

# Transboundary conservation of the last remaining population of the cao vit gibbon *Nomascus nasutus*

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**Abstract** The cao vit gibbon *Nomascus nasutus*, also known as eastern black crested gibbon, is categorized as Critically Endangered on the IUCN Red List and was considered one of the world's 25 most threatened primates. The only known population occurs along the border between China and Viet Nam. Accurate information on population size and dynamics is critical for the species' conservation, but population surveys conducted in only one country may over- or underestimate total population size because the home ranges of cao vit gibbon groups often cross the international border. In 2007 and 2016 we conducted two collaborative transboundary censuses of the cao vit gibbon populations in the Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area in Viet Nam and the Bangliang Gibbon National Nature Reserve in China. The results showed a population size of 102–110 in 2007, which increased to 107–136 in 2016. Our results indicate that previous surveys conducted separately in Viet Nam and China underestimated the global population size of this species. According to our more comprehensive surveys, the gibbon population is increasing slowly. The gibbons and their habitat are legally protected in both countries. Hunting and charcoal making have not been reported in this area since 2007. As habitat carrying capacity is a limiting factor, habitat restoration is required. However, lack of funding to protect the cao vit gibbon remains a challenge.

**Keywords** Cao vit gibbon, China, *Nomascus nasutus*, population size, threats, transboundary conservation, Viet Nam

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## Introduction

Political borders rarely coincide with the natural boundaries of wildlife populations (Vitkalova et al., 2018) and often artificially separate animal populations. Transboundary populations that live along international borders are often subject to different management regimes on each side of the border (Gervasi et al., 2016; Linnell et al., 2016; Thornton et al., 2018). Language barriers, lack of trust, and differences in sampling designs and data collection protocols can make transboundary information exchange difficult (Vitkalova et al., 2018), hindering the effective conservation of such populations.

The cao vit gibbon or eastern black crested gibbon *Nomascus nasutus* was once widespread in south China and north-east Viet Nam, east of the Red River (Tien 1983; Geissmann et al., 2000; Rawson et al., 2011). Hunting and habitat loss have led to a dramatic population decline (Geissmann et al., 2000) and by the 1960s the cao vit gibbon was thought to be extinct in both countries (Tan, 1985; Geissmann et al., 2003). The species was rediscovered in 2002 in a small karst forest patch in Trung Khanh District, Cao Bang Province, Viet Nam, close to the Chinese border (La & Trinh Dinh, 2002; Geissmann et al., 2003). In 2006 the species was observed in the same forest patch on the Chinese side (Chan et al., 2008), making it a transboundary population.

Because only one small population survives, the cao vit gibbon is considered the second rarest ape species. Only the Hainan gibbon *Nomascus hainanus* has a smaller population size (ca. 29 individuals; Bryant et al., 2016). The cao vit gibbon is categorized as Critically Endangered on the IUCN Red List (IUCN, 2017) and was considered one of the world's 25 most threatened primates during 2008–2014 (Mittermeier et al., 2009, 2010, 2012). The species' habitat has been seriously degraded as a result of selective logging, charcoal making, farming and livestock grazing (Fan et al., 2013). To conserve the last population of the cao vit gibbon, the Vietnamese government established the Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area in 2007, and the Chinese government set up the Bangliang Gibbon Autonomous Nature Reserve in 2009 and upgraded it to national protection level in 2013 (Fig. 1).

Accurate information on population size and dynamics is critical for conservation of threatened species. However, population surveys conducted on only one side of a political

