-0.27	-0.053	0.008	-0.088
mb11_sl6	0.792	-0.092	-0.035	0.084	0.202	-0.125	-0.097	0.057	-0.182	-0.018	-0.048	-0.008	-0.173	0	-0.155
mb12_sl6	0.795	-0.212	-0.053	0.054	0.242	-0.101	-0.076	-0.021	-0.2	-0.043	0.006	0.135	-0.069	-0.058	-0.12
mb13_sl6	0.788	-0.239	-0.061	0.094	0.228	-0.087	-0.046	-0.033	-0.153	-0.178	0.05	0.036	0.151	0.009	-0.036
mb14_sl6	0.741	-0.284	-0.094	0.036	0.234	-0.127	-0.055	-0.026	-0.126	-0.2	0.06	-0.087	0.273	0.05	-0.044
mb01_sl7	-0.102	0.296	-0.684	0.296	0.324	0.269	0.1	0.03	-0.114	0.129	-0.012	0.076	0.083	0.028	-0.003
mb02_sl7	0.278	0.686	-0.303	0.272	0.176	-0.127	-0.043	0.131	-0.082	-0.086	-0.062	-0.016	0.037	-0.162	0.124
mb03_sl7	0.156	0.705	0.36	0.147	0.103	-0.317	-0.056	0.128	-0.085	0.049	-0.087	0.014	0.006	0.092	-0.12
mb04_sl7	0.234	0.474	0.521	-0.24	0.141	-0.115	0.31	0.077	-0.122	0.15	0.09	0.048	0.072	-0.098	0.086
mb05_sl7	0.361	0.555	0.386	-0.189	0.094	0.116	0.007	-0.025	-0.18	0.339	0.153	-0.047	0.181	0.034	-0.012
mb06_sl7	0.584	0.315	0.18	-0.352	0.022	0.282	-0.275	0.103	-0.116	0.124	0.043	-0.084	0.123	-0.043	0.054
mb07_sl7	0.685	0.135	0.085	-0.374	0.045	0.244	-0.182	0.237	-0.112	-0.017	-0.082	0.071	0.069	0.014	0.001
mb08_sl7	0.702	-0.087	0.11	-0.345	0.15	0.049	0.155	0.294	-0.047	-0.019	-0.114	0.107	0.123	0.135	0
mb09_sl7	0.702	-0.23	-0.075	-0.212	0.242	-0.007	0.242	0.162	-0.05	0.013	-0.134	-0.182	0.11	0.092	-0.015

mb10_sl7	0.784	-0.087	-0.149	-0.074	0.21	-0.054	0.023	0.022	-0.16	0.061	-0.116	-0.293	-0.025	0.076	0.032
mb11_sl7	0.811	-0.053	-0.1	-0.044	0.177	-0.138	-0.085	-0.036	-0.214	0.068	-0.119	-0.054	-0.11	0.078	-0.051
mb12_sl7	0.789	-0.138	-0.143	-0.075	0.209	-0.144	0.008	-0.119	-0.222	0.005	-0.076	0.092	-0.021	0.039	-0.034
mb13_sl7	0.808	-0.164	-0.162	-0.062	0.198	-0.164	0.001	-0.09	-0.182	-0.088	-0.005	-0.022	0.135	0.076	0.023
mb14_sl7	0.774	-0.176	-0.183	-0.093	0.129	-0.147	-0.033	-0.063	-0.138	-0.13	0.051	-0.098	0.277	0.109	0.047
mb01_sl8	-0.07	0.37	-0.689	0.251	0.223	0.287	0.105	-0.025	-0.069	0.109	-0.071	0.098	0.033	0.033	0.057
mb02_sl8	0.29	0.737	-0.335	0.181	0.051	-0.094	-0.061	0.073	-0.029	-0.087	-0.132	0.01	0.009	-0.167	0.134
mb03_sl8	0.199	0.774	0.253	0.04	-0.006	-0.3	-0.077	0.089	-0.001	0.045	-0.107	0.058	-0.024	0.086	0.005
mb04_sl8	0.263	0.587	0.378	-0.312	0.013	-0.165	0.279	0.046	-0.03	0.16	0.043	0.11	0.005	-0.125	0.179
mb05_sl8	0.369	0.648	0.261	-0.259	-0.051	0.059	-0.021	-0.085	-0.11	0.306	0.08	-0.011	0.109	0.03	0.086
mb06_sl8	0.548	0.417	0.077	-0.402	-0.092	0.232	-0.259	0.048	-0.052	0.102	-0.059	0.007	0.045	0.018	0.178
mb07_sl8	0.656	0.252	-0.003	-0.47	-0.108	0.172	-0.122	0.147	-0.009	-0.019	-0.14	0.111	-0.017	-0.028	0.143
mb08_sl8	0.692	0.093	-0.02	-0.452	-0.035	-0.009	0.181	0.158	0.022	-0.012	-0.174	0.159	0.045	0.049	0.133
mb09_sl8	0.733	-0.052	-0.174	-0.317	0.112	-0.011	0.249	0.035	-0.016	0.028	-0.189	-0.103	-0.023	0.034	0.146
mb10_sl8	0.773	0.053	-0.232	-0.152	0.1	-0.068	0.075	-0.077	-0.09	0.085	-0.185	-0.217	-0.129	0.05	0.132
mb11_sl8	0.788	0.088	-0.178	-0.135	0.084	-0.125	-0.054	-0.117	-0.16	0.057	-0.215	0.072	-0.185	0.031	0.084
mb12_sl8	0.787	-0.034	-0.204	-0.174	0.137	-0.108	0.02	-0.182	-0.179	0.048	-0.154	0.151	-0.127	0.025	0.114
mb13_sl8	0.801	-0.046	-0.256	-0.139	0.063	-0.129	0.027	-0.168	-0.163	-0.049	-0.03	0.087	0.078	0.064	0.138
mb14_sl8	0.772	-0.05	-0.272	-0.186	0.047	-0.154	-0.006	-0.129	-0.089	-0.081	-0.045	0.002	0.166	0.098	0.132
mb01_sl9	-0.036	0.395	-0.699	0.22	0.174	0.305	0.132	-0.051	0.035	0.06	-0.064	0.089	0.037	0.046	-0.02
mb02_sl9	0.342	0.711	-0.382	0.138	-0.047	-0.07	-0.057	0.037	0.05	-0.091	-0.059	-0.003	0.031	-0.118	0.039
mb03_sl9	0.254	0.802	0.132	0.025	-0.069	-0.273	-0.085	0.034	0.052	-0.017	-0.059	0.043	0.014	0.058	-0.086
mb04_sl9	0.332	0.653	0.255	-0.296	-0.102	-0.111	0.25	-0.001	0.056	0.102	0.09	0.107	0.059	-0.104	0.095
mb05_sl9	0.394	0.712	0.131	-0.224	-0.143	0.054	-0.006	-0.118	-0.031	0.221	0.131	0.01	0.086	0.044	-0.01
mb06_sl9	0.568	0.479	-0.037	-0.378	-0.156	0.175	-0.226	-0.046	0.033	0.025	0.027	-0.014	0.052	-0.007	0.088

mb07_sl9	**0.658**	**0.348**	**-0.124**	**-0.422**	**-0.179**	**0.149**	**-0.081**	**0.069**	**0.098**	**-0.074**	**-0.053**	**0.089**	**0.042**	**0.002**	**0.008**
mb08_sl9	**0.696**	**0.195**	**-0.161**	**-0.439**	**-0.104**	**-0.003**	**0.148**	**0.044**	**0.161**	**-0.042**	**-0.049**	**0.117**	**0.019**	**0.05**	**0.038**
mb09_sl9	**0.722**	**0.056**	**-0.285**	**-0.366**	**0.006**	**0**	**0.242**	**-0.045**	**0.104**	**0.015**	**-0.081**	**-0.105**	**-0.055**	**-0.006**	**0.054**
mb10_sl9	**0.756**	**0.147**	**-0.301**	**-0.204**	**0.006**	**-0.043**	**0.101**	**-0.16**	**-0.005**	**0.072**	**-0.081**	**-0.178**	**-0.112**	**0.008**	**0.028**
mb11_sl9	**0.777**	**0.189**	**-0.258**	**-0.195**	**0.008**	**-0.069**	**0.027**	**-0.189**	**-0.063**	**0.037**	**-0.12**	**0.048**	**-0.155**	**0.007**	**-0.012**
mb12_sl9	**0.774**	**0.075**	**-0.297**	**-0.188**	**0.053**	**-0.102**	**0.056**	**-0.245**	**-0.025**	**0.016**	**-0.073**	**0.114**	**-0.141**	**-0.004**	**0**
mb13_sl9	**0.775**	**0.059**	**-0.334**	**-0.17**	**-0.026**	**-0.096**	**0.036**	**-0.23**	**-0.02**	**-0.023**	**0.05**	**0.064**	**0.031**	**0.05**	**0.015**
mb14_sl9	**0.748**	**0.055**	**-0.338**	**-0.202**	**-0.075**	**-0.13**	**0.017**	**-0.186**	**0.017**	**-0.05**	**0.051**	**0.043**	**0.103**	**0.069**	**0.04**
mb01_sl10	**0.018**	**0.365**	**-0.695**	**0.221**	**0.145**	**0.287**	**0.119**	**-0.057**	**0.149**	**-0.005**	**-0.004**	**0.011**	**0.034**	**0.097**	**-0.11**
mb02_sl10	**0.361**	**0.645**	**-0.436**	**0.11**	**-0.064**	**-0.009**	**-0.029**	**-0.009**	**0.167**	**-0.167**	**-0.015**	**-0.067**	**0.005**	**-0.07**	**-0.053**
mb03_sl10	**0.325**	**0.778**	**0.003**	**-0.008**	**-0.117**	**-0.208**	**-0.105**	**0.001**	**0.155**	**-0.103**	**0.002**	**-0.034**	**0.021**	**0.06**	**-0.149**
mb04_sl10	**0.369**	**0.64**	**0.075**	**-0.301**	**-0.162**	**-0.082**	**0.233**	**-0.026**	**0.202**	**-0.035**	**0.181**	**0.001**	**0.064**	**-0.087**	**-0.005**
mb05_sl10	**0.434**	**0.683**	**-0.031**	**-0.201**	**-0.188**	**0.072**	**-0.007**	**-0.107**	**0.125**	**0.085**	**0.215**	**-0.094**	**0.061**	**0.03**	**-0.114**
mb06_sl10	**0.572**	**0.458**	**-0.194**	**-0.312**	**-0.211**	**0.199**	**-0.11**	**-0.038**	**0.163**	**-0.064**	**0.147**	**-0.066**	**0.003**	**-0.02**	**-0.045**
mb07_sl10	**0.637**	**0.349**	**-0.247**	**-0.335**	**-0.22**	**0.16**	**-0.038**	**0.063**	**0.248**	**-0.139**	**0.065**	**0.014**	**-0.018**	**-0.009**	**-0.107**
mb08_sl10	**0.661**	**0.279**	**-0.301**	**-0.353**	**-0.14**	**0.052**	**0.139**	**0.019**	**0.247**	**-0.119**	**0.036**	**0.043**	**-0.037**	**-0.002**	**-0.118**
mb09_sl10	**0.654**	**0.176**	**-0.455**	**-0.269**	**-0.066**	**0.033**	**0.222**	**-0.061**	**0.2**	**-0.056**	**0.019**	**-0.114**	**-0.062**	**-0.028**	**-0.09**
mb10_sl10	**0.708**	**0.22**	**-0.431**	**-0.155**	**-0.082**	**0.003**	**0.109**	**-0.147**	**0.151**	**0.011**	**0.02**	**-0.176**	**-0.106**	**-0.017**	**-0.118**
mb11_sl10	**0.72**	**0.272**	**-0.372**	**-0.109**	**-0.088**	**0.014**	**0.032**	**-0.189**	**0.088**	**-0.046**	**0.021**	**-0.023**	**-0.148**	**0.017**	**-0.195**
mb12_sl10	**0.699**	**0.19**	**-0.423**	**-0.148**	**-0.017**	**-0.05**	**0.053**	**-0.21**	**0.103**	**-0.08**	**0.003**	**0.069**	**-0.122**	**-0.047**	**-0.139**
mb13_sl10	**0.691**	**0.173**	**-0.459**	**-0.129**	**-0.055**	**-0.057**	**0.066**	**-0.217**	**0.077**	**-0.087**	**0.122**	**0.044**	**-0.01**	**0.003**	**-0.124**
mb14_sl10	**0.68**	**0.178**	**-0.458**	**-0.164**	**-0.11**	**-0.028**	**0.065**	**-0.175**	**0.134**	**-0.078**	**0.113**	**-0.073**	**0.022**	**0.049**	**-0.12**

Six Principal Components based on acoustic parameters

Component number	1	2	3	4	5	6
% of Variance	5.831	2.68	2.221	1.883	1.139	1.021
Cumulative %	36.441	16.749	13.88	11.767	7.117	6.379
Total	36.441	53.189	67.069	78.836	85.954	92.333
	Loadings					
F0min	0.957	0.008	-0.157	0.101	0.19	-0.015
F0mean	0.906	-0.021	-0.357	0.186	0.016	-0.023
F0start	0.852	0.022	-0.463	-0.002	0.064	-0.027
F0end	0.789	-0.009	-0.081	0.514	0.009	-0.007
F0absslope	0.774	-0.026	0.456	-0.239	0.176	0.034
F0max	0.734	0.001	-0.549	0.33	-0.174	-0.025
F0var	0.717	-0.009	0.531	-0.255	-0.23	0.102
Sumvar	0.717	-0.009	0.531	-0.255	-0.23	0.102
F0stdev	0.693	-0.006	0.437	-0.269	0.41	-0.016
Q50%	0.021	0.977	0.034	0.025	-0.054	0.03
Q25%	-0.065	0.922	0.025	0.035	0.001	0.083
Q75%	0.126	0.881	0.054	0.055	-0.189	0.015
pt2max	0.107	0.039	-0.509	-0.787	-0.08	0.076
pt2min	-0.094	-0.115	0.549	0.751	-0.07	0.031
duration	-0.238	0.19	-0.086	0.11	0.791	0.413
Fm_Rate	0.02	-0.216	-0.112	0.067	-0.295	0.901

Chapter 4 First Quantitative Description of *Rhinopithecus brelichi* Vocal Repertoire

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Primates, in preparation

Abstract

Bioacoustics opened new scenarios on the species social behaviour, adaptation to the environment, showing the characteristics of species communication in association with ecological aspects. The Guizhou snub-nosed monkey (*Rhinopithecus brelichi*) is an Asian colobine belonging to the odd-nosed monkey group that exclusively survived within the Fanjingshan National Nature Reserve (Guizhou Province – China). Because of their peculiar morphology, their characteristic social structure, the restricted distribution in areas with high anthropic pressures, and the lack of knowledge about their communication processes, *R. brelichi* represents a perfect candidate for vocal behaviour studies. The main aim of this study was to describe quantitatively the vocal repertoire of *R. brelichi* providing a detailed description of its vocal types. We identified nine different vocal types using spectrographic investigation, which showed significant differences concerning duration, source- and filter-related properties. Moreover, we identified peculiar acoustic features in *R. brelichi* acoustic signals, such as the presence of ventriloquial calls and the surprisingly high number of vocalization showing an unusual high fundamental frequency and harmonics in the ultrasound domain. We contributed critical information for future behavioural studies, which are necessary for a better understanding of the ecological needs of endangered primate species and thus fundamental for the conservation of *R. brelichi*. Further studies on the acoustic propagation and phonation mechanisms are required to clarify the adaptive significance of *R. brelichi* vocal communication.

Key words

Vocal behaviour; Guizhou snub-nosed monkeys; *Rhinopithecus brelichi;* Fanjingshan National Nature Reserve

Introduction

Nonhuman primates frequently use vocalizations to communicate with conspecifics (Todt *et al.* 2012; Zuberbühler *et al.* 1997). For arborealgroup-living species, vocalizations may be especially important because transmitting visual signals can be limited by vegetation (Altmann 1967; Waser and Waser 1977). The role played by vocal communication can reflect peculiaritiesin a single signal of the vocal repertoire of a species that areprerequisites for species and individual recognition (Waser 1977; Snowdon and Cleveland 1980; Rendall *et al.* 1996; Gamba *et al.* 2012a; 2012b). Thus, understanding a species' vocal repertoire is important because it provides researchers with insights into an animal's social behaviour and sets the basis for a broad range of comparative studies (Fischer and Hammerschimidt 2002). For instance, knowledge of the vocal repertoire allows studying the contextual occurrence of specific vocalizations, determining the role of vocal individuality in regulating the social interaction within a species, and it is crucial to decoding the biological relevance of communication (Gamba and Giacoma 2005; Favaro *et al.* 2014). Studies of vocal behaviour can also reveal specific adaptations of an animal's communication signal to its environment. A better understanding of the behaviour ecology of signalling represents a starting point for future investigations, and is also relevant for setting effective conservation policies (Terry *et al.* 2005;

Laiolo 2010). Bioacoustics can, therefore, add fresh input to conservation biology, and provide principles and a methodology of conservation significance. Moreover, recent bioacoustics research has opened new scenarios showing that comparative studies on vocal behaviour may be crucial to understanding the pressures underlying evolutionary processes (Lemasson *et al.* 2011; Gamba *et al.* 2015). These processes include investigating the role of genetics (Thinh *et al.* 2011), morphology (Gamba *et al.* 2012b) and social complexity (McComb and Semple 2005; Bouchet *et al.* 2013) in shaping communication systems.

The Guizhou snub-nosed monkey (*Rhinopithecus brelichi*) is an Asian colobine belonging to the odd-nosed monkey group (Groves 2001; Sterner *et al.* 2006; Liedigk *et al.* 2012). As the name indicates, this species along with other members of the genus are recognized for their unique nasal morphologies that are characterized by tiny nasal bones, and thin and an abbreviated bony nasal septum and septal cartilage (Chaplin and Jablonski 1998). Further anatomical modifications of the nasomaxillofrontal region are evident as they give rise to a wide nasal cavity in combination with an enlarged frontal area and a reduced snout (He *et al.* 1987). Accordingly, we speculate that this suite of craniofacial features may provide a resonance chamber for various vocal outputs in *Rhinopithecus* species.

Another hallmark of *Rhinopithecus* species is their fluid grouping pattern; consequently, their group sizes are highly variable and may contain hundreds of individuals (Yang *et al.* 2002; Tan *et al.* 2007; Grueter 2009; Niu *et al.* 2010; Ren *et al.* 2012). The core of the group is composed of several polygynous units (also known as one-male units). One or two bachelor male units may stay on the periphery of the polygynous units (Kirkpatrick *et al.* 1998; Kirkpatrick and Grueter 2010). In the wild, *R. brelichi* may travel in groups ranging from <30

to >400 individuals (Yang *et al.* 2002; Niu *et al.* 2010).

The current distribution of *R. brelichi* is limited to the area of Fanjingshan in northeastern Guizhou province, China. The monkey occurs in the subtropical evergreen broadleaf and deciduous broadleaf forest ranging from 800 to 2,200 m above sea level (Bleisch and Xie 1998; Yang *et al.* 2002; Niu *et al.* 2010). In this area, the seasons are well-defined with frost and snow commonly occurring in November-April, a period when deciduous trees are devoid of leaves (C. Tan *et al.* unpublished data).

Both these peculiarities that characterize the species and the lack of knowledge about its communication processes, motivated us to investigate the vocal repertoire of *Rhinopithecus brelichi* and to provide a quantitative description of the vocal types emitted by Guizhou snub-nosed monkeys.

Our first specific aim was to verify whether Guizhou snub-nosed monkeys emit vocalizations with prominent high frequencies as it has been documented in several other animal species living in China (Holman and Seale 1991; Narins *et al.* 2004; Feng *et al.* 2006; Shen *et al.* 2011). Previous research on *Rhinopithecus roxellana* (Li *et al.* 1993), *R. bieti* (Grueter 2003), *Simias concolor* (Erb *et al.* 2013) and *Nasalis larvatus* (Srivathsan and Meier 2011; Roper *et al.* 2014) showed that indeed some odd-nosed monkeys produce high-frequency calls. Our first prediction is that high-pitched, frequency- modulated frequency calls are present also in the repertoire of *Rhinopithecus brelichi*. We also hypothesized that the ventriloquial calls reported by Tenaza and colleagues (1988) in *Rhinopithecus roxellana* are shared across the congeneric species as it has been shown for other calls in the repertoire. For instance, Tenaza and colleagues (1988) recognized ventriloquial calls, emitted by both sexes, which

occurred without apparent facial and mouth movements. Our prediction is that *Rhinopithecus brelichi* also emits ventriloquial calls, in the form of low-pitched vocalizations given with closed mouth. We have also hypothesized that the repertoire of *R. brelichi* included sex-specific sexual calls. We predicted that in agreement with findings of Grueter (2003, *R. bieti*), Cui and Xiao (2004 *R. bieti*), and Clarke (1990 *R. roxellana*) in congeneric species, the Guizhou snub-nosed monkey would show sexual calls emitted by adult males especially before or during copulation. The fourth aim was centered on determining the overall size of the Guizhou snub-nosed monkey's vocal repertoire. The lack of quantitative studies on the vocal behaviour of *Rhinopithecus brelichi* prevented a comparison with previous studies on this species. Based on previous findings from captive and free-ranging *R. roxellana*, we hypothesized that Guizhou snub-nosed monkey would show a repertoire size comprised between six (Li *et al.* 1993) and 18 vocal signals (Ren *et al.* 2000).

Method

Subjects and data collection

We conducted the study at the Wildlife Rescue Center of Fanjingshan National Nature Reserve (FNNR) in Panxi (E 108°44', N 28°54'; 950 m a.s.l.). We studied five individuals belonging to two family groups (Table 4.1). Each group lived in a separate enclosure with an indoor (3 x 3 x 2.8 m) and an outdoor (4 x 3.6 x 3 m) area. These areas were connected, and the monkeys were free to move between them. On alternative days, each group had access to a larger outdoor enclosure (30 x 10 x 8 m). The keepers fed the monkeys twice a day. The diet consisted of natural browse (about 2–3 kg per individual per feeding), and fruit or

vegetables. The browse species varied according to the seasonal availability. Additionally, the animals received a daily supplement of pumpkin seeds and hard-boiled eggs. The soil was available only for the individuals in the outdoor enclosure while water was continuously available throughout the day. All subjects were maintained on a natural light/dark diel cycle.

Code	Age[a] categories[a]	Sex	Date of birth
G019	Ad	F	08/04/1995
G020	Ad	F	11/04/1996
G027	Ad	M	-
G030	Ad	M	22/06/2004
G032	SubA	F	03/04/2005

Table 4.1 Study group composition

[a]the abbreviation Ad is used to identify an adult individual, SubA for subadult. The age classes are referred to the Chinese congeneric *Rhinopithecus roxellana*(Zhang et al., 2006): adult male (>7 yrs old), adult female (>5 yrs old), subadult male (5-7 yrs old), subadult female (3-4 yrs old), juvenile(1-3 yrs old) and infant (<1 yrs old).

We recorded monkey vocalizations from November 26th to December 13th, 2009 (16 days). Recordings were carried out between 07:00 h to 10:30 h and from 13:30 h to 17:00 h. We used *ad libitum* sampling (Altmann, 1974) during all recording sessions. The recordings were made using a digistal recorder (Sound Devices 702 or Marantz PMD 671), equipped with a shotgun microphone Sennheiser ME66 (with Sennheiser MZW66 windscreen). Recordings made with a Pettersson Ultrasound Detector D1000X often paralleled recordings made using Sound Devices 702 or Marantz PMD 671 because animals might produce vocalizations whose

frequency peak limit exceeded 20 kHz. All vocalizations were collected with a sample rate of 96 kHz and 16-bit amplitude resolution. Vocalizations were recorded while the monkeys were in the outdoor or indoor enclosure, and the researcher that operated the recorder and microphone remained outside the enclosure. The distance between the researcher and the monkeys varied from 0.1 to 10 m. We recorded spontaneously occurring vocalizations without the use of visual or acoustic playbacks. During recordings, we documented information on the behavioural context. We did our best to avoid stressing the subjects, and we never modified their usual housing condition. Our research protocols have been approved by the Institutional Animal Care and Use Committee (IACUC) of the Zoological Society of San Diego.

Acoustic analysis

Recordings were screened and analyzed at a sample rate of 96 kHz (16-bit resolution, mono format) with Soundtrack Pro (Apple Inc., U.S.A.). After a preliminary qualitative analysis of the entire recording (using spectrogram visual inspection of each recording session), we selected those vocalizations that might be suitable for the acoustic analyses (e.g. absence of overlapping with other calls, high contrast with background noise, known emitter identity). We saved single vocalizations into separate files. Two sounds were considered as two distinct vocalizations if they occur separately and if the temporal interval between them exceeded 0.03s. The total sample of selected vocalizations comprised 1275 calls.

PARAMETER CODES	DESCRIPTION
TEMPORAL VARIABLES	
Duration (s)	Time between the onset and offset of an utterance
LARYNX-RELATED VARIABLES	
MeF0 (Hz)	Average fundamental frequency
MaxF0 (Hz)	Minimum fundamental frequency
MinF0 (Hz)	Maximum fundamental frequency
F0StDev (Hz)	Fundamental frequency standard deviation
F0Start (Hz)	Fundamental frequency at the beginning of the vocalization
F0End (Hz)	Fundamental frequency at the end of the vocalization
Enst F0 (Hz)	End F0–start F0
Range F0 (Hz)	Max F0–min F0
Pt2min (%)	Time between the onset of a vocalization and the time of minimum F0
Pt2max (%)	Time between the onset of a vocalization and the time of maximum F0
VOCAL TRACT-RELATED VARIABLES	
F1me (Hz)	Average first formant frequency
F2me (Hz)	Average second formant frequency
F3me (Hz)	Average third formant frequency

Table 4.2 Acoustic parameters considered during data processing and acoustic analyses.

