

Letter to the editor

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Population and conservation status of a transboundary group of black snub-nosed monkeys (*Rhinopithecus strykeri*) between China and Myanmar

We examined the distribution, population, and conservation status of the critically endangered Myanmar or black snub-nosed monkey (*Rhinopithecus strykeri*) via field surveys over 26 months (2019–2021) in the Pianma region of the China-Myanmar border. Contrary to previous reports, we only identified one group in the region, which was a cross-border group occupying a multi-year home range of 51.50–57.02 km². The current group size was much larger (155–160 individuals) than that in 2012–2014 (*ca* 100 individuals), and the group appeared to be growing. However, confirmed poaching, mining, and transboundary forest fires on the Myanmar side of the border threaten their survival. Our findings provide the latest information on the distribution and population demography of the imperiled *R. strykeri*, signifying new hope for population recovery of this rare primate species. We highlight cross-border challenges to their conservation and call for transboundary actions between China and Myanmar to protect *R. strykeri*.

With only five known groups (400 individuals minimum) dwelling in remote forests of Mt. Gaoligong along the northern China-Myanmar border (Meyer et al., 2017), the Myanmar or black snub-nosed monkey (*R. strykeri*) is among the rarest of non-human primates (Geissmann et al., 2011). This critically endangered species is seriously threatened by human disturbances such as hunting, logging, and infrastructure construction (Geissmann et al., 2020; Meyer et al., 2017). However, the huge differences in conservation capabilities between China and Myanmar likely affect its distribution and population level, resulting in a distinct conservation status for each group (Supplementary Materials). Clarifying the distribution and population status of *R. strykeri* is a prerequisite for coordinating effective conservation in remote border areas (Chapman, 2018; Meyer et al., 2017; Wang et

al., 2021).

However, current knowledge on species distribution and population remains limited, even ambiguous, thereby hindering accurate evaluation of the conservation status of each group (Geissmann et al., 2011; Ma et al., 2014; Meyer et al., 2017). No comprehensive population census of the Myanmar groups has been conducted due to the extreme difficulties in observations, with group size and distribution estimates largely based on reports from locals (Geissmann et al., 2011; Meyer et al., 2017). A local interview-based study in China suggested the existence of four groups (160–260 individuals), including three putative cross-border groups in the Pianma region (Figure 1A; Supplementary Table S1) (Ma et al., 2014). However, subsequent surveys identified only one domestic group (*ca* 100 individuals) occupying a home range of 22.90 km² (Chen et al., 2015; Li et al., 2014). Sporadic poaching, selective logging and herb collecting have contributed to population decline (Fan et al., 2022; Li et al., 2014; Ma et al., 2014), resulting in a strong population skew towards adults compared to juveniles (Supplementary Table S2). However, these short-term surveys likely missed some individuals and covered only a small portion of the species' home range, thus providing limited insight into the distribution, population, and conservation status of *R. strykeri*. Additionally, the presence and extent of cross-border groups remain unclear.

To elucidate the population and conservation status of *R. strykeri* groups near the Chinese-Myanmar border, we conducted field surveys from 1 January 2019 to 28 February 2021 in the Pianma region in China (Lushui city, Nujiang Lisu

Received: 09 February 2022; Accepted: 22 April 2022; Online: 25 April 2022

Foundation items: This work was supported by the Biodiversity Survey, Monitoring and Assessment Project of Ministry of Ecology and Environment (2019HB2096001006), Strategic Priority Research Program of Chinese Academy of Sciences (XDA23080000, XDA19050000), National Natural Science Foundation of China (31670397, 32171487), State Forestry Administration of China, and Rufford Foundation (24816-1)