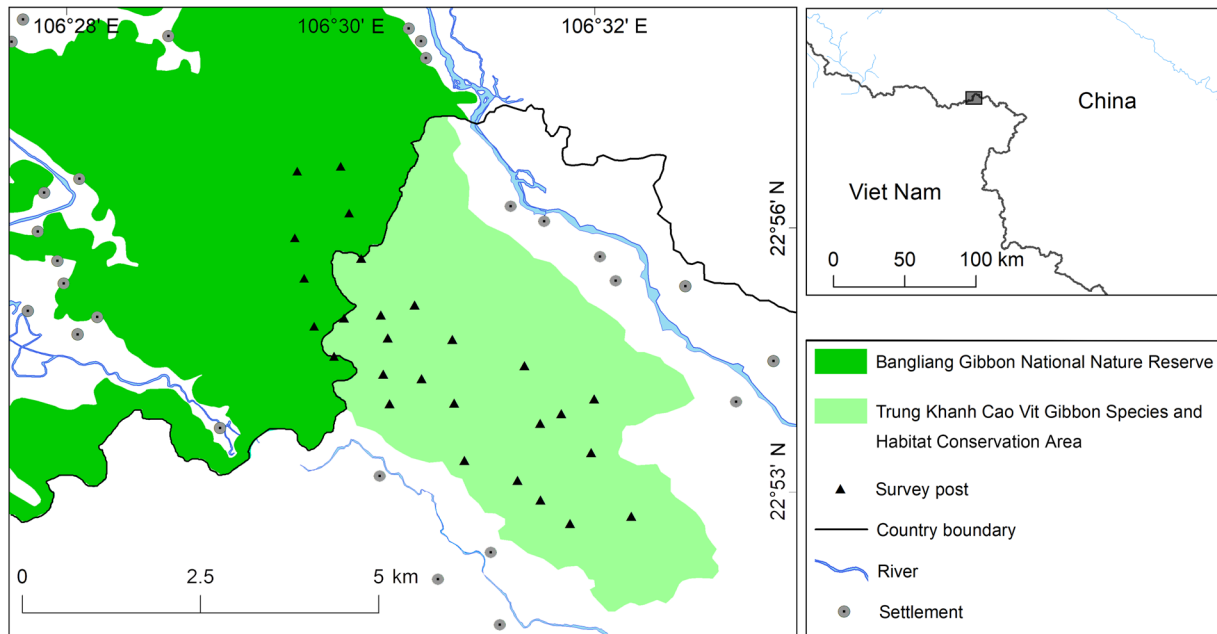


FIG. 1 The study site and survey posts in the Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area, Viet Nam, and the Bangliang Gibbon National Nature Reserve, China.

border may overestimate total population size as individuals or groups travel across the border and are counted by both countries (Vitkalova et al., 2018), and researchers may underestimate total population size because areas adjacent to political borders are avoided because of security concerns. Since the rediscovery of the cao vit gibbon in 2002, several surveys and censuses have been conducted on the Vietnamese side of the border in the Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area. These surveys recorded a population with 26–28 individuals in 2002 (Geissmann et al., 2002), 37 in 2004 (Trinh Dinh, 2004), and 27–35 in 2005 (Vu et al., 2005). These surveys underestimated the species' population size because three more groups also exist on the Chinese side, as was discovered in 2006 (Chan et al., 2008).

To obtain an accurate estimate of the total population size of the cao vit gibbon, two transboundary censuses were conducted, in 2007 and 2016, by the Management Board of Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area and the Administrative Bureau of Bangliang Gibbon National Nature Reserve, with the support of Fauna & Flora International (FFI) Viet Nam and China Programmes. Here, we report the results of these surveys, analyse population trends since the species' rediscovery, discuss factors that limit gibbon population increase, and propose potential solutions.

### Study area

We conducted surveys along the Chinese and Vietnamese international border in the Bangliang Gibbon National

Nature Reserve in Guangxi Province, China, and the Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area in Cao Bang Province, Viet Nam (Fig. 1). The study area is characterized by a typical karst limestone landscape consisting of densely packed outcrops, sharp-peaked mountains with steep slopes, ridges and vertical cliffs, interspersed with lowland valleys. Altitude is 400–950 m and the vegetation is monsoon tropical forest that has been degraded by selective logging, fuelwood collection, charcoal making, and agriculture prior to the establishment of the nature reserves (Fan et al., 2011). On the Chinese side of the border, 113 tree species and 46 woody liana and epiphyte species were recorded in 44 20 × 20 m plots, and mean canopy height was 10.5 m (Fan et al., 2011). Diversity of tree and woody liana species was higher in the valleys and slopes than on the cols and ridges (Fan et al., 2011). Previous studies found cao vit gibbons consumed foods from > 81 tree and liana species, with 19 species accounting for 77.8% of total feeding time (Fan et al., 2011). Fruits made up 58% of the gibbons' diet, and leaves and buds accounted for 16.9 and 14.3%, respectively (Fan et al., 2011). No comparable information is available for Vietnamese cao vit gibbon groups, but we assume that habitat quality and gibbon ecology and behaviour are similar on both sides of the border.

