RESEARCH ARTICLE

Social Organization of Black-and-White Snub-Nosed Monkeys (Rhinopithecus bieti) at Deqin, China

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Data on social organization of two bands of black-and-white snub-nosed monkeys (Rhinopithecus bieti) were collected when the monkeys were crossing an open spot at Nanren and Bamei (northwest of Yunnan, China) using a sampling rule where individuals within one social unit are spatially closer to each other than individuals between social units. The typical pattern of social organization in this sample was multiple adult females (AFs) and their offspring with one adult male (AM) in a one-male unit (OMU), similar to that of many other colobines. In such units, on average one male is associated with 4.0 AFs and 2.5 of their offspring. Moreover, there are multimale/multifemale units and monogamous units besides OMUs. All bisexual units traveled together with at least one all-male unit as a cohesive band. In two bands of monkeys, 87% of AMs in bisexual units were within OMUs, 7.8% within monogamous bands and 5.2% within multimale, multifemale units. In the Bamei band, 6.7% of AMs were in the all-male unit. The size of OMUs in the Nanren band was larger than that of the Bamei band, which may be related to better conservation in the Nanren band’s habitat. For the Nanren band, the average number of AFs in OMUs varied across time, increasing from 4.3 in 1994 to 5.1 in 2001, and then decreasing to 3.8 in 2005. This article suggests three possible explanations for this variation, but more data are needed for these hypotheses to be tested. Am. J. Primatol. 70:169–174, 2008.

Key words: social organization; one-male unit; monopolization; Rhinopithecus bieti

INTRODUCTION

Colobine monkeys show great diversity in their social organization, including monogamy, matrilineal-harem, matrilineal-multimale and patrilineal-multimale societies [Newton & Dunbar, 1994]. In Asian colobines, the typical pattern of bisexual groups is multiple females and their offspring with a single male (one-male units [OMUs]), usually associating with at least one all-male unit (AMU) or solitary males; in some species, however, bisexual groups contain multimales, with two or, rarely, three or more males [Kirkpatrick, 2007]. It has been reported that both single and multimale groups are found in Trachypithecus leucocephalus [Li & Rogers, 2003], sometimes within one population [e.g., Presbytis entellus: Newton, 1988; Nasalis larvatus: Boonratana, 2002].

There is wide variation in OMU size and the number of adult females (AFs) in OMUs among species and within populations of the same species of Asian colobines. The extremes of OMU size range from 11–34 monkeys with only 4–12 AFs in P. entellus [Newton, 1987] to 5–13 animals with 2–5 AFs in Presbytis pileata [Stanford, 1991a]. The percentage of adult males (AMs) in bisexual units within OMUs varies between species, ranging from...
zero in *Trachypithecus cristatus* [Curtin, 1980; Furuya, 1961] to 100 in *Rhinopithecus brelichi* [Bleisch et al., 1993]; and also varies among different populations of a species [refer to Kirkpatrick, 2007]. The ratio of AMs to AFs in OMUs can differ to a large extent between species, ranging from 1:0.1 in *Simias concolor* [Watanabe, 1981] to 1:0.8 in *N. larvatus* [Boonratana, 2002], and also between different populations of a species [refer to Kirkpatrick, 2007].

The number of AMs in a group should be related to the monopolizability of females [Emlen & Oring, 1977; Wrangham, 1980]. If a male can monopolize reproductive access to multiple females and defend them against other males, the optimal male strategy will be harem-defense polygyny [Emlen & Oring, 1977]. When a male cannot monopolize females, a multimale group will form and reproductive competition will be most pronounced within rather than between groups. In these cases, the optimal male strategy may then be to share females rather than risking lost reproductive chances [van Schaik & van Hooff, 1983].

Black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) inhabit a restricted area (<25,000 km²) of the trans-Himalayas between the Mekong River (to the west) and Yangtze River (to the east), and between latitudes of 26°14’N and 29°20’N [Long et al., 1996]. The physical condition of the area is harsh for fieldwork because of steep slopes, deep gorges and 4–6 months of snow-covered winter. *R. bieti* monkeys mainly live in fir forests where visibility is very poor, and they are also very shy of humans. Under these conditions, short-term surveys of the monkeys indicated that <1,700 individuals lived in 15 isolated groups of this species in its whole range [Xiang et al., 2007; Xiao et al., 2003] of which about 80% of the populations resided in the northwest of Yunnan, and 20% in southeast Tibet [Long et al., 1996]. Moreover, only six of 15 groups have been counted since 1979, they are Nanren group [≈300; G. MacLennan, personal communication], Lijiang group [≈50; Yang, 2000], Fuheshan group [≈80; Liu & Zhao, 2004], Gehuaqing group [≥360] and Xiangguqing group [≥200] in Yunnan [Xiao et al., 2003]; and the Xiaochangdu group in Tibet [≥210; Xiang et al., 2007]. Information on the social organization of this species has been limited to one study of the Wuyapiya population [Kirkpatrick et al., 1998]. The population was composed of 15–18 OMUs that traveled together in a cohesive band with at least one AMU. The largest OMU was composed of 14–16 members; the AMU was variable in composition with a core of two AMs and several juveniles. Sub-AMs were most often associated with the AMU [Kirkpatrick et al., 1998]. These findings offer useful base counts of the population, but lack any systematic data on the species’ social organization.

