

## Birth seasonality and pattern in black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) at Mt. Lasha, Yunnan

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**Abstract:** Seasonal variation in environmental factors is vital to the regulation of seasonal reproduction in primates. Consequently, long-term systematic data is necessary to clarify the birth seasonality and pattern of primates in highly seasonal environments. This study indicated that black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) at Mt. Lasha exhibited strict birth seasonality with a pulse model. Infants were born with a certain degree of synchronization. Birth distribution showed three birth peaks, and the birth pattern showed a “V” style in even-numbered years and a gradual increase in odd-numbered years. The beginning date, end date and median birth date were earlier in even-numbered years than those in odd-numbered years. The higher latitude of their habitats, earlier birth date, shorter birth period, fewer birth peaks and stronger birth synchrony might be adaptations for strongly seasonal variation in climate and food resources. After the summer solstice when daylight length began to gradually shorten, *R. bieti* at Mt. Lasha started to breed during the period with the highest environmental temperature and food availability, which implied that photoperiod may be the proximate factor triggering the onset of estrus and mating. It appears that *R. bieti* coincided conception and mid-lactation with the peak in staple foods, and weaning with the peak in high quality of foods. Thus, food availability was the ultimate factor regulating reproductive seasonality, and photoperiod was the proximate factor fine-tuning the coordination between seasonal breeding and food availability.

**Keywords:** *Rhinopithecus bieti*; Birth seasonality; Birth pattern; Birth synchrony

In wild environments, birth seasonality exists in many animals. Primates show reproduction continuum from seasonality to un-seasonality like other mammals (Brockman & van Schaik, 2005). The typical reproduction patterns of primates include seasonality (births within a specific period), peaks (birth peaks in certain months) and irregularity (births within the entire breeding cycle without regularity) (Struhsaker & Leland, 1987; Brockman & van Schaik, 2005). In high and moderate birth seasonality,  $\geq 67\%$  and  $33\%–67\%$  of infants were found to be born within three months, respectively (van Schaik et al, 1999). External environmental factors (e.g. temperature, precipitation, food resources, photoperiod, seasonal climate, and food availability) and biological rhythms affect reproductive seasonality (Bron-

son & Heideman, 1994; Negus & Berger, 1972; Andelman, 1986; Bronson & Heideman, 1994; Brockman & van Schaik, 2005; Tecot, 2010; van Schaik & Pfannes, 2005). In natural environments, seasonal food resources are the most important factor that determine birth pattern, while

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precipitation, temperature and daylight cycle function as proximate factors (Wikleski et al, 2000). Animals synchronize their critical reproductive period with the optimal phase of environments to maximize survival (Negus & Berger, 1972). Photoperiod and temperature in temperate regions, as well as precipitation in tropical areas, affect seasonal food resources, and eventually induce reproductive seasonality (Vivien-Roels & Pevet, 1983). Under some circumstances, however, photoperiod has no influence on conception, and food availability is the only determining factor of reproductive seasonality (Huang et al, 2012; Carnegie et al, 2011; Kowalewski & Zunino, 2004). With increases in both latitude and altitude, climate and food seasonality change significantly. In certain primate species (e.g. *Macaca thibetana*), the median birth date occurs earlier with the increase in altitude (*M. fuscata*: Fooden & Aimi, 2003; *P. entellus*: Newton, 1987). During the breeding season, an individual's weight gain indicates the accumulation of nutrients, which not only guarantees the nutritional requirements of mating individuals, infants and nursing activities, but also ensures that the critical period of infant survival falls into the next autumn with enriched food resources (Zhao & Deng, 1988). Reproductive seasonality is more obvious among species living in areas with high altitude and latitude (Janson & Verdolin, 2005; *R. brelichi*: Yang et al, 2009; *R. roxellana*: Qi et al, 2008; Ren et al, 2003; Zhang et al, 2000; *P. entellus*: Newton, 1987; *C. polykomos*: Dasilva, 1989; *P. pileatus*: Stanford, 1990). In addition, reproductive peaks can be significantly correlated with climate and food seasonality (e.g. *P. entellus*: Newton, 1987), while relatively stable food acquisition (e.g. provision or crop stealing) can induce reproductive irregularity (Bishop, 1979).

Black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) are endemic to the Trans-Himalayas, which are bound by the upper rivers of the Yangtze to the east and the Mekong to the west (N26°14'–N29°20') (Long et al, 1994). From north to south, the altitudes of groups of this species decrease, habitat transits from dark coniferous into dark coniferous-broadleaf mixed forest, and gradient trends manifest in photoperiod, temperature, precipitation and food availability (Xiang & Sayers, 2009; Ding & Zhao, 2004; Huang et al, 2012). The birth period of the Xiaochangdu group (N29°15') was found to occur from February 4 to March 14, with the median birthdate on February 24 and standard deviation of 6.5 days (Xiang & Sayers, 2009). The birth period of the Mt.

