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Authors: Wang, Haohan, Xu, Huiming, Li, Yanpeng, Xu, Zeming, Ding, Wei, et al.

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New distribution records for the endangered black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) in Yunnan, China

Haohan WANG[1,2,3], Huiming XU[3,4], Yanpeng LI[2,3], Zeming XU[5], Wei DING[6], Wen XIAO[2,3]* and Hui YE[1]*

[1] *College of Life Sciences, Yunnan University, Kunming, Yunnan 650091, China; e-mail: yehui@ynu.edu.cn*
[2] *Institute of Eastern-Himalaya Biodiversity Research, Dali University, Dali, Yunnan 671003, China; e-mail: xiaow@eastern-himalaya.cn*
[3] *Collaborative Innovation Center for Biodiversity and Conservation in the Three Parallel Rivers Region of China, Dali, Yunnan 671003, China*
[4] *Bureau of Tianchi National Nature Reserve, Yunlong, Dali 672700, China*
[5] *School of Life and Geography Sciences, Qinghai Normal University, Xining, Qinghai 810008, China*
[6] *Yunnan-Guizhou Plateau Institute of Biodiversity, Qujing Normal University, Qujing, Yunnan 655011, China*

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Abstract. Black-and-white snub-nosed monkey (*Rhinopithecus bieti*) is an IUCN-Endangered primate endemic to China. There are currently 15 groups separated into five units based on genetic and geographic character analysis. Among these, the southern groups being on the species' most marginal distribution is the most susceptible to extinct in the near future due to most forest fragmentation and human activities. To determine the population dynamics and conversation needs in the southern unit, we conducted interviews and investigation-based interviews in Yunlong and Lanping Counties from December 2013 to February 2018. A new group contains approximately > 10 members, Tianchi group, was found in Tianchi National Nature Reserve and a known group with approximately > 20 *R. bieti* individuals, Heishan group, which had historically disappeared, was rediscovered in Yunling National Nature Reserve in the southern unit. As a consequence of this survey, the number of groups in the southern unit has increased from three to five, and the total groups has increased from 15 to 17, and the Tianchi group has become the southernmost group and totally isolated group with irreplaceable conservation value. These results indicate that *R. bieti* groups in the species' southern distribution range may be undergoing recovery and that nature reserves are playing a critical role in conservation efforts. However, small group size, highly fragmented habitats, and marginal distribution in reserves mean that these two groups are still vulnerable to extinction. We accordingly make recommendations and propose management policies for their protection: the Chinese government should commit to protect the new groups by funding academic research and conservation; the reserves, conservationists, and NGOs should take appropriate actions to ensure the establishment of long-term survey and monitoring programs.

Key words: recover, fragmented habitat, southernmost range, 3D map-based interview survey

Introduction

Black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) are categorized as Endangered in the IUCN Red List and are First-class State Protection animals in China (Xiang et al. 2007, IUCN 2017). This species is endemic to China and has the highest altitudinal distribution range (> 4000 m) among all non-human primates (Long et al. 1994, Xiao et al. 2003). Prior to this study, there were 15 known groups comprising approximately 2500 individuals distributed in a narrow area between the River Mekong and Yangtze (98°37′-98°59′ E, 26°14′-29°40′ N) (Jin & Long 2010). The northernmost group is the Zhina group in Mangkang County, Tibet (29°40′ N) and the southernmost group is located in Mt. Longma region at the junction of Lanping and Yunlong Counties in Yunnan (Long et al. 1994). Within its overall distribution range, the remaining groups of *R. bieti* has been separated into five units for conservation purposes based on genetic and geographic character analysis: the northwestern, northern, central, southeastern and southern units (Liu et al. 2015) (Table 1 and Fig. 1).

Historical records show that the southernmost margin of the *R. bieti's* distribution range was Fengqing County in Yunnan Province in 1904 (Qing Dynasty), which indicates that the distribution range has contracted by

* *Corresponding Author*

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Table 1. The demographics information of the 17 groups of *Rhinopithecus bieti*.

