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Volume 36, Issue 3 18 May 2015

CONTENTS

Editorial

A reflection on the significant findings published in *Zoological Research* over the past 35 years

..... Yong-Gang YAO, Yun ZHANG (117)

Articles

New observations - with older ones reviewed - on mass migrations in millipedes based on a recent outbreak on Hachijojima (Izu Islands) of the polydesmid diplopod (*Chamberlinius hualienensis*, Wang 1956): Nothing appears to make much sense..... Victor Benno MEYER-ROCHOW (119)

Molecular characterization of an *IL-1 β* gene from the large yellow croaker (*Larimichthys crocea*) and its effect on fish defense against *Vibrio alginolyticus* infection

..... Jun WU, Yu-Hong SHI, Xue-Heng ZHANG, Chang-Hong LI, Ming-Yun LI, Jiong CHEN (133)

Selective recruitment of host factors by HSV-1 replication centers..... Feng-Chao LANG, Xin LI, Olga VLADMIROVA, Zhuo-Ran LI, Gui-Jun CHEN, Yu XIAO, Li-Hong LI, Dan-Feng LU, Hong-Bo HAN, Ju-Min ZHOU (142)

Reports

Social organization of Shortridge's capped langur (*Trachypithecus shortridgei*) at the Dulongjiang Valley in Yunnan, China..... Ying-Chun LI, Feng Liu, Xiao-Yang HE, Chi MA, Jun SUN, Dong-Hui LI, Wen XIAO, Liang-Wei CUI (152)

Establishment of HIV-1 model cell line GHOST(3) with stable DRIP78 and NHERF1 knockdown

..... Lin ZHANG, Xu-He HUANG, Ping-Ping ZHOU, Guo-Long YU, Jin YAN, Bing QIN, Xin-Ge YAN, Li-Mei DIAO, Peng LIN, Yi-Qun KUANG (161)

Autophagy prevents autophagic cell death in *Tetrahymena* in response to oxidative stress

..... Si-Wei ZHANG, Jiang-Nan FENG, Yi CAO, Li-Ping MENG, Shu-Lin WANG (167)

Purification and characterization of cholecystokinin from the skin of salamander *Tylototriton verrucosus*

..... Wen-Bin JIANG, Ma HAKIM, Lei LUO, Bo-Wen LI, Shi-Long YANG, Yu-Zhu SONG, Ren LAI, Qiu-Min LU (174)

Note

New Record of *Lycodon liuchengchaoi* in Anhui

..... Liang ZHANG, Li-Fang PENG, Lei YU, Zheng-Ping WANG, Li-Qun HUANG, Song HUANG (178)

Social organization of Shortridge's capped langur (*Trachypithecus shortridgei*) at the Dulongjiang Valley in Yunnan, China

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ABSTRACT

Non-human primates often live in socially stable groups characterized by bonded relationships among individuals. Social organization can be used to evaluate living conditions and expansion potential. Bisexual group size, ratio of males to females and group composition are essential elements determining the type of social organization. Although the first report on Shortridge's capped langurs (*Trachypithecus shortridgei*) was in the 1970s, until now, the species only inhabits forests of the Dulongjiang valley in northwest Yunnan, China, with c. 250-370 individuals in 19 populations. To understand its social organization, we collected data from five groups of Shortridge's langurs at Silaluo in the Dulongjiang valley during August 2012-October 2013. Family groups consist of one adult male, 2-3 adult females and up to five young. Group size averaged 8 (7-9) individuals. The ratio of adult males to females (M/F) was 1:2.9, infants to adult females was (I/F) 1:2.2; and ratio of adults to immatures was 1:1.2, indicating the potential of a population increasing. Birth season was during March-July and the inter-birth interval was two years.

Keywords: *Trachypithecus shortridgei*; Social organization; One-male, multi-female group; Multi-male, multi-female group; Group size