Lasha group (N26°20') was found to occur from February 15 to April 7 in 2009–2010, with the median birth date on March 27 (Huang et al, 2012), but was from February 19 to April 12 in 2011, with the median birth date on March 17 (Wang et al, 2012). It appears, therefore, that reproductive patterns are influenced by differences in habitat altitude and latitude, with monkeys in high altitude and latitude areas showing earlier birth dates but shorter breeding periods, as well as by differences year to year. Mating behaviors are triggered by various factors, such as photoperiod (Sadlier, 1972), so for some species living in highly seasonal environments, maintaining high energy levels may not always be necessary for conception (Brockman & van Schaik, 2005; Drent & Daan, 1980).

Reproductive seasonality in black-and-white snub-nosed monkey groups (especially the Xiaochangdu group) is not induced by photoperiod, but is determined by the enriched food resources during the conception period (Huang et al, 2012; Xiang & Sayers, 2009). Reproduction of *R. bieti* is also characterized by birth synchrony, with spatial-temporal differences (Huang et al, 2012; Wang et al, 2012). Reproductive synchrony refers to the way species maximize food quality and availability with high energy consumption periods (e.g. nursing and weaning) (van Schaik & van Noordwijk, 1985). Black-and-white snub-nosed monkeys, also called snow monkeys (Elliot, 1912), inhabit areas with high altitude (Long et al, 1994), as well as significant seasonal climate changes and food resources (Kirkpatrick et al, 1998; Xiang & Sayer, 2009; Huang et al, 2012). However, limited short-term data have been unable to provide a strong interpretation of the reproductive seasonality and corresponding environmental factors in the breeding of black-and-white snub-nosed monkeys. In this study, reproductive data of the Mt. Lasha black-and-white snub-nosed monkey group were collected to determine the: (1) reproductive seasonality; (2) birth pattern (peaks and variations); and (3) mechanisms of regulating reproductive seasonality.

## MATERIALS AND METHODS

### Study areas and animal subjects

Our study site is located at Mt. Lasha (N26°20', E99°15') in the Yunling National Reserve, Lanping County, Nujiang Prefecture, Yunnan Province, China. The highest peak is 3 854 m in elevation. Only one black-and-white snub-nosed monkey population with

130 individuals has been observed at Mt. Lasha, and is comprised of eleven one-male multi-female units (OMUs) and two all-male-units (AMUs) (Huang et al, 2012; Wang et al, 2012). Home range of this population covers an area of 14 km<sup>2</sup> and is surrounded by villages and farmland at low altitude (<2800 m), as well as alpine pastures at high altitude (>3600 m). Its habitat is patchy with sporadic pastures, fire grasslands, and charcoal burning lands (from oak). The vegetation from low to high altitude forms zonal distributions of coniferous forest, mixed broadleaf-conifer forest, broad-leaved deciduous forest and dark coniferous forest (Huang et al, 2012; Wang et al, 2012).

Annual average temperature at Mt. Lasha is 12.42±6.81 °C, with lowest and highest monthly average temperatures of -1.88±7.15 °C (-4.15–1.00 °C, January) and 25.84±5.97 °C (15.86–34.06 °C, October), respectively. An extreme temperature fluctuation occurred from August 2012 to July 2013 (-4.15–34.16 °C). Annual precipitation is 767.60 mm, with the highest proportion falling from March to September (695.60 mm), and can be subdivided into precipitation peak (July to September) and sub-peak (March to May). The snow season occurs from November to the following March.

#### Data collection and statistical analyses

Data collection was scheduled ahead of the monkey breeding season (from February to April) (Huang et al, 2012; Wang et al, 2012). At panoramic view points (e.g. ridges and rocks) opposite monkey activation areas, we recorded numbers of infants and female adults when they are crossing an open area and foraging in the wide-field forests using a monocular telescope (Leica, T77). Newborns were characterized by overall white hair (except a hint of dark hair on the head), black tip of the tails (one third), as well as red and hairless auricles and extremities. Newborns less than 1.5 months old are carried by adult females. To ensure the accuracy of the data, only observations with more than half of adult females of the group were used for further analysis since its interbirth interval is two years (Huang et al, 2012; Wang et al, 2012). When multiple observations were carried out in one day, only the most reliable (e.g. best view, most individuals included) was used in statistical analysis. Reproductive seasonality was analyzed by considering the numbers of infants and the ratio of infants to female adults (I/F).