Acoustic properties of the vocalizations were measured using Praat (Boersma and Weenink, 2006, Institute of Phonetic Sciences, University of Amsterdam). Praat software is usually applied to study human speech but can be modified to study animals' utterances due to its flexibility and programmability (Rendall *et al.* 2004; Harris *et al.* 2006; Gamba *et al.* 2012a; Gamba *et al.* 2012b). As both vocal fold vibration and supra-laryngeal filtering shape the communicative system in primates (Fitch 1997; Rendall *et al.* 2005; Gamba and Giacoma 2005; 2006), we analyzed sounds from the perspective of the source filter theory (Fant 1960). For each call, we measured its total duration. We then collected 10 larynx-related parameters (Table 4.2) to investigate the contribution of the larynx to the phonation mechanism. For

multiple acoustic units calls, composed of two or more distinct acoustic elements, the larynx-related features were measured from the main vocalization unit. To detect source features (F0 parameters), Fast Fourier transforms were generated for all calls (frequency range: 0-24000 Hz; Dynamic range: 60 dB; pre-emphasis: 6.0 dB/oct; dynamic compression: 0.0). We measured the variation of the fundamental frequency using the autocorrelation method after adjusting the analysis parameters according to the range of variation in each of the vocalizations. For details, see Gamba and Giacoma(2005; 2007).

To define the influence of supra-laryngeal vocal tract on phonation, we measured for a total of 1022 vocalizations in total, three vocal-tract-related acoustic parameters (Table 4.2). Formants (F1, F2, F3) were estimated using linear predictive coding (LPC). LPC assumes that the vocal signal is produced by a buzz generated at the glottis and then passes through the vocal tract. The vocal tract has particular resonance frequencies, or formants. Because the vocal signals usually vary with time, this process was done all along the signal frames, and then average formants were calculated. Due to the acoustic characteristics of the vocalizations, a window length of 0.01 s was used. Two methods were used to check the formants predicted by LPC. First, we superimposed formant analyses over a sound spectrogram. Second, LPC spectra were overlaid on an independently derived FFT spectrum to verify the goodness of the LPC analysis for a particular signal. Typical settings were 12000 Hz for the maximum formant and 50 dB for the dynamic range. A Praat script was used to automate file opening, editing and file saving of the measurements.

Quantitative analysis

Studies on the vocal repertoire of a species were often based on a statistical classification that followed the visual categorization of call spectrograms. We have chosen this traditional approach and used the Discriminant Function Analysis (DFA) to identify linear combinations of predictor variables maximizing the differences between vocal types (Lehner 1998). DFA was run using a stepwise procedure (Gamba and Giacoma 2007). To avoid pseudo-replication, DFA analyses were carried out on the individual mean values of each acoustic variable per vocal type. We ran DFA for larynx-related parameters first, then we added the vocal-tract-related variables to this first set of parameters. Eight of the nine recorded vocal types (Kee was excluded due to insufficient sampling) were submitted to DFA using fundamental frequency (f0) parameters. We included in the analyses either vocalizations showing a prominent proper fundamental frequency or a prominent higher periodical source (g0, see Reby et al., 2016). In the case that g0 had more acoustic energy than f0, we entered the g0 frequency value in the DFA. In a second DFA, we investigated the acoustic variation of vocal-tract-related features using formants F1-F3 (Gamba et al., 2012; 2015). In this second DFA, we could enter only six vocal types (Uhm, Ga, Oow, Exhaled Uff, Uaaa, and Uchack) for which we could measure formants. To validate the results of the DFA performed on the average individual means, we applied the permuted Discriminant Function Analysis (pDFA) to test the assignment of each vocalization to the putative vocal type (Favaro *et al.* 2016). This procedure determines the significance of the observed correct assignment while controlling for the individual (Mundry and Sommer 2007). We ran a first crossed pDFA based on larynx-related

parameters on the dataset comprising all eight call types (Uhm, Ga, Oow, Exhaled Uff, Uaaa, Uchack, Iii, and High-Pitched Call) emitted by two adult females for whom we recorded all the vocalization types. We performed a second pDFA using both larynx- and vocal tract- related parameters on the vocalization types Uhm, Ga, Oow, Exhaled Uff, Uaaa, and Uchack, again emitted by the two adult females mentioned above. We ran the crossed pDFAs using a script written by Roger Mundry and implemented in R (The R Foundation for Statistical Computing, Vienna, Austria). We have reported the cross-validated results only.

Result

Visual classification of the vocal types

We identified qualitatively nine major vocal types in the *R. brelichi* vocal repertoire (Figure4.1). All of these types are distinguishable by visual inspection of the spectrograms and by ear. We found three ubiquitous calls (Uhm, Exhaled huff, Uaaa) and a vocalization used during affiliative interactions (Oow). We identified two high-pitched signals that occurred during arousal (e.g.; before feeding; during feeding distribution; after agonistic interactions), termed the Iii and the High-pitched call (hereafter HPC). We recorded an agonistic call, the Ga,emitted when threatening conspecifics or towards a human observer. In the presence of a snake which has entered the cage, we recorded the Uchuck, a call type that has also been recorded in the wild in the presence of potential terrestrial predators (MG, unpublished data). We recorded also a male sexual vocalization emitted to obtain females' attention, before and during the initial stages of a copulatory act. We provided a detailed

description of the vocal types and indicated the most common contextual occurrence in the Supplementary Material ESM1. This information is summarized in Table 4.3.

Quantitative discrimination of the vocal types

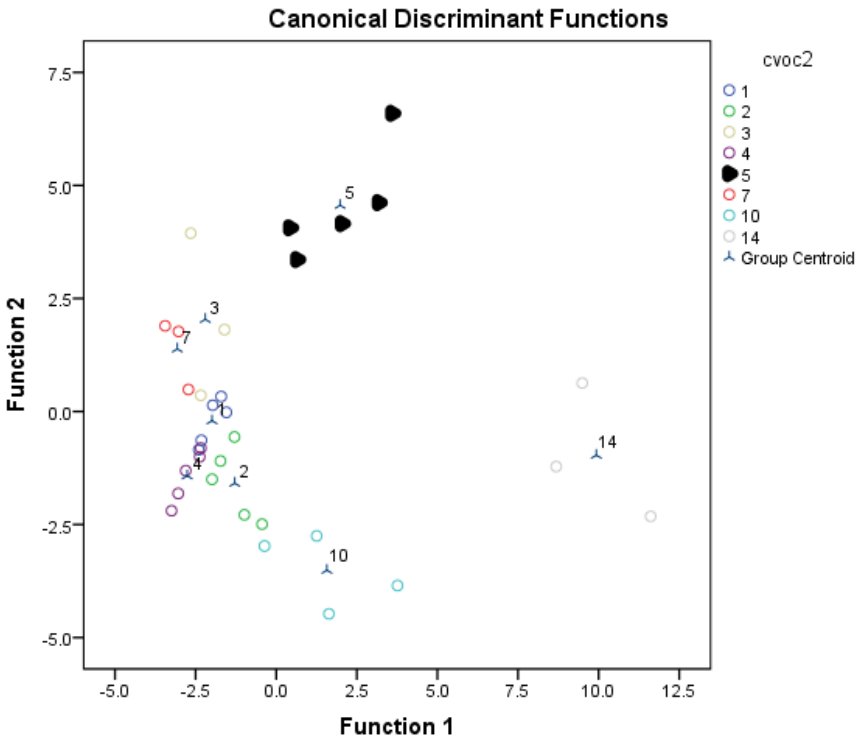

Figure4.2 Larynx-related parameters DFA scatter-plot. Vocal type 1 = uhm, vocal type 2 = ga, vocal type 3 = Oow, vocal type 4 = Exhaled huff, vocal type 5 = Iii, vocal type 7 = Uaaa, vocal type 10 = Uchuck, vocal type 14 = High Pitched Call.

The results of the DFA on the larynx-related parameters (Figure 4.2) supported our labeling of eight putative vocal types. The classification assigned the average individual means to the correct vocalization type in 87.9% and 72.7% of the cross-validated cases (N = 33, Wilk's Lambda = 0.070, F28, 81 = 19.821, P < 0.001).

The most important acoustic features that contributed to the discriminant model were: Duration (F = -0.083), MaxF0 (F = 3.789), F0end (F = -2.757), and Pt2min (F = 0.405). By adding vocal-tract-related parameters to the statistical model (Figure4.3), we found that the correct classification rate for the six putative vocal types for which formants could be measured, increased to 100.0% for the original model and 92.0% for the cross-validated model (N = 25, Wilk's Lambda = 0.030, F20, 54 = 63.827, P < 0.001). RangeF0 (F = 0.440), F1me (F = 1.067), F2me (F = -1.130), and F3me (F= 1.037) were indicated as the most important parameters in the classification process.

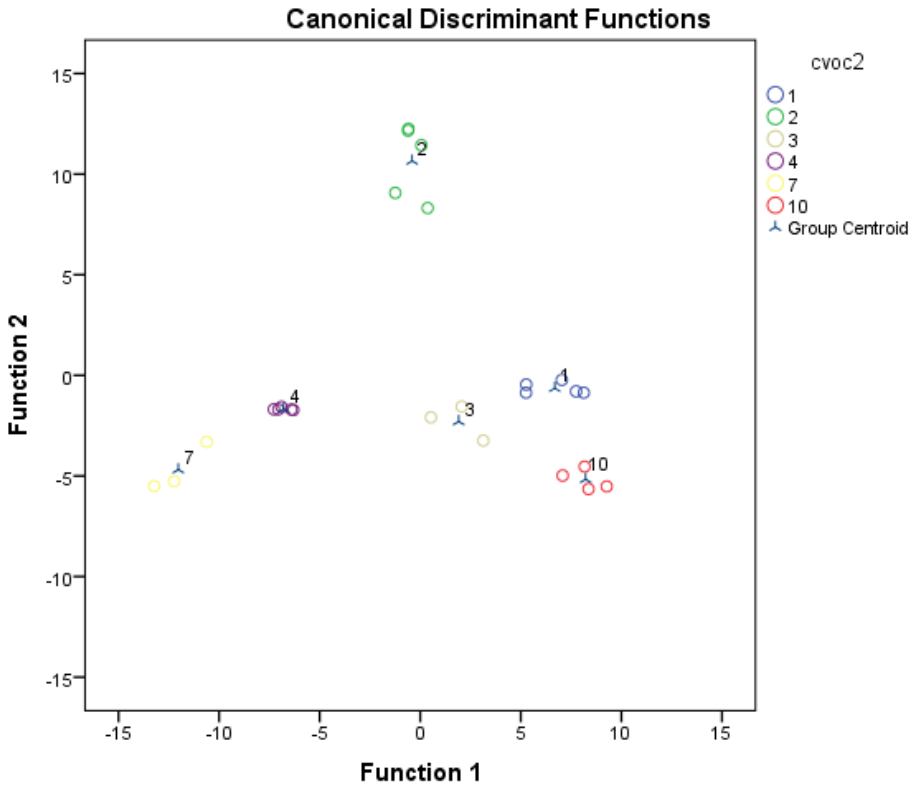

Figure4.3 Larynx – and vocal tract – related parameters DFA scatter-plot. Vocal type 1 = uhm, vocal type 2 = ga, vocal type 3 = Oow, vocal type 4 = Exhaled huff, vocal type 7 = Uaaa, vocal type 10 = Uchuck.

Four out of eight vocal types (Exhaled Huff, Iii, Uaaa, and HPC) showed a 100% correct classification rate in the DFA based on the larynx-related parameters. At least the 67% of the other four vocal types were correctly assigned to their putative category. We observed that 20% of the Uhms were classified as Exhaled Huffs; 20% of Gas and 33% and Oows classified as the Uhms; and 25% of Uchucks were classified as the Gas. In the cross-validated model, only HPC were 100% correctly assigned, while the assignation rate of the other vocal type ranged between 33% and 80%. The second DFA assigned correctly 100% of all the vocalizations types while in the cross-validated model 20% of Uhms were assigned to the Gas and 33% of Oowsto the Uhms.

The cross-validated pDFAs confirmed the results reported above. We found that only 37.4% of the calls were assigned correctly using the larynx-related parameters (N = 353, P = 0.032, expected correct classification rate = 25.4%) and 71.5% when testing for larynx-related and vocal-tract-related parameters (N = 295, P = 0.015, expected correct classification rate = 42.8%). In ESM2, we summarized, for each vocal category, mean and standard deviation of the acoustic parameters used in the DFAs.

Discussion

The analyses of the vocal repertoire of *Rhinopithecus brelichi* represent a significant contribution to the study of this species and its family because of the very limited number of studies available on Asian colobines vocalizations. We identified peculiar acoustic structures that characterized the vocal emission of this species.

We found that *R. brelichi* produced at least two vocal types with an unusually high pitch: the Iii,

and the High Pitched Call. In the Iiis, the average maximum fundamental frequency was 4337 ± 1113 Hz. Our finding showed that HPCs had an average maximum frequency of the higher periodic component of 7944 ± 716 Hz. A third vocalization, the Uchuck, very frequently contained ultrasonic harmonics. Thus, we can confirm the prediction of our first hypothesis, the presence of vocalizations showing high f0 and g0 components in the vocal repertoire of *R. brelichi*. These results are in agreement with those studies indicating that, whereas few mammals can emit and receive pure ultrasonic signals (e.g.; cetaceans, Au 1993; bats, Griffin 1958; Pearl and Fenton 1996; and rodents, Ehret and Haack 1981; Randall 1994; Sales and Pye 1974), nonhuman primates can emit and respond to calls with ultrasonic elements (e.g.; *Callithrix jacchus*, Bezerra and Souto 2008; *Cebuella pygmaea*, Pola and Snowdon 1975; *Cheirogaleus medius*, Cherry *et al.* 1987; *Microcebus spp*, Braune *et al.* 2005, Cherry *et al.* 1987; *Prolemur simus*; Bergey and Patel 2008; *Tarsius syrichta*, Ramsier *et al.* 2012). Ramsier and colleagues (2012) documented pure ultrasound signals in tarsiers, but larger *Nasalis larvatus*, which is phylogenetically closer to our study species, has shown ultrasonic components of high-pitched vocalization (Srivathsan and Meier 2011; Roper *et al.* 2014).

Our findings are particularly interesting when seen in the light of the comparative work of Marc Hauser (1993) on the relationship between the fundamental frequency of vocalizations and primate body size, which suggested a negative correlation between body size and high-frequency pitch. Contrary to the species mentioned above (excluding *N. larvatus*), *R. brelichi* is a larger body-sized primate with an average body mass of 14.5 kg and 7.8 kg for adult males and females respectively (Kirkpatrick and Grueter 2010). In agreement with previous studies on the proboscis monkeys, we recorded HPCs uttered by adult and juvenile

females (Srivathsan and Meier 2011; Roper *et al.* 2014). We can indicate HPCs as "food-associated calls" (vocalizations emitted during feeding but also uttered in nonfood contexts, Clay *et al.* 2012) because they were often recorded during the arousal anticipating feeding. Our findings are in agreement with the data of Roper and colleagues (2014), who reported that high-frequency calls are apparently produced in agitated states (p. 193, Roper *et al.* 2014), such as the response to disturbances. Even if the adaptive significance of high-pitched vocalizations in large body-sized primates is currently unknown, our findings apparently confirm one of the two potential functions suggested by Srivathsan and Meier (2011). High-frequency calls have the advantage of being clearly distinct from ambient environmental sounds (Snowdon and Hodun 1981), and this characteristic can be particularly important in dense vegetation, where high-frequency calls retain their discernable nature and could be used as advertisement calls in short-distance communication (Srivathsan and Meier 2011).

In agreement with the observations of the Sichuan snub-nosed monkeys (*R. roxellana*) by Fitch *et al.* (1987), Tenaza *et al.* (1988), Clarke (1990), and Li *et al.* (1993), we found ventriloquial calls in *R. brelichi* and could confirm our second prediction. The Uhms are ventriloquial vocalizations uttered without evident facial movements or mouth articulation, which has also been found in the congeneric Yunnan snub-nosed monkey (Grueter 2003). The phonation of the Uhms is similar to that observed for nasal vocalizations in other primate species: the mouth was closed or involved in other activities; the nostrils were visibly dilated, and abdominal movements could be observed (Gamba *et al.* 2012). The contextual occurrence of the Uhms in our study (foraging, traveling, and affiliative displays) contradicted the findings of previous studies, which suggested that ventriloquial vocalizations may serve an anti-predator

function in some primate species (Snowdon and Hodun 1981; Brown 1982).

In agreement with the observations of Clarke (1990) and Grueter (2003), our findings confirm our fourth prediction since we found that the Kee was exclusively uttered by males towards females before and during sexual copulation. The Kee was not the only case in which a vocalization type was not shared across sexes and ages. The Uchack were mainly uttered by the adults and especially by females. A more frequent emission of the alarm calls by females and the finding that wild *R. brelichi* males also gave these calls (MG, unpublished data) appear to overlap with the observations of *R. roxellana* (captive, Tenaza *et al.* 1988; and free-ranging, Li *et al.* 2003), and *R. bieti* (Grueter 2003).

Focusing on the overall size of *R. brelichi* vocal repertoire, we found evidence in agreement with studies of *R. bieti* and *R. roxellana*. We identified nine putative vocal types using spectrographic investigation. This number of vocalization types fell within the range of those described for the Chinese congeneric species (Fitch *et al.* 1987; Tenaza *et al.* 1988; Clarke 1990; Li *et al.* 1993, Grueter 2003). The putative vocal types were confirmed quantitatively using robust discriminant models. In sum, we could confirm our fourth prediction, the repertoire of *R. brelichi* consisted of at least nine discrete vocalization types, which showed significant differences in their duration, source- and filter-related properties.

We contributed critical information for future behavioural studies, which are necessary for a better understanding of the ecological needs of primate endangered species and thus are fundamental for the conservation of *R. brelichi*. Further studies on the acoustic propagation and phonation mechanisms are needed to clarify the adaptive significance of *R. brelichi* vocal communication.

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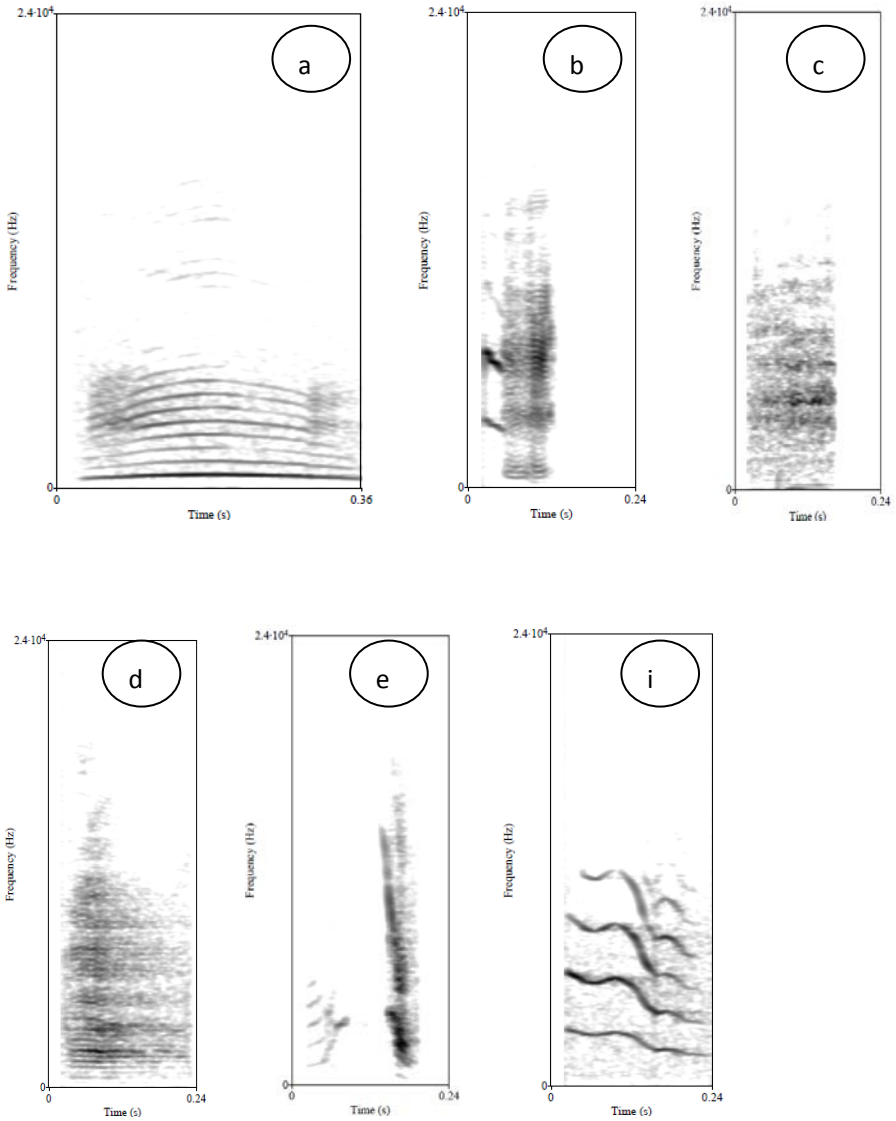

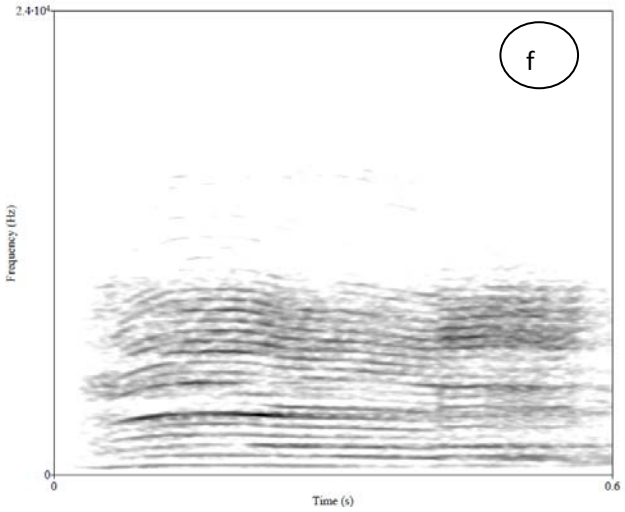
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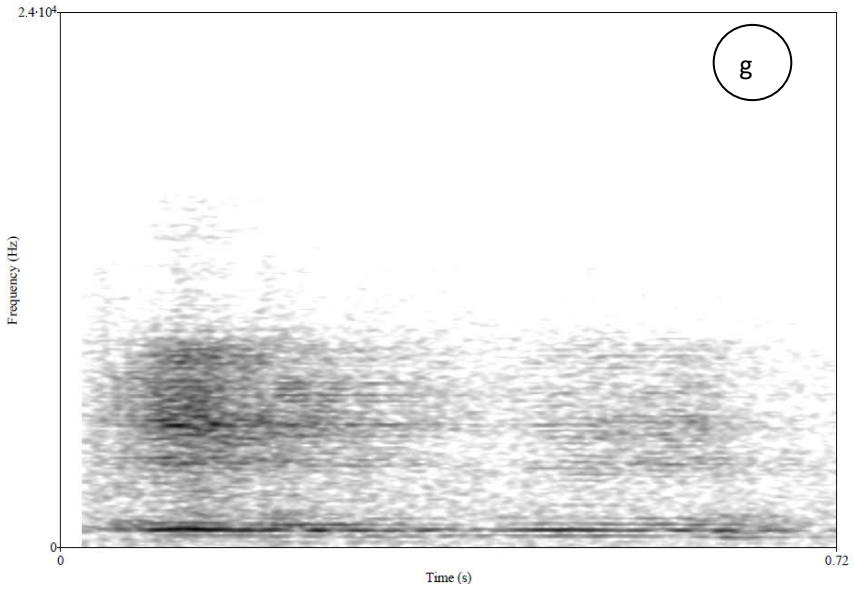
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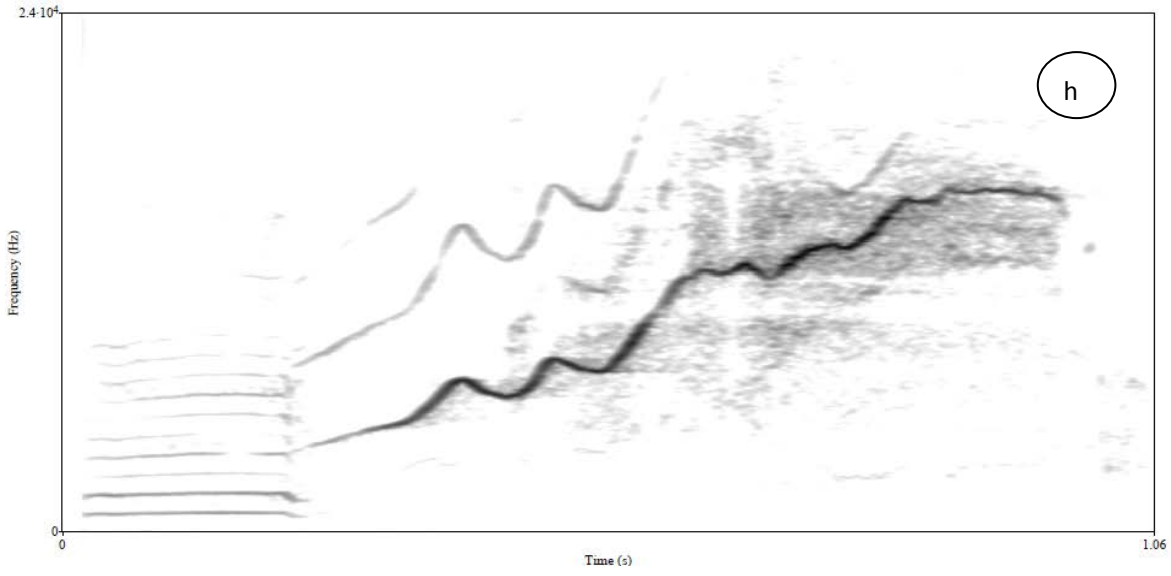
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Figure4.1 Sound spectrograms of vocalizations of the snub-nosed monkey, *Rhinopithecus brelichi*. a)Uhm, b) Ga, c) Exhaled Huff, d) Kee, e) Uchack, f) Uaaa, g) Oow, h) High-Pitched Call, i) Iii. All spectrograms were generated with Praat.

Vocalization	Description	BehaviouralContext	Individuals
Uhm	Low-intensity tonal call. Ventriloquial emission.	Ubiquitous	All
Ga	Short-duration, loud and pulsed call. Mouth partially open.	Agonistic	All
Oow	Long, low-intensity tonal call.	Affiliative	Adult male/females
Exhaled Huff	Low-intensity exhaled call. Mouth widely open.	Ubiquitous/ Agonistic	All
Iii	Intense call, harmonics clearly visible. Mouth partially open.	Arousal	All
Kee	Long and low call. Mouth barely open.	Sexual	Adult male
Uaaa	Long and loud call. Mouth widely open.	Ubiquitous	Adult/ subadult female
Uchack	Short and loud call. Mouth widely open.	Agonistic	Adult male/female
High Pitch Call	High, loud and long call. Mouth widely open.	Arousal	Adult/ subadult female

Table4.3*Rhinopithecus brelichi* vocal type description. We reported information on emission, behavioural context and emitters.