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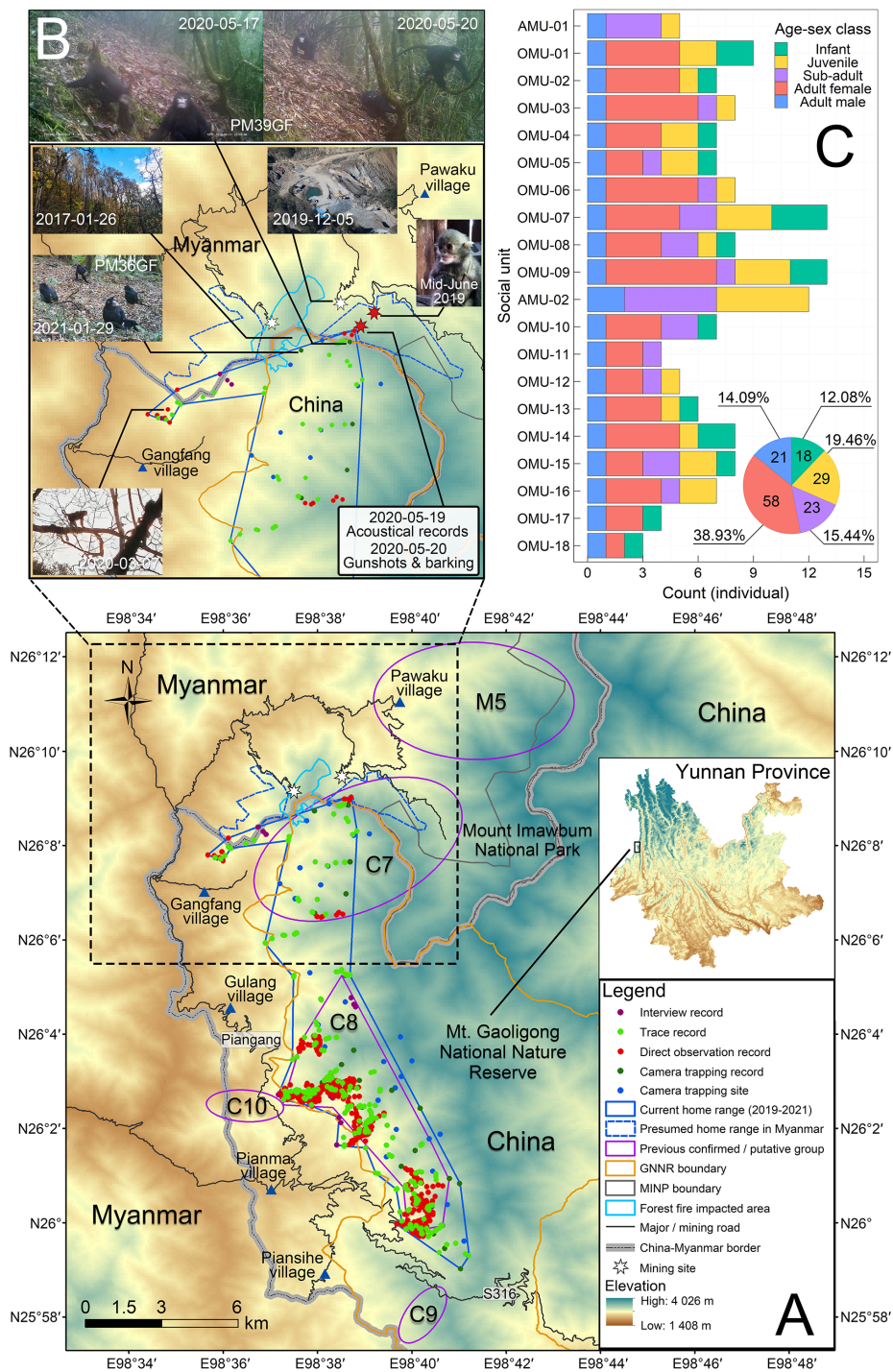


Figure 1 Survey area, recorded threats/transboundary activities, and population composition of *Rhinopithecus strykeri*