No.	Group name	Group size	Geographical units	Reference
G1	Zhina	ca 50	northwestern	Xiang et al. 2007
G2	Xiaochangdu	> 210	northwestern	Xiang et al. 2007
G3	Milaka	ca 50	northwestern	Xiang et al. 2007
G4	Baime	> 60	northwestern	Cui et al. 2008
G5	Nanren	> 185	northern	Cui et al. 2008
G6	Yiyong	< 50	central	Long et al. 1996
G7	Cikatong	< 150	central	Long et al. 1996
G8	Shiba	ca 200	central	Wan et al. 2013
G9	Xiangguqing	> 450	central	Li et al. 2010
G10	Samage	> 400	central	Grueter et al. 2017
G11	Jinsichang	170-180	southeastern	Ren et al. 2009
G12	Dapingzi	< 50	southeastern	Long et al. 1996
G13	Fuhe	80	southern	Liu & Zhao 2004
G14	Lasha	130	southern	Li et al. 2014
G15	Longma	127	southern	Xu et al. 2015
G16	Tianchi	> 10	southern	This study
G17	Heishan	> 20	southern	This study

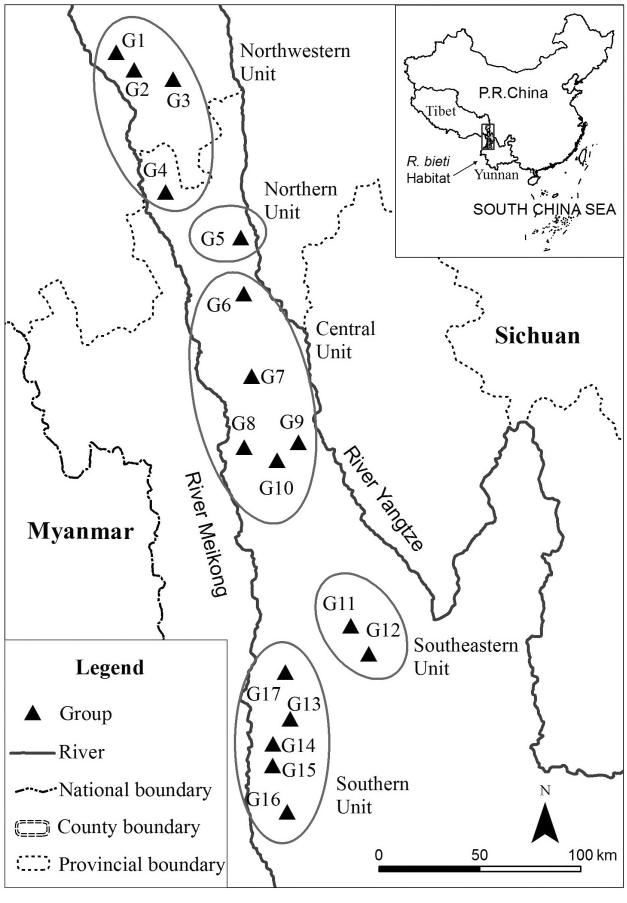


Fig. 1. Distribution of five separated units of all groups of *Rhinopitheucs bieti*.

one-third over the past 100 years, principally due to human disturbance (Li et al. 2002). Establishment of nature reserves as an *in situ* conservation strategy is considered the most effective approach for protecting rare species and local biodiversity (Li et al. 2016), and several nature reserves have been established in Yunnan and Tibet since 1983 to protect this endangered primate. In response, the group size of some *R. bieti* groups have shown an increase in past years, such as Lasha and Longma groups in southern unit, the group size has increased from 50 to 130 during 1988 and 2004, and from 50 to 127 during 1988 and 2015, respectively (Long et al. 1994, Li et al. 2014, Xu et al. 2015, Huang et al. 2017). However, in the monkeys' southernmost distribution range, the high-quality habitats are currently limited in size, highly fragmented, and disturbed by urbanization, roads, grazing, farmland and firewood collection of local people (Clauzel et al. 2015, Li et al. 2015, Li et al. 2017). Habitat loss and group isolation may prevent gene exchange between groups in the southern unit, making them highly vulnerable to extinction due to environment change (Xiao et al. 2003, Liu et al. 2009). Accordingly, there is a necessity to determine the population dynamics and conversation needs in the southern unit, in order to be able to propose suitable conversation measures for urgent protection. Interview-based surveys can cost-effectively and promptly evaluate the population status and distribution of rare and poorly known large animals, particularly in the case of primates such as *R.*