Chapter 5 Exploring Local Perceptions and Attitudes toward Endangered François' Langurs (*Trachypithecus francoisi*) in A Human-modified Habitat

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Abstract

The dynamic interactions between local people and François' langurs (*Trachypithecus francoisi*) have become a challenge for conservation of this endangered species in Mayanghe National Nature Reserve (MNNR) in China. To inform better conservation management strategies, we conducted a series of questionnaire surveys and ethnographic interviews with local households in the Qinglong village of MNNR to understand the main reasons and key factors that determine local perceptions and attitudes toward François' langurs from March to August 2015. We found that 53.3% (40, $N = 75$) of the interviewees liked François' langurs presence around the village while 26.7% (20, $N = 75$) disliked the François' langurs. Respondents with favourable attitudes associated the langurs mainly with tangible benefits from local tourism and their positive aesthetic and emotional values. Respondents with negative attitudes associated the langurs with tangible costs such as crop feeding and the destruction of their houses. Respondents with neutral attitudes (15, $N = 75$) primarily associated langurs with various cost and benefit trade-offs. Overall, local people tended to have slightly negative perceptions on the langurs' impacts at household level, while they had very positive perceptions on their impact at community level. Ordinal logistic regression models revealed that four variables, including age, gender, and impact perceptions at household and community levels, were significantly associated with local residents' attitudes towards the langurs. We found that higher perceived benefits at household and community levels would lead to more positive local attitudes toward the langurs while higher perceived costs lead to more negative attitudes. We further

discussed how understanding community perceptions and attitudes toward flagship species may support the planning and implementation of effective conservation and development programmes. We also suggested that such socioeconomic monitoring efforts should be periodically conducted in protected areas like MNNR, especially in the context of fast economic and infrastructure development.

Key words

Local Attitude, Perception, Human and Primate Co-existence, Primates Conservation, Flagship Species

Introduction

Nonhuman primate (primate hereafter) is an important but fragile order and they are part of the environmental context of the people who co-exist with these animals (Estrada *et al.* 2017; Hvenegaard 2014; Lee and Priston 2005). A common strategy for protecting endangered primate species is to restrict the access of human to natural resources in the species' habitat, which sometimes could exacerbate human-wildlife conflict (Ellwanger *et al.* 2015; Hill 2000, 2005). On the other hand, conservation initiatives that contribute some tangible or intangible benefits for local people such as local infrastructure improvement may result in positive conservation attitude (Ellwanger *et al.* 2015; Xiang *et al.* 2011). It is important for conservation management to understand interactions between species with the stakeholders in order for

people and primate to co-exist harmoniously (e.g. Bennett 2016; Fuentes and Hockings 2010; Setchell *et al.* 2017).

Attitudinal studies that help us understand, predict and influence human behaviour are the most prevalent type of investigation in human dimensions of wildlife (Manfredo and Bright 2008). The study of local people's perceptions and attitudes toward primates has received considerable attention (e.g., Alexander 2000; Chalise and Johnson 2005; Lee and Priston 2005; Rocha and Fortes 2015). Some researchers have examined how tangible costs (i.e., crop raiding) and tangible benefits (i.e., economic benefits of ecotourism) influence local residents' perceptions and attitudes of protected species (Ellwanger *et al.* 2015; Hill 2000; McLennan and Hill 2013; Sousa *et al.* 2014). Positive attitudes towards primates can also be informed by intangible benefits such as a human-like appearance and the behaviour of a species or cultural dimension while negative attitudes towards species can be driven by intangible costs such as negative emotional connection (i.e., fear of animals) (Campbell-Smith *et al.* 2010; Costa *et al.* 2013; Hill and Webber 2010; Riley and Priston 2010; Xiang et al. 2010). Overall, perceived costs and benefits of human-wildlife interactions have generally been considered to be one of the primary determinants of people's attitudes toward wildlife (Bennett 2016; Kansky and Knight 2014).

In this study, we examine a case of human-primate interaction, focused on local perceptions and attitudes towards the Endangered François' langurs (*Trachypithecus francoisi*) (Bleisch *et al.* 2008) and human-langur relationship in Mayanghe National Nature Reserve (MNNR), China (Figure 5.1, N28°37′33″ ～ 28°54′27″, E108°3′39″ ～ 108°20′25″). The François' langur is distributed at nearly 30 isolated locations in the limestone hills and valleys

of Northern Vietnam and Southern China (Li *et al.* 2007; Nadler *et al.* 2007; Niu *et al.* 2016). Their survival is mostly threatened by hunting and habitat loss and fragmentation (Hu *et al.* 2004; Li *et al.* 2007; Nadler *et al.* 2007; Niu *et al.* 2016). Our latest review indicates that the global wild population of François' langur has decreased to around 1700 individuals and the sizes of about 70% of the subpopulations are less than 50 individuals (author *et al.* in prep.). The conservation status of this species warrants urgent attention.

MNNR is home to the largest wild population (about 554 individuals) of François' langurs in the world and the survival of the langurs in this reserve is a key for conservation of species (Niu *et al.* 2016). Human-langur interaction is common in MNNR. For instance, due to the dense human population and the severe degradation of natural habitats in the reserve, the langurs have been observed to feed on cultivated plants (e.g. corn and sweet potato) and forage in homes, causing considerable crop and property damages. Local youth injured three langurs to prevent crop damages in 2011 and one langur was killed by a dog in 2013 (Niu *et al.* 2016; Zhu *et al.* in press). To address the complaints of local residents concerning property damages caused by langurs, the reserve administration began to financially compensate local residents for economic losses in 2011. Unfortunately, direct financial compensation was discontinued due to unstable funding sources. Furthermore, government policy encouraged goat farming in local villages, leading to dietary competition between goats and langurs (Chen *et al.* 2012). With the likelihood of human-langur conflict continuing in the future, investigation of local perception and attitudes toward François' langurs is key to protect these species in social-ecological systems.

China is home to 1.4 billion of people and 693 mammalian species (Jiang *et al.* 2016, 2017). Over-exploitation by humans, habitat loss and human interference are the three leading threats to many of these animals (Jiang *et al.* 2016). Among them, primates (28 species) are highly threatened in China (Pan *et al.* 2016; Jiang *et al.* 2016, 2017). Recently in China, a new National Park system has been proposed and piloted, with the intention of promoting harmonious coexistence between human and nature (Overall plan on the development and management of national parks, 2017). For instance, local residents in the "gate community (refer to key communities living near and around national parks)" near national parks are encouraged to participate in nature education programmes and the co-management of ecosystem in this national plan (Overall plan on the development and management of national parks, 2017). Although examining attitudes within a particular context is helpful for wildlife conservation and the engagement of local residents, there have only been a few studies on local perceptions and attitudes toward primates and other flagship wildlife in China (e.g. *Rhinopithecus brelichi*, Ellwanger *et al.* 2015; *Elephas maximus*, He *et al.* 2011). Our study used a mixed analysis technique to investigate the key cost-benefit perception and socio-demographic factors that influenced local attitude toward the François' langurs. Our study will help in a better understanding of human-langur interaction and provide key information for developing effective conservation programmes in MNNR.

Method

Study site

MNNR was established in 1987 as a provincial nature reserve to protect François'

langurs and its habitat. In 2003, it was upgraded to a national nature reserve. It is located at the juncture of Yanhe County and Wuchuan County of Guizhou province, one of the poorest regions in China. MNNR is about 31, 113 ha, consisting of core (10, 543 ha), buffer (10, 522 ha) and transition (5, 548 ha) zones (Figure 5.1) (Zhu *et al.* 2017).

By 2015, there were about 23,000 residents living in MNNR. Our study site is the Qinglong village in the south of MNNR (Figure 5.1 and Figure 5.2a). At least three groups of François' langurs (32 individuals in total) were observed around this village (Figure 2b, author's personal observation 2015). We selected Qinglong village because it has been a laboratory for several pilot conservation programmes and provides a model system to study the relationship between local residents and François' langurs. For example, Qinglong village is supported by local government and MNNR to develop a François' langur tourism programme, in which at least 3 million Yuan (~450,000 USD) has been invested in the construction of infrastructure such as the roads, walking paths and a square in the village since 2011 (Figure 5.1).

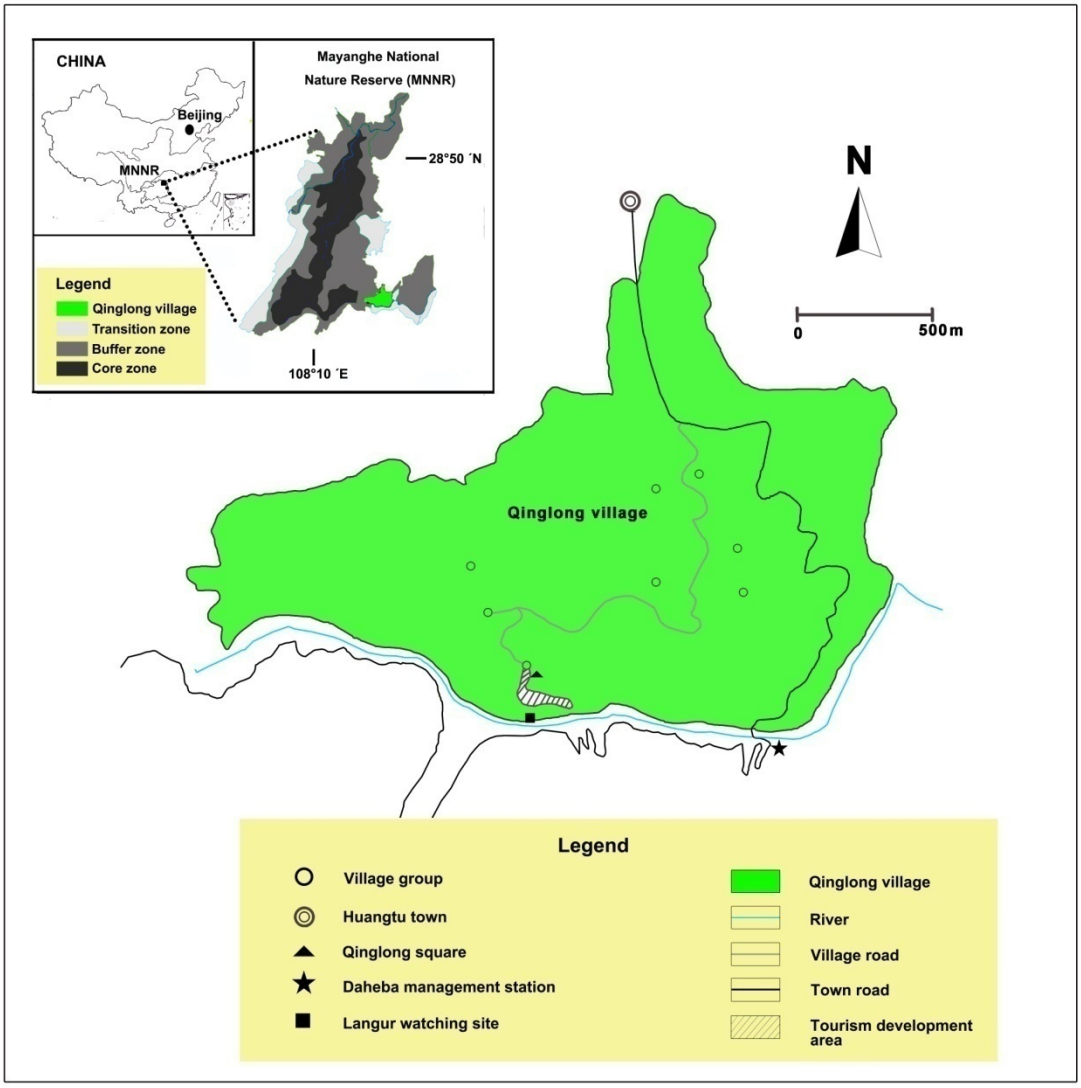

Figure 5.1 Qinglong Village and Mayanghe National Nature Reserve in China

Questionnaire design and sampling

We sampled at the household-level (one adult per household, ⩾18 year old) to collect data using a questionnaire. Only 110 of 232 households were occupied in the village because over half of the residents were working in the cities during most of the year. Through an online sample size calculator (http://www.surveysystem.com/sscalc.htm), combining confidence interval (5) and 95% confidence level, we determined that a sample size of 86 households would be sufficient.

Prior to designing the questionnaire, we conducted a pre-interview field visit in

December 2014 with two MNNR staff to gain a locally informed understanding of the positive and negative aspects of MNNR and François' langurs. The main problems suggested by MNNR staff for inclusion in our questionnaire related to natural resource use by local residents, interaction between human and langurs, and financial compensation and related policies. We also included questions about local agriculture practice, land use, and food resource competition with the langurs. After preliminary interviews with three local people, we added a few additional questions about langur tourism into our questionnaires. Subsequently, we designed a questionnaire (see Appendix III) that included four parts: 1) socio-demographic information (Table 5.1) and local beliefs about animals, 2) farming income (mainly income generated from crops, livestock and governmental subsidies and human-wildlife information, 3) local people's knowledge of MNNR, François' langur, and views about wildlife crop-feeding, damages and remedies, and 4) local people's perceptions and attitudes toward François' langur and MNNR. In this paper, we explored local attitudes toward the langurs as well as costs and benefits perceived by people in order to understand key predictors of attitudes for future conservation (Table 5.1). Perceived costs and benefits are categorized as tangible benefits (TB), tangible costs (TC), intangible costs (IC, Indirect cost as perceived by the respondent, such as individual psychological costs of fear, danger or risk from species) and intangible benefits (IB), based on definitions from Allendorf *et al.* (2006) and Kansky and Knight (2014), and modified in consideration of the local context (Table 5.2).

Data collection

From March to August 2015, we conducted ethnographic interviews, involving structured, semi-structured, and open-ended interview techniques. Although the local dialect is

similar to Mandarin, we hired a local interpreter/facilitator to overcome certain language and cultural barriers (Ellwanger *et al.* 2017). This person was not affiliated in any way with the local authorities of Qinglong village or the MNNR Administration; to our knowledge, his presence did not have any significant influence on the answers given by the respondents during the interviews.

Before each interview, we introduced ourselves and informed the interviewees a statement on the scientific purpose of our survey. Once the respondent orally consented; we would interview the respondent using the standard questionnaire. We also asked whether the respondent can accept our audio recording about the interviewing. With agreement from the interviewees, we also recorded the interview process and the audio data and transcript were used to support further analysis.

In terms of the attitudinal questions, we used the term "liking (Do you like the François' langur living around your village?)" to assess a respondent's degree of positive attitude toward the François' langur (Allendorf 2007; De Boer and Baquete 1998). Respondent answers were divided into positive (like), neutral (i.e., no strong opinion of François' langur), and negative (dislike) responses. Participants also shared their reasons for selecting their answers.

Furthermore, we also designed ten questions to assess the costs and benefits respondents associated with the langurs in terms of local specific interactions (Table 5.4) (Allendorf *et al.* 2006; Kansky and Knight 2014). We used a 5-point Likert scale to evaluate the degree for each question: very important benefits, important benefits, no significant benefits or costs from langurs, important costs, and very important costs. We also recorded participators'

comments on the types of cost or benefit from langurs.

Data analysis

Attitudes analysis

Respondent attitudes were classified as positive, neutral, or negative. We used open coding and grounded theory to analyze the open-ended comments from attitude questions (Bernard and Ryan 1998; De Boer and Baquete 1998; Ellwanger *et al.* 2015). Open coding and grounded theory are techniques used to analyze text by identifying important emerging themes in the data (Bernard and Ryan 1998). These techniques are suggested for text analysis when searching for evidence of social conflict, social welfare and cultural contradictions (Bernard and Ryan 1998; Silverberg *et al.* 1996; Spradley 1979). We identified concepts that emerged from interviews with regards to respondent attitudes and created codes to provide further description of respondent attitudes (Table 5.2). These codes were grouped by similarity into reason types and then we classified these reason types into the four sub-categories of costs and benefits. We calculated the frequency of different reasons types and each cost-benefit sub-category (Table 5.2). To explain the attitudinal reason difference between male and female, we calculated the percentage of respondents based on the cost-benefit sub-category (Table 5.3).

Cost-benefit perception from langur

Similar to Carter et al. (2014), we consolidated responses of the respondents on cost-benefit questions from five scales to three scales: positive perception including very important benefits and important benefits (coded “1”), neutral responses including no strong impact from langurs (coded “0”), negative response including important costs and very

important costs (coded "-1") plus all unsure answer (coded "NA"). To overview cost and benefit variables, we calculated the percentage of respondents on perceived François' langurs related benefits and costs and aggregated scores of all the costs and benefits questions (Table 5.4). Then ten cost-benefit questions were divided into two groups: one group (fl1, fl4, fl6~fl9) was used for calculating the average perceived cost-benefit value at household level and the other was used for calculating the perceived cost-benefit value at community level (fl2, fl3, fl5, fl10).

To further examine effect of various factors on local attitude, we ran an ordinal logistic regression with local attitudes at three levels (positive "3", neutral "2", and negative "1").

$$\text{Logit}\,[P\,(Attitudes \leqslant j \mid X)] = \alpha_j + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_n X_n$$

The probability of attitudinal category (j) can be expressed as $P\,(Attitudes \leq j \mid X)$. X : vector of explanatory variables; α_j stands for the intercept; Regression coefficients $\beta_n = \beta_1, \beta_2, \cdots \beta_n$.

The independent variables include the following:

Age: how old the respondent is;

Gender: female = 0, male = 1;

Edu: how long the respondent received the formal education;

flperc.hh: the average cost and benefit perception score at household level;

flperc.comm: the average cost and benefit perception score at community level;

Income: ln (the household income of the respondent in one year).

To test collinearity among independent variables, we calculated the variance inflation factors (VIFs), where (VIFs < 4) implies absence of collinearity (O'Brien 2007). Model 1

includes all above independent variables, while variable "*income*" was excluded in Model 2 (Table V). In Model 1, the sampling size is smaller ($N = 63$) comparing to Model 2 because 12 respondents did not report their income clearly.

All the significances level (P value) in this study was set at $P < 0.05$. All the data were entered and coded using MS Excel and statistical analysis were conducted using software SPSS 20.0.

Ethical notes

Data were collected in accordance with the legal requirements of People's Republic of China, and with the permission of the Guizhou Forestry of Department, Mayanghe National Nature Reserve Administration, and Committee of Qinglong village. We read each interviewee a statement explaining the scientific purpose of our survey and requested their permission to participate in the interview process, including their permission to audio record the interview.

Result

A total of 105 households in the Qinglong village completed the description of socio-demographic information (Table 5.1). A total of 502 residents, including 261 males and 241 females, lived in the 105 households. The mean household size was 4.8 people. The mean age of 105 respondents was 47.8 years old. Overall, the education level in the community was low and the average annual income of each household is about 32,359 Yuan (~5,123 USD) in 2014.

Among all the respondents, 30 participated in the interview incompletely. Therefore, available sampling size to evaluate local people's perceptions and attitudes was 75. In general,

the socio-demographic information of 75 respondents was similar to 105 respondents except gender (Table 5.1). Only one third of respondents were females (N = 75) due to the lower comprehension ability of local women on questions of perceptions and attitudes. More details are shown in Table 5.1.

Demographic information

Table 5.1 Description of socio-demographic factors

Socio-demographic Information	Mean ± SD		Percentage and number of respondents	
	All[a]	Part 4[b]	All[a]	Part 4[b]
Age	47.8±14.7(105)	48.4 ± 13.8 (75)		
Gender				
Male			59.0% (62)	66.7% (50)
Female			41.0% (43)	33.3% (25)
Family size	4.8±1.8 (105)	4.7 ± 1.7 (75)		
Education				
None (0 year)			35.2% (37)	29.3% (22)
Primary school (≤6 years)			30.5% (32)	32.0% (24)
Middle school (≤9 years, > 6 years)			26.7% (28)	28.0% (21)
Higher level (> 9 years)			7.6% (8)	10.7% (8)
Income within last year (RMB)[c]	32359 ± 35269 (91)	32791±35039 (63)		

[a] This includes all households who at least finished part 1 of the questionnaire (N = 105).

[b] This includes all households who finished both part 1 and part 4 of the questionnaire (N = 75).

[c] Effective sample size (note that not all households reported annual income).

Local attitude and reasons

Out of the 75 respondents, 40 (53.3%) of the respondents said they liked the fact that the langurs occur in their village; 20 (26.7%) responded negatively; 15 (20%) were neutral. Nine respondents did not clearly articulate the reasons for their responses; thus, our effective sample size was 66 respondents when we analyzed their reasons using text analysis (Table 5.2

and 5.3).

Table 5.3 Gendered differences in explaining attitudes

Gender	Reason frequency of TB	Reason frequency of TC	Reason frequency of IB
Male (N = 44)	40.9% (18)	25% (11)	36.4% (16)
Female (N = 22)	31.8 (7)	45.5% (10)	31.8 (7)

A total of 33 respondents clearly articulated the reason for their positive responses. Those who are in favor associated the langurs mainly with tangible benefits and intangible benefits (Table 5.2). The most important tangible benefits related to langur-tourism while the most important intangible benefits related to cultural perceptions such as aesthetic value and emotional connection to François' langur (Table 5.2). On the one hand, some respondents explained that langur can bring “investments and tourists attraction”, “local infrastructure construction and development”, “economic benefits and development” (Table 5.2 and Figure 5.2c, d). Even one older respondent said, “we are getting good luck (“福” economic benefit in the local dialect) from langurs. If monkeys do not occur in our village, some of young men here cannot find a wife”. On the other hand, local people enjoyed seeing François' langurs (Table 5.2). For instance, a few respondents described the reasons why they like the langur, such as “langur is a beautiful animal”, “graceful jumping postures of monkeys”, “when monkeys jumped on the trees, they are more beautiful than a dance”. It is worthwhile to notice that two respondents felt that crop feeding by langurs was not serious and they still had a positive attitude. One respondent said “(the langurs) just fed little crops, no big deal. They benefit us”,

while the other one thought the “monkey can bring us luck. Although they feed on crops, they are still good for us”. In addition, one respondent claimed that these intangible benefits can be offset by some tangible benefit. She thought she liked the langur because the langur is beautiful but continued to say that “people from outside need spend some money to come here and watch them”.

For negative respondents, only one was unable to clearly articulate the reason for their response. Negative attitudes primarily related to tangible costs from the langurs presence such as crop (57.9%) or fruit (5.3%) feeding, destruction of house / property (26.5%), or conflict between people and langurs (31.6%) (Table 5.2, Figure 5.2e and f). Some respondents directly expressed that they disliked the langurs because langurs they fed on their corns and one respondent complained that “I worked so hard for my crops. However, the langurs can eat the crop and nobody provides financial compensation for my economic losses”. Some other human-langur conflicts (e.g., damage house, fruit feeding) also shape local attitudes in Qinglong village. A few respondents said, “langurs are hateful because they can damage our house and enter our house to search for food”. The strongest expression from one respondent was that “I cannot survive here because of the existence of these langurs here”.

Table 5.2 The frequency and its percentage of each specify reason type mentioned by local residents

Reasons sub-category of cost and benefit [a]	**Code and key description of the answers (original in Chinese)**	**Positive** *N*=33	**Negative** *N*=19	**Neutral** *N*=14	**Total** [b] *N*=66
Tangible Benefits (TB): Those where the respondent receives direct monetary benefits due to the presence of the species on their land. For example, from compensation programmes, development projects (infrastructure building), subsidies for implementing mitigation measure, hunting fees or tourism or reputation.	1, Langurs give luck or improve personal income (享猴子的“福”或个人致富); financial compensation (经济补偿) ; attracts investments (带来资金)	11 33%	0	3 21%	14 21%
	2, Attracts tourists, making their village a bustling place (带来游客，闹热，外来人会来玩)	5 15%	0	3 21%	8 12%
	3, More infrastructures and better roads, etc. (搞建设，修路等)	4 12%	0	1 7%	5 8%
	4, International recognition, media attention, proud of François' langur （国际重视或外来人知道，村子因为黑叶猴可以上电视，以黑叶猴为傲）	3 9%	0	1 7%	4 6%
Intangible Benefits (IB) Benefits as perceived by the respondent, such as existence value of the species, conservation and ecosystem services, aesthetic /esthetics value or use for cultural purposes (e.g. education).	5, Lovable （可爱）	5 15%	0	1 7%	6 9%
	6, Humans and animals have a close relationship in general（人与动物有密切的关系）	1 3%	0	0	1 2%
	7, Beautiful, acrobatic, with graceful postures（好看，飞跳美观，姿势优美）	7 21%	0	1 7%	8 12%
	8, Good or funny playing with (好玩，好耍）	7 21%	0	1 7%	8 12%
	9, Others (Improves environment; national animal protection policy) (绿化环境以及国家动物保护政策）	1 3%	0	2 14%	3 5%
Tangible Costs (TC): Those where the respondent receives direct monetary losses due to the presence of the species on their land. For example losses to their livelihoods by wildlife (e.g.	10, Conflicts; troublemaking animal （猴子生活到这个地方，自己就生活不下去；有害，讨嫌）	0	6 32%	1 7%	7 11%
	11, Crop (corn) feeding (吃庄稼或吃玉米(苞谷))	2 6%	11 58%	8 57%	21 32%

economical income such as livestock killed, crop or fruits feeding, house damage) as well a driver of social conflicts or impacts (e.g. evictions, restrictions on resource access such as trees cutting, wildlife hunting, mining, grazing, etc.)	12, Ransacking houses, damaging property and stealing food (破坏房子，翻房子，进房子偷东西)	0	5 26%	5 36%	10 15%
	13, Eats fruits (吃果实)	0	1 5%	0	1 2%
Neither costs nor benefits				3 21%	3 5%

[a] Definition of costs (sub-categories) or benefits (sub-categories) in this paper was modified from Kansky and Knight (2014), Allendorf *et al.* (2006) plus local context

[b] Effective number of respondents equals 66. Respondents sometimes gave multiple reason types in a response, so total frequencies may be higher than the number of respondents

For neutral respondents, one respondent was unable to articulate the reason for their response. Most of them claimed that the presence of langurs in the village was a trade-off with good and bad aspects (N = 11). In terms of trade-offs, respondents recognized a connection between tangible benefits and tangible costs or a trade-off between intangible benefits and tangible costs. For instance, one respondent said, “I like the langur because the langurs can attract the tourists to visit our village and I can get some economic benefit from this. I dislike them because they feed my crops.” Meanwhile, one respondent told us that “I like the langurs because these animals are beautiful while I dislike them because they feed my crops and damaged my house”. One neural respondent connected local financial compensation with her attitude. She expressed that “I would like the langurs if my economic losses were compensated; otherwise, I dislike the langur.” Moreover, three neutral respondents also thought that there are neither costs nor benefits for them because of the existence of langurs.