A: Survey area in Pianma region, Yunnan Province, China. Blue polygon represents current home range based on surveys from 1 January 2019 to 28 February 2021. Purple polygon (C8) and ellipses (C7, C9, C10, and M5) are previously confirmed or provisional group distributions. Group names and ranges follow Chen et al. (2015), Ma et al. (2014) and Meyer et al. (2017). B: Recorded transboundary activities of *R. strykeri* near border between Gangfang village (China) and Pawaku village (Myanmar). Two captions (in rectangular box) and seven images pinpoint several key locations and dates of transboundary group activities and human disturbances. "PM36GF" and "PM39GF" are camera trap sites that captured images of *R. strykeri* near the border. Four asterisks (*) indicate interview and acoustic records of species poaching (red) and mining sites (white). Photo of captured infant was provided by an anonymous witness (relative of one of the Pianma region interviewees) in Pawaku village, Myanmar. C: Population and social unit composition of group based on 18 November 2020 census. Order of social units (OMU: one-male, multi-female unit; AMU: all-male unit) on y-axis (from top to bottom) follows temporal sequence during the census.

Autonomous Prefecture, Yunnan Province, China; N25°56'–26°09', E98°35'–98°41') and adjunct region in Myanmar (Figure 1A). The survey area was primarily within the Mt. Gaoligong National Nature Reserve (GNNR), which contains pristine evergreen broadleaf, conifer, and bamboo forests (1 900–3 800 m above sea level (a.s.l.)) (Chen et al., 2015). The survey area is administered by the Piansihe, Pianma, Gulang, and Gangfang villages. Two major roads (S316 and Piangang, paved prior to late 1992) have created artificial barriers within the GNNR and adjacent areas (Figure 1A). The northern part of the survey area (Gangfang village) adjoins Pawaku village and the recently designated Mount Imawbum National Park (MINP) in Myanmar, and forests along the national border are contiguous (Meyer et al., 2017).

Interviews, direct tracking, observations, and infra-red camera traps were used to record the presence and geographic locations of *R. strykeri* groups (Supplementary Materials) (Chen et al., 2015; Ma et al., 2014). When the monkeys crossed open areas, we censused the group to record the number of adult males, adult females, sub-adults, juveniles, and infants based on morphological traits (Supplementary Figure S1; Supplementary Table S3), and further categorized the latter three age-sex classes as “immature”. We also identified one-male, multi-female units (OMUs) and all-male units (AMUs) from census observations. During the surveys, we recorded human disturbances, particularly poaching with guns, crossbows, or hounds, selective logging, and forest fires within the home range, as direct threats to the species (Meyer et al., 2017).

We mapped the multi-year home range of *R. strykeri* from all recorded locations using the 100% minimum convex polygon approach (Chen et al., 2015). We assessed current population composition by calculating the ratios of adult male-to-adult female, adult female-to-infant, and adult-to-immature, then compared them with previous census data from 2012–2014 (Supplementary Table S2) to detect composition differences. Details on survey and analysis methods are available in the Supplementary Materials.

We spent 212 working days in the forests searching for *R. strykeri* and managed to locate and follow them for a total of 46 days. We obtained 1 002 geographic locations of the species (Figure 1A; Supplementary Materials). Of these, 33 were located near the China-Myanmar border (<1 km) between the Gangfang and Pawaku villages (Figure 1B). Interviewees in Gangfang village reported that the species (≥ 40 individuals) crossed the border once in mid-January 2016. We recorded the species crossing the border into unprotected forest around Pawaku village (Myanmar) on three occasions (7 March, 17 May, and 19 May 2020), and into protected forest on the Chinese side of the border on one occasion (20 May 2020) (Figure 1B; Supplementary Materials). The species was only found at the Pianma, Gulang, Gangfang, and Pawaku villages (Figure 1A). On the days we encountered *R. strykeri*, temporally separated sub-groups (3–70 individuals) were detected half the time (on 23 days), suggesting frequent group fission-fusion. However, except for temporally separated AMU members, we only detected *R. strykeri* in same area (village) during same period (2–3 days), and never

recorded breeding bands (OMU clusters) simultaneously at any two locations more than 3 km apart, suggesting only one cross-border group (C8+C7) in the Pianma region (Supplementary Table S1). The group covered an altitudinal range of 2 143 m to 3 372 m a.s.l. and occupied a multi-year home range of 51.50 km², with an additional 5.52 km² presumed range on the Myanmar side (Figure 1A).