### Methods

We applied auditory techniques that were developed especially for gibbon surveys (Brockelman & Ali, 1987) and were used in this area in previous surveys (Geissmann et al., 2002, 2003; Chan et al., 2008). In 2007 we set up 18

TABLE 1 Survey results for the cao vit gibbon *Nomascus nasutus* population in 2007 and 2016.

| Year | No. of gibbon groups | No. of transitory individuals | Total no. of individuals | Country  | Survey dates | No. of surveyors | No. of listening posts |
|------|----------------------|-------------------------------|--------------------------|----------|--------------|------------------|------------------------|
| 2007 | 17–18                | 0                             | 102–110                  | Viet Nam | 07–19 Sep.   | 22               | 18                     |
|      |                      |                               |                          | China    | 07–14 Sep.   | 17               | 6                      |
| 2016 | 20–22                | 3–4                           | 107–136                  | Viet Nam | 11–24 Sep.   | 31               | 21                     |
|      |                      |                               |                          | China    | 11–16 Sep.   | 16               | 8                      |

survey posts in Viet Nam and six in China (Supplementary Table 1), located on outcrop peaks and ridges, where we could record gibbon vocalizations from several nearby valleys. The surveys posts covered all potential gibbon habitats (Fan et al., 2013) and all locations where gibbons had been recorded during previous surveys and routine patrols. In 2016 we used the same survey points from 2007 and set up three new posts in Viet Nam and two in China (Supplementary Table 1), to sample an area of regenerating habitat that was considered suitable for gibbons (Fig. 1).

The survey dates and number of researchers involved in the surveys are presented in Table 1. To ensure that the field teams used the same techniques for all surveys, all researchers attended a 2-day training course prior to the field surveys, although most had already participated in previous gibbon surveys in this area and were familiar with the morphological characteristics and calls of cao vit gibbons.

A previous study of three groups found cao vit gibbons vocalized mostly (96.4% of recorded calls) in the mornings, from 30 minutes before to 4 hours after sunrise (Fei et al., 2010). Individual groups vocalized on a mean of 69.6% of all monitoring days and the mean number of singing bouts on days when they did vocalize was 1.24 per day (Fei et al., 2010). As the sun rises at c. 6.30 in September in our survey area, we monitored all survey points during 06.00–11.00 for at least 4–6 successive days. We occasionally occupied the survey points until 17.00 to observe gibbons when they were foraging nearby. Once the gibbon songs were heard, researchers recorded the date, location of survey posts, direction and estimated distance between survey posts and gibbon groups, and the start and end time of each song bout. We recorded the call type and the number of individuals producing a particular type of call. Call types included duet song bouts, male solo song bouts, female solo song bouts, isolated great-calls, and alarm calls (Feng et al., 2013). Song bouts or isolated great-calls were defined as distinct vocalization events if they were separated from previous calls by an interval of at least 5 minutes.

During the survey, we tried to locate and observe gibbon groups if they were calling close to the survey points. Because gibbons are canopy dwellers and canopy height is low in our study area, researchers could observe gibbons from survey points using binoculars (Fan et al., 2011, 2012). Once we located a gibbon group, we recorded the

start and end time of the sighting, and the direction and distance of the gibbons from the researchers. We also recorded the group size and composition (including adult male, adult female, juvenile and infant), to distinguish between neighbouring groups. Adult male cao vit gibbons were defined as fully grown and black in colour. Adult females are yellow with a white facial ring and a large black crest extending from head to the centre of their back. Juveniles are black, smaller than adult males, and fully independent from their mother. Infants are black and still dependent on their mother (Mootnick & Fan, 2011). In addition, we also recorded floating individuals; i.e. young adults that have emigrated from their natal group and, at least temporarily, live on their own.