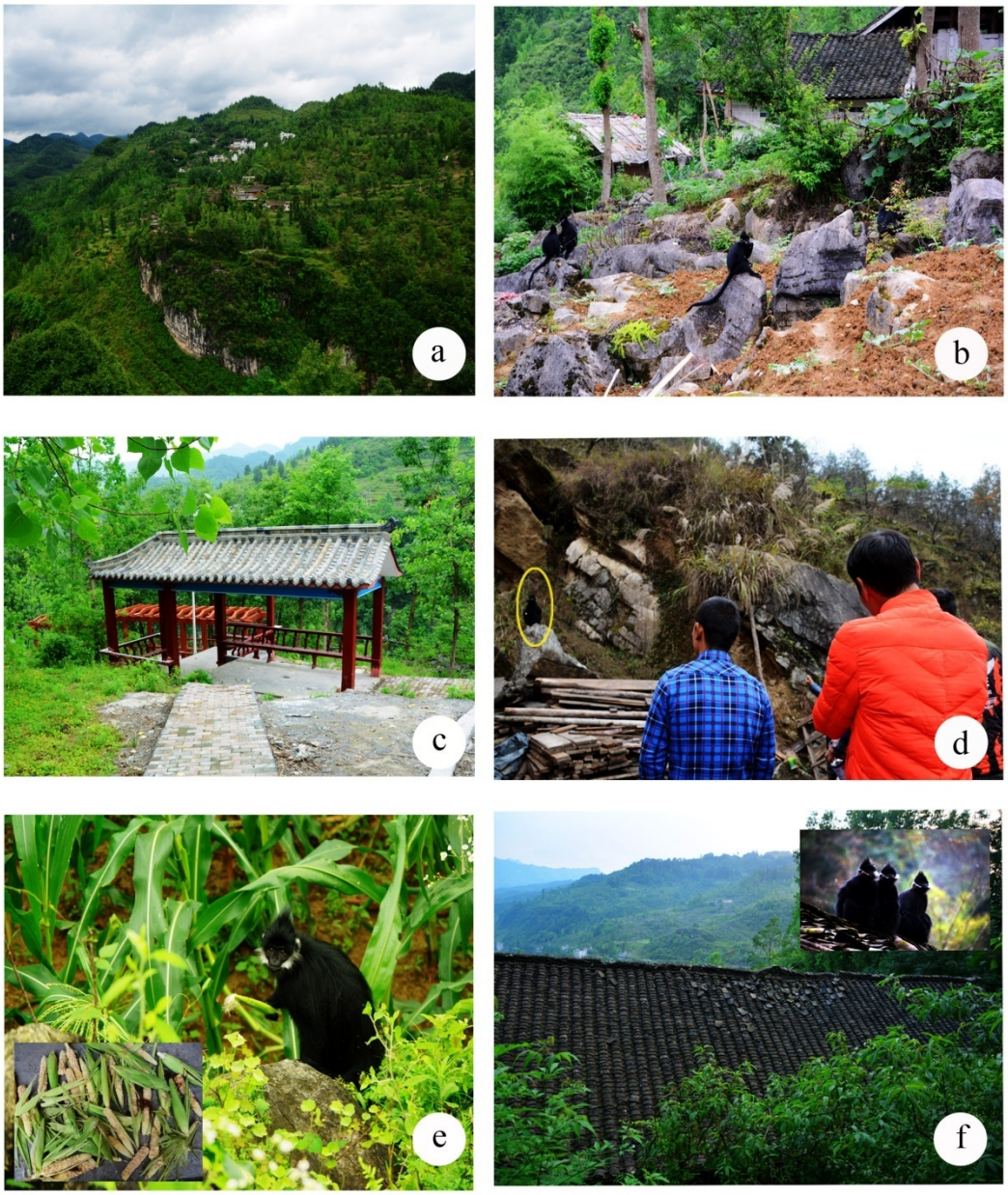

Figure 5.2a A corner of Qinglong Village in MNNR; b François' langur seen in Qinglong Village; c New infrastructure construction in Qinglong village because of langur related tourism programme; d François' langur watching by local residents and tourists; e Crop (corn) feeding by François' langurs; f A house damaged by François' langurs. (Photo credits: Photo e by *Wu A.* and the rest of photos by *Niu K.*)

Local cost-benefits perception

Table 5.4 Percentage of respondents on perceived François' langurs (FL) related benefits and costs (N = 75)

Code	*Question*	*Positive*	*Negative*	*Neutral*	*Unsure*
fl1	*Does the FL have any impact on your economic income?*	4.0%	49.3%	44.0%	2.7%
fl4	*Does the FL have any impact on the education of your next generation?*	16.0%	5.3%	58.7%	20.0%
fl6	*Does the FL have any impact on tree cutting in the mountain of your village?*	5.3%	54.7%	32.0%	8.0%
fl7	*Does the FL have any impact on your use of wildlife resource (eg. hunting) from the forest?*	2.7%	41.3%	50.7%	5.3%
fl8	*Does the FL have any impact on mining activities in the mountains around your village?*	1.3%	37.3%	26.7%	34.7%
fl9	*Does the FL have any impact on grazing around your village?*	6.7%	8.0%	72.0%	13.3%
fl2	*Does the FL have any impact on the environment of your village?*	9.3%	4.0%	62.7%	24.0%
fl3	*Does the FL have any impact on the reputation of your village?*	88.0%	0.0%	2.7%	9.3%
fl5	*Does the FL have any impact on the development of local infrastructure?*	76.0%	2.7%	12.0%	9.3%
fl10	*Does the FL have any impact on the development of local tourism?*	80.0%	1.3%	8.0%	10.7%

Overall, the average perception score is neutral (0.1±SD 0.2). The mean cost-benefit perception at the households level was slightly negative (-0.3±SD 0.3) while that at community level was positive (0.7± SD 0.3). The most important benefit associated with François' langurs included the reputation of their village (88.0%), the development of local tourism (80.0%), and the development of local infrastructure (76.0%) (Table 5.4). The most important costs associated with the langurs' presence included the impact on tree cutting in the mountain (fl6, 54.7%), personal economic income (fl1, 49.3%), and use of wildlife resources (e.g. hunting) in the forest (fl7, 41.3%) (Table 5.4).

Key predictors determining perception and attitude towards the langurs

The respondents' perception on langurs' costs and benefits at household and community levels, age and gender were significantly associated with local people's attitudes

towards langurs while education level were not significant to predict local attitudes in both of models (Table 5.5). Model 1 also showed that *income* was not a significant factor to predict local response. We used Model 2 to explain our result since it has a bigger sampling size.

The ordinal logit model showed that when keeping all independent variables constant, the household level cost and benefit perception was significantly associated ($P< 0.05$) with local residents' attitudes toward langurs; for one unit increase in *flperc.hh*, the odds for the attitude to increase by one level (i.e., from negative to neutral, or from neutral to positive) increased by 44.70 times. Likewise, the langurs' impacts on cost and benefit perceptions at community level was also significantly associated ($P< 0.05$) with local residents' attitudes toward langurs, and for one unit increase in *flperc.comm*, the odds for the attitude to increase by one level increased by 12.15 times, given that the other variables in the model are held constant. In general, perceived benefit at household or local community levels tends to increase the likelihood of local people having a positive attitude toward langurs. *Age* was also significantly associated ($P< 0.05$) with local residents' attitudes toward langurs. As the age of respondent increases by one year, the probability of having a more positive attitude toward langurs would decrease by 8%, given that the other variables in the model are held constant. *Gender* was significantly associated ($P< 0.05$) with local residents' attitudes toward langurs; men were more likely to have a more positive attitude toward the langurs than women in the village, given that all of the other variables in the model are held constant.

Table 5.5 Variables included in the ordinal regression model

Variable	Model 1 (with income, *N*=63)				Model 2 (without income, *N*=75)			
	Estimate (*b*)	Standard Error	Odds Ratios	*P*	Estimate (*b*)	Standard Error	Odds Ratios	*P*
age	-0.07	0.03	0.94	0.025	-0.09	0.03	0.92	0.001
income	0.20	0.25	1.22	0.418				
flperc.hh	3.36	1.14	28.82	0.003	3.80	1.10	44.70	0.001
flperc.comm	2.50	1.15	12.20	0.030	2.50	0.99	12.15	0.011
edu	-0.09	0.34	0.91	0.793	0.01	0.33	1.01	0.977
gender=0 (1 = reference)	-1.81	0.69	0.16	0.009	-1.68	0.65	0.19	0.010

Note: -2 Log Likelihood=100.5, χ^2=28.1, df=6, *P*=0.000, Nagelkerke Pseudo R-Square =0.41 -2 Log Likelihood=117.1, χ^2=34.3, df=5, *P*=0.000, Nagelkerke Pseudo R-Square = 0.42

Discussion

Overall, our results suggested that perceived costs and benefits explained well the local attitudes toward the primate. Higher perceived benefits would lead to more positive local attitude toward the langurs while higher perceived costs lead to more negative attitudes. The results are similar to previous studies in that perceived costs and benefits are the main drivers of attitudes (e.g., Kansky and Knight 2014). However, the relative importance of four sub-categories of costs and benefits perception is different from the conclusion in one previous study that intangible costs were the most important category to explain attitudes towards larger mammals (e.g., Kansky and Knight 2014). In our study, intangible costs were not a main reason in shaping local attitudes toward François' langurs. This could be due to the less aggressive nature of the langurs than those larger mammals (Campbell-Smith *et al.* 2010; Hockings *et al.* 2010; Kansky and Knight 2014).

The results also showed that local people's perceived benefit and cost associated with langurs at household level tended to be negative overall while that at community level was quite positive. This difference of positive and negative responses at household and community levels appeared to be a common pattern (Khatun *et al.* 2012; McLennan and Hill 2013; Sousa *et al.* 2014; Hardwick *et al.* in press) although this point has not been examined quantitatively in attitudinal studies on primate species. For example, researchers found that chimpanzees (*Pan troglodytes*) were regarded by local people as a good "crop raider" at Bulindi in Uganda and Cantanhez National Park in Guinea-Bissau since they play both a positive (flagship for tourism) and a negative (crop feeding) role on livelihoods of local people (McLennan and Hill 2013; Sousa *et al.* 2014).

Tangible costs and local attitude

Among these perception predictors of household, impacts on tree cutting in the mountain, personal economic income and use of wildlife resources in the forest were three important perceived costs of local people because of the existence of langurs. However, these negative perceptions appeared to unevenly explain local attitudes toward langurs. Few respondents mentioned that wood and wildlife resource use were the reasons to explain their attitudes towards langurs. According to our text analysis, we found that langur crop feeding is a top factor in explaining negative attitude of local people toward langurs in Qinglong village. This result is not surprising. Local residents' economic losses because of crop feeding can detract from community support of species conservation. Crop feeding by primates have caused negative interactions between primates and local people in many areas (e.g., Hill 2000, 2005; Khatun *et al.* 2013; Lee and Priston 2005; McLennan and Hill 2013; Sousa *et al.* 2014).

Meanwhile, we also found that property destruction caused by langurs as well as simply living in the same area as langurs drove negative attitudes in Qinglong village. Certain negative interactions (e.g, crop feeding, houses and property destruction) between humans and langurs were most likely to influence respondents' household economic losses, and then drive negative perceptions and attitudes of local residents.

However, two respondents felt that crop feeding by langurs was not serious as they only fed little crops. Indeed, in some cases economic losses such as crop feeding by some primate species might not always be a significant factor for driving negative sentiments in local farmers if it is not a major problem (Khatun *et al.* 2012; Radhakrishna 2017). Previous studies showed that it is possible to have different extent of crop damages which then lead to varied attitudes of local people (Carter *et al.* 2014; Kansky and Knight 2014). In addition, Qinglong village is only one of 25 villages where the langurs occurred within the reserve (author's unpublished data). Future studies should cover the other villages to better understand inter- and intra- village variations in human-langur relationship, which would provide more information to inform reserve wide conservation management and community development planning.

Benefit and local attitude

We found that langur's impact on cost and benefit perception at community level is very positive and significantly shapes local people's attitudes. Among them, the impact of langurs on the development of local tourism has the most important potential to shape local people's attitudes. In this study, 80% of the respondents thought the existence of langurs has a positive influence on local tourism development. Meanwhile, local langur-related tourism results in multiple benefits including the bolstering of local economy and improving village

reputation and infrastructure in Qinglong village. This is similar to a few previous studies that local tourism associated with flagship wildlife species appeared to have positively affected local attitudes toward wildlife (Sekhar 2003; Waylen *et al.* 2009; Khatun *et al.* 2012; Sousa *et al.* 2014). In particular, primate tourism has delivered measurable economic benefits, funding for conservation activities, improved agricultural markets, and improved attitudes towards conservation in some countries (Uganda, Hvenegaard 2014; China, Xiang *et al.* 2011). It may be a useful option to improve human-langur relationship through tangible benefits sharing such as public investment into local community and species related-tourism development.

However, some researchers debated that while wildlife ecotourism in nature reserves positively affects local attitudes, it may not result in positive conservation behaviours toward wildlife (Waylen *et al.* 2009), and may even contribute to socio-ecological problems that further harm conservation efforts (Desmond and Desmond 2014; Liu *et al.* 2012, 2016; Russon and Susilo 2014; Russon and Wallis 2014). Among them, the relationship between local residents and protected area and tourism management bodies may change as the development of tourism evolves (Liu *et al.* 2016). Local people might be positive at the early stage of local tourism development since they have obtained or seen some benefits (Ellwanger *et al.* 2015; Xu *et al.* 2006, 2009); but as tourism develop in areas like MNNR, local residents often benefit from tourism disproportionally, with the poorer benefiting less, such as in the Wolong National Nature Reserve (Liu *et al.* 2012, 2016). In case of MNNR, although the majority of Qinglong village residents had not yet received significant economic benefits from langur-related tourism, local people perceived the existence of langurs as a major attraction and thus had high expectation of future tourism development (and potential benefit). However, this higher

expectation of local residents may lead to a higher management risk if it can't be met in the near future. Liu *et al.* (2016) pointed out that when tourism development starts to materialize, only a small proportion of local population can benefit directly from ecotourism in Wolong Nature Reserve, China. The lack of direct participation or the unequal distribution of economic benefit in the long run may result in a negative attitude of local people toward the nature reserve (Hvenegaard 2014; Xu *et al.* 2006; Liu *et al.* 2016). In our study, we found that only 4.0% of residents claimed that they currently benefited economically because of the existence of the langurs. This point might be explained by current situation of the development of local tourism in Qinglong village. Although more and more tourists came to this village for langur watching, all of these visitors are free to access Qinglong village and most of these tourists merely spent half a day watching the langurs and then drive to the city for lodging and food (author's personal observation). Thus, their expenditure in Qinglong village is very limited. Local investments for tourism industry are limited because of low financial capacity of local residents. Future policy should combine the goal of species conservation and poverty alleviation, such as providing trainings in tourism services to local people. Meanwhile, similar to guidelines for best practice in great ape tourism (Williamson and Macfie 2014), the government and local community can consider developing langur-watching ecotourism guidelines in a responsible way to ensure a better balance between species conservation and local economic development.

In additional to benefits of langur-related tourism, it is worthwhile to notice that intangible benefits such as positive emotions and aesthetic values might positively influence the relationship between human and langurs in our case. For instance, adjectives such as "beautiful" were used to describe the langurs. Similarly, in Tombali, south of Guinea-Bissau,

the aesthetic values (i.e. pretty or ugly) can be key components in determining people's attitude toward baboon (*Papio papio*) (Costa *et al.* 2013). Moreover, local residents also used "loveable" and "good or funny playing with" to describe the interaction between human and langurs. The values associated with these codes indicate that local residents have "good" emotional disposition toward François' langur, which can be an important factor to determine people's response toward wildlife (Jacobs *et al.* 2012). This positive emotional disposition toward the langurs may have its roots in traditional Chinese culture (Jacobs *et al.* 2012; Cui *et al.* 2012; Kansky and Knight 2014; Zhang 2015). Chang (2001) showed that the Chinese believe that both people and monkeys benefit from interacting which results in harmony. In this case, a "good" emotional disposition supports positive local attitudes towards the François' langur. The further study on cultural background and emotional interaction of human-langurs would be helpful to better understand the role of intangible benefits on local attitudes in MNNR.

Furthermore, we found a trade-off between cost and benefit shaping local attitudes toward langurs. On one hand, some respondents viewed a trade-off between tangible benefits and tangible costs. For instance, one respondent liked the langurs because they can attract tourists to visit the village and economic benefits can be derived; however, she disliked them because they fed her crops. Previous studies had also linked tangible costs and benefits to explain local attitudes toward species (Khatun *et al.* 2012; McLennan and Hill 2013; Sousa *et al.* 2014). For instance, Sousa and colleagues (2014) considered that local perceptions of chimpanzees might be driven by not only crop feeding but also by benefits of species tourism. On the other hand, we found a trade-off between intangible benefits and tangible costs. Although we did not examine this quantitatively, our text analysis showed that intangible

benefits appeared to have an effect on local attitude. While the langurs might be favoured due to their beauty, they were disliked because they fed on crops and damaged houses. This trade-off appeared to be one important facet to explain local attitude toward primates in a few previous cases (Costa *et al.* 2013; Hill and Webber 2010; Lee and Priston 2005; Sousa *et al.* 2014). For instance, several studies have also found that the human-like appearance and behaviour of some primate species can contribute to positive attitudes, while crop-raiding by species makes them perceived as pests (Costa *et al.* 2013; Hill and Webber 2010).

Key demographic factors

Demographic factors such as age and gender may influence attitudes toward wildlife both positively and negatively case by case, which co-variates with the cultural/historical context or knowledge or experiences (e.g., Ellwanger *et al.* 2015; Kansky and Knight 2014; McLennan and Hill 2013; Sousa *et al.* 2014). For instance, researchers found that adults emphasized chimpanzee behaviour and narratives about the shared history of humans and chimpanzees while youngsters emphasized morphological aspects of human-chimpanzee similarities (Sousa *et al.* 2014).

In our case, effect of age on local attitude toward langurs might stem from a shift of historical experience on the existence of langurs between older people and younger people. Experience changes led to a variation of local perception toward the langurs and then influence local attitude (Kansky and Knight 2014). According to one respondent, “before the reserved was established (1987); the langurs could be caught and sold. The price was up to 500 Yuan (about 80 USD) per individual.” Hunting might be an important income source for some local people in the past. However, it was forbidden to hunt the langurs by the law since reserve was

built. At this point, the langurs have not brought any direct economic benefits for those older residents. Second, income sources of older people are less than younger people. Younger people prefer going to city for earning money while older people might more depend on crops planting. When langurs are protected and habituated to human gradually, these animals already occurred more frequently near the village now than before. This would bring relatively more and stronger economic losses (crop feeding and property losses) and negative perceptions for older famers, although we did not identify a direct and significant effect of local income level on local attitude. On the other hand, the improvement of langurs' related-tourism and infrastructure make younger people convenient to go to city for work and even bring some opportunities to earn money in the village. These experiences might lead to more positive perception of younger people then shape positive attitude toward the langurs.

Men's attitudes toward langurs in this study were more positive than women. According to the text analysis, we found that when they explained the reasons of their attitudes, more women care about tangible costs while more men pay attention to the benefits of langur existence. This result was very similar to several studies in Myanmar and China (Allendorf and Allendorf 2013, Allendorf and Yang 2015). Researchers found that men are more likely to have a positive attitude toward the protected areas and also men are more likely to perceive conservation and ecosystem service benefits than women, which is a direct determinant of attitude (Allendorf and Allendorf 2013). Allendorf and Yang (2015) further pointed out that difference of knowledge about the reserve between male and female contributed to the understanding of gendered perceptions of problems and benefits of the reserve. In our case, local people's knowledge of benefits of François' langurs in MNNR can be

considered as knowledge on species ecosystem services and men might be more knowledgeable about this due to more involvements in local management information communication in male-led households. Similar phenomenon was described in a few studies in China (Allendorf and Yang 2015; Xu *et al.* 2006).

And similar to the opinion of Sousa *et al.* (2014), crop feeding by François' langurs was knowledge on species ecology. Local women might be more familiar about knowledge on species ecology since it seems that more females take care of farmland most of the time in the village (author's personal observation). The researcher found that women, as compared to men, are more knowledgeable about the Guizhou snub-nosed monkeys in Fanjingshan National Nature Reserve in China, which is not far from our study site in MNNR (Ellwanger *et al.* 2015). Reasons above might lead to a gendered difference between cost knowledge and benefit knowledge, and then cause a difference of perception and attitude toward langurs.

Conclusions and conservation implication

In this study, we supported the importance of perceived cost and benefit in determining local attitudes toward the langurs in Qinglong village of MNNR. Meanwhile, we found the respondent's cost and benefit perceptions at household level are different from at community level although both have a strong effect on shaping local attitude. It indicated that local people's attitudes toward this species are constructed through a multifaceted set of interactions. It is worthwhile for researchers to note that a sole focus on costs or benefits and at only one level may miss critical information in understanding people's attitudes toward primate.

Crop feeding, house damage and langurs-related ecotourism are the major reasons to influence on local attitude toward langurs. It is likely more useful for species conservation management to better deal with these interactions and those related policies such as direct financial compensation for negative interactions and langur-related tourism. For instance, funding for the financial compensation should be set by local government regularlyand reserve adminstration should provide the compensation for local farmers in time. And scientifically informed; tourism guidelines based on langur conservation must be outlined prior to industry development. In addition, a positive emotional connection and a local cultural context such as “good playing with langurs” in this study might have a negative outcome for langur conservation if managers are unable to provide positive instruction to local people. Biocultural conservation programmes (for instance, storytelling or storybook) that embed a positive conservation message may be a useful strategy to shift people’s traditional cultural values of “monkey playing”. We recommend that local communication and education programmes on langurs’ conservation and skills training on langurs tourism services should be conducted, and to include local women and older people in these programmes. In general, we suggest that such socioeconomic monitoring efforts for human-langur should be periodically conducted in protected areas like MNNR, especially in the context of fast economic and infrastructure development.

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Appendix III

调查问卷 Questionnaire

□号 Code：_____ □□□ Investigator：_____

日期 Date: _____

□□地点 Place of Interview：_____ □ county ____ □□ town____村 village_____□ Subsettlement____

□卷起止□□ Start to End Time：（ ------ ）

调查对象及人口信息 Part I Demographic Information

所属村名/□ Village and Subsettlement				年□ Age		
性□ Gender				宗 教 Religion		
民族 Ethnic group				GPS location		
家庭成□人数（包括自己）No. of family members (including yourself)	在本村出生的□？如否，哪儿出生？ Were you born in this village? If not, where?				您已□在当前的地方生活了多久? How long have you lived here?	
□属关系 Relationship	性□ Gender	年□ Age	教育程 度 Education level	□□ Occupation	有无□城□工? Have you worked in the city before?	何□（年/月）开始□工? When did you start working in the city? (Month/year)
1）自己 Myself						
2）						
3）						

您主要的家庭收入来源有哪些? What are your main sources of income?

A.□□ Farming B. 外出□工 Work in the city C. 当地固定工作 Office work in the village

D. 社会保障和□政□□ Government subsidies E. 其他 Others

您去年全家的收入大□是多少？ How much money did your household totally earn last year?

当地的□物有哪些是象征□来好运的?

According to local culture and beliefs, what animal is a symbol of good luck?

又有哪些当地的□物是有所忌□的?

According to local culture and beliefs, what animal is a symbol of bad luck?

Part II 第二部分： 家庭生计 Family livelihood

	您□在□在种庄稼□？是 / 否 Do you plant the crops? Yes / No
	您□在都种了些什么？（□填下表。）What kind of crops are you planting (please fill form below) ?

□作物种□ Types of Crops	面 □（□） Size (Acre)	种植月份 Planting Month	收成月份 Harvesting Month	估□年□量（公斤） Weight of Annual Harvest (kg)	自用（公斤） Use by yourself (kg)	□用（公斤） Use by selling (kg)	□价（¥/公斤） Price per kg (¥)	有无□物盗食破坏？如有，哪些？ Does any wildlife raid crops? If yes, which animals?	开始□□ When did they begin raiding (Date)?	盗食/破坏月份（__月至__月，何□最□重？） Which months are the worst in terms of crop raiding?	估□□物盗食面□/重量（□/公斤） Affected area/weight of harvest raided (Acre/kg)
水稻 Rice											
2）玉米 Maize											
□薯 Sweet potato											
土豆 Potato											
花生 Peanut											
烤烟 Tobacco											
西瓜 Watermelon											
蔬菜 Vegetable											

9）其他 Others											
□荒 Have you abandoned farmland before? 是 / 否 Yes / No 面□（□） Size					□什么□荒? Why did you abandon the farmland?					从什么□候开始□荒？When did you abandon the farmland?	

B. 家里有无养殖？有或无。（如有，都养了些什么物种？□填下表。） Do you own any farm animals? If yes, which species?					□□收入 Financial subsidies			
物种 Animal	数量（□/只/筒） Number	□ 重 量（斤） Weight	自用/□用（斤） Use /Selling	□价（¥/斤） Price	□□□型 The types of subsidy	有无此款□？ Do you have it? Yes/No	□□金□ How much? (¥)	其他 Others
1）猪 Pig					山林款 Forest Subsidy			
2）牛 Cattle					2）种粮□□/早稻□□/粮食直□ Farming subsidy			
3）羊 Goat					3）□机具□置□□ Farm machinery purchase subsidy			
4）□ Chicken					4）烤烟烘制□□ Tobacco baking subsidies			
5）□ Duck					5）畜牧□□ Animal husbandry allowance			
6）□ Goose					6）高□□□ Old age allowance			
7）蜜蜂 Bee					低保□□ Subsistence allowance			
8）其他 Others					8）其他 Others			

Part III 第三部分：保护区和猴子的知识 Knowledge of Reserve and Langurs

1	你知道你生活的地方是保□区□？Do you know that you are living in a reserve? A. 知道 B. 不知道 Yes /No 若知道，□□叫什么名字？ If yes, what is the name of the reserve?
2	成立保□区的目的是什么？ Do you know the purpose of this reserve?
3	保□区有哪些□定？ Do you know what rules govern the reserve?
4	□些□定□你的生活有什么影响？Do these rules have an impact on your daily life?

