

## 23 YEARS RESEARCH OF SICHUAN SNUB-NOSED MONKEYS (*Rhinopithecus roxellana*) IN ZHOUSHI NATIONAL NATURE RESERVE, CHINA

Da-peng Zhao<sup>1,2</sup> and Bao-guo Li<sup>1</sup>

<sup>1</sup> College of Life Sciences, Northwest University, Xi'an, China.

<sup>2</sup> College of Nature Conservation, Beijing Forestry University, Beijing, China.

### ABSTRACT

The mountainous 52,931 ha Zhouzhi National Nature Reserve (ZNNR) in the Qinling Mountains of China is home to one of the world's most threatened primates, the Sichuan snub-nosed monkey (*Rhinopithecus roxellana*). Although no accurate numbers are available, a recent census in ZNNR estimated the total population at 1,100-1,200 individuals. The habitat has been severely degraded due to unsustainable exploitation of natural resources from human economic activities, especially from commercial logging, and there is rapid loss and changes in its habitat. Since the late 1980s, various ecological and behavioral studies on this China-endemic primate species have been conducted in ZNNR. In this paper, we give an overview on some key findings based on our 23-year research experience and provide some recommendations to efficiently protect the species in ZNNR.

**Keywords:** *Rhinopithecus roxellana*, Zhouzhi National Nature Reserve, China, ecology, behavior.

### INTRODUCTION

The Zhouzhi National Nature Reserve (ZNNR) (107°33'–108°20'E, 33°33'–33°56'N) was established in 1985 to protect 52,931 ha of temperate forest on the northern slopes of the Qinling Mountains in Shaanxi province, China. ZNNR experiences a semi-humid montane climate, with spring from March to May, summer from June to August, autumn from September to November, and winter from December to February. The composition of the forest in ZNNR varies with altitude, from deciduous broadleaf forest at low elevations to mixed coniferous broadleaf forests above 2,200 m and coniferous forest above 2,600 m. The Reserve was established because it provides habitat for the China-endemic and Endangered Sichuan snub-nosed monkey (*Rhinopithecus roxellana*) (Long & Richardson, 2008). The most recent census conducted in 1998 estimated the *R. roxellana* population in ZNNR at 1,100-1,200 individuals in 12 groups (Li *et al.*, 2001), which is about 5% of the world population (Quan & Xie, 2002).

The Sichuan snub-nosed monkey of the Qinling Mountains was first reported on by Liu (1959). Studies on this species in ZNNR have been undertaken systematically since the late 1980s. Many aspects of its ecology, social organization, behavior, and protection have been reported by researchers, mainly from

Northwest University of China. Information on the species is mainly based on studies undertaken by the second author and his students since 1989. The information is supplemented with personal observations and communication with local communities. However, research on the species is better known from studies at Shennongjia and Baihe Nature Reserves in the Hubei and Sichuan provinces, respectively (Kirkpatrick *et al.*, 1999; Gron, 2007). This paper attempts to review some key findings of long-term habitat surveys and behavioral observations. In addition, we discuss the conservation prospects for the Sichuan snub-nosed monkeys in ZNNR.

### 1. Threats to *R. roxellana* in ZNNR

Although this species has been on China's list of First-class Protected Animals since 1975, its survival status is not assured. For a long time due to unsustainable exploitation of natural resources for human economic activities, especially commercial logging, its habitat has rapidly diminished and changed dramatically (Li *et al.*, 2002; Li *et al.*, 2003a). According to the Institute of Forestry Research and Design of Shaanxi, about 40,000 m<sup>3</sup> of logs were removed from the Qinling Mountains annually in the last century. From 1996 to 1997, the habitat of one *R. roxellana* troop of Yuhuangmiao region in ZNNR was subjected to commercial logging.

Although its range still contained enough food, and the vegetation continued to provide a safe refuge from peoples and predators, the activities of the two logging companies seriously disrupted the limited surrounding habitat, threatening the troop's survival (Li *et al.*, 1999).

