



# Leopard predation on wild Sichuan snub-nosed monkeys

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## Abstract

Predation is widely recognized as a powerful selective pressure on primate behavior and ecology, although knowledge of predator–prey relationships remains limited partly due to the rarity of directly observed attacks on primates. Here, we describe four confirmed or suspected instances of leopard (*Panthera pardus*) predation on free-ranging Sichuan (golden) snub-nosed monkeys (*Rhinopithecus roxellana*), a highly endangered colobine species endemic to China. We recorded predation events and the reactions of monkey group members. We suggest that the evolution of a multilevel society may be an adaptive response by Sichuan snub-nosed monkeys to the risk from leopards as well as other potential predators, one that balances the pressures of predation and intra-species competition and conflict.

**Keywords** *Rhinopithecus roxellana* · *Panthera pardus* · Predatory attacks · Alarm calls

## Introduction

Predation has long been considered to be a key selection pressure in primate behavioral evolution (Cheney and Wrangham 1987; Treves 1999; Zuberbühler and Jenny 2002; Miller and Treves 2011; Shultz et al. 2011). Group living is thought to have evolved as an anti-predator strategy in primates; it enhances collective alertness, dilutes the risk of predation for group members, and increases defensive capabilities against predators (van Schaik 1983; Isbell 1991; Boinski et al. 2000; Treves 2000; Hart 2007). In parallel, however, pressures arising from group living, such as increased competition for food and mates, and a greater likelihood of being detected by predators have also influenced the evolution of individual and social behaviors (Isbell 1991; Boinski et al. 2000; Majolo et al. 2008).

Large cats are known to prey on primates in all regions where both occur. Although immaturity and being on the ground may increase vulnerability to attacks by felids (discussed by Isbell 1994), many of the latter are excellent climbers and can also kill adults in trees. Numerous reports of predatory attacks in South America (e.g., Peetz et al. 1992; Ludwig et al. 2007; Matsuda and Izawa 2008; Santos et al. 2014) and Africa (e.g., Busse 1980; Boesch 1991; Tsukahara 1993; D'Amour et al. 2006; Isbell et al. 2018; Matsumoto-Oda 2015; McLester et al. 2019; Lin et al. 2020) testify to the danger posed to extant primates by felids. In

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Asia, nonhuman primates are preyed upon by tigers (*Panthera tigris*, Karanth and Sundquist 1995; Støen and Wegge 1996; O'Brien et al. 2003), leopards (*Panthera pardus*, Seidensticker 1983; Naha et al. 2018), snow leopards (*Panthera uncia*, Lyngdoh et al. 2014), and clouded leopards (*Neofelis diardi*, Matsuda et al. 2008; Morino 2011). However, with rare exceptions (e.g., Zhang et al. 1999; Matsuda et al. 2008), most accounts concerning predation on Asian primates rely on indirect evidence, such as contents of the stomach or feces of likely predators. Reports of primates' responses to encounters with any potential predators are therefore useful for improving our understanding of predator–prey relationships (see, e.g., Isbell 1991; Tutin et al. 1981).

The Sichuan snub-nosed monkey (*Rhinopithecus roxellana*, also called the golden snub-nosed monkey) is an Endangered colobine species endemic to China, with a declining population of fewer than 20,000 individuals (Li et al. 2001; Li and Zhao 2007; Yongcheng and Richardson 2021), mainly distributed in the montane forests at 1000–4100 m above sea level in Hubei, Shaanxi, Sichuan, and Gansu provinces (Qi et al. 2011). Our study population in the Qinling Mountains of Shaanxi Province has been studied since 2011 (Zhang et al. 2006; Qi et al. 2011; Yang et al. 2016a, b, c, 2022, 2023). These monkeys live in large groups of 100–400 members, in a multilevel society in which a group contains several one-male units (OMU) and one or more all-male units (AMU). Each OMU contains a single resident adult male and several adult females, juveniles, and infants; an AMU contains only adult and subadult males.

Here, we present four confirmed or suspected incidences of leopard predation, and we describe the reactions of members of the group to which the victims belonged.