5	你□不□□□种□物？（□展示黑叶猴、□猴及黑叶猴□猴的照片）Do you know what animal it is in the photo？(I presented the adult female of François' langur, Adult male of Rhesus macaque, and an infant of François' langur) A. 黑叶猴 François' langur (成体 adult；□猴 infant) B. 猕猴 Rhesus Macaque C.其他 Others
6	你□当地叫它什么名字？What is the local name of this animal?
7	你有没有□眼□□□种猴子？Have you seen this monkey before?有 yes 没有 no 若"有"，您最近一次□到□种猴子是 (If yes, when and where did you last see it? How many individuals were there? What was/were it/they doing at that time?)：若"没有"，你是通□什么途径知道的 (if no, how did you get the information about the monkey)？ 日期 Date： 地点 where： 有多少只 how many individuals： 猴子的活□□型 Activity types：
8	若知道"黑叶猴"，□□你知道黑叶猴是受法律保□的□物□？If you know about the François' langur, do you know that it is protected by the law? A. 是 Yes B. 不是 No C. 不清楚 Un
9	如果"家庭生□"部分，未提到□黑叶猴盗食庄稼，□□：你知道黑叶猴采食庄稼□? 知道 不知道 不清楚 If you did not mention the crop raiding of François' langur, do you know if François' langur raid crops? Yes No Un 如果"家庭生□"部分，提到□黑叶猴盗食庄稼或如果"知道"，□□□□: If you mentioned the crop raiding of Francois langur, or said "Yes" to the above question, do you know why François' langur raid crops? 你□□黑叶猴□什么采食庄稼？ 你有没有采取什么措施防止黑叶猴盗食庄稼？Do you have any solutions to avoid the crops raiding by François' langur? A. 有 yes B. 无 no 如果"有"，是何措施？If yes, what methods/solutions did you apply?
10	一旦□生黑叶猴采食庄稼，□□如何解决因盗食而受到的□失？由□来解决？ Once the François' langur raids crops, what do you should be the solution and who do you think should be responsible for providing solution(s)?

11	除了采食庄稼，黑叶猴□你的生活□有哪些影响？ Besides crop-raiding, are there any other impacts on your life? 一旦□生上述事件，□□如何解决因上述事件而受到的□失？由□来解决？ Once it happens, how do you deal with it? Who should be responsible for providing solution(s) to this impact?

第四部分：态度和需求 Part IV Attitude and Need

你喜不喜□□里是一个保□区？Do you like it is a reserve here? A. 喜□ Yes B. 不喜□ No C. 中立 Neutral D.□不清 Unsure

若“喜□”，□什么？If yes, why？ 若“不喜□”，□什么？if no, why? 若“中立”，□什么？

□于保□区，你以前的□度和□在的看法有□□□？Is your attitude toward the reserve different between the past and now?

A. 有 Yes B. 无 No C. □不清 Unsure

若“有”，是什么□□？ If yes, why has it changed?

□于保□区，未来你是不是会□□保持□有的□度？ A. 是 B. 不是 C. □不清

Does your attitude change on reserve now and in the future? A. Yes B. No C. Unsure

序号	保□区的存在□（ ）有影响□？	有无影响	好□	利大于弊	利弊相等	弊大于利	坏□	□不清	□注
1	你的家庭□□收入上								
2	你的生活□境□量上								
3	你的家□的名气上								
4	你的后代的教育□量上								
5	当地基□□施建□（例如修路、建□等）上								
6	你的山林的利用上								
7	你的野生□物利用（如打□捕□等）上								
8	□□□源利用上								
9	你家的养殖（如养牛放羊）								
10	当地的旅游								

No.	***Does the reserve have any impact on the listed items below? What impact?***	***Impact (tick boxes)***	***Good***	***Good>Bad***	***neutral***	***Good<Bad***	***Bad***	***Unsure***	***Notes***
1	*your economic income*								
2	*the environment of your village*								
3	*the reputation of your village*								
4	*the education of your next generation*								
5	*the development of local infrastructure*								
6	*tree cutting in the mountain of your village*								
7	*your use of wildlife resource from the forest*								
8	*mining activities in the mountains around your village*								
9	*grazing around your village*								
10	*the development of local tourism*								

你喜不喜□黑叶猴生活在□里？Do you like the François' langur living around your village?

A.喜□ like B. 中立 Neutral C. 不喜□ Dislike D. No □不清 Unsure

若“喜□”，□什么？ If yes, why?

若“不喜□”，□什么？ If no, why?

若“中立”，□什么？ If neutral, why?

□于黑叶猴，你以前的□度和□在的看法有□□□？Is your attitude toward the François' langurs different between the past and now? A. 有 Yes B. 无 No C. □不清 Unsure

若“有”，是什么□□？ If yes, why has it changed?

以后黑叶猴如果不再采食庄稼，你会不会喜□它？If François' langurs cannot raid crops any more, do you like it more? A. 会 Yes B.不会 No C. □不清 Unsure

序号	黑叶猴的存在□(　　) 有影响□？	有无影响？	好□	利大于弊	利弊相等	弊大于利	坏□	□不清	□注
1	你的家庭□□收入上								
2	你的生存□境□量上								
3	你的家□的名气上								
4	你的后代的教育□量上								
5	当地基□□施建□（例如修路、建□等）上								
6	你的山林的利用上								
7	你的野生□物利用（如打□捕□等）上								
8	□□□源利用上								
9	你家的养殖（如养牛放羊）								
10	当地的旅游								

No.	***Does the François' langur have any impact on the listed items below? What impact?***	***Impact (tick boxes)***	***Good***	***Good>bad***	***neutral***	***Good<Bad***	***Bad***	***Unsure***	***Notes***
1	*your economic income*								
2	*the environment of your village*								
3	*the reputation of your village*								
4	*the education of your next generation*								
5	*the development of local infrastructure*								
6	*tree cutting in the mountain of your village*								
7	*your use of wildlife resource from the forest*								
8	*mining activities in the mountains around your village*								
9	*grazing around your village*								

10	*the development of local tourism*								

7. 您知道或听□□当地黑叶猴死亡的事情□？ Do you know or have you heard of some stories about the death of François' langur?

A. 知道/听□ Yes B. 不知道/没听□ No 若“知道/听□”，造成死亡的原因有哪些？□□述。If yes, please describe the stories

Chapter 6 Local People's Knowledge and Attitudes Matter for the Future Conservation of the Endangered Guizhou Snub-nosed Monkey (*Rhinopithecus brelichi*) in Fanjingshan National Nature Reserve, China

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Abstract

Ethnoprimatology seeks to untangle the complex relationship between human and nonhuman primates, and in doing so, can provide a better understanding of how the local cultural context affects conservation initiatives. Fanjingshan National Nature Reserve in China is the last stronghold for the remaining global population of the Endangered Guizhou snub-nosed monkey (*Rhinopithecus brelichi*). In an effort to contribute to conservation management plans, our goal was to explore local people's knowledge and attitudes towards the Guizhou snub-nosed monkey and conservation in the reserve using an ethnoprimatological approach. We conducted ethnographic interviews, involving structured, semi-structured, and open-ended interview techniques, with 104 households in 11 villages located in and around the reserve. The results indicate that knowledge about the reserve and the monkey is unevenly distributed among respondents; men are significantly more knowledgeable about the reserve than women and women are significantly more knowledgeable about the monkey than men. Respondents are aware of the rules of the reserve but do not always agree with the rules or understand the rationale behind them. Nonetheless, respondents describe conservation as a "trade-off" and their attitudes towards the monkey and efforts to conserve it are generally positive and supportive. They expressed a feeling of connectedness with the Guizhou snub-nosed monkey because of its observable, humanlike behaviours, a mutual dependence on the forest, and a shared ancestry. While our goal was to provide specific recommendations to park officials at our study site, our results also more broadly inform conservation management efforts for protected areas globally. For example, we recommend improving communication between reserve officials and local communities, appreciating the role local folklore can play in

conservation, incorporating villagers' perspectives into conservation planning, and implementing educational programs that target a wide demographic, with a particular emphasis on women.

Key words

Conservation; attitudes; ethnoprimatology; trade-offs; gender; education; *Rhinopithecus brelichi*

Introduction

Although protected areas may be an effective way to conserve threatened flora and fauna, through this process many local residents lose their rights to access land and important resources that they may depend on for food, construction materials, or their economic and social livelihoods. It is widely recognized that understanding local people's attitudes towards the environment and conservation is an important component of developing successful, long-term conservation and management strategies (Alexander 2000; Allendorf 2007). Beyond simply understanding local attitudes, initiatives that incorporate local communities in the decision-making process may receive greater community support and adherence to the rules. However, if communities feel that the restrictions to their livelihoods are unjust or participation in the decision-making process is limited, it may fuel negative perceptions of management and low support for conservation initiatives (Mbora and Meikle 2004; Wieczkowski 2005; Méndez-Contreras *et al.* 2008; Dahlberg and Burlando 2009).

The development of effective primate conservation initiatives can benefit from a greater understanding of local people's attitudes towards conservation and the interconnections between people and nonhuman primates. Ethnoprimatology represents one such approach. First coined by anthropologist Leslie Sponsel (1997), "ethnoprimatology" examines the ecological, biological, and cultural interconnections between humans and primate populations, and the implications of these interconnections for conservation (Fuentes 2006). Using diverse theoretical frameworks and methodologies from primatology, cultural anthropology, ecology, and conservation biology, this perspective provides researchers with an integrative approach and a powerful toolbox to understand people's attitudes towards nonhuman primates, the environment, and conservation management (Riley *et al.* 2011; Fuentes 2012; Riley and Ellwanger 2013).

Previous research has shown that cultural perceptions are extremely powerful in shaping human interactions with nonhuman primates and the environment. For example, in Sulawesi, Indonesia, Riley (2005) found that culture, ethnicity, religious background, and immigration affect villagers' perceptions of the forest. Whereas indigenous Lindu residents viewed the forest as a source of livelihood, immigrant residents viewed the forest as potential agricultural land. Conservation attitudes and knowledge are also influenced by other important variables, such as education level and length of residency. In terms of education, more educated respondents have more positive attitudes towards conservation (Infield 1988) and more awareness about protected areas (Badola *et al.* 2012). Similarly, length of residency in an area may play an important role, with longer-term residents placing a greater value on conservation activities and environmental services (Riley 2005; Sodhi *et al.* 2010).

Gender is another important, understudied demographic variable influencing conservation attitudes, knowledge, and participation. Men and women may interact differently with the environment so it cannot be assumed that they share the same knowledge base. Moreover, many approaches to conservation, including those that rely on local political and social institutions, can marginalize women's participation in conservation and exacerbate existing inequities (Mukadasi and Nabalegwa 2007; Bandiaky 2008). The level of women's participation in conservation may influence the success of a conservation initiative. In India and Nepal, forest management groups with a higher proportion of women involved in governance have significantly higher forest regeneration and canopy growth compared to other groups, particularly in the case of all-female management groups (Agarwal 2009). Agarwal (2009) hypothesizes that involving both women and men in conservation management improves community knowledge of rules and increases the number of community members who are aware of and committed to conservation issues.

Cultural perceptions of nonhuman primates in China are based on a mix of religion, traditional Chinese culture, and popular images in literature and children's stories (Burton 2002; Qin 2008). Such "monkey culture" may play an important role in people's attitudes toward and interactions with monkeys. For instance, the monkey is one of the 12 animals in the Chinese zodiac and bestows health, protection, and success (Burton 2002). A famous character from the classic Chinese epic novel The Journey to the West is the Monkey King, Sun Wukong, who many believe is based on the Hindu monkey deity, Hanuman (Burton 2002). Thus, Buddhist monks in China encourage releasing monkeys into the forest and people give gifts to monkeys, who are thought to be SunWukong's "mortal manifestations" (Burton 2002, p.137). There are

also reports of monkeys at some religious temples benefitting from positive associations with folktales from both tourists and visitors who feed the local monkeys for enjoyment or to acquire religious merit (Zhao 2005).

Folktales and religious perspectives that strengthen positive attitudes toward primates may provide a basis to build conservation policy (Burton 2002). In Tibet, traditional socioeconomic activities, including marriage patterns and agricultural practices, combined with Buddhist beliefs positively influence conservation of the Yunnan snub-nosed monkey (*Rhinopithecus bieti*: Xiang *et al*.2010). Similar to studies conducted elsewhere, demographic variables, i.e., age, occupation, and education level, also have been shown to influence people's attitudes toward protected area conservation in China. For example, in the Protected Area of Jinyun Mountain (PJM), conservation attitudes and knowledge vary among stakeholder groups (Liu *et al*.2010). Respondents with a higher level of education have more positive attitudes and a better understanding of ecological processes compared to older or lower-educated respondents, who have more negative attitudes toward PJM. Local farmers report more negative attitudes toward the protected area compared to employees (Liu *et al*. 2010). Conservation is still a novel concept in Chinese culture and there are few systematic investigations of people's attitudes toward conservation in China (Qin 2008).

Fanjingshan National Nature Reserve (FNNR) in Guizhou province, China is an important Buddhist holy site and a popular destination for tourism (Fanjjingshan National Nature Reserve Administration 2004). The reserve is home to the remaining global population of the Endangered Guizhou snub-nosed monkey (*Rhinopithecus brelichi*), currently estimated

at about 750 individuals. The monkey prefers mixed deciduous and evergreen broadleaf forest (Bleisch *et al.* 1993; Yang *et al.* 2002; Niu *et al.* 2010) and has a diverse diet but is highly folivorous when leaves are available (Bleisch and Xie 1998; Yang *et al.* 2002; Niu *et al.* 2014). Like the other *Rhinopithecus* species, many one-male, multi-female units travel, forage, and rest in semi-cohesive, coordinated bands of as many as 430 individuals at a time (Bleisch *et al.* 1993; Yang *et al.* 2002; Tan *et al.* 2007). The main anthropogenic threats to the Guizhou snub-nosed monkey include poaching and the destruction and fragmentation of forest habitat within the core area and the buffer zone of the reserve (Yang *et al.* 2002; Fanjingshan National Nature Reserve Administration 2004). Currently, there is no information available on local people's knowledge or cultural beliefs about the monkey, the protected area, or their conservation.

In FNNR, the management staff faces a tough choice. Studies of the behavioural ecology of the Guizhou snub-nosed monkey indicate that the population depends on large tracts of undisturbed forest (Bleisch and Xie 1998; Yang *et al.* 2002; Niu *et al.* 2010). In addition to farming (e.g., potato, sweet potato, corn, and rice) on crop land (*tian* 田) and breeding pigs, local communities living in and around the reserve also rely on the following forest resources for their livelihoods, which are often collected from their family's forest (*tu* 土): household consumption of live and dead wood (i.e., firewood, construction materials, and charcoal), mushrooms, and bamboo shoots; household use and sale of medicinal plants; and commercial sale of goods made from live wood and bamboo (i.e., woven mats, chopsticks) (Fanjingshan National Nature Reserve Administration 2004; Sheres 2010). There is little information available on local people's perceptions of the Guizhou snub-nosed monkey or their

environment, which could limit the scope and effectiveness of community-engaged conservation efforts.Using an ethnoprimatological approach, our aim and objective was to fill this void by providing a comprehensive, mixed-methods analysis of local people's knowledge of and attitudes towards the Guizhou snub-nosed monkey, Fanjingshan National Nature Reserve (FNNR), and conservation of the monkey and forest resources. To meet this objective, we examined the following research questions: how do people view the Guizhou snub-nosed monkey in relation to the environment or their livelihood; what do people know about the Guizhou snub-nosed monkey and the reserve; is the Guizhou snub-nosed monkey important to people culturally; is the relationship between the Guizhou snub-nosed monkey and local people mutually beneficial, hostile, or neutral; and what are the conservation implications of this relationship?

Method

Study site

Fanjingshan National Nature Reserve is located in the northeastern part of Guizhou Province, in southwest China between 27°46'50"N and 28°1'30"N, 108°45'55"E and 108°48'30"E (Figure 6.1). This area falls under the jurisdiction of three counties: Jiangkou, Songtao and Yinjiang (Bleisch and Xie 1998; Yang *et al.* 2002). The reserve encompasses a total of 41,900 hectares, including a buffer zone of 2,800 hectares and a core area of 26,227 hectares (Yang *et al.* 2002). All human activity is illegal in the buffer and core areas, except scientific research conducted with official permission. FNNR employs a centralized system of

governance: eight stations located in villages around the protected area report to three central stations, which report to the main FNNR office in Jiangkou Township. The main job of these stations is to manage resources and stop or report any illegal activity in the area under their jurisdiction (Fanjingshan National Nature Reserve Administration 2004). FNNR is home to three nonhuman primate species: Guizhou snub-nosed monkeys, Tibetan macaques (*Macaca thibetana*), and rhesus macaques (*Macaca mulatta*). However, only the snub-nosed monkey and Tibetan macaque are found near our study site in Lengjiaba (now Taohuayuan). Neither the snub-nosed monkey nor macaques consume people's crops, as farming occurs at a much lower elevations than where the monkeys range.

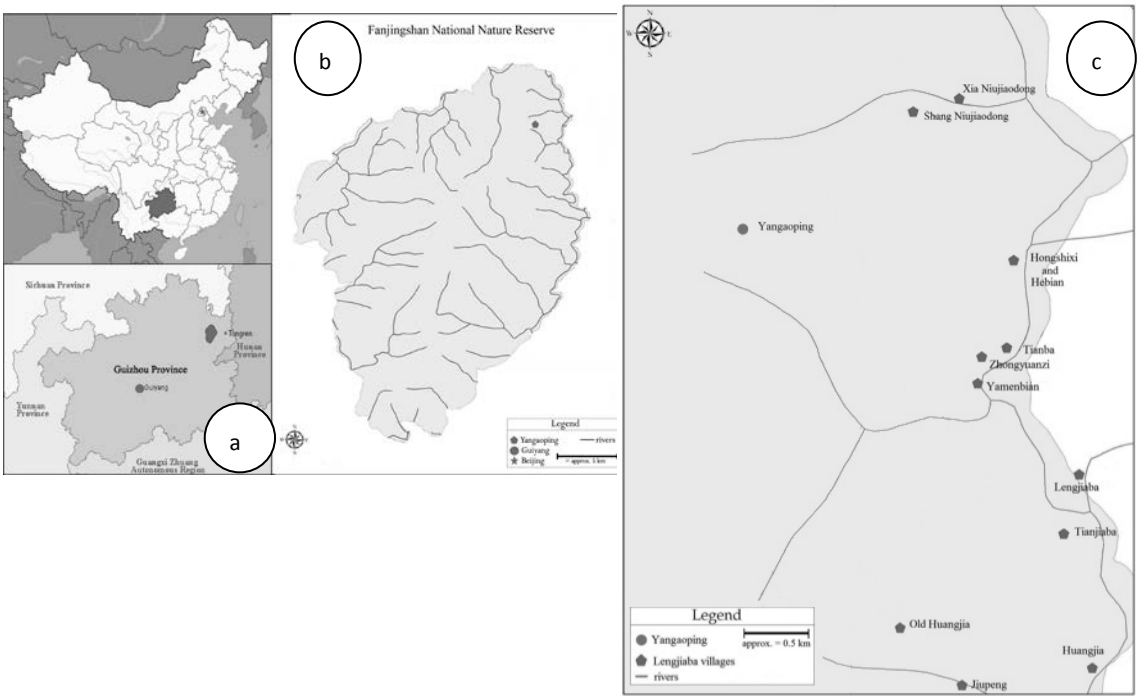

Figure 6.1 (a) Fanjingshan National Nature Reserve is in the northeast corner of Guizhou province in the southwest of China. (b) Yangaoping, the research station, is in the northeast corner of the reserve. (c) The study site comprises 11 of 13 sub-settlements of Lengjiaba village. Guizhou province is in dark grey and the reserve is in light grey. Map created by Yang JW, FNNR. Adapted by Ellwanger AL

Study population and sampling

As of 2013, there were 24 villages located in the reserve including 11,379 residents. However, only 470 residents in 142 households actually resided within the core area of the reserve (Shi *et al.*2013). We collected data in the village of Lengjiaba from June 26 to August 22, 2009. Lengjiaba village consisted of 13 subsettlements with ca. 252 households and 1200 people (Figure 6.1). We selected Lengjiaba because it is the access point for Yangaoping, the research station on top of Fanjing Mountain. When we approached potential respondents, we introduced ourselves, stated our institutional affiliations —San Diego State University, San Diego Zoo Global, Guizhou University (K. Niu's former affiliation)— described our interest in the human–primate interface, and provided respondents with informed consent. Previous research in the area focused on the Guizhou snub-nosed monkeys at Yangaoping (Bleisch *et al.*1993) or socioeconomic status in villages around the reserve but not in Lengjiaba (Gong 2004; Xiang *et al.*2009). According to respondents, FNNR facilitated some limited conservation outreach in the community. Although a Global Environment Facility project provided local communities with energy-efficient stoves and apiculture assistance, nongovernmental organizations have not had a consistent or long-term local presence in Lengjiaba. Therefore we do not anticipate that our results reflect a bias or influence stemming from interactions between the community and previous researchers or institutions.

We conducted interviews with the primary household resource collectors in 11 of the 13 subsettlements in the village. We defined the primary household resource collector as the household-identified individual who spends the most time collecting resources. We used this sampling method because we wanted to interview the person in each home with the most knowledge and experience in resource collection. We selected respondents, aged 18 or older,

based on their willingness to be involved with the study and their role in resource collection. Two of the subsettlements were not included in the sample owing to their remote location and hazardous travel route. There were ca. 213 households in the 11 villages sampled. We used the formula provided by Bernard (1995) to estimate an appropriate sample size for interviews, which contains a built-in correction for sampling from small populations. Following this formula, we determined the appropriate sample size to be 137. We used this formula as a guideline for the ideal sample size. However, the actual number of interviews conducted was slightly smaller owing to time constraints and respondents' availability.

We used a combination of freelist exercises, semi-structured interviews, and Likert surveys to create a robust methodological approach (Briggs 1986; Bernard 1995). We used non-probability sampling to locate potential respondents (Bernard 1995). For each sub-settlement in Lengjiaba, we determined the number of respondents to interview based on the ratio of households in the sub-settlement to the number of households in Lengjiaba. This strategy ensured that we sampled an appropriate proportion of households in each sub-settlement. We translated and back-translated all interview questions from English to Mandarin Chinese to assure the integrity of the meaning. Due to dialect differences, we conducted some interviews with the help of a local resident from the community who could help clarify dialectal variation or differences in meaning. We collected all data following approval from the Institutional Review Board of San Diego State University and adhered to the legal requirements for conducting research in China.

Data collection

We divided data collection into two phases. In phase 1 of data collection (26 Jun 2009 – 22 Aug 2009), we interviewed 104 respondents from 11 of the 13 sub-settlements about individual and household demographics (Table 6.1). We collected data on respondent's religion but had some issues during the data collection process so we did not feel that we could include this variable in the analysis. Moreover, the community is fairly homogeneous in other demographic variables so we feel that religion is unlikely to alter the results. We began phase 2 of data collection (11 Jul 2009 – 22 Aug 2009) after this census was completed to study people's knowledge and attitudes towards the snub-nosed monkey, conservation, and FNNR. Our aim was to interview a representative number of people from each of the 11 sub-settlements. Some individuals who participated in phase 1 were unavailable when we returned to conduct interviews for phase 2; 40% of the households interviewed in phase 2 were previously interviewed during the census in phase 1. In phase 2, we interviewed 72 respondents (63.9% male and 36.1% female), including 29 respondents from phase 1, using semi-structured and structured interview techniques including open-ended questions and Likert scale statements about resource use, the Guizhou snub-nosed monkey, and attitudes towards FNNR (Bernard 1995). A Likert scale is a useful tool to test cultural models because they allow researchers to rapidly measure multiple dimensions of attitude and is a common tool used in conservation research (Kellert and Berry 1987; Alexander 2000; Braga and Schiavetti 2013). We scored responses to the statements as one of the following: agree, neutral, disagree, or don't know. In addition to these answers, we recorded any comments noted by the respondents.

Data analysis

We entered and coded all quantitative and qualitative data using MS Excel. Quantitative data were then analyzed using SPSS version 16.0. We used descriptive statistics to analyze demographic information including age and sex of respondents, ethnicity, education level, and occupation. We used grounded theory and open coding to analyze open-ended questions and additional comments from the Likert scale statements. Grounded theory is a technique used to analyze text by identifying important emerging themes and the relationships among themes (Bernard and Ryan 1998). Rather than identifying themes of interest prior to collecting or coding data, open coding identifies themes in the text as they are observed during data analysis (Bernard and Ryan 1998).

We counted and summed the frequency of responses to the Likert scale statements (e.g., agree, neutral, disagree, or don't know). Statements one through seven asked respondents about their attitudes towards the Guizhou snub-nosed monkeyand statements eight through 15 asked respondents about their attitudes towards resource collection (see Table 6.2). To further elucidate respondents' attitudes towards the monkey, we converted answers to Likert statements one through five to a score (e.g., positive response = 1, moderate response = 0.5, and negative response = 0) to create a composite measure for each respondent (following Braga and Schiavetti 2013). We did not convert statements six through 15 because they asked respondents about more specific attitudes and did not lend themselves to combination. We did not score responses of "don't know". We derived a final indicator score by summing the scores for each respondent and dividing by the highest possible score, excluding the number of times the respondent answered, "don't know." Final indicator scores were divided into three attitude classes: negative (0 – 0.33), moderate (0.34 – 0.66), and positive (0.67 – 1). To examine the

influence of education on respondents' attitudes, we used a Kruskal-Wallis test. To examine the influence of gender on some questions, we used Fisher's exact test. All statistical tests were two-tailed with α set at 0.05.

Results

Demographic information

Respondents interviewed for the household census during phase 1 reported a total of 509 individuals in the Lengjiaba sample population: 295 males (58%) and 214 females (42%). The mean household size was 4.9 people (range: 1 – 11). The mean age of Lengjiaba residents was 31.2 years old (range: 1 day – 90 years). Nearly a quarter of the population fell between the ages of 11 to 20 years old. The ethnic composition of the sample population was largely dominated by Han (78.9%) followed by Miao and Tujia (both 10.2%) and "other" (0.6%). The "other" category is composed of one person who reported as Dai and two people who were unsure of their ethnicity. Overall, the education level in the community was low (Figure 6.2). The highest percentage of the population had received some level of primary schooling. Individuals above a high school level and involved in special education (school for the deaf) accounted for less than 2% of the sample. The sub-settlements are largely patrifocal but almost half of the female respondents were born somewhere in Lengjiaba, if they were not currently living in their natal sub-settlement.