We managed to conduct a census of the group on 18 November 2020, when the monkeys openly crossed a rivulet over a distance of ~30 m as a large cohesive group. We counted 149 individuals, including 21 adult males, 58 adult females, 23 sub-adults, 29 juveniles, and 18 infants, within 18 OMUs and two AMUs (Figure 1C; Supplementary Table S2). As peripheral units or individuals may have been missed, we conservatively estimated the actual group size at 155–160 individuals. The mean OMU size was 7.33 ± 2.56 individuals (range=3–13) and the mean number of adult females per OMU was 3.22 ± 1.27 (range=1–6). The adult male-to-adult female, adult female-to-infant, and adult-to-immature ratios were 1:2.76, 3.22:1, and 1.13:1, respectively (Figure 1C; Supplementary Table S2).

We did not record *R. strykeri* poaching, selective logging, or herb gathering in GNNR. However, interviewees reported three anecdotes of *R. strykeri* poaching in mid-January 2016, mid-June 2019, and late-February 2021 in the unprotected forest of Pawaku village, Myanmar. At least five individuals, including one adult female and four infants (Figure 1B), were captured as pets in mid-June 2019 in Pawaku village. On 20 May 2020, we recorded one case of targeted poaching near the border, involving gunfire and dogs on the Myanmar side (Figure 1B). On 26 January 2017, a transboundary forest fire broke out on the Myanmar side and damaged ca 1.83 km² of forest, which partially included the multi-year home range of *R. strykeri* (Figure 1B). We also recorded two mining sites located close to the species' home range (300–800 m) on the Myanmar side (Figure 1B).

Contrary to previous reports of the existence of four groups (Ma et al., 2014), our findings indicated only one cross-border *R. strykeri* group (C8+C7) in the Pianma region (Figure 1A; Supplementary Table S1). Due to frequent fission-fusion within the multi-level societies of snub-nosed monkeys (Kirkpatrick & Grueter, 2010), earlier interview-based surveys may have misidentified temporally separated sub-groups as distinct populations (Ma et al., 2014). Thus, we propose that C7 (ca 30 individuals), a previously identified putative cross-border group, is a sub-group or breeding band of confirmed group C8 (Supplementary Table S1). As we did not find any evidence of *R. strykeri* in Piansihe village, coupled with the impact of artificial barriers (paved roads and villages) (Figure 1A), two other small putative groups (C9 & C10, ca 10–20 individuals) should be historical records of temporally separated sub-groups (Supplementary Table S1). However, further surveys in neighboring areas are needed to clarify the status of C9, as it may have moved to another region (Meyer et al., 2017). As the forest along the border is contiguous, the unconfirmed Myanmar population M5 (ca 30–100 individuals) also requires additional investigation to clarify its status and relationship to the C8+C7 group in the Pianma region (Figure 1A) (Meyer et al., 2017).

The current multi-year home range (51.50–57.02 km²) of the group is much larger than the previously estimated 22.90 km² (Chen et al., 2015), suggesting a considerable underestimation in previous surveys. However, the large social groups of snub-nosed monkeys (100–450 individuals) tend to prefer vast home ranges over multi-year periods when contiguous pristine habitats are available (Fan et al., 2019; Kirkpatrick & Grueter, 2010). A larger home range means more available resources and potential reduction in conspecific competition and aggression (Kirkpatrick & Grueter, 2010; Zhang et al., 2019). We observed that free-ranging *R. strykeri* preferred uncommon and seasonal foods (e.g., lichens, flowers, and fruits of *Michelia* and *Actinidia* spp.), rather than abundant items from dominant trees (e.g., mature leaves of *Quercus* or *Rhododendron* spp.) (Chen Y., unpublished data). These socioecological traits imply that extra-large home ranges are likely a behavioural strategy of *R. strykeri* for conspecific competition dilution and energy requirements.