INTRODUCTION

Social organization, including group size, sexual composition and bonded relationships among individuals (Kappeler & van Schaik, 2002), is the most basic characterization of non-human primate societies (Clutton-Brock & Harvey, 1977; Crook & Gartlan, 1966; Eisenberg et al, 1972). Three fundamental types of social

organization can be categorized into solitary, pair-living and group-living species (Kappeler & van Schaik 2002). Solitary individuals typically forage alone (Boinski & Garber, 2000) and their activities are desynchronized with each other both spatially and temporally (Charles-Dominique, 1978). Except for orangutan, most solitary primate species are nocturnal (Kappeler & van Schaik, 2002). Pair-living species refer to couples of one adult male and one adult female (Kappeler, 1999), such as gibbons. Most primates live in bisexual groups (van Schaik & Kappeler, 1997), which are much more stable compared with other mammals, and consist of more than two adults. Group living primates displayed a diversity with respect to the size, sex ratio and temporal stability of composition. Accordingly, polyandrous, polygynous and multi-male, multi-female groups (MMGs) have been distinguished (Kappeler, 2000). Variation in the number of adult males is the most prominent feature of primate group composition (Hamilton & Bulger, 1992; Preuschoft & Paul, 2000; van Hooff, 2000), and can thus be categorized as one-male, multi-female groups (OMGs) or MMGs. The number of adult males in each bisexual group related to the predatory pressure (van Schaik & Hörstermann, 1994), is positively associated with the number of adult females (Mitani et al, 1996) and temporal overlap of female receptive periods (Nunn, 1999).

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Group size is another vital feature of the social organization of group living primates, and may be influenced by birth rate, mortality rate and the transfer of individuals (Kappeler & van Schaik, 2002). Significant variations can be found in colobine species, e.g., group size in Mentawai langurs (*Presbytis potenziani*) is less than four, whereas, golden snub-nosed monkeys (*Rhinopithecus roxellana*) can include approximately 400 individuals (Grueter, 2013; Newton & Dunbar, 1994). Social organization of langurs includes monogamy, such as found in Mentawai langurs (*P. potenziani*); matrilineal-harem, such as seen in Sumatran surilis (*P. melalophos*), maroon leaf monkeys (*P. rubicunda*), Nilgiri langurs (*Trachypithecus johnii*), Gee's golden langurs (*T. geei*), capped langurs (*T. pileatus*), dusky leaf monkeys (*T. obscurus*), proboscis monkeys (*Nasalis larvatus*), and Northern plains gray langurs (*Semnopithecus entellus*) at Abu and Jodhpur; matrilineal-multimale, such as observed in Northern plains gray langurs (*S. entellus*) at Orcha and Rajaji; and patrilineal-multimale, such as found in black-and-white colobus (*Colobus polykomos*), olive colobus (*Procolobus verus*) and western red colobus (*P. badius*) monkeys. However, the most typical social organization is the one-male, multi-female unit (OMU). A large population can be composed of several OMUs, and one or several all-male units (AMUs) (Cui et al, 2008; Grueter, 2013; Kirkpatrick, 1996; Li et al, 2014; Newton & Dunbar, 1994; Qi et al, 2009, 2014).

Group size of *Trachypithecus* species can range from a dozen to approximately 100, and their social organization includes OMGs and MMGs (Koenig & Borries, 2012; Fan et al, 2014). Bisexual groups of white-headed langurs (*T. leucocephalus*) are composed dominantly of OMGs, occasionally of MMGs (9.1%, $n=11$), with 3-30 individuals in each group. Non-breeding individuals can live solitarily or in groups (Jin et al, 2009; Li & Rogers, 2004). Non-breeding groups are either AMUs or include males (82.6%) and juvenile females (17.4%) (Jin et al, 2009). A bisexual group usually lives in an OMG with 6-12 individuals in François' langurs (*T. francoisi*) (Hu et al, 2011; Zhou et al, 2009). Bisexual groups of Delacour's langurs (*T. delacouri*) mostly live mostly in OMGs, and occasionally in two-male, multi-female groups (TMGs), with 5-30 individuals in each group (Harding, 2011). Golden langur (*T. geei*) groups, which inhabit the rubber forests of Assam in India, usually consist of 7-26 (17.3 on average) individuals. Among three observed groups, two were TMGs with 19 and 26 individuals, respectively, and one was an OMG with only seven individuals (Medhi et al, 2004). Silvered langur (*T. cristatus*) groups consist of 7-40 individuals (Timmins et al, 2013), one OMG includes seven individuals (Boonratana, 1998). Small OMGs and occasionally MMGs have been found in capped langurs (*T. pileatus*) (Green, 1981; Mukherjee, 1978; Mukherjee et al, 1995; Stanford, 1991). Most Phayre's leaf monkeys (*T. phayrei*) form bisexual groups (Bose, 2003; Koenig & Borries, 2012; Mukherjee, 1982) or AMUs (Mukherjee, 1982). Each group consists of 6-33 (Koenig & Borries, 2012) up to 45 individuals (Zheng, 1993), including 1-5 adult males and 3-12 adult females. Large groups of Indochinese gray langurs (*Trachypithecus crepusculus*) (60-100 individuals, $n=6$) were observed at Wuliangshan Mountain (Fan et al, 2014). Bisexual groups of