We used each 7-day period to calculate all births, to infer the median birth date (Md), mean birth date (Mn)

and standard deviation (*SD*) (Caughley, 1977, but see Eisenberg et al, 1981). We then transformed each day into degrees of a circle (360°) for testing birth seasonality by circular statistics, the mean vector length *r* was calculated to measure birth season dispersion, ranging from 0 (uniform) to 1 (clustered) (Batschelet, 1981). The Rayleigh test ( $Z=nr^2$ ) was used to determine whether the birth data were unevenly distributed throughout the year (Batschelet, 1981; Zar, 1999; Huang et al, 2012).

The I/F data of the Xiaochangdu group obtained from either close tracking recording or field scope scanning were used to determine birth pattern. When an I/F was obtained by both methods at the same time, the former had priority (Xiang & Sayers, 2009).

## RESULTS

### Birth timing

The first *R. bieti* infant at Mt. Lasha was born on February 20, 2013. The I/F value indicated that the breeding season ended on April 14. The numbers of newborn infants peaked (13) on April 8, and thereafter, stabilized on 13. Because the I/F value was rather unstable than the I-value, and the F-value also included adult females that had given birth in the last year, the I-value was the more reliable index reflecting the birth timing. The end of the breeding season inferred from the I-value was April 8 (Figure 1A). Therefore, in 2013, there were 13 new-born infants at Mt. Lasha and the breeding season was from February 20 to April 8. By referring to the I-values, the birth data of *R. bieti* at Mt. Lasha from 2009 to 2012 was analyzed (Figure 1). Although the beginning of the breeding season was consistent in the two estimations based on the I-value and I/F, the latter was overall postponed with deviations (-1 to 8 days) (Table 1).

**Table 1 Breeding seasons of Mt. Lasha monkey group inferred from different indexes**

Year	Beginning of breeding season	End of breeding season		
		I/F	I	Deviations (day)
2009	2-21	4.02	4-03	-1
2010	2-15	4.04	4-04	0
2011	2-19	4.20	4-12	8
2012	2-17	4.07	4-06	1
2013	2-20	4.14	4-08	6

I: Infants; F: Female adults; I/F: Ratio of infants to female adults.

### Birth seasonality

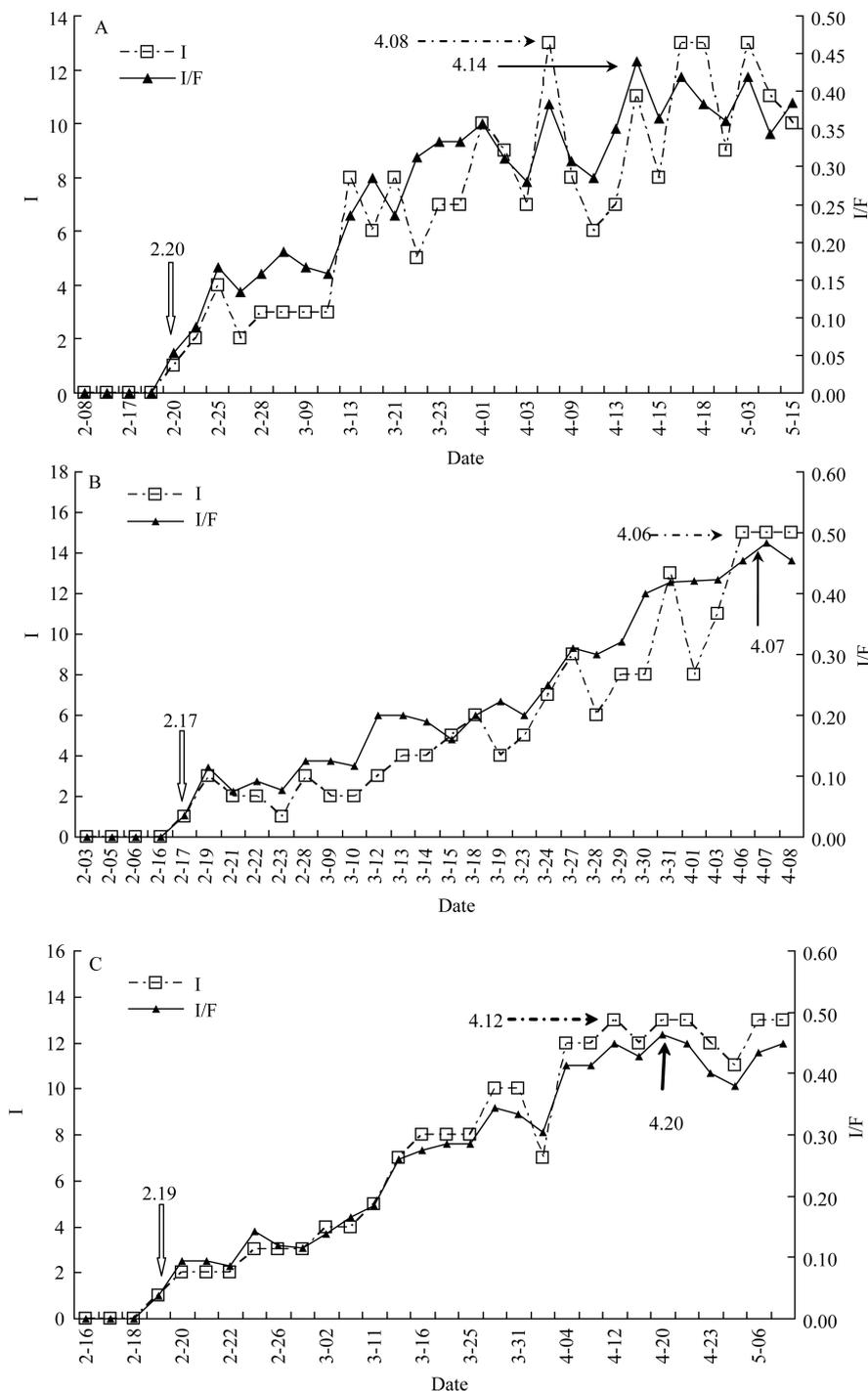
Strict birth seasonality with a pulse type ( $SD < 30$  days) was observed in *R. bieti* at Mt. Lasha. The