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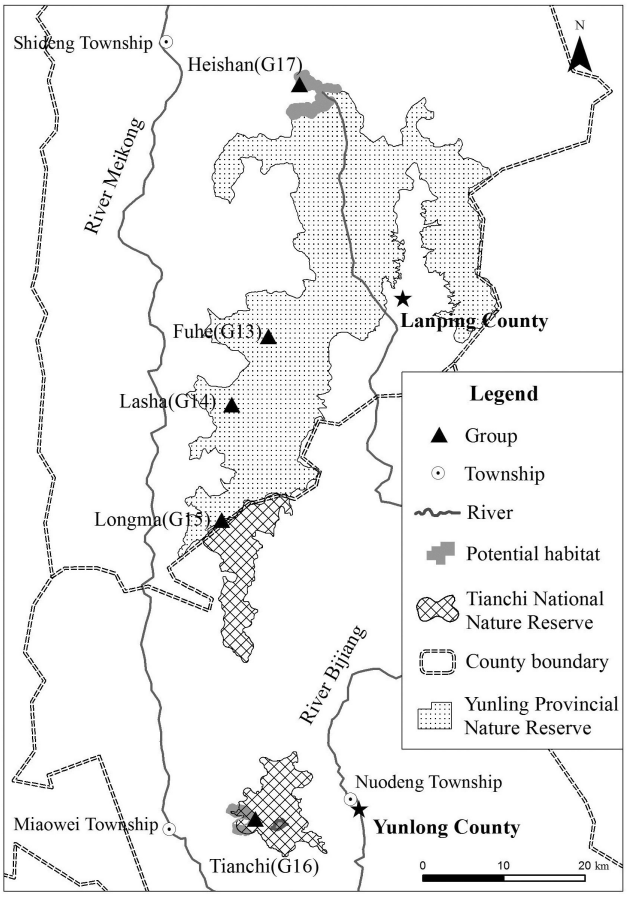


Fig. 2. The study area and five groups in the southern units (two new groups).

bieti that have a distinctive appearance (Ma et al. 2014, Cui et al. 2015, Turvey et al. 2015, Ren et al. 2017). In this study, during the period from October 2013 to November 2015, we therefore conducted interviews and field investigation-based interviews on the southern unit of *R. bieti* in Yunlong and Lanping Counties.

Material and Methods

Interview surveys

During the period from December 2013 to December 2015, we visited 54 villages near the high-altitude forests and interviewed 381 villagers who frequently entered the forests in Shideng and Lajing townships in Lanping County (72 interviewees in 11 villages) and in Miaowei and Nuodeng townships in Yunlong County (309 interviewees in 43 villages) (Fig. 2).

We interviewed people in local villages who entered the forests frequently or hunters. First, we asked interviewees to describe the characteristics of monkeys that they have observed, and showed them photos of 15 primates in Yunnan to let them identify the species. Furthermore, we asked interviewees to identify locations of monkeys on a three-dimensional map of the local terrain and mapped it on Google Earth. Finally, other information such as number of individuals and forest type of sightings was also recorded in questionnaire as much as possible (Ma et al. 2014) (Table S1).

Field investigation

We selected forests for field search according to the locations provided by interviewees and used walking transects of 5 m wide and 50 m interval to search for monkeys in Heishan area and Tianchi area during October 2015 to December 2015 (28 days) and October 2014 to October 2015 (10 days per month, 120 days), respectively. We collected feces that were assumed to be of *R. bieti* origin and recorded locations. Collected feces samples were examined by primatologists through the appearance and residual lichens within the feces.