In this survey, we systematically collected data on the social organization of two bands of *R. bieti* whenever the monkeys were crossing open areas in a field. This study is designed to present quantitative data on the social organization, analyzing the difference in composition of OMUs between bands and changes in each band over time.

**MATERIALS AND METHODS**

**Study Sites and Study Populations**

Data on the social organization of two bands of *R. bieti* were collected at two different sites when the monkeys were observed crossing an open gully. One band of over 175 individuals inhabited the forests around the village of Nanren, Yunnan, China (99°40’E, 28°34’N, Baima Snow Mountain Nature Reserve) at the northernmost range of the Wuyapiya band [Kirkpatrick et al., 1998]. The vegetation in this area is typified by striking altitudinal zonation. In general, alpine meadows change into conifer forests at <4,300 m, giving way to oak forests at 3,800–3,600 m and oak shrubs at <3,600 m [Cui et al., 2006a]. The second monkey band observed is estimated to include <50 individuals [Long et al., 1996] and inhabits the relatively undisturbed forests around the village of Bamei, Yunnan (98°43’E, 28°54’N), northwest of the Nanren band. The vegetation here is primarily composed of conifer forests at higher altitudes and oak forests at lower elevations.

**Social Composition of the Band**

Characters for determining age–sex classes of *R. bieti* individuals [Kirkpatrick, 1996] were used during the course of sampling. An AM can be distinguished from an AF on the basis of the striking sexual dimorphism in body weight (M/F ≈ 2) [Kirkpatrick, 1996]. Female *R. bieti* become mature at 4.5 years of age, and males at about 6.5–7.0 years of age [Zou, 2002]. A sub-AM is larger than an AF in body weight, and characterized by longer and more strongly contrasting black-and-white hair; they are usually excluded from OMUs and appear in AMU or as solitary males. Immatures clapping their mothers’ bellies were considered infants during the course of movements, and other immature individuals moving independently on the ground were regarded as juveniles [Cui et al., 2006b]. Because these monkeys were not habituated enough to be observed at close distances (<100 m), they were observed with a monocular telescope (Nikon ED II, 25–56X: Nikon Corporation, Tokyo, Japan) from a protruding ridge opposite a slope used by the monkeys. But from a distance of >300 m, it was difficult to consistently differentiate sub-AMs from AFs; we may therefore report a biased estimate of sex ratios of males to females.
Bisexual units of *R. bieti* traveled together and often used the same travel path, but boundaries existed between units. Units were obvious particularly when they crossed gullies terrestrially or traveled above the tree line [Kirkpatrick et al., 1998]. Social units within these bands could be distinguished because the individuals within social units were spatially closer to one another than individuals between social units when the monkeys were crossing an open area, such as gullies and bald rocks at higher altitudes [Cui et al., 2006b].

Data on the social organization of the Nanren band of *R. bieti* were collected three times. The first set of data was obtained from a June 1994 video-recording (made by Zhi-Nong Xi on a Sony, PVW-537: Sony Corporation Company, Tokyo, Japan) of the monkeys' crossing an open gully of $\geq20\text{ m}$ in width. The distance between the photographer and the monkeys was approximately $500\text{ m}$. Only 17 bisexual units could be distinguished in part because of frequent changes in the focus of the video. AMUs were not recorded. Additional observations were made directly using a telescope.

The second observation was carried out on November 6, 2001 when the majority of the monkeys were passing orderly through a 20-m width of gully. The distance between the observer and the monkeys was estimated to be approximately $600\text{ m}$. As the monkeys traveled quickly across the gully in two parallel lines and the anterior individuals mingled together, only 15 social units could be recorded in their entirety. Again, AMUs were not observed.