To avoid double counting groups that live along the border and could be heard simultaneously by both teams, researchers from both countries exchanged and discussed survey results after the field surveys, in May 2008 and October 2016. We calculated mean group size based on groups that had been observed and counted, and then multiplied mean group size by the number of groups to estimate total population size.

## Results

### Population size of cao vit gibbons

The combination of listening and sighting information from the surveys indicated there were 17–18 groups in 2007 and 20–22 groups in 2016 (Table 1). In addition, we recorded 3–4 floating individuals in 2016 (none were recorded in 2007). During the survey we counted all members of 14 groups in 2007, and of 13 groups in 2016. The mean group size was  $6.3 \pm \text{SD } 2.02$  ( $n = 14$ , range 3–9) in 2007, and  $6.4 \pm \text{SD } 1.50$  ( $n = 13$ , range 4–8) in 2016 (Tables 2 & 3). Consequently, the estimated population size was 102–110 in 2007 and 107–136 in 2016 (Table 1).

### Group structure of cao vit gibbons

Most groups had two adult females (11 of 14 fully observed groups in 2007, and 12 of 13 groups in 2016). In 2016, we recorded one group with three females. Two females both

TABLE 2 Group composition of cao vit gibbons recorded in 2007.

| Group             | Group composition |              |            |        | Total            | Record <sup>1</sup> | Locality <sup>2</sup>             |
|-------------------|-------------------|--------------|------------|--------|------------------|---------------------|-----------------------------------|
|                   | Adult male        | Adult female | Immature   |        |                  |                     |                                   |
|                   |                   |              | Adolescent | Infant |                  |                     |                                   |
| G1 <sup>3,4</sup> | 1                 | 2            | 4          | 1      | 8                | L, O                | North of Lung Gu                  |
| G2 <sup>3</sup>   | 1                 | 2            | 2          | 1      | 6                | L, O                | West of Lung Gu                   |
| G3 <sup>3,4</sup> | 1                 | 2            | 2          |        | 5                | L, O                | West of Lung Nha Nhung            |
| G4 <sup>3</sup>   | 1                 | 2            | 3          | 1      | 7                | L, O                | West of Lung Ky Gia               |
| G5                | 2                 | 2            | 2          | 1      | 7                | L, O                | North of Lung Nguom               |
| G6                | 1                 | 2            | 2          |        | 5                | L, O                | West of Lung Chi                  |
| G7                | 3                 | 2            | 1          | 1      | 7                | L, O                | North-west of Lung Che            |
| G8                | 2                 | 2            | 3          | 2      | 9                | L, O                | North of Lung Dac                 |
| G9                | 1                 | 1            | 1          |        | 3                | L, O                | East of Lung Dac                  |
| G10               | 1                 | 1            | 1          |        | 3                | O                   | South-west of Lung Co (Nguom Dam) |
| G11 <sup>4</sup>  | 1                 | 2            |            |        | (3) <sup>5</sup> | L                   | South-east of Lung Hoai           |
| G12               | 2                 | 2            | 2          |        | 6                | L, O                | West of Lung Nam (Tap Toan)       |
| G13               | 2                 | 2            | 3          | 2      | 9                | L, O                | North-west of Tap Toan Lon        |
| G14 <sup>3</sup>  | 1                 | 2            | 2          | 2      | 7                | L, O                | Between Nguoc Man & Nguoc Ri      |
| G15               | 3                 | 2            | 2          | 1      | 8                | L, O                | Lung Gia Ray                      |
| G16               | 2                 | 2            | 2          | 2      | 8                | L, O                | Lung Bong Bip                     |
| G17               | 1                 | 1            | 1          |        | 3                | L, O                | Lung Tu Noc                       |
| G18               | 1                 |              | 1          |        | (2) <sup>5</sup> | L, O                | China only                        |

<sup>1</sup>L, listening; O, observation.

<sup>2</sup>Local name of the valley.

<sup>3</sup>These groups' home ranges overlapped the border.

<sup>4</sup>The total number of individuals in these groups is uncertain because they were observed only briefly or were not seen at all (group record based on vocalization only).