Current group size estimate (155–160 individuals) is 1.5–1.6 times larger than that reported previously (Chen et al., 2015; Li et al., 2014). More importantly, while the group composition of adults has remained largely stable (Supplementary Tables S2, S4), it now contains significantly more infants and immature individuals (46.98%) than in 2012–2014 (Figure 1C; Supplementary Tables S2, S4) (Supplementary Materials). Notably, the adult-to-immature ratio (1.13:1) is much lower than the 2012–2014 ratio (2.13:1 and 2.04:1) (Supplementary Table S4) and is comparable to other stable snub-nosed monkey populations (Supplementary Table S2). We therefore suggest that the group has experienced population growth in recent years, which is promising for population recovery of this critically endangered species (Chapman, 2018).

Although currently well protected in China, further population growth of this firstly confirmed cross-border group is facing serious challenges from poaching, mining, and transboundary forest fires on the Myanmar side (Figure 1B). The skewed adult female-to-infant ratio suggests low reproductive and high infant mortality rates (Figure 1C; Supplementary Table S4), which may further impact *R. strykeri* survival under high human disturbance. Therefore, we urge immediate transboundary collaborations to bridge the protection gaps of *R. strykeri*. Coordinated joint border patrols and law enforcement by local governments and protected area administrations (GNNR and MINP) are needed to combat illegal activities (e.g., poaching and logging) and prevent forest fires. Joint surveys of unconfirmed populations (e.g., M5 and C9) along the border are also required. Furthermore, recruiting and training local people as forest rangers will simultaneously improve local livelihoods and strengthen conservation capabilities (Supplementary Materials). To further protect *R. strykeri*, we also emphasize the integration of conservation action with nationwide policies (e.g., Ecological Poverty Alleviation) and international cooperative mechanisms (e.g., the Belt and Road Initiative).

SCIENTIFIC FIELD SURVEY PERMISSION INFORMATION

Before conducting surveys, we gained approval from the State

Forestry and Grassland Administration of China, Nujiang and Lushui Bureaus of GNNR, local government, and Institutional Animal Care and Use Committee of Central South University of Forestry & Technology. All data collected were purely observational.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Y.X.C., Z.F.X., and J.C. designed the study. Z.F.X., Z.S.X., M.L., J.C., and Y.X.C. contributed to project/funding administration. Y.X.C. led and carried out the field surveys. G.W.Z., Z.J.Z., and X.W.W. participated in the field surveys and provided logistic support. Z.F.X., Z.S.X., and M.L. provided camera trap support. Y.X.C., Y.Y., and C.L. analyzed the data and drafted and revised the figures. Y.X.C. drafted the manuscript. Y.X.C., Y.Y., C.L., and Z.F.X. revised the manuscript. All authors read and approved the final version of the manuscript.

ACKNOWLEDGEMENTS

We thank the Nujiang and Lushui Bureaus of GNNR and local government for their support. Local forest rangers, Mr. Pu Liu, San-Cai Pu, Huo Ran, Jian-Wen Su, Hua-Yi Zhou, Bo-Yi Pu, Liu-Yi Hu, Li-Fu Le, Cai-Fu He, Er-Xin Ma, Xin-Rong Ou, and Shao-Hua Dong provided important field assistance. Mrs. Yan-Hua Chen (CCTV-9), Mr. Gui-Pin He, and Bin Wang (GNNR) provided additional infra-red cameras. We are grateful to Mr. Michael Lawes, editors, and two anonymous reviewers for comments and suggestions during manuscript revision.

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