breeding season lasted 57 days. Reproductive variables had certain similarities every two years (e.g. beginning phase, ending phase, and Md). The breeding season began and ended earlier in even-numbered years than those in odd-numbered years, and Md was postponed by ten days (Table 2).

### Birth pattern

The birth of new-born infants at Mt. Lasha

exhibited certain synchrony, and showed three peaks on February 15–26, March 11–19 and March 20–April 12, respectively (Figure 2). The data on infant births using 3-day intervals indicated that the third peak occupied 50% of the entire breeding season, whereas the first and the second peaks accounted for 25% and 23.5%, respectively. The highest birth peak in both odd- and even-numbered years fell in the third peak period, whereas in odd-numbered years, the sub-peak fell in the second peak



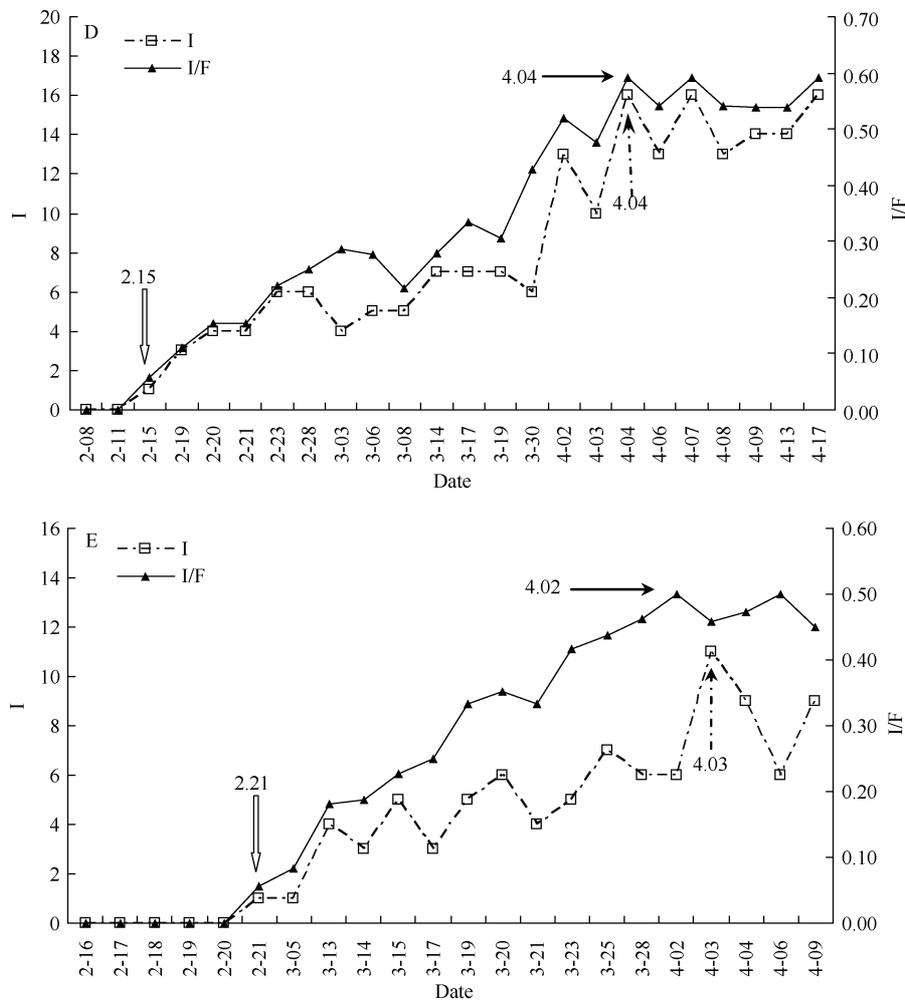


Figure 1 Values of I/F and I of *Rhinopithecus bieti* at Mt. Lasha from 2009 to 2013

A: 2013; B: 2012; C: 2011; D: 2010; E: 2009.