In ZNNR, *R. roxellana* is faced with deforestation and habitat fragmentation, caused not only by commercial logging but also by local villagers' daily activities (Li *et al.*, 2001; Li *et al.*, 2002; Li *et al.*, 2003a). During our fieldwork, we noticed that most local villagers in ZNNR practice traditional ways to cut wood for cooking and other daily energy-related purposes. Spring is the season for local villagers to collect medicinal plants and in fact, in April, there were about 40 people per day collecting plants within the home range of our study troop. Furthermore, tourism is having an increasing negative impact, mainly due to the development of roads and other infrastructure. Hence, the key research findings are reviewed, and some suggestions for further protection of Sichuan snub-nosed monkeys in ZNNR are offered.

## 2. Review of Research on *R. Roxellana* in ZNNR

Below we summarize some key findings of 23 years of ecological and behavioral research on Sichuan snub-nosed monkeys in ZNNR.

### A. Home range and feeding ecology

There is a seasonal change in home range of *R. roxellana* in ZNNR (Li *et al.*, 1999; Li *et al.*, 2000). Its home range size was 14.1 km<sup>2</sup> in spring, 9.5 km<sup>2</sup> in summer, 12.1 km<sup>2</sup> in autumn, and 12.3 km<sup>2</sup> in winter; the total area used was 22.5 km<sup>2</sup> (Li *et al.*, 2000). The monkeys used both logged and unlogged areas (Guo *et al.*, 2004) and their movement across the home range was extensive in spring and restricted in autumn (Tan *et al.*, 2007). The daily path length (DPL) varied from 0.75 km to 5 km, with a mean of 2.1 km. The monkeys occupied elevations 1,500–2,600 m above sea level, with an annual mean of 2,137 m (Tan *et al.*, 2007).

*R. roxellana* consumed 84 plant species and its overall diet consisted of 29.4% fruit/seeds, 29.0% lichens, 24.0% leaves, 11.1% bark, 4.2% buds, 1.3% twigs and 1.0% unidentified items

(Guo *et al.*, 2007). Once, *R. roxellana* preyed and consumed an Eurasian blackbird (*Turdus merula*) in ZNNR, and food-sharing behavior among higher-rank members occurred in the one-male unit when this vertebrate prey was obtained (Zhao *et al.*, 2008a). It has also been reported that *R. roxellana* in ZNNR will alter its diet rather than its home range when it is faced with a weather event that causes its main food items to become rare (Li *et al.*, 2003b).

### B. Social composition and hierarchy

Studies have found that the basic social and reproductive unit in *R. roxellana* is the harem or one male unit (OMU), consisting of a single resident male, and a number of adult females, sub-adult females, juveniles and infants (Zhang *et al.*, 2006). OMU size ranges from 5 to 14 individuals, with an averaging at  $9.0 \pm 2.3$  individuals. One OMU included only 1 adult male with 2-5 ( $3.3 \pm 0.9$ ) adult females, 0-2 ( $1.1 \pm 0.6$ ) sub-adult females, 1-4 ( $2.0 \pm 0.9$ ) juveniles and 0-2 ( $1.0 \pm 0.8$ ) infants and neonates (Zhang *et al.*, 2006). Both male and female dispersal occurred (Chen *et al.*, 1983; Zhao *et al.*, 2008b). Immigration/emigration rates of adult females are higher than those of sub-adult females (Zhao *et al.*, 2008b). Adult male *R. roxellana* may live with more than one unit of females during their lifetime (Zhao & Li, 2009).

Dominance index analysis showed a linear dominance ranking order existing within and between OMUs (Li *et al.*, 2006; Zhang *et al.*, 2008). Within an OMU, the resident male was the highest-ranking individual; followed by adult females, sub-adult females, and finally the juveniles. A female's rank within its OMU is not static, an adult female may rise in rank after she has given birth (Li *et al.*, 2006). The rank order of OMUs could change between the mating season and birth season (Li *et al.*, 2006). The dominance rank of OMUs was positively correlated with the duration of their stay in the band, and this may be attributed to the association of the resident male with adult females, rather than the fighting ability of resident males, as males do not fight seriously with each other. Subordinate units were observed to merge with dominant units resulting in an elevation of their rank (Zhang *et al.*, 2008).