<sup>5</sup>The number in parentheses is the minimum number of gibbons in this group (for groups that were observed only briefly and not all members could be counted, or where group size was estimated by vocalization only).

carrying infants were observed in four of the 11 bi-female groups in 2007. In 2016 we recorded only one group with two females that both carried infants. In 2007 seven of 14 fully observed groups contained more than one adult male. In 2016 only one of 13 fully observed groups contained more than one male.

## Discussion

### Global population size of the cao vit gibbon

Our results indicate the presence of c. 20 cao vit gibbon groups with a total population size of > 100 individuals during the 2007 and 2016 surveys. It is unlikely that we missed any groups living in this area, for a number of reasons. Firstly, our survey posts covered all potential gibbon habitats in the study area. Secondly, during a study of three cao vit gibbon groups, individual groups sang on c. 70% of monitoring days (Fei et al., 2010). We monitored each survey point for 4–6 consecutive days. According to a detection function, the chance of detecting a group during a 4-day survey is  $1 - (1 - 0.70)^4 > 0.99$ . In addition, we conducted surveys in September, when cao vit gibbons vocalize most frequently (P.F. Fan, unpubl. data). Thirdly,

the steep karst hills and low canopy, an unusual habitat for gibbons, facilitated gibbon detection in this area. We observed most groups while they were singing (Tables 2 & 3). In addition, we had monitored the population dynamics of gibbons on the Chinese side of the border every month since December 2007 and knew each of these groups, so this subpopulation provided a good control to evaluate the detection rate for our field surveys. We did not miss any known groups on the Chinese side during the surveys.

Based on the transboundary survey in 2007 we estimated the global population of cao vit gibbon to be > 100 individuals. However, population surveys recorded fewer than 40 individuals in Viet Nam prior to 2005 (reported population sizes were 26–28, 37 and 27–35 in studies by Geissmann et al., 2002; Trinh Dinh, 2004; and Vu et al., 2005, respectively) and only 18 individuals in China in 2006 (Chan et al., 2008). It is unlikely that the gibbon population doubled during 2005–2007. Cao vit gibbons mature at 8–10 years of age and the interbirth interval is 3–5 years (Fan et al., 2015). The long juvenile period and long interbirth interval make gibbon population recovery a slow process. We therefore conclude that surveys before 2007 must have underestimated the population size, possibly because they did not cover the area completely. For example, the three groups

TABLE 3 Group composition of cao vit gibbons recorded in 2016.