Phayre's leaf monkeys include OMGs (48.4%), TMGs (24.9%) and three-male, multi-female groups (15.9%) (Koenig & Borries, 2012). The diverse social organization of *Trachypithecus* species are adaptations to diverse habitat environments (including natural and social environments) and are also the result of both environmental pressure and phylogeny.

Shortridge's capped langurs (*Trachypithecus shortridgei*) (Wroughton, 1915) are now considered as a separate species from capped langurs (*T. pileatus*) (Groves, 2001) and to only distribute in the Dulongjiang valley, northwest Yunnan, China (Cui et al, 2015) and northeastern Myanmar (Groves, 2001; Htun et al, 2008; Pocock, 1939). *T. shortridgei* is categorized as Endangered on the IUCN Red List (Htun et al, 2008) and is listed in CITES Appendix I (CITES, 2014). In China it is a Category I protected species under Chinese animal conservation laws, and in Myanmar it is protected under the national Wildlife Protection Law (Htun et al, 2008). In India, capped langur (*Trachypithecus pileatus*) groups usually consist of 8-11 individuals (Solanki, 2007, 2008), usually forming OMGs and occasionally TMGs (Mukherjee, 1978) or MMGs (Green, 1981; Mukherjee, 1978; Mukherjee et al, 1995; Solanki, 2007; Stanford, 1991, 1987, 1988). Non-breeding individuals live solitarily or in AMGs (Choudhury, 1988; Green, 1981; Stanford, 1991, 1988).

Although Shortridge's langurs were first found in China since 1972, little is known about this species. Community interview indicated that they live in bisexual groups of 10-30 individuals, and only 19 groups with 250-370 individuals have been found in the Dulongjiang region of Yunnan, China (Cui et al, 2015). To date, knowledge on their social organization remains very little. In this study, we aim to clarify some basic information of *T. shortridgei*: (1) whether its bisexual group size is 10-30 or approximately 10 individuals similar to that of *T. pileatus*; (2) whether its social organization is OMG or MMG; (3) the number of adult females in bisexual group and (4) the age-sexal composition of bisexual group and its dynamic trends.

MATERIALS AND METHODS

Study area

The study area is located in the Dulongjiang region, Gongshan County, northwest Yunnan, China, and neighbors with Chayu in Tibet to the north and with Kachin in Myanmar to the south and west. East and west of Dulongjiang River are the west side of Gaoligongshan Mountain and the east side of the Dandanglika Mountains, respectively. The Gaoligongshan Mountain and Dandanglika Mountains are south-north oriented, descending from north to south and are featured with significant altitudinal differences (4 000 m maximum) and steepness. Under the influence of southwest monsoon and topographic features, the climate of the Drung River Basin is quite mild. Average yearly temperature was 14.5 °C during 2010-2012; the difference in average monthly temperature was 15.0 °C; the highest and lowest average temperature occurred in August (21.6 °C) and January (6.6 °C). The rain season is from February to October; average yearly precipitation was 2 745.1 mm, with two peak periods of precipitation from March to April and from June to September, respectively. The Drung region is characterized by

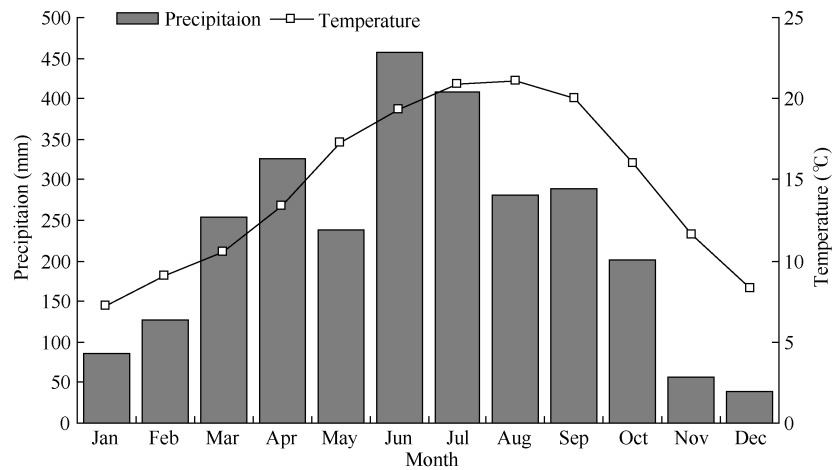


Figure 1 Average monthly temperature and precipitation in the Dulongjiang valley from January 2010 to December 2012