Table 2 Indexes of birth seasonality of *Rhinopithecus bieti* at Mt. Lasha

Year	Breeding period (day)	F	I	I/F	Mn	Md	SD (day)	R	Z
2009	2-21-4-03 (42)	24	11	0.46	3-26	3-21	11.58	0.974	10.44**
2010	2-15-4-04 (49)	27	16	0.59	3-23	3-31	19.48	0.938	14.08**
2011	2-19-4-12 (53)	29	13	0.45	3-24	3-17	17.23	0.960	11.98**
2012	2-17-4-06 (50)	33	15	0.45	3-28	3-28	17.27	0.966	14.00**
2013	2-20-4-08 (48)	34	13	0.38	3-24	3-19	16.90	0.961	12.00**
2009-10	2-15-4-04 (49)	-	27	-	3-24	3-27	16.95	0.953	24.51**
2009-11	2-15-4-12 (57)	-	40	-	3-25	3-22	16.72	0.955	36.47**
2009-12	2-15-4-12 (57)	-	55	-	3-25	3-24	16.73	0.958	50.46**
2009-13	2-15-4-12 (57)	-	68	-	3-25	3-22	16.86	0.958	62.43**
Odd-numbered year	2-19-4-12 (53)	-	37	-	3-25	3-19	15.81	0.964	34.37**
Even-numbered year	2-15-4-06 (51)	-	31	-	3-25	3-29	18.19	0.952	28.07**

I: Infants; F: Female adults; Mn: Mean birthdate; Md: Median birthdate; SD: Standard deviation; \*\*:  $P < 0.001$ .

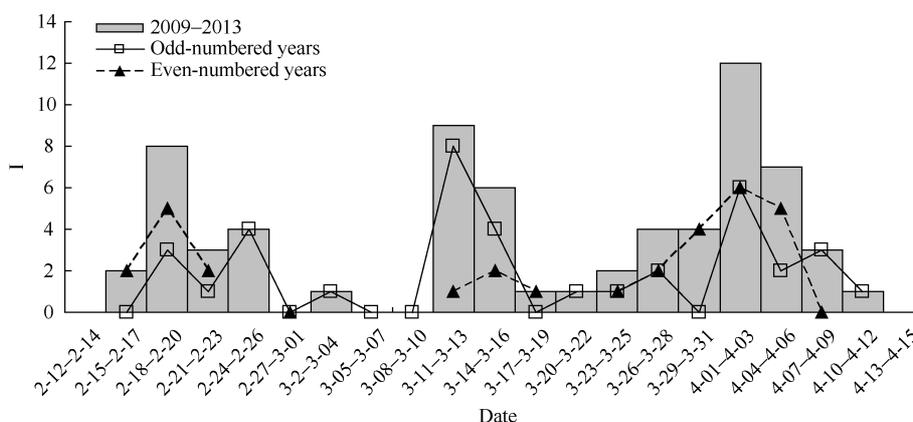


Figure 2 Birth patterns of *Rhinopithecus bieti* at Mt. Lasha from 2009 to 2013  
 Disconnected points mean no data was available or fewer infants were recorded than three days earlier.

period and in even-numbered years, the sub-peak fell in the first peak period (Figure 2).

**Birth pattern comparison of the northern and southern monkey groups**

The Xiaochangdu and Mt. Lasha monkey groups were 3° apart in altitude. With increasing altitude, the beginning phase, ending phase and Md of the monkeys shifted to an earlier date; moreover, the breeding season shortened and birth synchrony was strengthened (*SD* decreased by ten days) (Table 3). The birth pattern of *R. bieti* at Mt. Lasha was triple-pulse-type, whereas,

that of the Xiaochangdu group was double-pulse-type (peak: February 27–March 7, sub-peak: February 6–11) (Figure 3). However, no differences were found in the percentage of new-born infants between birth peaks of the two groups (Xiaochangdu vs. Mt. Lasha: 62.2% vs. 50%, proportion test:  $Z=1.20, P=0.11$ ).

**DISCUSSION**

**Regulation of birth seasonality**

Reproduction is strongly influenced by biological rhythms and external stimulation (e.g., photoperiod,

**Table 3 Birth indexes of *Rhinopithecus bieti* at Xiaochangdu and Mt. Lasha**

Populations	Breeding season (day)	Mn	Md	<i>SD</i> (day)	Altitude (m)	Latitude	Reference
Xiaochangdu	2-04–3-13 (38)	2-28	2-24	6.50	3 500–4 250	N29°15'	Xiang & Sayers, 2009
Mt. Lasha	2-15–4-12 (57)	3-25	3-22	16.86	2 850–3 800	N26°20'	This study

Mn: Mean birthdate; Md: Median birthdate; *SD*: Standard deviation.