We searched three sites and five sites with high potential in Heishan area and Tianchi area based on locations of traces and feces, respectively. We set up 3-5 camera traps on canopy in each site that could search for monkeys along passable ways in different directions. Ten camera traps (Ltl-Acorn 6210MC) in Heishan area and twenty in Tianchi area during October 2015 to March 2016 and October 2014 to February 2018, respectively. We checked cameras every three months to replace SD cards or batteries as necessary.

Table 2. Basic information of *Rhinopithecus bieti* in Heishan and Tianchi area.

Information	Heishan	Tianchi
Group size	> 20	> 10
Nearest *R. bieti* group (distance)	Fuhe group (25 km)	Longma group (40 km)
Patches size of fragmentation habitat	2.48 km^2, 2.20 km^2, 1.98 km^2 and 0.87 km^2	1.24 km^2 and 1.58 km^2
Number of corridors	3	2
Nearest village (distance)	Lvzhuping (1.3 km)	Batou (0.7 km)
Habitat isolated by	Village, mining area, road, temporary livestock shed and meadows	Village, road, meadow, burned area and farmland

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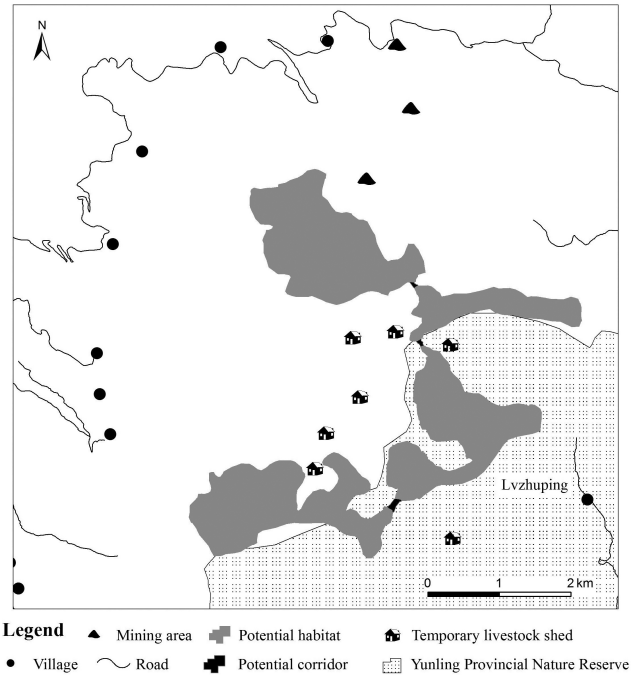


Fig. 3. Status of habitat condition of *Rhinopithecus bieti* in Heishan.

Data analysis

The group size is a range value be determined by minimum individuals from interview records. On the basis of the location of living traces, feces, and camera trap records, we evaluated the habitat ranges of *R. bieti* using ArcGIS 10.0 software (Liu & Zhao 2004, Cui et al. 2010, Xiang et al. 2015).

Results

Rediscovery of the Heishan group

On the basis of interviews, we obtained valid information on group size in 9 instances and distribution in 13 instances, as well as information on the location of two feeding trails and one *R. bieti* feces sample at Mt. Heishan (Table S2). From interviews and trace information, we estimated that approximately > 20 *R. bieti* individuals inhabit the Mt. Heishan area (Table 1 and 2).

This group inhabits the northernmost part of the Yunling Provincial Nature Reserve (YPNR), and is isolated from the Mt. Fuhe group, which is located in an area approximately 25 km away (Fig. 3). We call this group the "Heishan group". The habitat range of the Heishan group habitat consists of four forest patches of 2.48 km^2, 2.20 km^2, 1.98 km^2 and 0.87 km^2 in size, respectively, which are connected by three corridors (Fig. 3). The inhabited areas have been isolated by the surrounding villages, mining areas, and roads. Lvzhuping village is the nearest village of Heishan group, is only 1.3 km away (Table 2).