dense forests and obvious vertical zonality in vegetation. The vegetation type from low to high altitude is monsoonal evergreen broad-leaved forests (1 200–1 500 m), montane moist evergreen broad-leaved forests (1 500–2 400 m), mixed broadleaf-conifer forests (2 400–2 800 m), cold temperate coniferous forests (2 800–3 000 m), frigid-temperate coniferous forest (3 000–3 700 m) and alpine scrubs and meadows (>3 700 m) (He & Li, 1996).

Study subject

The study subjects included five groups (group A, B, C, D, E) of Shortridge’s langurs inhabiting the Silaluo region (N27°47’, E98°19’) in the Dulongjiang valley. Age-sex composition of the species was distinguished according to body size, body color and other morphological features (Table 1). Except for one adult female with a chopped tail (its length is approximately 10 cm), others were not individually differentiated.

Method

Although an observing location (1 500 m a.s.l.) with open view was found on the mountain facing the activity areas of the

langurs, the steep terrain and dense forests inhibited our observation. Therefore, all observations were conducted along the road opposite the activity areas of the monkey, so we only observed activities of the groups in areas between the riverside (approximately 1 420 m) and the elevation of 1 700 m.

From August 2012 to September 2013 (except December 2013), surveys were conducted daily during 0700–1830 in Silaluo-Pukawang region of the Dulongjiang valley. When monkeys were sighted, we observed them in the distance of 60–800 m by binoculars (Olympus 10×42 EXWP I) or monoculars (Leica Televid 77, 8×42). Age–sex compositions of the groups were recorded when they were crossing areas with open view (such as naked rocks or forest gaps). A topographic map (1: 50 000) of the study area was subdivided into small squares (250 m×250 m) and the locations of groups were recorded on the map every 30 min.

Due to the steep terrain and dense forests, it was not possible to continuously track groups or recognize individuals, so the birth season was only roughly estimated based on information acquired from group observations and the number and morphological characteristics of infants.

Table 1 Features of different age-sex classes of *Trachypithecus shortridgei*

Age/Gender	Features
Adult males	Largest (15–20%) and stronger than adult females; black face, hand and foot, and tip of tail; tail is long and strong, and light black except for white ventro-base; small black spots on top of head; color from center to peripheral of the back transits from black to gray-black; gray-black in lateral thigh; color from waist to base of tail is silvery white; other body parts is silver; whiskers long and obvious along both sides of face; penis occasionally shown.
Adult females	Larger than juveniles; body color close to males; whiskers less obvious than males; tail long and slim; nipples flesh-color or pink, long and downward; usually found around infants.
Juveniles	Larger than infants; face and extremities black; back and lateral limbs gray-black; abdomen and internal limbs silver; whiskers appears along both sides of face; tail slim and black; tip of tail white in juveniles 1–2 years old.
Infants	Under a year old; an orange body except flesh-colored face, limbs and ears, but with a black line in the center and lateral back; face and extremities black and base of tail silver in two-month-olds; silver body, tail silver to black from base to tip in eight-month-olds; top of head white; long and white whiskers; usually accompanied by females or juveniles.

RESULTS

Bisexual groups of Shortridge's langur at the Dulongjiang valley were composed of one-male, multi-female and their immatures. Average group size was 8 (7-9) individuals, including one adult male, 2-3 adult females and up to five offspring. The ratio of adult males to females (M/F) was 1:2.9; infants (I/F) to females was 1:2.2 and adults to immature individuals (Ad/Im) was 1:1.2. Although a possible solitary male was observed at Qinlangdang south (30 km straight distance) of our study area and 12 single male individuals were previously surveyed at Pianma, Lushui; neither a all-male group nor solitary males were observed in our study area. The increasing size of group D was directly resulted from the birth of infants in the group. However, as we were unable to recognize individuals, it was not possible to determine the underlying mechanisms of variations in the number of individuals (Table 2).