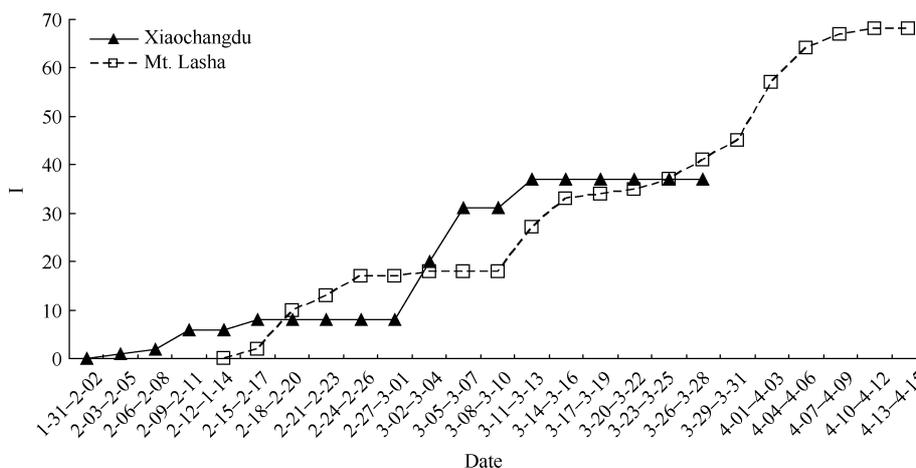


Figure 3 Accumulative numbers of *Rhinopithecus bieti* infants at Xiaochangdu and Mt. Lasha. Data on Xiaochangdu group was collected in 2005 and data on Mt. Lasha group was from 2009 to 2012

temperature, precipitation and food abundance) (Amroso & Marshall, 1960; Lancaster & Lee, 1965). Energy requirements and allocation have been considered the ultimate regulation factors in reproductive patterns. Other factors may play roles in regulating birth seasonality, including temperature and food abundance, to meet the requirements of infant survival, nursing and development (Brockman & van Schaik, 2005; Janson & Verdolin, 2005). Reproduction in Xiaochangdu and Mt. Lasha groups showed strong seasonality. However, because Xiaochangdu group's habitat was 3° higher in altitude than that of the Mt. Lasha group, its reproduction was more concentrated over a shorter breeding season with an earlier beginning date (Table 3).

More obvious seasonality was found in the climate

and food resources in Xiaochangdu area (Table 4). The mating period of both Xiaochangdu and Mt. Lasha groups was from July to October (Xiang & Sayers, 2009; Huang et al, 2012; Wang et al, 2012; Li, unpublished). The breeding season of black-and-white snub-nosed monkeys began after midsummer with shortening daytime, high temperature, abundant food and they started mating in July. This indicated that photoperiod initiated estrus and mating. Huang et al (2012) found that low temperature, especially the lowest temperature during midsummer, triggered reproductive behavior in the Mt. Lasha group. Cozzilino et al (1992) also found that temperature and its variations initiated the beginning of estrus and mating in *Macaca fuscata*.

**Table 4 Seasonality of food resources in the Xiaochangdu and Mt. Lasha monkey groups**

Xiaochangdu (Xiang et al, 2007; Xiang & Sayer, 2009)		Mt. Lasha (Huang et al, 2012; Li, unpublished)	
Climate	Food	Climate	Food
Maximum precipitation from June to August;	Usnea thrives, other vegetation buds in mid-May;	Maximum precipitation from June to October;	Vegetation buds in late-February;
Monthly average temperature (10.2–12.5 °C);	Buds, leaves, flowers and fruits/nuts are in abundance from June to August;	Monthly average temperature (15.0–18.2 °C) from June to September;	Usnea and leaves are in abundant from June to September, buds, flowers and fruits/nuts are in abundance from April to May;
Monthly average lowest temperature (3.7–5.4 °C)	Leaves fall in mid-October	Monthly average lowest temperature (12.2–14.7 °C) from June to September;	Leaves fall in mid-November

Photoperiod, temperature and precipitation affect food abundance, and, in turn, the reproduction period (Bronson, 1988; Sadleir, 1969). Based on birth date (Xiang & Sayer, 2009) and lactation period (195–204 days) of black-and-white snub-nosed monkeys (Ji et al, 1998), the conception period of Xiaochangdu group was calculated to be from July 24 to September 2 (median August 13), whereas, the conception period of the Mt. Lasha group was from August 6 to September 30 (median September 9). *R. bieti* at Xiaochangdu began to conceive after one month of food abundance peak, and monkeys at Mt. Lasha did after two months of food peak. Although the conception of Xiaochangdu and Mt. Lasha groups began at different time points, they all terminated before the end of the food summit. Moreover, the median date of conception of the two monkey groups occurred in the middle of the last month of the peak in food availability. The long cold winter with limited food consumed the energy stores of the monkeys. Breeding individuals recovered, restored energy and completed

conception during the peak in food availability. Therefore, complete conception during the peak in food availability played an important role in regulating reproductive seasonality, and food abundance instead of photoperiod initiated ovulation and conception (Huang et al, 2012; this study).