## Observations and results

Between 2011 and 2021, we recorded one confirmed and three highly likely instances of leopards preying on a wild group of Sichuan snub-nosed monkeys. In each case, while the monkeys were being followed or observed by members of our research team, a leopard suddenly attacked the monkeys; more specifically, one monkey. Predation targets were three adult males from the AMU of the study group, and an old female member of an OMU. The prey individual had sometimes either strayed out of the group or, in the case of the old female, lagged behind the group as it moved. In all four incidents, members of the group emitted alarm calls (“WU-GA,” transcribed as “Wuka” by Li et al. 1993, who provide a sound spectrogram). This is a general warning call, usually given in response to a disturbance in the environment, or danger. The monkeys did not attempt to mob the leopard, but ran and climbed quickly into the tree canopy, where they engaged in frequent grooming and huddling,

appearing tense and anxious. Our study site is in a mixed forest with brush, bamboo, grass, and rocks, all of which provide good hiding places for a leopard to wait undiscovered by monkeys before suddenly attacking.

### Observation 1. Capture of an AMU older male

On March 23, 2013, at about 16:50, the monkeys left their feeding site and climbed higher up the mountain, feeding as they moved toward a sleeping site. The AMU headed the group movement, and one OMU trailed behind the rest of the group. At 17:23, a scream came from the front of the group, which caused many group members to start “WU-GA” alarm calling. An adult male was the first to emit alarm calls, followed by other adult males, adult females, and juveniles. The group ran quickly back in the direction they had come from and climbed high into trees, from where they continued alarm calling while looking in the direction of the screams. Some minutes later, our field assistants discovered a leopard dragging a dead male snub-nosed monkey along the ground, about 200 m away from the group. The distance between the leopard and the closest field assistant was approximately 150 m. At this time, the group was still occasionally alarm calling from the trees, and some adult females, juveniles, and infants were huddling, vocalizing, and grooming. The monkeys remained in the trees, feeding and grooming, after the leopard left. At about 18:10, they began to move in another direction. We established that an older adult male (more than 17 years old) was missing from the AMU; this male usually fed and moved around the group alone, and moved relatively slowly. We found no corpse in the area, but we found some leopard footprints.

### Observation 2. Capture of an OMU older female

On July 10, 2019, at approximately 08:40, as the group moved forward to feed, one older female (estimated to be more than 16 years of age) moved very slowly and lagged about 300 m behind the group. The field assistants heard an “Aaa” cry from the female's position, and then silence. The distance between the incident and the closest field assistant was about 200 m. The monkey group gave “WU-GA” alarm calls (an adult female first, followed by adult males, adult females, and juveniles), and all members ran to the trees and looked in the direction from which the female's cry had come. After about 10 min, the group calmed down and continued to move forward to forage. About 6 h later, we went to see if we could find the old female. We saw blood on the ground, but no corpse. We searched in an area of about 100 m<sup>2</sup> and found some leopard footprints. An infrared automatic

camera about 1000 m away had taken a photo of a leopard earlier that morning (at 07:17; Fig. 1A).

### Observation 3. Capture of an AMU adult male

On April 23, 2020, at about 16:15, the monkeys were feeding below trees by the river. However, one AMU adult male was alone, more than 400 m away; he had been following the group at a distance as he had been attacked by group members several times when he got closer. At 16:21, from the direction of the lone monkey we heard a sudden crash of vegetation and an “Aaa” cry and screams from the monkey, and then silence. The closest field assistant was about 150 m away from the incident. The group emitted many “WU-GA” alarm calls (an adult female first, and then other members of the group), climbed high into the trees, and moved further away. After moving more than 500 m, they stopped and occasionally looked back toward the direction of the incident. After about another 10 min the monkeys became calm again, fed, and started to move towards a sleeping site farther away. The next day, we climbed to the place where the lone monkey had screamed and found some bloodstains, but no corpse. We searched in an area of about 200 m<sup>2</sup> and found some leopard footprints. An infrared automatic camera about 500 m away from here had taken a photo of a leopard at 19:55 the previous evening (Fig. 1B).