One infant in group D was born sometime between 9 March and 6 April 2013. According to its morphological characteristics, we assumed the infant to be two weeks old on 6 April. Another infant in group D was born sometime during 7 April-23 May, 2013. One infant in group E was approximately 1-2 weeks old when it was first sighted and it was assumed born sometime during 22-31 July 2013. Therefore, we concluded that the birth season of Shortridge's langurs in the Dulongjiang valley was from March to July.

In 2012, 11 females gave birth to six infants (birth rate=0.55), and three infants were produced by six females (birth rate=0.5) in 2013, which demonstrated an overall birth rate of 0.56 during the study period. From 2012 to 2013, three infants were produced by three females in group D. These results indicate that Shortridge's langurs produce one infant every two years.

This study ran for 299 days (2 343.9 h), of which 69 days was used for observation and 63 days for scanning record (273 h). Thirty-nine habitat squares, totaling 2.44 km², were utilized by the five groups. Although habitat overlap among the different groups was 33%, no direct competition was observed. We therefore assumed that the monkeys might avoid competition through using habitats at different time periods.

DISCUSSION

Group size in colobine varies from three to several hundred, living in small families or larger group (Newton & Dunbar, 1994). Shortridge's langurs at the Dulongjiang valley usually live in small groups of 7-9 (8 on average) individuals, which were much smaller than those estimated in community interviews (10-30 individuals, Cui et al, 2015), but were comparable with group sizes (approximately 10 individuals) of capped langur (*T. pileatus*) (Kumar & Solanki, 2008; Solanki et al, 2007), Delacour's langur (*T. delacouri*) (Workman, 2010), white-headed langur (*T. leucocephalus*) (Jin et al, 2009), purple-faced langur (*T. vetulus*) (Vandercone et al, 2012), François' langur (*T. francoisi*) (Huang et al, 2006, 2007; Li & Wei, 2012) and Gee's golden langur (*T. johnii*) (Roy et al, 2012); whereas, smaller than those of other species, such as cantor's dusky leaf monkey (*T. obscurus halonifer*) (Md-Zain & Ch'ng, 2011) and

Javan lutung (*T. auratus sondaicus*) (Tsuji et al, 2013).

Group size is affected by the spatial and temporal distribution of food resources, predator pressures and foraging strategies of individuals. When predator pressure is low and food patches are small and/or abundant, group sizes are usually small; when food patches are large and food is high in variety but low in abundance, group sizes are usually large. When population densities are high, populations are limited by habitat quality (Newton & Dunbar, 1994). Fan et al (2014) found that large groups of Indochinese gray langurs (*Trachypitecus crepusculus*) were dependent on the high variety of food resources. The high overlap (33%) of habitats observed in the Shortridge's langurs at the Dulongjiang valley indicated that habitat limitations may have confined population expansion. During our study, no natural enemies of the Shortridge's langurs were found, suggesting low predator pressure, whereas, human activities (such as illegal hunting) may have disturbed the populations. The small Shortridge's langur populations may be the result of all these interactions. However, the specific factors underlying population size can only be determined by systematic research in gradient environments (various habitat qualities and human disturbance).

Bisexual groups of many *Trachypitecus* species are OMGs, though MMGs are occasionally observed (Kirkpatrick, 2007; Newton & Dunbar, 1994). Bisexual groups in Shortridge's langurs at the Dulongjiang valley usually included one male adult, 2-3 female adults and up to five immature offspring, which is quite similar with that of *T. vetulus* (Vandercone et al, 2012), *T. francoisi* (Huang et al, 2006, 2007; Li & Wei, 2012), *T. obscurus* (Md-Zain & Ch'ng, 2011), *T. phayrei* (Koenig et al, 2004), *T. johnii* (Roy et al, 2012) and *T. auratus* (Tsuji et al, 2013).