The third observation was conducted on January 1, 2005 when the monkeys were crossing orderly a gully of about $15\text{ m}$ width between conifer forests. The distance between the observer and the animals was estimated to be approximately $400\text{ m}$. Several individuals in the front of the procession were not identified because they had entered the opposite forests before sampling. A total of 29 social units and two AMUs were recorded.

The *R. bieti* observed at Bamei traveled through a large area characterized by bald rocks on November 27, 2004. The distance between the observer and the group was approximately $300\text{ m}$. Because this band of monkeys moved in sequence, the whole procession was recorded in its entirety.

### Data Analysis

A two-level nested analysis of variance with the Tukey Honestly Significantly Different test was used to compare various characteristics of OMUs composition in the Nanren band across time and between the Nanren and Bamei band. The statistical analyses were conducted using STATISTICA 6.0 (StatSoft, Inc. Tulsa, OK). The tests were two-tailed and the threshold for significance was set at $P \leq 0.05$.

### RESULTS

#### Composition of Social Units of the Nanren Band Across Time

A total of 133 individuals were recorded within 17 social units in June 1994, of which 88% were OMUs ($n=15$), 6% were monogamous units ($n=1$) and 6% were multimale, multifemale unit (MMU) ($n=1$). The single MMU consisted of two AMs, three AFs and two juveniles. In November 2001, a total of 152 monkeys were recorded, including 151 animals within 15 bisexual units (93.3% of the units were OMUs [$n=14$], and 6.7% were MMU [$n=1$]) and one solitary AM. The MMU consisted of two AMs, seven AFs, three juveniles and three infants. In January 2005, a total of 225 monkeys were recorded in 31 units, of which 83.9% were OMUs ($n=26$), 9.7% were monogamous units ($n=3$), and 6.4% were AMUs ($n=2$). Of three monogamous units, one unit was composed of one AM, one AF and their single infant; and the remaining both consisted of pairs of adult monkeys. The two AMUs consisted of one all-AM unit (nine monkeys) and one all-sub-AM unit (24 individuals). Age–sex composition of OMUs in the band across time is shown in Table I.

#### Composition of the Band of *R. bieti* at Bamei

A total of 73 individuals were recorded in 15 social units, of which 80.0% were OMUs ($n=12$), 13.3% were monogamous units ($n=2$) and 6.7% were AMU ($n=1$). Composition of OMUs for this band is also shown in Table I. One of the monogamous units was composed of an AM and AF, and the other included a bisexual pair and a single infant. The AMU consisted of one AM and possibly eight sub-AMs. All bisexual units were at the front of the procession, and the AMU was at the rear.

#### Changes in OMUs Composition

OMU size of the Nanren band was significantly larger than that of the Bamei band ($F_{1,63}=17.34$, $P<0.001$), with more AFs ($F_{1,63}=13.66$, $P<0.001$), more juveniles ($F_{1,63}=9.48$, $P<0.01$) and no difference in the number of infants ($F_{1,63}=2.82$, $P>0.05$). There was a significant difference in OMU sizes among the different periods for the Nanren band ($F_{2,63}=4.98$, $P<0.01$). The Nanren band showed more individuals per unit (HSD, $P<0.05$), more AFs ($F_{2,63}=4.97$, $P<0.01$; HSD, $P<0.05$) and more juveniles ($F_{2,63}=4.06$, $P=0.02$; HSD, $P=0.044$) in 2001 than in 2005 and no difference between the other 2 years (HSD, $P>0.05$ for all). No difference was found in the number of infants per unit ($F_{2,63}=0.40$, $P=0.67$).
DISCUSSION

The modal pattern of bisexual units observed in these two bands of *R. bieti* is of multiple females in OMUs with their offspring, findings consistent with the previous report for this species [Kirkpatrick et al., 1998]. In such units, one AM associated with 4.0 AFs and 2.5 offspring on average. In the two bands of monkeys, 87% of AMs within bisexual units were in OMUs, 7.8% in monogamous units and 5.2% in MMUs. In the Bamei band, 6.7% of AMs were found in the AMU. All bisexual units formed a large cohesive band traveling together, just as reported previously [Kirkpatrick, 1996]. In addition, there existed at least one AMU in each band, though their composition varied widely within one band [Kirkpatrick et al., 1998] and across bands. Thus, this study quantitatively supports the previous report of the social organization of *R. bieti* [Kirkpatrick, 1996], and is also similar to reports for many other colobines [Kirkpatrick, 2007; Newton & Dunbar, 1994].