### Observation 4. Capture of an AMU adult male

On January 9, 2021, at about 11:10, most members of the monkey group were feeding at the roadside of a ravine. Suddenly, shrieks were heard coming from about 300 m above

the group. The monkeys ran away while “WU-GA” alarm calling (an adult female first, and then other members of the group), and most of them quickly climbed high into trees. They continued to scream and alarm call intermittently in the trees, looking in the direction of the shrieks. After more than 10 min, the group moved quickly down into the ravine and down river until they were more than 1000 m away, when they stopped moving and started to feed and groom. About an hour later, author BY and several field assistants went to check the place where the original sound had come from. They carried shovels, machetes, and other objects for self-defense in case of danger. From a distance, they saw a leopard walking up the mountain. After the leopard disappeared, the team moved to the side of the road near to where the shrieks had come from, and found the corpse of a Sichuan snub-nosed monkey, devoured except for one leg, tail, two forelimbs, and back skin; the head, internal organs, and other body parts were missing. The remains of the carcass were consistent with consumption by a leopard. The remains were of an adult male monkey, and we subsequently confirmed that the AMU was missing one member. In a search in an area of about 200 m<sup>2</sup> around where the remains were found, we found some leopard footprints. Within the next 2 days an infrared camera about 1 km away photographed a leopard.

### Discussion

These observations, made in the context of a long-term study, confirm that leopards kill and eat wild Sichuan snub-nosed monkeys in the Qinling Mountains. Although clouded leopards also exist at this site, as yet we have no record of them preying on the monkeys. Our report also presents the first detailed descriptions of how Sichuan snub-nosed monkeys react to predatory attacks by leopards. When



Fig. 1 Photos related to predation events

such encounters occurred, the monkeys emitted alarm calls, grouped closer together, and fled into the tree canopy. We saw nothing resembling mobbing behavior, but clear signs of fear and nervousness, with grooming and hugging behaviors likely employed to relieve the tension.

Infrared automatic cameras installed in the field frequently photographed leopards, indicating their prominence in the study area and their role as a predator of these monkeys. In each of the recorded attacks, the leopard had probably detected the researchers but continued preparing its attack on the monkeys, which would suggest habituation to researcher presence. Also, in each attack the victim was an isolated or a peripheralized individual, which supports the hypothesis that predators maximize their chance of success by preferentially targeting the most vulnerable individuals in the group (Hamilton 1971; Quinn and Cresswell 2006; Josephs et al. 2016). However, we do not rule out the possibility that even individuals within the group, where vigilance may be relatively relaxed, may also be the target of predatory attacks.

As in several other primate species, adult male Sichuan snub-nosed monkeys may be particularly vulnerable to attacks by leopards. Male primates are often seen around the periphery of the group, foraging or moving (patas monkeys: Burnham and Riordan 2012; geladas: Snyder-Mackler et al. 2012), making them potentially more likely targets for ambush predators. In the cases reported here, AMU males, particularly those who were attacked, were almost always on the periphery of the larger group; elderly or sick females may also become separated from the group and thus more likely to be attacked. Furthermore, adult males may be more likely than other age-sex classes to directly confront predators, putting themselves at greater risk of being killed (van Schaik et al. 2022, and see Nautiyal et al. 2023).

Our observations suggest that predation risk for the study group of monkeys varied with the nature of the vegetation: long grass and shrubs afford concealment for ambush predators (Loarie et al. 2013). All attacks reported in this study occurred in low-visibility microhabitats, consistent with other reports of ambush attacks by felids on primates (e.g., baboons: Cowlshaw 1994; chimpanzees: Boesch 1991).

If they spot a potential predator either lurking or approaching, the monkeys typically emit alarm calls and flee. In the cases described here, however, the monkeys emitted alarm calls only after an attack occurred, which suggests that they were unaware of the leopard's presence before the attack. Post-attack, they showed high levels of arousal and fear. Alarm calling thus appears to be an important anti-predation response of Sichuan snub-nosed monkeys. These reactions highlight the monkeys'

perception of leopards as a source of serious danger. We hypothesize that predation, particularly by large felids, has been a selective factor in the formation of Sichuan snub-nosed monkeys' large groups and multilevel society, adaptations that address not only the pressures of predation but also intra-species competition and conflict. The study of the effects of predation pressure on primates requires more scientific evidence, which is one direction of our future research on Sichuan snub-nosed monkeys.

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**Author contributions** BY conceived of the study; BY, JRA, NNG, BH, SYC, JL, YFC and KFW analyzed the data; BY, NNG, BH, SYC, JL, YFC, WWF, WFW, BJC, BGL and KFW collected the data; BY and JRA wrote the manuscript, and all authors revised and approved the final manuscript.

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**Data availability** All data are available upon reasonable request.

## Declarations

**Conflict of interest** The authors declare that they have no competing interests.

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