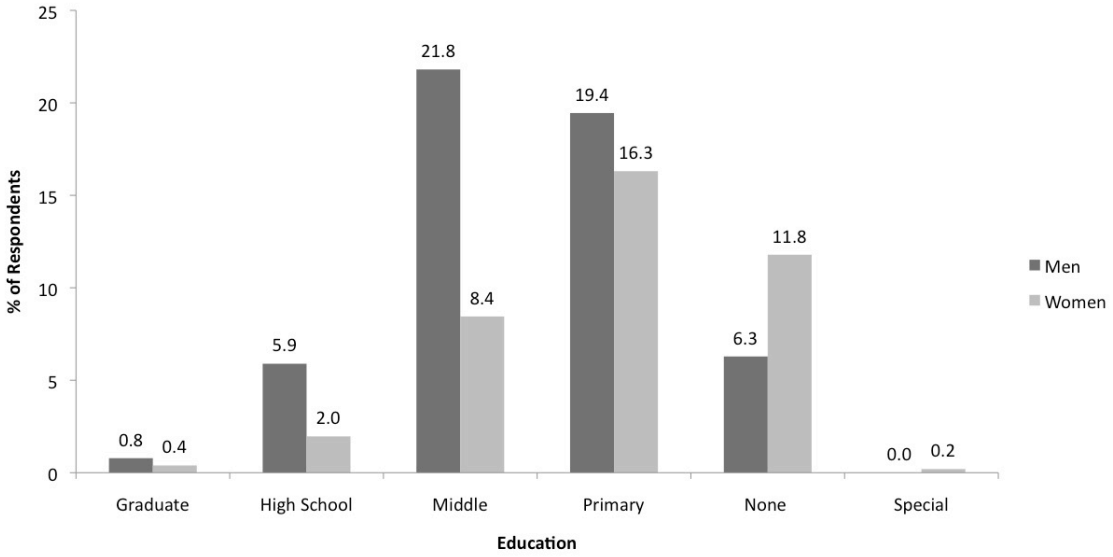

Figure 6.2 The education level of Lengjiaba residents (N=509) living in 104 households interviewed during phase 1, 26 June 2009 – 22 August 2009

Table 6.1 Demographic information of Lengjiaba respondents in phase 1, 26 June 2009 – 22 August 2009 (N=104).

Sex	**# of Respondents**	**Mean Age**	**Education**		**Occupation**		**Ethnicity**		**Born in Village**	
Male	65	46	None	11	Farmer	60	Han	54	Yes	64
			Primary	23	Farmer & Other	3	Miao	6		
		range (22-80)	Middle	27	Teacher	1	Tujia	5	No	1
			High	4	Other	1	Other	0		
Female	39	45	None	22	Farmer	35	Han	29	Yes	7
			Primary	13	Farmer & Other	1	Miao	7		
		range (18-70)	Middle	3	Teacher	1	Tujia	2	No	32
			High	1	Other	2	Other	1		

Knowledge and awareness of FNNR and the Guizhou snub-nosed monkey

When asked about the purpose of Fanjingshan National Nature Reserve, the majority

of respondents (64%) mentioned some aspect of protection and management but 33% did not know. The remaining respondents were split between: for the purpose of tourism (1%) and no purpose at all (1%). Significantly more men (n=40) knew the purpose of the reserve than women (n=8) (Fisher's exact test, df=1, P<0.001).

The majority of respondents were able to answer how many types of monkeys live in FNNR. We asked respondents about "types" (*zhong* 种) of monkeys, rather than using the word "species" (*wuzhoung* 物种), because we were not certain that the species concept would be relevant to local people. Nearly two-thirds responded two types (46.2%) or three types (15.3%), which is the correct answer depending on the location within FNNR. However, 20.8% of respondents were unable to identify the number of monkey types living in the reserve. Of those (N=57) who did list a number of monkey types, when asked to name the types of monkeys, all but two (96.5%) knew the name(s) of the monkeys. The remaining 55 respondents listed the names of one to four types of monkeys during interviews (Table 6.3). Some respondents listed multiple vernacular names for the same type of monkey but believed that they were naming different types of monkeys. For example, seven of 55 respondents thought that *jinsihou* and *niuweihou* were different monkeys but these names both refer to the Guizhou snub-nosed monkey. After seeing a photo of the Guizhou snub-nosed monkey, seven of the 15 respondents who did not know any monkeys living in the forest still did not recognize the Guizhou snub-nosed monkey.

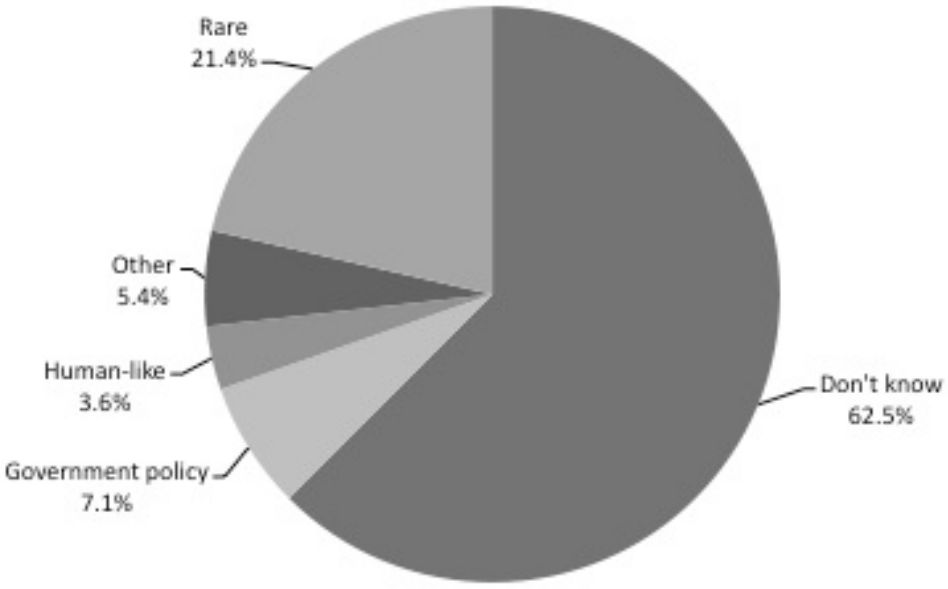

Figure 6.3 Respondents (N=56) perceptions on why the Guizhou snub-nosed monkeyis protected

Knowledge of the snub-nosed monkey's population size and distribution was low among respondents. When asked how many snub-nosed monkeys live in FNNR, 82.4% of respondents answered, "don't know." Of the remaining respondents who attempted to answer the question, only 4.4% answered correctly. The majority of respondents (63%) were able to identify a location in the forest where the monkey is found. However, the remaining respondents either answered incorrectly (5%) or responded "don't know" (32%).

A majority of the respondents (92%) were aware that the Guizhou snub-nosed monkey is a Class I protected animal in China. Respondents learned that the Guizhou snub-nosed monkey is protected through three main outlets: FNNR Administration or the government (45.7%), through word of mouth (31.4%), and news media (11.4%). Men and women did not differ significantly in whether they learned about the protected status of the monkey from

FNNR or the government compared to another source (Fisher's exact test, df=1, P=0.228). Despite their awareness of the monkey's protected status, 62.5% of respondents did not know *why* and only 21.4% reported that the monkey is protected because it is rare. The remaining 16.1% thought the monkey is protected because it is: a government policy, human-like, an animal of China, or harmless to people (Figure 6.3). Significantly more women (n=16) knew why it was important to protect the Guizhou snub-nosed monkey than men (n=13) (Fisher's exact test, df=1, P=0.033).

Table 6.3 The scientific, common, and local vernacular names of the monkeys that live in Fanjingshan National Nature Reserve and the percent of respondents who listed the name during interviews.

Scientific Name	Common Name	Mandarin	Local Vernacular	% of respondemts
Rhinopithecus brelichi	Golden-haired monkey	金□猴	*Jinsihou*	81.8
	Ox-tailed monkey	牛尾猴	*niuweihou*	32.7
Macaca thibetana	Tibetan macaque	藏酋猴	*zangqiuhou*	74.5
Macaca mulatta	Rhesus macaque	□猴	*mihou*	5.5
	Rock bay monkey	石湾猴	*shiwanhou*	7.3
	Yellow monkey	黄猴	*huanghou*	9.1

Attitudes towards FNNR and the Guizhou snub-nosed monkey

Open coding of semi-structured interviews revealed five major themes regarding people's perceptions and attitudes toward the reserve and the primates living within: 1) protection of the forest and animals; 2) development; 3) financial hardship; 4) government influence; and 5) primate-human interconnections.

Table 6.2 Responses of Lengjiaba residents, in percentages, to Likert scale statements (N=72).

Statement	Agree	Neutral	Disagree	Don't Know
1. The people and the GSNM can both use the forest.	93.1	0.0	1.4	5.6
2. The GSNM is harmful to your livelihood.	2.8	1.4	94.4	1.4
3. The GSNM is an important part of your daily life.	72.2	4.2	12.5	11.1
4. Our lives would be better not to have the GSNM here.	8.3	48.6	37.5	5.6
5. It is important to protect the GSNM for our children.	93.1	2.8	2.8	1.4
6. It is important to protect the area for the GSNM.	94.4	0.0	0.0	5.6
7. Without FNNR, the GSNM would die.	55.6	0.0	34.7	9.7
8. People should be able to hunt in FNNR.	16.7	29.2	52.8	1.4
9. People should be able to gather (dead) firewood in FNNR.	75.0	4.2	16.7	4.2
10. People should be able to cut (live) timber in FNNR.	19.4	0.0	77.8	2.8
11. People should be able to gather plants from FNNR.	31.9	9.7	52.8	5.6
12. It is important to my livelihood that I can collect (live) timber in FNNR.	55.6	1.4	43.1	0.0
13. It is important to my livelihood that I can collect plants in FNNR.	38.9	4.2	55.6	1.4
14. People collect too much from the forest and there won't be any left for our children.	87.5	0.0	5.6	6.9
15. There are fewer resources present in the forest today than there were for my parents.	34.7	4.2	55.6	5.6

Attitudes towards FNNR

Respondents were split on whether or not FNNR provides any benefit to their livelihoods. Out of 72 respondents, 49% reported that FNNR provided some benefit to their livelihoods. Of these respondents, 14 described more than one benefit of the reserve, resulting in a total of 82 responses in the analysis. The primary benefit discussed by respondents concerned protection of forest resources (24.4%), followed by local infrastructure development and increased tourism (14.6%), a clean environment and beautiful sights (12.2%), and government supplements (3.7%). Some respondents mentioned that there are no benefits currently, but there is the potential for benefits in the future (6.1%).

Themes of forest and animal protection and development were prevalent throughout

the interviews. Respondents discussed protection in a variety of contexts including the benefits of the reserve, the purpose of the reserve, and the community's role in resource collection. A quarter of respondents reported that protection of the forest and/or animals was a benefit to their livelihoods. Some respondents discussed the benefits of protection in terms of bequest values, future use of resources, living in a clean environment, and beautiful sights. Respondents mentioned development and tourism of FNNR frequently during discussions of the benefits to their livelihoods. The construction of stoves for households is an excellent example of a form of development that the community received from the reserve's previous conservation project. According to a man in his 70s, "FNNR built [my] stove. Before [I] used fire but [the] stove uses less wood and conserves heat." Other respondents discussed the benefits of improvements to infrastructure like roads and looked towards tourism to develop the local economy.

Despite the benefits associated with the reserve, like resource protection and development, the majority of respondents (60%) felt that the presence of FNNR imposed restrictions on their livelihoods. The main complaints voiced by respondents concerned the restricted access to forest resources like firewood or charcoal (36.5%), destruction of crops by wild pigs (22.1%), and the inability to hunt (5.8%). Other concerns included the loss of farmland (1.9%), forced relocation (0.9%), and restricted access to resources to sell (3.9%). A woman in her 50s conveyed, "the monkey is good but the reserve is bad for local people." This respondent felt that although the monkey did not harm her livelihood directly, the reserve caused financial hardship to her because she is forbidden to access or sell resources from the core area. Some respondents discussed the issue of land tenure and how FNNR affected their ability to access resources on their family's land. According to a man in his 50s,

> In the past, the forest belonged to [the] people but now [the] forest is forbidden to enter so [we] can't make a living. So FNNR has limited [us], but not absolutely.

This respondent felt that although FNNR limited his livelihood, he still had alternatives to using the forest. Often, themes of financial hardship were linked with discussions of government influence and the need for financial supplements. According to a woman in her 40s: "[We had to] move [the] village and now [there is] not enough farmland to earn money." During interviews, 13% of respondents complained that there is no supplement from the government to offset the costs incurred to the local people by FNNR. For example, a woman in her 40s stated that the "wild pig destroys sweet potato. [We] are not permitted to hunt them. [I] want [the] government to give [a] supplement for crops destroyed."

Respondents discussed the role of government in terms of their decisions about resource collection, protection of the Guizhou snub-nosed monkey, and financial supplements. The influence of the government was especially clear in the open-ended responses to the Likert scale statements about resource use. Respondents' choices and responses appear to be heavily influenced by what the government says is prohibited and what is acceptable. For example, when asked if people should be allowed to hunt in FNNR, many respondents responded "disagree, because it is forbidden" or "illegal." We designed questions like this one to ask respondents about their opinions, not to test their knowledge of reserve rules.

Attitudes towards resource use

Respondents' attitudes towards resource use varied widely (Table 6.2). While there was a high level of support for people being allowed to gather dead wood for personal use, nearly 80% of respondents did not support cutting live timber in the forest. Over a third of respondents

agreed that there are fewer resources in the forest compared to their parents' generation yet the majority of respondents did not agree with that statement. However, nearly 90% of respondents felt that people collect too much from the forest, leaving very little for future generations. The majority of people (52.8%) did not support hunting in the reserve. Nearly a third responded neutrally to this statement and the remainder (16.6%) supported hunting. However, 67% of the people who supported hunting and 100% of the people who responded "neutral" specified that only harmful animals, like the wild pig, should be hunted.

Some questions used the wording "it is important to my livelihood" to better understand respondents needs compared to the perception of community needs. A comparison of these responses yielded some interesting results. Although over half of respondents agreed that it was important to their livelihoods to collect live timber from the forest, over 75% did not believe that people in general should be allowed to do so. In contrast to the disagreement about timber collection, over half of respondents did not believe people should be allowed to gather plants from the reserve and did not feel that gathering plants was important to their livelihoods.

Attitudes towards the Guizhou snub-nosed monkey

Attitudes towards the Guizhou snub-nosed monkey ranged between positive and neutral (Table 6.2). An overwhelming majority of respondents support conservation action aimed at protecting the monkey, including protecting the monkey for future generations (93.1%) and protecting the area for the monkey (94.4%). Moreover, a majority of respondents (93.1%) believe that people and the monkey can share the forest. Finally, a large majority of respondents do not believe that the snub-nosed monkey is harmful to their livelihoods. Of the 68

respondents who responded this way, 20 respondents reported during the open-ended follow up question that the wild pig is harmful to their livelihoods but not the snub-nosed monkey.

Some respondents felt neutral towards the monkey stating that the monkey had no influence on people's lives because the monkey lives on the mountain and people live in the village. This feeling of indifference is apparent in some of the responses to the Likert scale statements, as nearly half (48.6%) responded "neutral" when asked whether their lives would be better not to have the monkey there. Out of these 35 respondents, 80% stated that the monkey has no influence on their lives. Of the 27 people who disagreed with this statement, 18.5% mentioned that if there were no monkey, no tourists would come to the reserve. In a similar difference of opinions, just over half of respondents agreed that the snub-nosed monkey would die without FNNR but around a third of respondents believed that the monkey would survive without the reserve. Twenty percent of those who agreed that the reserve is important to the monkey's survival mentioned that if there were no reserve, residents would probably hunt the monkey.One respondent linked the role of conservation to the responsibility of a united community action stating: "only if we protect the monkey together can we protect the monkey successfully" (male, 30s).

The composite analysis of the Likert statement data revealed that, overall, respondents had a very positive attitude towards the monkey. The average value for respondents' attitudes was 0.88, with 94% of respondents classified as positive and 6% moderate (N=72). There were zero negative attitudes towards the monkey recorded. There was no significant difference in attitude scores among respondents of different education levels (N=71, X^2=0.227, df=3, P=0.973).

The majority of respondents (76%) did not know any stories or myths about the Guizhou snub-nosed monkey. Sixteen percent of respondents told stories about their experiences with the Guizhou snub-nosed monkey during their lifetime. For example, a woman in her 30s described the following story:

> When my brother and I were children, we went to school. On the way, [we] often saw the monkeys. [My] brother was afraid of monkeys. Monkeys are afraid of fire. In order to keep [us] safe, my brother wore red clothes and put red bags on [his] head to keep safe.

Eight percent of respondents told us stories that took place before their lifetimes. For example, a man in his 50s described the following story:

> 100 years ago, [my] ancestors lived at Yu Quan Gou. When they cooked food, the monkeys would come to their house and they'd feed them…One day, they went to farm and left the kids alone at home. At this time, a group of monkeys came to the house and cut the baby up (dismember) and boiled the baby. [The monkey] said to the housekeeper, the baby is like the potato.

Two respondents discussed the similarities between the monkey and humans. For example, a woman in her 50s said:

> People look like the monkey. People came from the monkey. The monkey wears some leaves and people wear clothes.

Other respondents recognized that, although the lives of monkeys and people don't cross paths very regularly, there is still an important connection:

> [The monkey] lives on the mountain and eats leaves. [It's] good for local people because they are very happy when they know the monkey lives here. (woman, 50s)

Respondents expressed a feeling of interconnectedness between the Guizhou snub-nosed monkey and humans in response to a variety of questions during the interviews. For example, when asked why it was important to protect the monkey, a woman in her 30s stated, "Because the monkey's life is like the life of a human. The monkey is similar to people." Respondents discussed the similarities between humans and monkeys such as the important relationship

between mothers and infants, a mutual dependence and influence on the forest, and a shared ancestry.

Discussion

Perceptions of the costs and benefits of conservation: A trade-off

Respondents in this study described both costs and benefits of living near Fanjingshan National Nature Reserve, recognizing people would have to make sacrifices in order to successfully conserve the habitat and animals. Restricted access to forest resources was the most common complaint about the reserve. Many authors have found a similar result in other studies of attitudes towards conservation (e.g., Wang *et al.* 2006; Allendorf 2007; Méndez-Contreras *et al.* 2008). Another complaint respondents had about the reserve was that they were forbidden to hunt wildlife, such as wild pigs, despite the massive damage caused by these animals to crops. Wild pigs are common culprits in crop destruction in Asia and Southeast Asia (Rao *et al.* 2002; Xu *et al.* 2006; Linkie *et al.* 2007). On one occasion, we witnessed the aftermath of the destruction of up to 90% of one man's maize crop by wild pigs. It is not uncommon for people to have negative attitudes towards conservation as a result of crop and livestock losses to wildlife (e.g., Akama *et al.* 1995; Wang *et al.* 2006; Baral and Heinen 2007). Although respondents frequently cited the wild pig as a cause of financial hardship, it did not negatively affect their attitudes towards the snub-nosed monkey or conservation, even though residents attributed crop damage by the wild pig to hunting restrictions in FNNR. Many respondents remarked that some animals, like wild pigs, were destructive or harmful to people's livelihood but that the snub-nosed monkey was a beautiful or good animal and not

harmful. This finding is congruent with research on people's perceptions of "good" and "bad" animals in relation to their aesthetic qualities, dangerous or destructive behaviours, and utilitarian uses (Costa *et al.* 2013).

Respondents frequently mentioned that the government should offer financial compensation to local people, particularly for crop losses. According to one respondent, "people should help FNNR to protect the forest and mountain…but the government should give a supplement to local people." Direct financial compensation to farmers for crop losses has been proposed at other sites where human-wildlife conflict occurs (e.g., Bhutan, Wang *et al.* 2006), particularly as a way to encourage biodiversity conservation within protected areas (meta-study, Bruner *et al.* 2001). However, direct financial compensation may not be an efficient or effective means to counteract loss and may not be a financially sustainable use of conservation funds (Nyhus *et al.* 2005). Moreover, the monetary value of compensation may be viewed as inequitable compared to physical displacement or actual crop and wildlife losses (Nyhus *et al.* 2005; Cernea and Schmidt-Soltau 2006).

Another cost of living near the reserve is the potential for forced relocation. According to one respondent in the study, when his household was forced to relocate from the core area of the reserve to the edge of the buffer zone, the government provided them with a one-time supplement of 6,000 Yuan (approximately $990 USD) to offset the moving costs. However, the total cost for the family to move was approximately 20,000 Yuan (approximately $3,300 USD). This particular respondent described relocation in terms of trade-offs. The supplement was not enough to cover moving expenses and the location of the new village was far away from his family's forest. However, because the location of the new village was closer to the road, it was

more convenient for his sons to go to school and for his household to have electricity. Previous research indicates that many residents were not willing to relocate, even with government subsidies, because they value the health benefits of clean air and water inside the reserve and are unsure what livelihoods are available outside of the reserve (Gong 2004).

Despite the financial burden caused by the reserve, respondents still recognized a number of positive aspects of living near the reserve including both aesthetic and utilitarian benefits. This finding is congruent with previous work on local people's attitudes towards conservation and nature reserves where researchers found that respondents enjoyed aesthetic benefits like living near beautiful scenery and seeing wildlife (Allendorf 2007), as well as utilitarian benefits like clean water and air, flood protection, and crop pollination (Sodhi *et al.* 2010). Respondents in this study discussed benefits like a clean environment, beautiful views, the joy of seeing wild animals like the snub-nosed monkey, and future use of protected resources. For example, one respondent stated, "if the tree is useful, like to build a house, then it should be protected so it can grow up and then be used." Respondents like this felt that a major benefit of the reserve is that resources are protected for when the community needs to use them.

Although respondents felt the reserve limits their livelihoods, they believe that the reserve and the monkey will help bring development, tourism, and economic opportunity to their village. In Lengjiaba, respondents felt that without the Guizhou snub-nosed monkey, no tourists would come to visit their village. Similarly, Xu *et al.* (2006) found that villagers believed the development of tourism associated with the Wolong Biosphere Reserve in southwest China would stimulate the local economy. The presence of FNNR, and the potential for tourism, has indeed facilitated the development of local infrastructure including a paved

road from the village to the city. Lengjiaba residents view development as a positive by-product of living near the reserve. For example, one respondent described the expectations for future development:

> The FNNR will accelerate development and the local economy. [They will] build the street. [It] only protects at first but now [it] can develop. If [there is] no reserve, [there is] no development. (male 30s)

Many of the respondents in the present study expressed similar sentiments and looked toward development to stimulate the local economy and improve their livelihoods. Stem *et al.* (2003) show, however, that benefits derived from ecotourism may not change local people's attitudes towards conservation. Moreover, tourism is not a reliable source of income because it is dependent upon weather, politics, and economic stability (Jacobson and Robles 1992; Stem *et al.* 2003). Although Lengjiaba may receive some benefits of development due to the proximity to the reserve, it may not receive any large-scale benefits from tourism. The village is not geographically close enough to the main tourist attraction, the Golden Peak, to receive many visitors. Some visitors may visit to try and see the Guizhou snub-nosed monkey, but it is a very challenging species to locate or follow due to the mountainous terrain and because the monkey is an unhabituated, arboreal species, with a low population density (Yang *et al.* 2002). Nonetheless, even if tourism never grows to become a profitable or dependable industry for Lengjiaba residents, they are already experiencing some benefits of development.

Attitudes towards and knowledge of the Guizhou snub-nosed monkey and FNNR

A large majority of respondents had positive attitudes towards the snub-nosed monkey and supported its conservation. Some studies have shown that the length of residence in a place may influence perceptions and attitudes towards conservation (e.g., Riley 2005; Sodhi *et*

*al.*2010). For example, in Lore Lindu National Park in Central Sulawesi, Indonesia, Riley (2005) found that long-term residents value the forest for future generations, whereas migrants were looking for agricultural development and short-term gains. Many of the respondents in this study have lived in Lengjiaba their entire lives, which may positively influence their attitudes towards conservation and knowledge of the area. Other researchers have found that respondents with higher education levels have more positive attitudes towards conservation (e.g., Infield 1988; Sodhi *et al.* 2010). In this study, education level did not have a significant effect on attitudes. Despite an overall low level of education, respondents still have overwhelmingly positive attitudes towards the snub-nosed monkey.

We found that knowledge about the monkey and reserve is unevenly distributed among male and female respondents. Interestingly, women in this study were more knowledgeable about why the snub-nosed monkey is protected. This finding differs from gender differences in knowledge of wildlife in the United States, where mean were significantly more knowledgeable about animals, particularly endangered and rare species, than women (Kellert and Berry 1987). However, women scored higher on humanistic and moral attitudes towards animals, showed stronger emotional attachments, and had a higher rate of anthropomorphic feelings towards animals. In this study, both men and women provided emotional and anthropomorphic responses. At this point, it is unclear why women were more knowledgeable about the snub-nosed monkey's protection status.

Men in this study were more knowledgeable than women about the purpose of the reserve. This finding mirrors Xu *et al.* (2006), who found that men living in and around Wolong Biosphere Reserve have more knowledge about the reserve than women. Two possible reasons

may explain this discrepancy in knowledge. First, with the exception of looking for cows, the type of resource collection in which women engage does not require them to go very far into the forest or up the mountain. The women who participated in this study primarily engaged in collecting vegetation to feed pigs. We suggest that knowledge about the reserve may be less important to women because of the type of resource collection activities in which they participate. This conclusion supports Ayantunde *et al.* (2008), who report that in southwest Niger significantly more men were able to identify herbaceous species than women because livestock graze on herbaceous species and herd management is primarily a man's responsibility. The second possible explanation is that the way information about the reserve is conveyed favors men. Xu *et al.* (2006) state that in rural parts of China information is mainly disseminated through a village committee, which is typically composed of male heads of household. This system of information communication may also be in place in Lengjiaba. However, in this study men and women were equally likely to learn about the protected status of the monkey from FNNR or the government.