The number of male adults in a breeding group is irrelevant to population density, weather conditions and male mortality rate (Newton & Dunbar, 1994), but is correlated with predator pressure, number of females and reproduction synchronicity (Kappeler & van Schaik, 2002; Mitani et al, 1996; Nunn, 1999; van Schaik & Hörstermann, 1994). For example, predator pressure (such as eagles) increased the numbers of adult males from one to two in breeding groups of howler monkeys and colobus monkeys, whereas, breeding groups of langurs that inhabit the same environment, but without predator pressure, are composed of OMG (van Schaik & Hörstermann, 1994). The number of males is also affected by the number of females, which are restrained by food resources and population size (Andelman, 1986; Crockett & Eisenberg, 1987; Dunbar, 1988; Terborgh, 1986). The reproduction strategy of males depends on the number of estrous females that can be monopolized by males, which is correlated with both the number of adult females and their reproduction synchronicity (Emlen & Oring, 1977, Wrangham, 1980). Moreover, the percentage of OMGs is also influenced by the number of adult females and their reproduction synchronicity (Srivastava & Dunbar, 1996). Theoretically, one male HanumanLangur (*Semnopithecus entellus*) can monopolize up to 12 adult females, but once the number of females has exceeded this limitation, more than one male would be expected in a breeding group (Newton, 1988).

Table 2 Social organization of Shortridge's capped langur (*Trachypithecus shortridgei*) at the Dulongjiang Valley, Yunnan, China

Period	Code	Group composition	M	F	J	I	GS	M:F	I:F	Ad:Im	Birth rate	Home range (km ²)
16 Aug-22 Nov 2012	A	M, F, F, J, J, J, I ₀₂	1	2	3	1	7	1:2	1:2	1:1.3	0.5	0.56
04 Sep 2012-22 Mar 2013	B	M, F, F, F, J, J, J, I ₀₂ , I ₀₂	1	3	3	2	9	1:3	1:1.5	1:1.3	0.67	0.88
23-29 Mar 2013	C	M, F, F, F, J, J, J, I ₀₂ , I ₀₂	1	3	3	2	9	1:3	1:1.5	1:1.3	0.67	0.38
12 Jan-08 Mar 2013		M, F, F, Fb, J, J, I ₀₂	1	3	2	1	7	1:3	1:3	1:0.8	0.33	1.06
06 Apr 2013	D	M, F, F, Fb, J, J, J, I ₀₃	1	3	3	1	8	1:3	1:3	1:1	0.33	
23 May-10 Sep 2013		M, F, F, Fb, J, J, J, I ₀₂ , I ₀₃ , I ₀₃	1	3	3	2	9	1:3	1:1.5	1:1.3	0.67	0.38
06-10 Aug 2013	E	M, F, F, F, J, J, I ₀₃	1	3	2	1	7	1:3	1:3	1:1.3	0.5	
Mean±SD			1±0	2.9±0.4	2.7±0.4	1.4±0.5	8±1 (7-9)	1:2.9	1:2.2	1:1.2		0.65±0.31

M: Adult male; F: Adult female with chopped tail; J: Juvenile; GS: Group size; I₀₂: Infant born in 2012; I₀₃: Infant born in 2013; Ad: Adults; Im: Immature individuals; Color of tails of two infants in group B turned from orange to gray on 22 March 2012; Color of tip (tip of 1/6) of the tail of one infant in group C was orange on 23-29 March 2012; Group E in the activity area of group B at 06-10 August 2013; Group E was either an independent group or evolved from group B or C (i.e. through death or migrations).