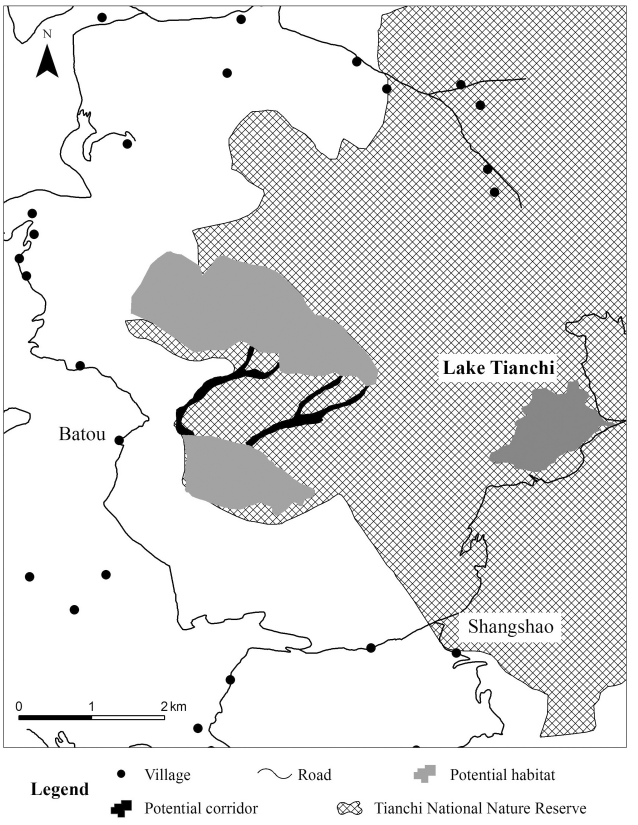


Fig. 4. Status of habitat condition of *Rhinopithecus bieti* in Tianchi.

But also, the inhabited areas further fragmented by the construction of temporary livestock sheds and expansion of areas of alpine meadows.

Discovery of the Tianchi group

We obtained 18 instances on group size and 25 instances on distribution, based on interview surveys, as well as further information on three living traces and four feces samples. In addition, camera traps set up in the Tianchi area provided direct evidence of the presence of monkeys on 15 occasions (Table S2). Furthermore, on May 7, 2015 an injured adult male *R. bieti* was rescued by reserve personnel from Shangshao village nearby the Tianchi area, and maintained in the Tianchi National Nature Reserve (TNNR) (Fig. 4 and Fig. S1). We also heard *R. bieti* vocalizations on August 11, 2015, observed three individuals (one infant and two juveniles) on September 15, 2015, the monkey saw us and escaped quickly, and discovered the corpse of a male *R. bieti* on January 16, 2018 in the same area (Fig. S1). On the basis of a comprehensive analysis of all information obtained, we confirmed that this *R. bieti* group contains approximately > 10 members (Table 1 and 2).

The Tianchi group inhabits the southwestern edge of the TNNR, which is approximately 3 km west of Lake

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Tianchi (Fig. 4), and approximately 40 km south of the Longma group. These two groups are isolated by 5-m-wide roads and villages (Fig. 4). We estimated that the habitat of the Tianchi group is only 3.23 km^2 in extent and comprises two forest patches (1.24 km^2 and 1.58 km^2) linked by two corridors (Fig. 4). The habitat of the Tianchi group is also surrounded by villages and roads. The nearest village, Batou, is only 0.7 km distant (Fig. 4). Furthermore, the forest here has been fragmented by the creation of meadows and burned area, and by slash-and-burn agricultural practices (Table 2).

Discussion

As a consequence of our survey, the total number of known *R. bieti* groups in the southern unit has increased from three to five, and the total groups has increased from 15 to 17. The two new records of *R. bieti* distribution can be used as a basis for further studies on *R. bieti*, and will provide important information for planning a conservation network and creation of corridors between the groups of the southern unit, as well as for formulating measures to protect their genetic diversity in the future.