OMUs of *R. bieti* varied widely in their sizes and in the number of AFs within and between bands and across time. Such variation raises new questions and demands for additional study to arrive at convincing explanations. The OMU size of the Nanren band in 2001 was as large as 17 monkeys with as many as eight AFs. However, in 1994 the OMU size was as low as five individuals with three AFs. In the Bamei band, the largest OMU comprised nine monkeys with up to five AFs; the smallest OMU included only three individuals with two AFs. Such within-species variation has also been reported in other colobines [*S. concolor*: Watanabe, 1981; *P. entellus*: Newton, 1987; *N. larvatus*: Boonratana, 2002]. A single Hanuman langur male has been reported to be able to monopolize up to 12 AFs [Newton, 1988], far more than in the largest bisexual unit found in this study. Additional information about the degree of estrus synchrony in this species is needed to understand why there appears to be a threshold in the number of AFs that can be monopolized by one male. For the Nanren band, the average number of AFs in OMUs varied across time; AFs increased from 4.3 in 1994 to 5.1 in 2001, and then decreased to 3.8 in 2005. This fluctuation has three possible explanations. First, AFs in OMUs increased to a threshold larger than 5.1 after 2001, then were reduced rapidly by the fissions of units. Second, the AFs per unit increased up to 5.1 on average, and then began to decrease for unknown reasons. Third, the fluctuation might be because of changes in the surrounding environment over time. Additional systematic and long-term data must be gathered to test these hypotheses.

In our study bands of *R. bieti*, six monogamous units were recorded, four in the Nanren band and two in the Bamei band. The monogamous units may be the residual parts of larger OMUs or MMUs,

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OMUs, one-male units; AM, adult male; AF, adult female; IM, immatures; AD, adults.

**TABLE I. Age-Sex Composition of OMUs in Bands of* Rhinopithecus bieti***

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OMUs, one-male units; AM, adult male; AF, adult female; IM, immatures; AD, adults.
which split into two or more smaller units, or formed by a pair of solitary adults. It is also possible that they may consist of a young male that is just in the process of attracting females to him to form an OMU, or an older AM who has lost all of his females but one. Moreover, females may sometimes leave their group to join a lone male following OMUs [Stanford, 1991b; Steenbeek et al., 2000]. These pairs may be transitory in these cases. However, more data are needed to track the dynamics of bisexual units.

In our study, the two MMUs may be formed by sons maturing in an OMU and tolerated by their father, or a male unable to monopolize the females in his OMU or tolerating other males only if the potential fitness is greater than the costs. However, the temporary MMUs in Asian colobines might be related to the gradually increasing aggression between males which resulted in a group split [Kirkpatrick, 2007].

The similar habitat types and lichen food sources distributed in large patches in Bamei and Nanren led us to predict similar demographic features in these two bands of R. bieti. However, the Nanren band consisted of larger OMUs with more AFs and juveniles. The Nanren band ranged inside a national nature reserve established in 1988, whereas no nature reserve has yet been established for the Bamei group. Thus, the differences in composition may be related to the difference in conservation status and disturbance in their habitats; poaching, logging and other human disturbances have previously been reported to affect group size [Dunbar, 1987; Struhsaker, 1997].

The percentage of AMs in bisexual units within OMUs of R. bieti was not consistent over time and within bands. Observations of the Nanren band in 2005 and the Bamei band in 2004 found the percentage to be 100, consistent with previous reports of R. bieti [Kirkpatrick et al., 1998] and R. brelichi [Bleisch et al., 1993; Bleisch & Xie, 1998]. But the percentage of AMs in bisexual units was lower in the Nanren band in 2001 and 1994, 93.3 and 91.4 respectively. In Rhinopithecus roxellana species, this percentage ranged from 77 to 100 within different bands [Ren et al., 1998]. These percentages in all the four species of Rhinopithecus were within the range seen in other colobine monkeys, ranging from 66 to 100 [Pygathrix nemaeus: Lippold, 1977] to 100 [R. brelichi: Bleisch et al., 1993; N. larvatus: Bennett & Sebastian, 1988; Yeager, 1990; S. concolor: Watanabe, 1981].

CONCLUSIONS

This study describes the social organization of two bands of R. bieti. The basic social unit of this sample is multiple females and their offspring with one male in an OMU, which is consistent with the social organization seen in many other colobines. Multimale/multifemale units and monogamous units are also found. All of the above noted social units travel together with at least one AMU as a cohesive band. The OMUs size and composition varies within bands and across time. Thus, it is necessary that further research is done on the social organization of populations of this species at other sites under different environmental conditions to clarify what factors determine this diversity.

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