Overall, people's knowledge about the Guizhou snub-nosed monkey was limited. The majority of respondents knew how many monkey types lived in the reserve and could also list the Guizhou snub-nosed monkey as one of the types. Beyond this most basic information, respondents had limited knowledge about the monkey's population size and distribution. Interviews also revealed that although respondents understand the rules of the reserve very clearly, they do not fully understand the rationale for rules. For example, nearly every respondent was aware that the Guizhou snub-nosed monkey is protected but the majority of respondents did not know *why* it was important to protect the monkey.

Previous research has highlighted that community participation and communication between local people and conservation officials concerning reserve objectives and activities are critical to avoiding negative attitudes towards conservation initiatives (e.g., Méndez-Contreras *et al.* 2008). Many conservation initiatives, including those in China, follow a top-down approach that may overlook the needs of local people and marginalize local participation in protected area planning and management (Xu *et al.* 2006). A case study of the Tana River Primate National Reserve (TRPNR) in Kenya serves as an example of how failure to consider the perspectives of local people can undermine conservation efforts (Mbora and Meikle 2004; Wieczkowski 2005). TRPNR was established to protect two endangered primate species: the Tana River red colobus, *Procolobus rufomitratus*, and the Tana mangabey, *Cercocebus galeritus*. Reserve management focused on relocating villages from the reserve, which was met with a high level of resistance by local residents. Residents increased deforestation efforts to destabilize management policy based on the view that if there were no forest or monkeys, there would be no need for management to relocate villages (Mbora and Meikle 2004; Wieczkowski 2005). The management system of FNNR follows a top-down approach to conservation and, consequently, the influence of the government was pervasive throughout many of the interviews. For example, when asked why it is important to protect the monkey, some respondents simply replied that it is important because the government says it is important. However, criticisms of the reserve largely centered on restrictions placed on people's livelihoods and rarely focused on reserve management except for one respondent who expressed frustration that while officials will enforce the reserve's rules for most of the community, they are lenient towards friends and family members.

The primate-human interconnection in Lengjiaba

Many communities that live in close proximity with nonhuman primates share unique biological, ecological, and cultural interconnections. In some of these cultures, there are rich mythologies detailing a shared origin of human and nonhuman primates (e.g., Shepard 2002; Cormier 2003). Although interviews revealed that Lengjiaba residents have no shared mythology or folklore about the Guizhou snub-nosed monkey, individual respondents reported various stories and personal experiences. The absence of any shared stories about the monkey might be a result of the low level of contact that people have with the monkey on a regular basis; many respondents reported encountering the monkey only once a year or less. This low level of contact likely reflects altitudinal differences between the monkey's home range and where people live and work as well as the fact that the snub-nosed monkeys are unhabituated to human presence.

Lengjiaba residents still feel a connection with the monkey. Ecologically, people recognize that their actions within the reserve may disturb the monkey because they live in a shared environment. Humanistically, some respondents attributed anthropomorphic or intersubjective qualities to the monkeys. For example, one respondent stated that the reason the Guizhou snub-nosed monkey doesn't harm people or crops is because they can understand human feelings. It is not uncommon for people to attribute anthropomorphic qualities, feelings, and agency to nonhuman primates (Cormier 2003; Costa *et al.* 2013). Emotional connections between people and the Guizhou snub-nosed monkey should be explored and incorporated into conservation education in FNNR (e.g., Patel *et al.* 2005). The perception of these

anthropomorphic qualities in the monkey has made lasting impressions on Lengjiaba residents and has possibly curtailed hunting. For example, one respondent described the following story:

> Grandpa hunted in the forest… Once there was a female and an infant golden monkey in a tree. [He] shot at the female and she was wounded. [She] fell on ground. Then the infant heard [the] voice [of] the female. [The] infant came to the female and drank the milk [from the female]. From then on, Grandpa did not allow [his] sons to hunt monkeys because they are too similar to humans. [The] monkeys are similar to man.

In this story, the respondent's grandfather was so affected by the human-like relation between the infant and the female that he created a familial taboo on hunting the snub-nosed monkey. Beyond behavioural or morphological similarities between humans and the Guizhou snub-nosed monkey, one respondent specifically recognized that people and monkeys share an ancestral history. In addition to the evolutionary implications of this statement, this parallels previous research on people's cultural beliefs about humans-nonhuman primate origins (Shepard 2002; Cormier 2003; Loudon *et al.* 2006). Informal institutions that govern behaviours, such as taboos, norms, and religious ideas may be more effective at conserving biodiversity than formal, institutionalized rules (Colding and Folke 2001; Jones *et al.* 2008). However, informal institutions can change over time due to changing economic and political situations, or migration patterns (Lilly 2005; Riley 2010).

Conclusions and Recommendations

In Fanjingshan National Nature Reserve, respondents view conservation as a trade-off between costs and benefits to their livelihoods. Respondents do not always agree with the rules

of the reserve and they recognize that the reserve causes financial hardship for their livelihood. However, a majority of respondents express positive attitudes towards the monkey and believe that it is important to protect the species. These attitudes provide evidence of local support for the continued conservation of the monkey. However, the reserve should seek to ameliorate costs, such as the problems that farmers experience with the wild pig as a result of hunting bans, in order to increase support for the reserve and lessen its negative impacts on local people's lives. Local people are aware of the rules of the reserve very clearly but do not always understand the rationale behind the rules. Beyond the most basic knowledge, local residents have a poor understanding about the Guizhou snub-nosed monkey's behavioural ecology. Accordingly, we suggest that FNNR reevaluate their methods of conservation education and seek to implement a community-based conservation education program that will complement the existing children's program (Tan *et al.* 2013) to reach a wider demographic that includes adults, particularly, women.

Direct interactions between local communities and the snub-nosed monkey are rare in FNNR. Although there is no shared mythology about the monkey, local people express a feeling of connectedness with the monkey, which may make local communities more willing to abide by the rules of the park, despite the costs of conservation, and more tolerant of the snub-nosed monkey. FNNR management should incorporate local perceptions and attitudes into their conservation strategies, creating a more participatory conservation policy that supports both local communities and the Guizhou snub-nosed monkey. Greater community participation, including an adult education program, and improved communication between officials and residents may strengthen conservation initiatives by increasing local knowledge

and understanding of the reasons behind the restrictions on their livelihoods. Finally, although we direct these recommendations to Fanjingshan National Nature Reserve, our results are also relevant to protected area management more globally. In particular, we recommend improving communication between stakeholders like reserve officials and local communities, appreciating the role local folklore can play in conservation attitudes, incorporating villagers' perspectives into conservation planning, and implementing educational programs that target a wide demographic.

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Xingda's Wildlife Explorations in Fanjingshan

Chapter 7 From Science to Practical: Science-Story Model for Future Collaborative Conservation

Abstract

Current cultural dimension as a synthesis may cause a tolerant attitude toward wildlife exploitation then it is compounded by poor wildlife conservation practices. It is a key point to effectively communicate with general public to discard an old-fashion and negative traditional culture about wildlife and rebuild a new nature culture system for a sustainable future. Science-Story model as a conservation tool showed a powerful vitality to bridge the gap between conservation science and practice in this case. It might be positive to bring a paradigm shift of traditional cultural challenge of wildlife exploitation through the embedding of positive conservation messages. We should pay more attentions on policies, human resources and investments to support a combination between conservation science and humanities through science-stories model at multiple levels in the future. And we encourage more field scientists and/or humanists and other professions to share their knowledge of conservation in an enjoyable way and create more ground biodiversity stories in their native language for future integrative conservation.

Introduction

Wildlife and biodiversity crisis is one of environmental issues which human are facing, an urgent need of public participation into conservation will benefit future mission of biodiversity conservation (Novacek 2008). Communication is the important step to engage the public (Pace *et al.* 2010; Bickford *et al.* 2012). In the past few decades, researchers already made great effort to create huge body of knowledge on biodiversity conservation and improve our communication for biodiversity crisis between researchers and public. Unfortunately, there is a huge gap between productive conservation researches and poor conservation communication exists if we can dare to admit (Novacek 2008; Pace *et al.* 2010; Bickford *et al.* 2012). For instance, several high-impact academic journals (e.g. conservation letter, conservation biology, biological conservation) in conservation science selected the English as the official language. This way indeed promoted the development and communication of conservation science communities. However, it is disadvantageous for on the ground conservation practitioners, educators and local residents who cannot understand English in the hot spot area of biodiversity to apply and share those excellent outcomes published in these journals.

The gap urgently needs to create more effective models to communicate with the public. Although there are diverse techniques for this purpose, the best way for conservation communication was considered to be from direct experiences on nature or wildlife (De Young1993a, 1993b;Jacobson *et al.* 2015). However, it is not easy to make the success of direct experiences come true in the real world. You can image the difficulty that a British or

an American go to China to watch wild Chinese giant panda (*Ailuropoda melanoleuca*). Even local residents around protected area or living nearby species' habitat, their ecological knowledge of local wildlife and biodiversity is passing from cultural memory in the developing countries (Zhang *et al.* 2014).

Beside direct experience, story based on conservation science as a good communication tool and substitutes for direct experience might help us communicate with the public on environmental issues (e.g. Schaller 1963, 1993; De Young *et al.* 1993a; Redford *et al.* 2012). In the theory, the advantages of stories for environmental education issues have been discussed in an academic way (De Young *et al.* 1993a, 1993b). It can simplify complex situations and help people make sense of the information given (De Young *et al.* 1993, 1993b). When science showed no promise of changing peoples' attitudes and behaviours, stories wield an ancient power over the human spirit and remain a vital part of building public support for conservation (Redford *et al.* 2012). This theory was also supported by psychologists and they used "storied conduct of human nature" to explain human's cognition and behaviour (e.g. Sabin 1986). And many education researchers also approved that story is an effective tool in natural science education such as physics (Stinner 2007).

However, although a few pioneers have pointed out the importance of story in commutation for conservation science whatever in academic or practice many years ago, still very few ground practice cases to combine science and stories to promote biodiversity conservation till presence (Schaller 1963; De Young *et al.* 1993a, 1993b; Leslie 2013). This obstacle may be caused that scientists have been shown to have a natural bias toward thinking,

perceiving and imagining according to a narrative structure (De Young *et al.* 1993b). Conservationists or science writers might tend to keep the baseline of non-fiction stories (e.g. Schaller 1993; Elizabeth 2014). On the other hand, humanities or psychologists considered that it should put more mystery or enjoyable contents into story and it will be more powerful and effective to attract people's attentions (De Young *et al.* 1993a, 1993b). The debate between both sides might be a key point needed to classify carefully and then decide what degree of science and story as a valid combination for final target of conservation communication.

A Practical Case of Science-Story model: A Good Tool for Future Conservation Communication?

Different from most previous perspectives, here we provided a novel trial about how to create a wildlife science story to promote biodiversity conservation in Fanjingshan National Nature Reserve (FNNR) in Guizhou, China. This story had a fictional character and story while it has accurate scientific knowledge about wildlife and conservation. The book is titled *Xingda's Wildlife Explorations in Fanjingshan*. The aims of this story are to inspire local children and their parents to appreciate the wonders of the natural world and their native species in their hometown. The story created an adult and a wildlife enthusiast named *Xingda* as fictional central character. While exploring Fanjingshan, he befriended several scientists and learned about the biology and threats to many amazing wildlife species

in four types of habitats. The whole story was divided into six chapters and had a sub goal for each chapter. Chapter 1 introduces what reserve is and wildlife and plant in FNNR. Four species were highlighted in the next four chapters of the book. In addition to the flagship species Guizhou snub-nosed monkey（*Rhinopithecus brelichi*）in FNNR, Chinese giant salamander (*Andrias davidianus*), mandarin duck (*Aix galericulata*) and butterflies and spiders (*Papilio polytes* and *spp.*) were included also. And then authors tried to pass down the readers and next generation some messages about emotions and cognitions between wildlife and human neighbors in the last chapter.

"One day when you grow up, by then if they (those wildlife) as your neighbors are still living with you in a harmonious and friendly way, you must be proud of yourself and everything you have done for them because you have shown the greatest quality of a life which is giving your love and respect to nature and lives."

----------*Xingda's wildlife explorations in Fanjingshan*

One Reserve, One Story

The process of creating the children's wildlife storybook is illustrated in Figure 7.1. Briefly, the book was an interdisciplinary collaboration among scientists, wildlife photographers, artists, graphics designers, educators, and language experts. The scientists selected several endangered animal species that represent the flagships or common species of FNNR. They created stories based on their accurate scientific knowledge about the biology and conservation issues of the selected species. Wildlife photographers, artists, graphics

designers, and scientists all contributed illustrations for the book (Figure 7.1). Wildlife photos, art, graphics, designing are helpful to wake up the attitude of public. Here we incorporate them into our stories to attract audiences. The text was written in Chinese, which was further improved by educators and language experts to make Chinese language correct. And before publishing the manuscript, we showed the book to a selected number of teachers and schoolchildren for comment to ensure the materials are age-appropriate for our target audience (ages: 9-15 years old). By illustrating these species' habits, behaviours and their habitat status, the book raises kids' awareness of wildlife conservation and introduces environmental protection initiatives in a fun and enjoyable way. As last, it encourages children and people to take action to protect locally endangered species.

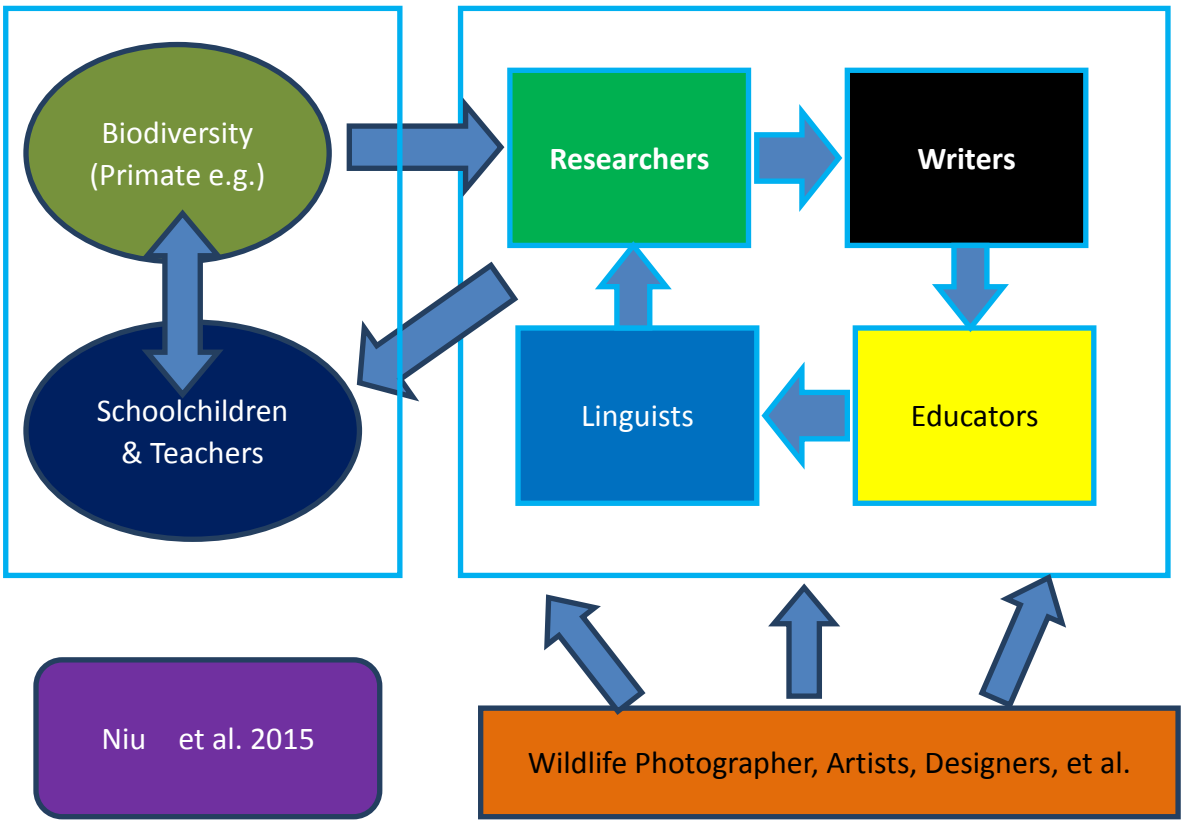

Figure 7.1 The process of creating and main wildlife species of Xingda's wildlife explorations in Fanjingshan

Through the Guizhou Wildlife Preservation Project, British Consulate-General Chongqing and Fanjingshan National Nature Reserve hosted a book launch in Guiyang, the capital of Guizhou in China. At this event, 3,100 copies were donated to 436 primary schools throughout the province. Another 1,800 copies were donated to 7 primary schools near FNNR during our Little Green Guards program activities (Niu 2012; Tan *et al.* 2013). Publication of the book was reported by at least eight (original) media agencies and the news reached an estimated 2.0 million audiences. After that, Young Pioneers, a well-known Chinese youth journal, reprinted this book and planned to publish the chapters in four issues. An estimation of six hundred thousand copies was sent into the primary schools throughout China.

What We Learned

Story is a synthesis which is easily mixed with knowledge and skills of different disciplines. In Xingda's wildlife explorations in Fanjingshan, not only the knowledge of researchers but also the contributions from wildlife photographers, artists, educators, linguists, and teacher and kids in local primary schools are designed and integrated into the story. It showed that story as a knowledge carrier has a great plasticity and inclusiveness. It can make story more imagery and interesting to better communicate with the audience (De Young *et al.* 1993a, 1993b).

Story could decrease the depth of scientific knowledge and improve the level of communication in diverse disciplines. Science has its own “language” which is different from daily words (Kueffer and Larson 2014). This characteristic of science leads to a difficulty to transfer scientific knowledge to general public. Story could decrease the depth of scientific knowledge through words adjusting and/or associated with other techniques of vision and make people understand science easily. It also can provide more effective communication even for kids with a good designing (Medress 2008; Stinner 2007). Recently, more and more writers or journalists had played an important role in conservation knowledge transmission with scientific communities’ help (e.g. Elizabeth 2014).

Story can transfer diverse information and can adjust the contents or structure to reach the diverse targets according to urgent conservation treats. For example, ecological knowledge such as behaviour, biological habit of Guizhou snub-nosed monkey were emphasized to communicate with audiences in Xingda’s wildlife explorations in Fanjingshan, while interaction between human and langur were described as a priority in another science story based on an urgent negative interaction in Mayanghe National Nature Reserve, China (Niu *et al.* 2015, Niu 2016). The stories more focused on their problems according to the different species.

What’s Next?

Like other environmental problems, this mass extermination constitutes the ecological crisis facing our present and future mankind. What exactly is the root cause of this

ecological crisis has always been one of our concerns. Because only by understanding this fundamental issue can we get out of the shadow of this crisis. In 1967, White published the famous article "The historical roots of our ecologic crisis" in the journal Science, proposing that the historical root cause of our current ecological crisis is a product of Christian religious culture. It is the sense of superiority that people in this religious culture are flooding with nature that determines people's attitudes and behaviours toward nature. Also, he tried pointed out “both our present science and our present technology are so tinctured with orthodox Christian arrogance toward nature that no solution for our ecologic crisis can be expected from them alone.”

Science Story should be positive to bring a paradigm shift of current cultural challenge of wildlife exploitation through the embedding of positive conservation messages. As one branch of literature, story can contain emotion and conservation messages of authors to promote the spiritual communication which influence people’s value, attitude and behaviour toward wildlife (Jacobs 2009). It is helpful for us to need to promote a new conservation culture system replacement of traditional old-fashion culture for the public in the global. In fact, a traditional cultural obstacle as a synthesis may have formed the primary challenge to current and future biodiversity conservation. This synthesis may cause a tolerant attitude toward wildlife overexploitation then it is compounded by poor conservation practices for wildlife. For instance, “monkey opera” is regarded as an intrinsic cultural heritage at some places of China (Figure 7.2). However, these shows and cultural activities might play a negative educated role on not only primate conservation but also primate welfare in China.

Figure 7.2 Monkey opera on the street in China

Conservation is not only our action of protecting biodiversity but also a value view in our mind. It means how we as “community of common destiny for all humankind” (Xi 2015) interact with the other species and our common earth in a physical and psychological way. Prosperity of humanistic science conservation will be helpful to locate and resolve these cultural and spiritual challenges on biodiversity conservation in the global (e.g. Goodall &Berman 2000). Under the circumstance, it will lead us to braver discard our old-fashion and negative traditional culture about wildlife in our own nations as quickly as possible and find better way to communicate with general public to rebuild a new nature culture system for a sustainable future.

Science-Story as a conservation model already showed a powerful vitality to combine conservation science and humanities to decrease the gap between sciences and

practice in this case (Figure 7.3). Actually this model might have been applied to attract with audiences through other media way like wildlife documentaries. Conservation science is not easy to communicate with general public or key stakeholders while story as a synthesis has a natural advantage on this point (De Young*et al.*1993a, 1993b; Medress 2008). It is time to take off our prejudice against stories and revisit the advantage of story as a communication tool.

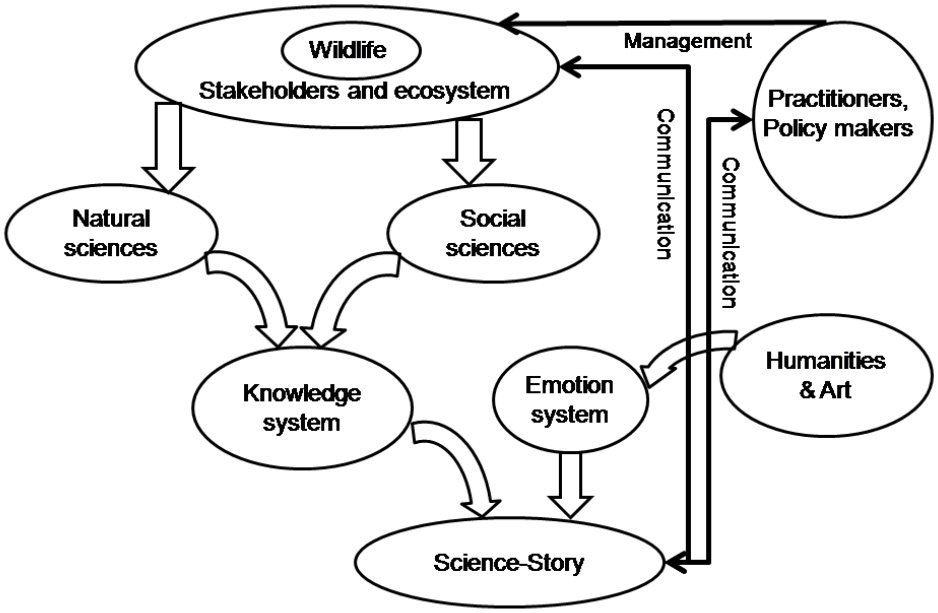

Figure 7.3 Linking sciences with humanities through Science-Story model for a collaborative conservation science and practice

We call for governments, biodiversity management authorities, biodiversity conservation organizations, institutions and universities, foundations should pay more attentions on policies, human resources and investments to support a combination between conservation science and humanities at multiple levels (local, region, national and international) in the future. Every protected area, region and country has its unique set of

natural, social, and cultural characteristics. When communicating with the public or stakeholders on specific sites, conservation knowledge and problems should be varied from input to output in unique place. That means that we should try to produce stories for each site for conservation communication and link local wildlife conservation with cultural ecosystem services. And it will help areas to create ground conservation culture to protect the biodiversity and save our earth.

Meanwhile, we encourage more field scientists and/or humanists and other professions to share their knowledge of conservation in an enjoyable way and create more ground biodiversity stories in their native language. To put conservation science and conservation messages together into these ground stories and then distribute these stories to general public and local residents through science storybook and/or social media. Conservation researchers should take a responsibility to contribute the development of this interdisciplinary field. Without any doubt, it will have greater effect on handing down the value of conservation and improving the level of conservation throughout the world once vivid stories walking side by side with powerful scientific knowledge about wildlife and conception of biodiversity conservation.

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Chapter 8 General Discussion

Nonhuman primates are an essential component of biodiversity which can contribute to forest regeneration and ecosystem health (Estrada *et al.* 2017). However, the survival of these animals has become threatened by human activity and disturbance in today's increasingly human-influenced world (Fuentes and Hockings 2010; Setchell *et al.* 2017; Estrada *et al.* 2017). Due to increasing impacts from anthropogenic intervention on the survival of nonhuman primates in the socio-ecological system, I applied a coupled human and natural systems approach (Carter *et al.* 2014) for my conservation research on two leaf-eating monkeys (*Rhinopithecus brelichi* and *Trachypithecus françoisi*) in China. This approach has been applied in previous wildlife research and conservation studies (Carter *et al.* 2014; Kalnicky et al. 2014), since the impact of both natural and social subsystems on wildlife conservation are highlighted in this model. My thesis used this approach to promote nonhuman primate research and conservation in two human-modified habitats. It provided a key linkage for understanding human-monkey interactions in order to promote the integrated conservation of two species and other nonhuman primates in the future.

Population Size, Distribution and Behaviour

In terms of the natural subsystem, I surveyed and estimated the population size and distribution of *T. françoisi* in MNNR. François' langur is counted as a limestone langur in Northern Vietnam and Southern China. Currently, the total of population size of this species around the globe is

about 1700 individuals at 30 isolated localities (Niu *et al.* in preparation). However, until now François' langur subpopulation sizes and distributions have not been clearly established (Insua-Cao et al. 2012; Han et al. 2013; Dine et al. 2012; Insua-Cao et al. 2012; Li et al. 2007). This is probably because there is limited access to their habitats. There is only one reported area in the world—Mayanghe National Nature Reserve in which more than 200 individuals are living (Li et al. 1994; Hu et al. 2011). Unfortunately, there was no scientific evaluation of the number of François' langurs in this Reserve before our survey although Li and his colleagues (1994) did an incomplete survey in 1994 and found 38 groups, about 395 individuals, in the south of MNNR. Population size and distribution in MNNR is invaluable informationwhen evaluating the current conservation status of the species worldwide. My study (Chapter 2) has provided first-hand data on the population size of François' langurs for the species conservation in MNNR. Meanwhile, the population size and conservation status of each management area in this reserve was also discussed and major strategies for future scientific conservation management were recommended. This will not only provide accurate background information for the management and protection of langurs in MNNR, but it will also provide a scientific basis for IUCN to assess the global conservation status of François' langurs.