Long et al. (1994) reported that a *R. bieti* group inhabited the Mt. Heishan area prior to 1980 based on interviews; however, later surveys suggested that this group had vanished from the area (Ding 2003, Huo 2005, Liu et al. 2009). The rediscovery of the Heishan group in this survey highlights to need to further study this group in order to restore this extremely small group of *R. bieti* in its fragmented habitat. Zeng et al. (1981) reported a *R. bieti* group inhabiting an area southeast of Lake Tianchi prior to 1976 based on interviews and obtained samples of *R. bieti* leather from a villager living near the lake. However, later surveys failed to detect any evidence of *R. bieti* in this area subsequent to the establishment of the TNNR in 1983. However, we have now confirmed the presence of a new *R. bieti* group to the west of Lake Tianchi. This marginal group has the smallest group size and the smallest habitat range among all the currently known groups of *R. bieti*, and thus must be considered vulnerable to extinction (Long et al. 1994, Huo 2005, Jin & Long 2010). Given that the Tianchi group is the southernmost group of *R. bieti* and inhabits an extreme habitat (the lowest elevation and southernmost distribution), and accordingly it will be important in the study of behaviour and ecology of the Tianchi group.

Although we presume that the two discovered *R. bieti* groups were on the verge of extinction in the 1980s because of hunting and habitat destruction, the remaining individuals and habitats have been protected since the establishment of the TNNR and YPNR, and group numbers of the two groups may currently be recovering. Our findings accordingly indicate that nature reserves can play a vital and irreplaceable role in the conservation and restoration of wildlife (Fabricius et al. 2010, Armsworth et al. 2011). Nevertheless, most of the available habitats for the two groups are located near to the boundaries of the nature reserves, which are areas of frequent human activity and adjacent to areas where large expanses of forest have been destroyed in the wake farmland and alpine meadow expansion (Xiao et al. 2003, Li et al. 2015). Although these two *R. bieti* groups can respond to human disturbance and habitat destruction by avoiding disturbance, becoming habituated to some disturbance, and adapting to a specializing diet (Huang et al. 2017), occasional migration and gene exchange between groups might have been prevented due to the isolated nature of the fragmented habitats, and given the small group sizes, they are considered to be very vulnerable to extinction due to future environmental change. Moreover, monkeys quickly escape in response to the researchers, which indicates that monkeys are frequently disturbed by human activities and the current habitat quality may be far from optimal. All these gives rise to concerns that their survival status is in jeopardy.

We hope that the findings of the present will provide a necessary stimulus promote future protection of this species. This study should alert the Chinese government of the necessity to protect the new groups by funding academic research and conservation. As individuals in small group are difficult to record visually (Grueter et al. 2017), monitoring of the populations and ecological behaviour for these two new groups will be a long process. We hope that the TNNR and YPNR, conservationists, and NGOs will take appropriate actions to ensure the establishment long-term survey and monitoring programs. We believe that conservation network planning, formulating cooperative conservation measures, habitat assessment and protection (Nüchel et al. 2018), and corridor construction in the TNNR and YPNR will play important roles in the conservation of the southern unit of the black and white snub-nosed monkeys and the protection of biodiversity in one of the world's most biodiverse areas, the Three Rivers Parallel Area (Mittermeier et al. 2011).

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Supplementary online material

Table S1. The example of the questionnaire for primates.

Table S2. Information on the living traces, feces, and visual data obtained in this study.

Fig. S1. Visual evidence of *Rhinopithecus bieti* in the Tianchi group. a) *R. bieti's* feces found in Tianchi area (27 January 2015); b) *R. bieti* captured by camera-trap in Tianchi area (24 September 2015); c) injured male *R. bieti* rescued in Tianchi area and housed in Tianchi National Nature Reserve; d) *R. bieti's* corpse found in Tianchi area (16 January 2018) (https://www.ivb.cz/wp-content/uploads/FZ-vol.-68-2-2019-Wang-et-al.-Table-S1-S2-Fig.-S1.pdf).

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