Table 3 Summary of *Trachypithecus* social organization

Species	SO (%)	AM	AF	IEI	Infant	MGS (range, n)	M:F	I:F	Ad:Im	Habitat	Source
<i>T. shorridgei</i>	OMG (100)	1	2.9(2-3)	2.7(2-3)	1.4(1-2)	8 (7-9, 5)	1:2.9	1:2.2	1:1.2	Evergreen-deciduous forest	This study
<i>T. pileatus</i>	OMG (75)	1	4.7(4-5)	1.3(0-2)	0.7(0-2)	8.3 (7-9, 3)	1:4.7	1:7	1:0.5	Evergreen-deciduous forest	Solanki et al, 2007
	TMG (25)	2	4	1	0	7 (7, 1)	1:2	0:4	1:0.2	Evergreen-deciduous forest	
	OMG (90)					7.5 (7-9, 24)	1:3.6			Evergreen-deciduous forest	Kumar & Solanki, 2008
	MMG (10)										
<i>T. delacouri</i>	OMG (71)	1(1-1)	5.4(2-8)	1.6(0-3)	3.6(0-6)	10.8 (4-16, 5)	1:5.4	1:1.5	1:0.7	Limestone karst	Workman, 2010
	TMG (29)	2(2-2)	1.5(1-2)	2(1-3)	0	5.0 (4-6, 2)	1:0.8	0:3	1:0.4	Limestone karst	
<i>T. geei</i>	OMG (33)	1	2	3	1	7 (7, 1)	1:2	0:2	1:1.3	Nature forest	Medhi et al, 2004
	TMG (67)	2	4.5(2-7)	10(4-16)	6 (6-6)	22.5 (19-26, 2)	1:4.5	1:0.8	1:2.5	Nature forest	
<i>T. leucocephalus</i>	OMU(91)	1	4.9(3-9)	3.8(0-8)	1.6(0-5)	9.7(5-14, 10)	1:4.9	1:3.1	1:0.4	Disturbed and natural vegetation	Li & Rogers, 2004
	TMU(9)	2	3			5 (5-5, 1)	1:1.5			Disturbed and natural vegetation	
<i>T. vetulus</i>	OMG (100)	1	5.1(1-14)	2.6(0-10)	2.9 (0-9)	11.7 (3-30)	1:5.1	1:1.8	1:0.8	Limestone karst	Jin et al, 2009
	OMG (100)	2.3(2-3)	3.0 (1-5)	3.3(0-9)	1.0(0-2)	9.7(3-19)	1:1.3	1:3	1:0.8	Limestone karst	
<i>T. francoisi</i>	OMG (100)	1	6		4	11	1:6	1:1.5	1:0.6	Dry zone forest	Vandercone et al, 2012
	OMG (100)	1	3		5	9	1:3	1:0.6	1:1.3	Limestone karst	Huang et al, 2006
<i>T. obscurus</i>	OMG (100)	1	5	11	1	18	1:5	1:5	1:2	Limestone karst	Huang et al, 2007
	OMG (100)	1	4	4	3	9	1:4	1:1.3	1:0.8	Limestone karst	Li & Wei, 2012
<i>T. phayrei</i>	OMG (100)	1	4	4	3	9	1:4	1:1.3	1:0.8	Evergreen forests	Mid-Zain & Chng, 2011
<i>T. p. crepusculus</i>	OMG/MMG	1-5	3-12	0-12	1-11	19(6-33)	1:3.5	1:1.3	1:1.1	Evergreen forests	Koenig et al, 2004
	MMG	10-11	30-31	30	20	90-91	1:3	1:1.5	1:1.3	Dry evergreen forest	Koenig & Borries, 2012
<i>T. johnii</i>	OMG (100)	1	2.0 (2-2)	4(2-6)	0.5(0-1)	7.5 (6-9, 2)	1:2	1:4	1:0.5	Evergreen broad	Fan et al, 2014
<i>T. auratus</i>	OMG (100)	1	14	8	1	24	1:14	1:14	1:0.7	Evergreen-deciduous forest	Roy et al, 2012
										-	Tsuji et al, 2013

SO: Social organization; AM: Adult male; AF: Adult female; IEI: Immature except infants; MGS: Mean group size; OMG: One-male, multi-female group; TMG: Two-male, multi-female group; MMG: Multi-male, multi-female group; %: Percentage of different social organizations in the report.

Extreme reproductive synchronicity (either too high or too low) decreases the ability of males to monopolize females, and only moderate reproduction synchronicity can enhance the monopolization (Emlen & Oring, 1977). Monopolization ability of the male can also be enhanced by the concentrated distribution of females and its more non-feeding time (van Schaik & van Van Hoof, 1983). On average, only five adult females were observed in OMGs of white-headed langur, which may result from low overall numbers of adult females (Jin et al, 2009). OMGs of Shortridge's langur at the Dulongjiang valley had only three adult females, whereas, the number of adult females in OMGs of other species of *Trachypithecus* are usually 4-5 (ranging from 2 to 14) (Table 3). Although the reproduction synchronicity of female Shortridge's langurs cannot be precisely determined, the scattered birth pattern suggests low synchrony. According to our study, females basically moved within the view field of males and the feeding time of adult males was 5.9%. Therefore, the number of adult males was correlated with both low predator pressure and the small number of adult females.

Although OMGs of Shortridge's langurs at the Dulongjiang valley contained only a few adult females, the ratio of adults to immature individuals (1:1.2) indicated their increasing potential. The ratio of OMGs in genus of *Trachypithecus* is 0.5-2, but that of most of other species is less than 1:1 (Solanki et al, 2007; Workman, 2010; Jin et al, 2009; Vandercone et al, 2012; Koenig et al, 2004; Koenig & Borries 2012; Roy et al, 2012; Tsuji et al, 2013), suggesting a significant trend of decreasing population. In the future, factors influencing population increase, such as human disturbance, habitat quality and inter-specific competition, should be explored.