The decrease in both food abundance and temperature during the conception period means that energy requirements increased. Infants were born during a period of low temperature and relatively limited food. *R. bieti* infants at Mt. Lasha began to wean at 13–14 months old (March–April of the following year) and ended at 18-months old (June of the following year) (Li, unpublished). This “bottle phase” (weaning) fell in the period with increased growth in “soft” and high nutrition foods (buds, leaves and flowers). Compared with the Mt. Lasha area, the peak in food availability at Xiaochangdu was one month shorter, buds formed 2.5 months later, and leaves fell one month earlier. Although we lacked weaning information on *R. bieti* infants at Xiaochangdu,

according to the relatively short food supply and the fact that infants at Mt. Lasha rarely foraged independently at six-months-old (Li, unpublished), we assumed that the chances of Xiaochangdu infants being weaned during the same year were quite low, and more likely occurred in late-May to early-June of the following year when abundant young vegetation was available. If no appropriate food is available during weaning, reproduction will ultimately fail and lead to the demise of an entire population, or perhaps even species. Thus, the weaning of *R. bieti* during a period of abundant high nutrition food is not only a prerequisite for successful reproduction, but also an adaptive strategy to environmental seasonality.

Early- and late-lactation period of this species occurred during relatively low temperature and limited food periods, whereas, highly energy-consumptive mid-lactation overlapped with the peak in food availability. Monkeys stored energy during pre-conception and mid-lactation to alleviate energy requirements during early- and mid-to-late-lactation. Compared with the Mt. Lasha monkeys, Xiaochangdu infants were born one month earlier and weaned 2.5 months later. Their lactation period was prolonged with relatively lower temperatures, and higher energy consumption phase (mid-lactation) fell during the second peak of food resources. We concluded that the high energy requirement of lactation may have induced the high infant mortality, which was 54% at Wuyapuya (N28°35') (Kirkpatrick et al, 1998), whereas that of the Mt. Lasha group was much more lower (6.7% in 2012) (Li, unpublished). To avoid energy overdraft of adult females during lactation (especially during winter) and increase infant survival, high frequency of male-infant-caretaking was found in Xiaochangdu group (Xiang et al, 2010), whereas such behaviors were only observed at low frequency in the Mt. Lasha group (Wang et al, 2012). The short breeding season with early start in the Xiaochangdu group appears to be an adaptive strategy to high environmental seasonality. Research on *M. fuscata* groups at higher altitude showed that infants born early but with a prolonged developmental period were able to survive the low temperature and lack of food experienced during through winter (Food & Aimi, 2003).

The reproduction of many high altitude species is affected by photoperiod, with the length of daytime and its variation triggering related neuroendocrine mechanisms (Van Horn, 1980; Bronson & Heideman, 1994; Goldman, 2001). The habitat of Xiaochangdu monkeys was located at a higher altitude than that of Mt. Lasha

monkeys; therefore, more obvious seasonality in both climate and food was shown. Although there were differences in birth patterns of two monkey groups, their birth peaks stabilized during the following 6 to 7 months after the peak in food availability. Thus, the relative stability of the breeding season seems to be an adaptation to seasonal environments, which was critical for its successful reproduction (Table 3). Previous research has shown that 100% of wild black-and-white snub-nosed monkeys and 96.3% of captive individuals start reproduction after mid-summer (Cui et al, 2006), indicating that photoperiod is the triggering factor of their estrus and mating behaviors. Although the stable food supply decreased the seasonality and synchrony of infants born, a birth peak was still observed in captive *Rhinopithecus* monkeys (*R. bieti*: Cui et al, 2006; *R. roxellana*: Zhang et al, 2000). These findings indicate the existence of biological reproductive rhythms that are not influenced by either photoperiod or temperature (Fooden & Aimi, 2003). This study indicated that conception and mid-lactation of *R. bieti* overlapped with the peak in staple food availability, and weaning overlapped with the abundance of high quality foods (new suitable vegetation). Therefore, food availability was the ultimate factor determining the reproductive seasonality of *R. bieti*, while other environmental factors, such as precipitation, temperature and photoperiod, functioned as proximate factors for fine-tuning coordination between seasonal breeding and food availability (Wikleski et al, 2000). However, whether conception or weaning has priority in this regulation of reproductive seasonality still needs long-term, systematic observations of monkeys in different habitats.