### C. Sexual behavior and reproductive strategy

For Sichuan snub-nosed monkeys, normal copulation behavior includes courtship, mounting, intromission and ejaculation (Li & Zhao, 2007). The intromission process can be further divided into two phases: intromission prophase and intromission anaphase (Zhao & Li, 2005). *R. roxellana* is a seasonal breeder although copulation occurs throughout the year, with the majority of copulations occurring between September and November (Li & Zhao, 2007). Females initiated 96.2% of courtship attempts, while males initiated only 3.8%. There is a skewed sexual competition with multiple females competing for a single male, which was shown in female courtship attempts and female sexual interference (Zhao, 2005; Li & Zhao, 2005 & 2007).

Habitat fragmentation has caused geographic isolation between various monkey populations. Within the social structure of the Sichuan snub-nosed monkeys, due to this habitat fragmentation, inbreeding is a strong possibility as a result of the resident male copulating with his offspring. Zaho *et al.* (2005) first reported extra-unit sexual behavior in wild *R. roxellana*, and that in such cases the female apparently prefers to choose a new resident male over a more established one. This extra-unit sexual behavior exhibited by wild *R. roxellana* appears to be a kind of genetic 'bet-hedging' strategy, which decreases the likelihood of inbreeding depression by increasing the degree of heterozygosity in their offspring.

It should be mentioned that monkeys could adopt a flexible behavioral strategy in the event of individual dispersal. For instance, after a male takeover, the new resident male and OMU females show different behavioral adjustments (Zhao *et al.*, 2008c). At the same time, the members' sexual interactions are consistent with an interpretation of behavioral adjustment towards male takeover, and of inbreeding avoidance. In addition, adult female *R. roxellana* employs various reproductive strategies related to female dispersal, which may increase their reproductive success (Zhao *et al.*, 2008b).

### 3. Past and Future Conservation Efforts

In China, some wildlife including the Sichuan snub-nosed monkey, are strictly protected by local laws and regulations, such as the "People's Republic of China Constitution", the "People's Republic of China Forest Law", the "People's Republic of China Wildlife Conservation Law", the "People's Republic of China Environment Law" and the "Management Methods for Forest and Wildlife Type Nature Reserves". Based on these laws and regulations, Shaanxi Province has issued additional laws and regulations, namely the "Rule of Wildlife Management of Shaanxi Province", the "Lists of Shaanxi Major Protected Animals" and the "Lists of Shaanxi General Protected Animals". The Shaanxi Provincial government gazetted 52,931 ha as the Zhouzhi Nature Reserve to protect wild Sichuan snub-nosed monkeys and their forest habitat in 1985. Three years later, the Chinese central government upgraded it to a National Nature Reserve, which falls under the management of the Administrative Bureau of Zhouzhi Nature Reserve in Zhouzhi County.

Since the 1990's Northwest University researchers have carried out surveys and research on this endemic species in cooperation with the ZNNR management authorities. This research has been supported by a number of successive national and international funding agencies, and include the Natural Science Foundation of China, Chinese Key Project of Ministry of Education, Chinese Shaanxi Natural Science Foundation, Primate Conservation Inc., Nippon Life Insurance Fund of Japan, Daiko Foundation of Japan, Zoological Society of San Diego, and Cosmo Oil Eco Card Fund some of which were directed towards the protection of the species. For instance, to recover the habitat of Sichuan snub-nosed monkeys in ZNNR, 27,000 trees were planted between 2005-2007 on obsolescent logging roads with the support from Cosmo Oil Eco Card Fund.

Knowledge about the ecology and behavior of Sichuan snub-nosed monkeys is critical for their conservation. A long-term comprehensive conservation and research project is imminently required for *R. roxellana* in ZNNR. Further research

should focus on traditional forest management, status investigations in severely degraded forests, periodical population surveys, and comparative ecological studies including *R. roxellana* populations in ZNNR and those in Shennongjia Nature Reserve and Baihe Nature Reserve. With this information, detailed conservation strategies for this Chinese endemic species can be established. Meanwhile, it is urgent that increasing development of local tourism in ZNNR should be effectively managed by both national and local administrations.

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