Meanwhile, we confirmed that François' langurs were mainly distributed along three major rivers. This pattern appears to be similar to the other subpopulations in Guizhou and Chongqing. For instance, Su and his colleagues (2000) found that the langurs were concentrated in the area near the Furong River at the junction of Wulong County and Pengshui County in Chongqing. Tian *et al.* (2012) conducted an investigation of the langurs in the Yezhong protected area in Guizhou, and they found that the langurs there were distributed

along the Beipan River. In primates, food distribution, abundance and availability can create variations in ranging and distribution patterns (Isbell, 1983; Bennett, 1986; Garber, 1993; Isbell *et al.*, 1990; Di Fiore, 2003; Tan *et al.*, 2007). However, in addition to ecological limitations on food distribution mentioned above, species distribution can also be affected by human activities including the development of farmland, artificial forests, and the construction of roads and housing. The current distribution pattern in MNNR can be interpreted as a trade-off by the species between adaption to the natural environment and adaption to the effects of historical and current anthropological activities on their habitat. As stated before, the langurs are concentrated along the rivers, probably due to the lack of human disturbance in these areas. In addition, suitable habitat for langurs in the Mayanghe Reserve is mostly distributed near the river (Zeng *et al.* 2013). That this appears to be common may have important implications for predictions of species distribution in a coupled human and natural system. As another example, the Guizhou snub-nosed monkey has a core altitudinal range in their mountain habitat (Niu *et al.* 2010). Likewise, I suspect that it may be a compromise to adapt to the ecological limitation of food distribution at the highest altitude while avoiding the extreme anthropogenic impact on food availability at the lower altitude. It may demonstrate a close relationship between the distribution patterns or ranging use of these species and those socio-ecological factors which can influence food distribution. In the future, to better predict the distribution patterns of nonhuman primate species, it is necessary to take into account the historical or current effect of human impact on species distribution. Meanwhile, to ensure the species' survival in Mayanghe Reserve and to reduce human-langur conflict, we recommend improved protection and

restoration of natural vegetation alongthe river banks, especially in areas densely populated by humans.

Next, my studies quantified the acoustic diversity of two Asian Colobines in China. We identified nine vocal types in *T. Françoisi* (Chapter 3) along with 9 vocal types related to the context in *R. brelichi* (Chapter 4). Comparing the vocal repertoire sizes of the two species, both species had the same number of vocal types. Because the social organization of François' langurs isbased on one male units while thesocial organization of Guizhou snub-nosed monkeys is a more complex multiple-level society (Zhang *et al.* 2006; Niu *et al.* 2010; Kirkpatrick and Grueter 2010), this tendency appearsto be inconsistent withthe co-evolution of vocal communication and sociality in primates,in which size is positively associated with social bonding (McComb and Semple, 2005). The difference may stem from various study conditions, efforts, or the species themselves. Future studies also should use more objective analysis techniques such as unsupervised acoustic analysisto studythe vocal repertoire sizesof more phylogenetic species, in order to provide more data to further compare and examine the co-evolution of vocal communication and sociality in nonhuman primates. Also, future studies should further examine each vocal type, combining the behavioural context of *R. brelichi* in the field. It will be beneficial to this species to further understand vocal communication and adaptation, whether to temperate habitats or complex social interactions.

Regarding the bioacoustic diversity of *T. Françoisi*, long and short loud calls were recorded under diverse contexts in the wild. A long loud call was identified as one of the most obvious call types in several Asian langurs (Herzog and Hohmann1984; Steenbeek and Assink 1998; Eschmann *et al.* 2008; Wich *et al.* 2003, 2008; Erb *et al.* 2013, 2016). Spectrograms of

long loud calls in this study are similar to compounds of long loud calls in other Asian langurs (Hohmann 1989, 1990; Steenbeek and Assink 1998; Eschmann *et al.* 2008). For instance, the long loud call of *T. nestor* was composed of three different structural units: harsh barks, whoops and residuals (Eschmann *et al.* 2008). These different structural units may contain specific functions as researchers already pointed out that the function of male long loud calls might include "mate defense, resource defense, mate attraction, and habitat" (Wich and Nunn 2002). Researchers also noticed that each note of compound calls of males in some wildlife species (Putty-nosed monkeys Cercopithecus nictitans, treefrogs Eleutherodactylus coqui) has a different communicative significance (Arnold and Zuberbühler 2006, Narins and Capranica 1978). A natural and synthetic acoustic stimuli playback experience should further be conducted to understand the ecological significance of long loud calls of this species and the relationship between this call and other calls such as harsh barks. Meanwhile, variations of long loud calls among individuals, subspecies or phylogenetically related species have been identified in Asian langurs (Steenbeek and Assink 1998; Wich *et al.* 2008). Future studies should collect more data on this call, for comparative studies to understand the evolutionary implications of long loud calls among individuals, subspecies or species.

Regarding the vocal communication of *R. brelichi*, we recorded an unexpected high-frequency signal. According to Hauser (1993), there is a negative correlation between body size and high-frequency pitch. Contrary to the study mentioned above, *R. brelichi* is a larger bodied primate with an average body mass of 14.5 kg and 7.8 kg for adult males and females respectively (Kirkpatrick and Grueter, 2010). The high-frequency pitch of *R. brelichi* may have a useful bearing on furthering understanding of the relationship between body size or

vocal tract length and vocal parameters in mammals.

In addition, anthropogenic intervention may have a negative impact on survival of individuals, and bioacoustics that serves as indicators may be sensitive to these negative impacts. Thus, understanding the vocal behaviour of species, reducing negative impacts and developing new acoustic monitoring tools through acoustic information will contribute to the conservation of endangered species (Laiolo 2010). Since both species interact with people (mainly local people and tourists) frequently, the information on acoustic communication may provide a basis for a bioacoustic approach to species conservation. Threat calls may be a useful indicator to monitor the effect of human disturbance on the species. Future studies should continue to study the relationship between human disturbance and the emission of this call.

Human-Monkey Interactions

People's attitude towards wildlife has a complex psychological determining system. We provided several case studies employing mixed techniques to conduct research on this topic in conservation social science (Chapter 5 and 6). The costs and benefits of human-wildlife interactions have generally been considered to be one of the primary determinants of people's attitudes toward wildlife (Bennett 2016; Chan *et al.* 2007; Kansky and Knight 2014). In this study, both cases supported the significance of perceived cost and benefit in determining local attitudes toward the nonhuman primate. Not only individual costs or benefits but also a trade-off between cost and benefit are important factors explaininglocal attitudes toward nonhuman primates. Thus, a study focusing solely on costs or benefits may miss critical information in understanding people's attitudes towards species. This result is consistent with previous attitudinal studies toward protected areas (De Boer and Baquete1998; Allendorf *et al.*

2006; Allendorf 2007; Bennett 2016)

Meanwhile, my results demonstrated that the respondents' cost-benefit perceptions at household level are slightly negative while cost-benefit perceptions at community level are very positive in Qinglong village. According to our text analysis, we found that langur crop feeding is a major factor in explaining negative attitudes of local people toward langurs, while the impact of langurs on the development of local tourism has the most potential to shape local people's attitudes among those predictors at community level. This appeared to be a common pattern, although this point has not been examined quantitatively in previous studies (Khatun *et al.* 2012; McLennan and Hill 2013; Sousa *et al.* 2014; Hardwick *et al.* in press). It indicates that local people's attitudes towards this species are constructed through a multipleset of interactions. It may be useful for future conservation toexplore this common pattern through political-economic theory.

According to qualitative analysis, I also noticed that two interesting points merit further study. First, when wildlife can cause an intangible cost (i.e., invokea physical threat or a feeling of fear) for people, it can lead to a negative attitude toward these animals (Hockings*et al.* 2010; Jacobs 2009; Jacobs *et al.* 2012). This makes intangible costs the most important sub-category when explaining attitudes towards large mammals (Campbell-Smith *et al.* 2010; Kansky and Knight 2014). However, unlike in the case of local attitudes toward larger nonhuman primates or carnivores, respondents recognized all the cost-benefit sub-categories in relation to the langurs, excluding intangible costs, and these all influenced local attitudes toward the François' langurs. This implies that the relative importance of cost-benefit calculations in determining attitudes toward medium body-sized primate species

may vary from its importance in attitudes towardslarger body-sized primate or mammals. Thus, attitudinal studies on nonhuman primate species should be applied across a broad variety of species in future.

Second, the aesthetic value of François' langurs and Guizhou snub-nosed monkeys to local residents and the positive emotional connection between humans and species are rooted in local and traditional Chinese “goodness seeking” culture (Zhang 2015), the influence of which cannot be ignored in regard to people’s attitude towards species (Jacobs *et al.* 2012). However, the intangible benefits of species to human are not always consistent with the goals of wildlife conservation. It is worth noting that a positive emotional connection in a local cultural context such as “good playing with langurs” in MNNR case might have negative outcomes for langur conservation if managers are unable to provide positive instruction to local people.

In chapter 5, I used a method combining quantitative and qualitative analysis techniques to explore the main reasons behind and key predictors of local attitudestoward François' langurs. In chapter 6, grounded theory and open coding are used to analyse open-ended questions on local people’s knowledge of and attitude towards Guizhou snub-nosed monkeys, with additional comments from Likert scale statements. Since the social sciences can further understand and improve conservation (Bennette *et al.* 2017), these social or ethnoprimatological approaches can be applied to a diverse variety of theoretical research questions and applied to conservation/management programs in the future.

In addition, both studies (Chapter 5 and 6) indicated that the effect of socio-demographic factors on local people’s knowledge of and attitudes towards species might co-vary with cultural/historical context or experiences case by case. In FNNR case, we found

that there is a gendered difference in local knowledge of the Guizhou snub-nosed monkeys and FNNR. And local people's attitudes depended on the education levels of the respondents, although most local people are supportive toward the reserve and the Guizhou snub-nosed monkeys. In the case of MNNR, there are differences in local people's attitudes depending on the age or gender of the respondents. This reflects the results of previous studies (e.g., Bragagnolo *et al.* 2016).

Science Story Approach for Conservation Communication

Alongside this, I created a science story model to add a cultural dimension to enhance conservation efforts (Chapter 7). The cultural dimension is one of the most important determiners of the relationship between humans and wildlife (Chang 2001; Costa *et al.* 2013; Zhang 2015; Cui *et al.* 2012; this study). The role that such stories and literature can play in wildlife conservation is increasingly recognized by researchers and conservationists (Nijman and Nekaris 2017; Fernández-Llamazares and Cabeza 2017; this study). For instance, the release of the Harry Potter films and novels in Indonesia may have caused a rise in the trade of owls as pets, while promotion of indigenous storytelling can lead to enhanced understanding of diverse values and perceptions around biodiversity, which may offer a constructive approach for greater inclusion of indigenous peoples in conservation pursuits (Nijman and Nekaris 2017; Fernández-Llamazares and Cabeza 2017). Currently, most storytelling materials are based on the writer's traditional religious and cultural values, or simplified scientific language (White 1967; De Young1993a, 1993b; Christoph et al. 2014). For the former, as White (1967) realized,

there is a risk that these religious and cultural values may themselves be the historical roots of our ecological crisis; for the latter, the effectiveness of communication to the public is lower, leading to a huge gap between conservation research and conservation practice at present (Pace *et al.* 2010, Bickford *et al.* 2012). I tried to combine the advantages of scientific output and story (for example, funny) to create an innovative model to communicate with stakeholders about these species and their conservation. This model can transmit natural, social and cultural knowledge alongside the conservation message in a more effective or funny way, to improve the cognition of stakeholders in a specific case. This case could be extended to any primate species to bridge the current communication gap between scientists and other stakeholders and promote integrated conservation of endangered species. It might be a positive way to encourage a paradigm shift relating to the traditional cultural challenge of the biodiversity crisis in "post-Christian" society.

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Activities

Publications

1. Luke R. Thompson, Jon G. Sanders, Daniel McDonald, Amnon Amir, Joshua Ladau, Kenneth J. Locey, Robert J. Prill, Anupriya Tripathi, Sean M. Gibbons, Gail Ackermann, Jose A. Navas-Molina, Stefan Janssen, Evguenia Kopylova, Yoshiki Vázquez-Baeza, Antonio González, James T. Morton, Siavash Mirarab, Zhenjiang Zech Xu, Lingjing Jiang, Mohamed F. Haroon, Jad Kanbar, Qiyun Zhu, Se Jin Song, Tomasz Kosciolek, Nicholas A. Bokulich, Joshua Lefler, Colin J. Brislawn, Gregory Humphrey, Sarah M. Owens, Jarrad Hampton-Marcell, Donna Berg-Lyons, Valerie McKenzie, Noah Fierer, Jed A. Fuhrman, Aaron Clauset, Rick L. Stevens, Ashley Shade, Katherine S. Pollard, Kelly D. Goodwin, Janet K. Jansson, Jack A. Gilbert, Rob Knight, Jose L. Agosto Rivera, Lisa Al-Moosawi, John Alverdy, Katherine R. Amato, Jason Andras, Largus T. Angenent, Dionysios A. Antonopoulos, Amy Apprill, David Armitage, Kate Ballantine, Jir˘í Bárta, Julia K. Baum, Allison Berry, Ashish Bhatnagar, Monica Bhatnagar, Jennifer F. Biddle, Lucie Bittner, Bazartseren Boldgiv, Eric Bottos, Donal M. Boyer, Josephine Braun, William Brazelton, Francis Q. Brearley, Alexandra H. Campbell, J. Gregory Caporaso, Cesar Cardona, JoLynn Carroll, S. Craig Cary, Brenda B. Casper, Trevor C. Charles, Haiyan Chu, Danielle C. Claar, Robert G. Clark, Jonathan B. Clayton, Jose C. Clemente, Alyssa Cochran, Maureen L. Coleman, Gavin Collins, Rita R. Colwell, Mónica Contreras, Benjamin B. Crary, Simon Creer, Daniel A. Cristol, Byron C. Crump, Duoying Cui, Sarah E. Daly, Liliana Davalos, Russell D. Dawson, Jennifer Defazio, Frédéric Delsuc, Hebe M. Dionisi, Maria Gloria Dominguez-Bello, Robin Dowell, Eric A. Dubinsky, Peter O. Dunn, Danilo Ercolini, Robert E. Espinoza, Vanessa Ezenwa, Nathalie Fenner, Helen S. Findlay, Irma D. Fleming, Vincenzo Fogliano, Anna Forsman, Chris Freeman, Elliot S. Friedman, Giancarlo Galindo, Liza Garcia, Maria Alexandra Garcia-Amado, David Garshelis, Robin B. Gasser, Gunnar Gerdts, Molly K. Gibson, Isaac Gifford, Ryan T. Gill, Tugrul Giray, Antje Gittel, Peter Golyshin, Donglai Gong, Hans-Peter Grossart, Kristina Guyton, Sarah-Jane Haig, Vanessa Hale, Ross Stephen Hall, Steven J. Hallam, Kim M. Handley, Nur A. Hasan, Shane R. Haydon, Jonathan E. Hickman, Glida Hidalgo, Kirsten S. Hofmockel, Jeff Hooker, Stefan Hulth, Jenni Hultman, Embriette Hyde, Juan Diego Ibáñez-Álamo, Julie D. Jastrow, Aaron R. Jex, L. Scott Johnson, Eric R. Johnston, Stephen Joseph, Stephanie D. Jurburg, Diogo Jurelevicius, Anders Karlsson, Roger Karlsson, Seth Kauppinen, Colleen T. E. Kellogg, Suzanne J. Kennedy, Lee J. Kerkhof, Gary M. King, George W. Kling, Anson V. Koehler, Monika Krezalek, Jordan Kueneman, Regina Lamendella, Emily M. Landon, Kelly Lane-deGraaf, Julie LaRoche, Peter Larsen, Bonnie Laverock, Simon Lax, Miguel Lentino, Iris I. Levin, Pierre Liancourt, Wenju Liang, Alexandra M. Linz, David A. Lipson, Yongqin Liu, Manuel E. Lladser, Mariana Lozada, Catherine M. Spirito, Walter P. MacCormack, Aurora MacRae-Crerar, Magda Magris, Antonio M. Martín-Platero,

Manuel Martín-Vivaldi, L. Margarita Martínez, Manuel Martínez-Bueno, Ezequiel M. Marzinelli, Olivia U. Mason, Gregory D. Mayer, Jamie M. McDevitt-Irwin, James E. McDonald, Krista L. McGuire, Katherine D. McMahon, Ryan McMinds, Mónica Medina, Joseph R. Mendelson, Jessica L. Metcalf, Folker Meyer, Fabian Michelangeli, Kim Miller, David A. Mills, Jeremiah Minich, Stefano Mocali, Lucas Moitinho-Silva, Anni Moore, Rachael M. Morgan-Kiss, Paul Munroe, David Myrold, Josh D. Neufeld, Yingying Ni, Graeme W. Nicol, Shaun Nielsen, Jozef I. Nissimov, **Kefeng Niu**, Matthew J. Nolan, Karen Noyce, Sarah L. O'Brien, Noriko Okamoto, Ludovic Orlando, Yadira Ortiz Castellano, Olayinka Osuolale, Wyatt Oswald, Jacob Parnell, Juan M. Peralta-Sánchez, Peter Petraitis, Catherine Pfister, Elizabeth Pilon-Smits, Paola Piombino, Stephen B. Pointing, F. Joseph Pollock, Caitlin Potter, Bharath Prithiviraj, Christopher Quince, Asha Rani, Ravi Ranjan, Subramanya Rao, Andrew P. Rees, Miles Richardson, Ulf Riebesell, Carol Robinson, Karl J. Rockne, Selena Marie Rodriguezl, Forest Rohwer, Wayne Roundstone, Rebecca J. Safran, Naseer Sangwan, Virginia Sanz, Matthew Schrenk, Mark D. Schrenzel, Nicole M. Scott, Rita L. Seger, Andaine Seguin-Orlando, Lucy Seldin, Lauren M. Seyler, Baddr Shakhsheer, Gabriela M. Sheets, Congcong Shen, Yu Shi, Hakdong Shin, Benjamin D. Shogan, Dave Shutler, Jeffrey Siegel, Steve Simmons, Sara Sjöling, Daniel P. Smith, Juan J. Soler, Martin Sperling, Peter D. Steinberg, Brent Stephens, Melita A. Stevens, Safiyh Taghavi, Vera Tai, Karen Tait, Chia L. Tan, Neslihan Tas¸, D. Lee Taylor, Torsten Thomas, Ina Timling, Benjamin L. Turner, Tim Urich, Luke K. Ursell, Daniel van der Lelie, William Van Treuren, Lukas van Zwieten, Daniela Vargas-Robles, Rebecca Vega Thurber, Paola Vitaglione, Donald A. Walker, William A. Walters, Shi Wang, Tao Wang, Tom Weaver, Nicole S. Webster, Beck Wehrle, Pamela Weisenhorn, Sophie Weiss, Jeffrey J. Werner, Kristin West, Andrew Whitehead, Susan R. Whitehead, Linda A. Whittingham, Eske Willerslev, Allison E. Williams, Stephen A. Wood, Douglas C. Woodhams, Yeqin Yang, Jesse Zaneveld, Iratxe Zarraonaindia, Qikun Zhang, Hongxia Zhao. (2017). A communal catalogue reveals Earth's multiscale microbial diversity, ***Nature***, doi: 10.1038/nature24621.

2. Wang H., Xiao Z., Yu B., Riondato I., Zhang P., Yan X., **Niu K.** (2017). Soil-eating behaviour by Francois' langurs in Mayanghe National Nature Reserve, China. in Gou G., Xie S., Wei L. Bioversity research in Mayanghe National Nature Reserve (2017), Guiyang: Guizhou Science and Technology Press, pp512-514

3. Wang B., **Niu K.**, Li W., Wang H., Xiao Z., Zou Q., Tan C.L., Gamba M., Giacoma C., Yang Y. (2017) Group size and structure of the François′ Langurs(Trachypithecus francoisi) in Mayanghe National Nature Reserve, China. in Gou G., Xie S., Wei L. Bioversity research in Mayanghe National Nature Reserve (2017), Guiyang: Guizhou Science and Technology Press, pp506-511.

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9. Tapley, B., Turvey, S.T., Chen, S., Redbond, J., Okada, S., Lv, J., Wei, G., Wu, M., Pan, Y., **Niu, K.**, Cunningham, A.A. (2015). Failure to detect the Chinese giant salamander (*Andrias davidianus*) in Fanjingshan National Nature Reserve, Guizhou Province. ***Salamander***, 51 (2): 206 -208.
10. **Niu K.**, Xiao Z, Wang B., Yang D., Tan Chia L., Zhang P., Yan X., Wang H., Yu B., Yang T., Fan J., Cui D., Zou Q., Wu A., Wei L., Zou H., Gamba M., Giacoma C., Yang Y. (2016) Population Estimates and Distribution of François' Langurs (*Trachypithecus francoisi*) in Mayanghe National Nature Reserve, China. ***Chinese Journal of Zoology***, *51*(6):925-938.
11. **Niu, K.**, Tan C.L., Cui D., Chen Shu, Shi L. (2015) Author and Editor, BOOK ***Xingda's Wildlife Explorations***. Guiyang: Guizhou Science and Technology Press. Also, this book was reprinted in the Young Pioneers' Weekly. Third Prize of Science and Technical books of Western China.
12. **Niu, K.**, Tan C.L., Cui, D., Chen, S. et al. (2015). Creating Wildlife Exploration Stories to Promote Conservation of the Endangered Guizhou Snub-nosed Monkey in Fanjingshan National Nature Reserve, China. The 6th European Federation for Primatology Meeting and XXII Italian Association of Primatology Congress, Rome, Italy. Abstract, ***Folia Primatol***, *86*:330.
13. Riondato I., **Niu K.**, Gamba M., Yang Y., Giacoma C. (2015). Can Their Sounds Find a Way? Primate Calls and Environmental Noise in China. The 6th European Federation for Primatology Meeting and XXII Italian Association of Primatology Congress, Rome, Italy. Abstract, ***Folia Primatol***, *86*:347.

In Submission:

14. **Niu K.**, et al. A quantitative analysis of the vocal behaviour of the François' langur (*Trachypitecus francoisi*) at the Mayanghe National Nature Reserve, China. ***American Journal of Primatology***, in submission
15. **Niu K.**, et al. Exploring Local Attitudes and Perception toward Endangered François' langurs in Mayanghe National Nature Reserve, China. ***International Journal of Primatology***, in submission

Congress, Awards & Grants

1. 2017 MAB Youth Forum, 18-23 September 2017. Organized by UNESCO and Po Delta Biosphere Reserve.

2. "*Local people's knowledge of and attitudes towards the endangered Francois' Langur in human modified habitat, China.*" Beijing Forum (SCCS) 2016, Supported by University of Turin and Peking University. in Beijing, China.

3. "*Linking Wildlife Conservation with Cultural Ecosystem Services through Conservation Education in Biosphere Reserves: A Case of Fanjingshan Biosphere Reserve in China*". Presented at the 4th World Congress of Biosphere Reserve, by UNESCO and Environmental Department of Peru, Lima, Peru, March 2016.

4. "*Creating Wildlife Exploration Stories to Promote Conservation of theEndangered Guizhou Snub-Nosed Monkey in Fanjingshan National Nature Reserve, China*". 6th European Federation for Primatology Meeting. Rome, Italy, August 25-28, 2015.

5. "*Local People's Knowledge of and Attitudes towards the Endangered Francois' Langur in Mayanghe National Nature Reserve, China*". Presented at the 6th National Congress of Zoology in Italy. Verona, Italy, October, 2015.

6. October, 2016, Xingda's Wildlife Exploration in Fanjingshan was awarded asThird Prize of Science and Technical Books of Western China.

7. July, 2016. Excellent prize, Chinese nature reserves 60 anniversary photo competitions

8. 2016-2018, Principle investigator: Primate Conservation, Incorporated, USA (No. PCI #1394)

9. UNI.COO project (No. 27164), 2015-2016: Cooperation, Education and Communication for Primate Conservation in China. University of Turin.

10. 2014-2015, Principle investigator: Guizhou Wildlife Preservation Project, FCO Strategic Programme Fund and Bilateral Programme Fund, British Consulate General Chongqing.

11. Travel Support from British Consulate-General, UK, Wildlife Trade and Conservation Event: Meet HRH Prince William (UK) and present the wildlife conservation storybook (*Xingda's Wildlife Exploration in Fanjingshan*) to HRH Prince William at Xishuangbanna, China

12. Wild China Photography training workshop, a part of support by Xi Zhinong and Wild China.

Summary

First of all, my study has provided first-hand data on the population size and distribution of François' langurs in MNNR. It has provided key basic information for conservation of the largest population of François' langurs. Moreover, for the first time we quantified the acoustic diversity of two Asian Colobines in China. We identified nine vocal types in *R. brelichi* and nine vocal call types in *T. Françoisi*using quantitative analysis techniques (ANNs and DFA). Since the two species are interacting with people (mainly local people and tourists) frequently, the information on acoustic communication may provide a basis for a bioacoustic approach to species conservation. Meanwhile, we recorded an unexpected high-frequency signal in *R. brelichi* and completed the first quantitative study on the vocal repertoire and related contexts of François' langurs in the wild, which is an important contribution to understanding of the vocal adaption of Asian leaf-eating monkeys. Thirdly, we demonstrated the dual importance of perceived cost and benefit in determining local attitudes towards primates using mixed techniques in MNNR and FNNR. This indicated that a sole focus on costs or benefits may miss critical information necessary for understanding people'sattitudes toward species. Meanwhile, we discovered that the effect of socio-demographic factors on local knowledge of and attitude towards species might co-vary with the cultural/historical context or experiences case by case. Thus, we suggest that attitudinal studies on each nonhuman primate species in particular contexts are needed in the future, and efforts to strengthen human-langur relations should be periodically conducted in protected areas like MNNR and FNNR, especially in the context of fast economic and infrastructure development. Finally, my case

demonstrated that it is feasible to protect species through the creation of scientific stories (or semi-virtual: based on science knowledge of species but including a fictional figure), which may be a good model of conservationinformation exchange. This approach is very practical for changing or forming a regional wildlife culture and promoting the protection of animals in a certain area.

Overall, my work provided a cross-disciplinary case with the potential to enhance the integrated conservation of two leaf-eating monkeys in China. We applied a coupled human and natural systems approach for ourresearch on nonhuman primate species in socio-ecological systems, while using a science story model to communicate with stakeholders about these species and their conservation in a more effective or funny way. It is an innovative and useful synthesis for integrated conservation of endangered species in socio-ecological systems.