### Birth synchrony

Restrictions in environmental conditions induce seasonal synchrony (Power, 2013). When reproduction of Northern Plains Gray Langur (*Semnopithecus entellus*) is not tied with seasonality, synchrony is lost. Obvious reproductive signals (such as menstruation) in females enable males to control mating, and thereafter decrease food competition and increase their fitness. However, the more restricted reproduction is by seasonality, the more significant the reproductive synchrony. Females may conceal reproductive signals to confuse paternity and or decrease the chance of adult males initiating infanticide (Power, 2013). In addition, strong reproductive seasonality results in greater synchronicity in female ovulation and birth (Power, 2013). *R. bieti* births at

Xiaochangdu were more synchronized than those at Mt. Lasha (*SD* was 6.5 and 16.9 days, respectively). This indicated that higher habitat altitudes resulted in stronger birth synchronicity, and may also be correlated with highly synchronized ovulations in female monkeys.

Reproductive synchrony of females, including estrus, birth and length of breeding season, prevents males from monopolizing mating (Carnegie *et al.*, 2011). The more females share reproductive synchrony, the more difficult it is for males to control the reproduction process (Power, 2013). Breeding patterns, such as polygamy and multi-male-female groups, are determined by reproductive seasonality because even the strongest male is unable to totally monopolize multiple females in synchronized pregnable states (Srivastava & Dunbar, 1996). As a result, reproductive synchrony is prone to induce monkey groups with multiple males and females, whereas polygenous groups are more common with reproductive non-synchrony, which is beneficial in ensuring paternity (Power, 2013). The Xiaochangdu monkeys showed a double peak in births, while the monkey at Mt. Lasha displayed three peaks. These phenomena resulted from the strong reproductive synchrony (brief breeding season) of the high altitude monkey groups, the rather large group size (Xiaochangdu group was 210 in 2003 and the Mt. Lasha group was 130 in 2012), and the birth synchrony among different OMUs.

#### Annual differences in birth patterns

The birth peak of the Mt. Lasha group was “V” shaped in even-numbered years, but exhibited an increasing trend in odd-numbered years. In odd-numbered years, the Md shifted ten days earlier than that in even-numbered years. Moreover, the commencement and termination of the breeding season occurred earlier. These phenomena may be correlated with annual differences in food resources or strategies adopted by

OMUs to decrease food competition; however, more evidence from long-term food detection and systematic research is needed.

#### Decrease in reproductive rate

Adult female *R. bieti* at Mt. Lasha gradually increased; however, no such trend was found in infants. From 2009–2011, all females successfully reproduced. In 2012, there were 33 adult females (including four females that reached maturation in 2012) in the group, but there were only 15 infants. In 2013, the numbers of adult females and infants were 34 and 13, respectively. These results indicate that either some adult females did not reproduce (e.g., in 2012, five females did not reproduce and in 2013, six did not), or some infants died. Further research is required to determine if this low reproductive rate is caused by individual aging, female sexual competition, habitat saturation, or by infant deaths.

#### Breeding season determination

Black-and-white snub-nosed monkeys inhabit original coniferous forests at high altitude in temperate regions. Due to the steep terrain and harsh climates of their habitats and the nature of monkeys to avoid humans, it is difficult to perform close observation or achieve individual recognition. Under such circumstances, only partial I/F data was acquired with one observation, and only I/F can be used to estimate breeding season (Xiang & Sayers, 2009). However, if all adult females and infants could be recognized in multiple observations, then the I-value alone is sufficient to infer accurate breeding seasonality and birth pattern (this study, Huang *et al.*, 2012).

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### ***Zoological Research* again recognized for Excellence and Impact in Science and Technology Publishing in 2014**

At the September 2014 conference hosted by the Institute of Scientific and Technical Information of China (ISTIC) in Beijing, *Zoological Research* (ZR) was ranked among the top 300 journals classified as “Outstanding S&T Journals of China” for 2014 due to its high academic value and the leading role it plays in advancing the quality of the S&T journals of China. Few journals in China ever receive this ranking, but this is the second time ZR has now been recognized by this award twice since 2008.

ISTIC also launched a new project to promote scientific communications and the growing internationalization of Chinese S&T journals of China called the “Project of Frontrunner 5000” (F5000). This project plans to highlight the 5000 top articles picked from among the 300 Outstanding S&T Journals of China—four articles published in ZR between 2009-2013 were included in the top 5000.

The Chinese Science Citation Database (CSCD) for 2014 was also released by the National Science Library of the Chinese Academy of Science, ranking ZR among the “Top 300 S&T Journals of China with the Highest Impact Factors.”

All in all, it has been a good year for ZR.