Bisexual groups of genus of *Trachypithecus* are composed typically of OMGs and occasionally of MMGs. For example, MMGs in *T. leucocephalus* and *T. pileatus* account for 9-10% and 10-25%, respectively; and TMGs in *T. delacouri* and *T. geei* account for 29% and 67%, respectively (Table 3). The number of adult males in MMGs is mostly two and occasionally three (Koenig & Borries, 2012) and their adult females are less than those in OMGs (*T. Pileatus*: Solanki et al, 2008; *T. delacouri*: Workman, 2010; *T. leucocephalus*: Li & Rogers, 2004; Jin et al, 2009), but the number of adult females in MMGs and OMGs of white-headed langurs (*T. Leucocephalus*) exhibit no differences. These phenomena indicate that MMG is not a strategy of males to monopolize more females (Jin et al, 2009). The occurrence of MMGs in white-headed langurs is the result of male replacement (Jin et al, 2009; Li & Rogers, 2004), which finally changes into OMGs or non-breeding groups (Jin et al, 2009). So the formation of MMGs in species of colobus may be age-graded or is only a temporary phenomenon during the process of male replacement (Jin et al, 2009; Sterck & Hooff, 2000).

Other than bisexual groups, there are also non-breeding groups and solitary males. Non-breeding groups mainly consist of males and occasionally females, suggesting that males play vital roles in sex dispersal (Jin et al, 2009; Kirkpatrick, 2007; Newton & Dunbar, 1994). In our study, no all-male group or a solitary male were observed, although 12 solitary males were previously reported in Fugong and Lushui counties near Myanmar. A similar phenomenon was also reported in species of colobus (Jin et al,

2009; Kirkpatrick et al, 1998; Newton & Dunbar, 1994). All-male groups were reported in white-headed langurs, but not in Shortridge's capped langurs, which are important for promoting genetic communication among different populations and in avoiding inbreeding. However, the reason why all-male groups were not observed in our study is worth future exploration, for instance, whether they were poached or immigrated into other groups.

Under the influence of the warm and humid current brought by the southeast monsoon, the Dulongjiang valley experiences high precipitation, and has small yearly temperature variations ($\leq 15^{\circ}\text{C}$), with an average yearly temperature of 14.5°C . The vegetation consists predominately of monsoon evergreen broad-leaved forests, warm temperate evergreen broad-leaved forest and broad-leaved deciduous forest, which provides many kinds of plant species and abundant food resources for wild animals. Shortridge's langurs at the Dulongjiang valley have a long birth period (March to July) and scattered birth pattern. At the Pakhui Wildlife Sanctuary in India, the average highest and lowest yearly temperature is 28°C and 19°C , respectively, and the yearly average precipitation is 2 040 mm. Its optimal weather results in various vegetations, dominated by tropical evergreen and semi-evergreen broad-leaved forests and semitropical forest (Champion & Seth, 1968). Although local capped langur (*T. pileatus*) exhibits a birth peak, the birth pattern is very scattered (December to April next year) (Solanki et al, 2007). The scattered birth patterns in these two primates are likely adaptations to abundant food and mild seasonal changes in weather conditions and food resources. Conversely, black-and-white snub-nosed monkeys inhabit temperate zones at high altitude with low temperatures, resulting in food shortage and severely seasonal changes in weather and food resources, and thus strict birth seasonality is found in their birth patterns. To ensure successful reproduction and increase fitness, these two primate species use different birth patterns to cope with specific environmental pressures.

In summary, Shortridge's langurs at the Dulongjiang valley are composed of one-male, multi-female groups without all-male groups, but with solitary males, which usually kept distances from the breeding groups. There were, on average, eight individuals in each group and large habitat overlap between groups. The number of adult females in bisexual group was usually 2-3, smaller than the number in most species of *Trachypithecus*, which suggests a possible correlation between small number of adult females and limited suitable habitat and illegal hunting. Age structure of Shortridge's langurs indicated a trend of increasing potential. In the future, suitable habitat and threatening factors regarding Shortridge's langurs should be explored, and their population densities should be more precisely evaluated, from which feasible protection suggestions can be established.

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