| Group             | Group composition |                 | Immature   |        | Total            | Record <sup>1</sup> | Locality <sup>2</sup>                                |
|-------------------|-------------------|-----------------|------------|--------|------------------|---------------------|--|
|                   | Adult male        | Adult female    | Adolescent | Infant |                  |                     |  |
| G1                | 4                 | 2               |            | 1      | 7                | L, O                | Lung Ky Gia  |
| G2                | 3                 | 1               | 1          | 1      | 6                | L, O                | Lung Ky Gia  |
| G3 <sup>3</sup>   | 1                 | 1               | 2          | 1      | 5                | L, O                | Lung Nguom   |
| G4                | 1                 | 2 <sup>4</sup>  |            |        | (3) <sup>5</sup> | L                   | Lung Thenh, Lung Chi, Lung Kep That, Lung Chi Dong   |
| G5/2 <sup>4</sup> | 1                 | 2               | 2          | 1      | 6                | L, O                | Lung Ky Gia  |
| G6                | 1                 | 1               | 1          | 1      | 4                | L, O                | Lung Bong Bip  |
| G7 <sup>7</sup>   | 1                 | 2               | 4          | 1      | 8                | L, O                | Lung Gu Nho  |
| G8                | 1                 | 2               | 2          | 1      | 6                | L, O                | Lung Nguom, Nguoc Man, Gia Ray                       |
| G9                | 1                 | 2               | 5          |        | 8                | L, O                | Lung Day   |
| G10               | 1                 | 2 <sup>4</sup>  |            |        | (3) <sup>5</sup> | L                   | Lung Tong On, Lung Dac                               |
| G11               | 1                 | 2               | 5          |        | 8                | L, O                | Lung Che, Lung Day, Lung Dac Dong                    |
| G12               | 1                 | 2               | 2          | 1      | 6                | L, O                | Lung San, Lung Chai Khuyet, Lung Co next to Lung Dac |
| G13 <sup>8</sup>  | 1                 | 1               | 1          |        | (3) <sup>5</sup> | L                   | Lung Co, Lung Dac, Lung Tam Deng                     |
| G14               | 1                 | 1               |            |        | (2) <sup>5</sup> | L                   | Lung Hoai, Lung Tau Lo, Lung Tong On                 |
| G15               | 1                 | 2               | 3          | 2      | 8                | L, O                | Lung Tap, Lung Nam                                   |
| G16 <sup>7</sup>  | 1                 | 2               | 2          |        | 5                | L, O                | Lung May Ri  |
| G17               | 1                 | 1 <sup>4</sup>  |            |        | (2) <sup>5</sup> | L                   | Lung Ngu Khop  |
| G18               | 1                 | 2               | 2          | 1      | 6                | L, O                | Lung Nam   |
| G19 <sup>7</sup>  | 1                 | 2               | 2          |        | 5                | L, O                | Nonglaolang (China only)                             |
| G20 <sup>7</sup>  | 1                 | 3               | 3          | 1      | 8                | L, O                | Lung Ky Gia, Lung Ky Gia Nho                         |
| G21 <sup>9</sup>  | 1                 | 2               |            | 1      | 4                | L, O                | Nongnianda, Nongnianxiao (China only)                |
| G22 <sup>10</sup> | 2                 | 2               | 1          |        | (5) <sup>5</sup> | L, O                | Lung Tong On   |
|                   | 1                 |                 |            |        | 1                | L                   | Lung Gia Ray (near Lung Nguoc Man)                   |
|                   |                   | 1 <sup>11</sup> |            |        | 1                | O                   | Lung Ky Gia  |
|                   | 1                 |                 |            |        | 1                | L, O                | Lung Ky Gia  |
|                   | 1 <sup>8</sup>    |                 |            |        | 1                | L, O                | Nongkou (China only)                                 |

<sup>1</sup>L, listening; O, observation.

<sup>2</sup>Local name of the valley.

<sup>3</sup>We were not able to count all gibbons in the group. There were at least three black individuals and a yellow female with an infant.

<sup>4</sup>The number of females was uncertain.

<sup>5</sup>The number in parentheses was the minimum number of gibbons in this group (for groups that were observed only briefly and not all members could be counted, or where group size was estimated by vocalization only).

<sup>6</sup>Group 5 was possibly the same as Group 2 plus a female. These two groups were recorded in the same valley (Ky Gia) and it was not always possible to count all gibbons in a group during our observations.

<sup>7</sup>These groups' home ranges overlapped the border.

<sup>8</sup>There was an immature male learning to sing.

<sup>9</sup>These groups or individuals were recorded only in China.

<sup>10</sup>Some individuals may have been missed during the observation and it is possible that this group was in fact Group 11 or Group 14.

<sup>11</sup>A single female; it is possible that the animal just split from one of the groups in the valley.

discovered on the Chinese side close to the international border in 2006 were not included in surveys in Viet Nam (Chan et al., 2008). This supports our contention that uncoordinated population surveys on only one side of the border resulted in an underestimation of the population size.

Since 2007 the cao vit gibbon population has been slowly increasing. A Chinese research team led by PFF intensively monitored gibbon population dynamics on the Chinese side of the border since September 2007. Three new groups formed during this period: one in 2009, a second in 2015 and a

third in 2017 close to the border (Fan et al., 2010; Wei et al., 2017; Ma Changyong, unpubl. data). In addition, five females from three groups gave birth to 13 infants during 2007–2013, but two infants died or disappeared (Fan et al., 2015). The mean interbirth interval for these 13 births was 31 months, which is comparable to other gibbon populations (Fan et al., 2015). Although the cao vit gibbon population has been slowly increasing, this is the only known population of the species. Increased attention therefore needs to be focused on its conservation.



## Bi-female groups prevail amongst cao vit gibbons

Although most gibbons live in monogamous groups, the majority of cao vit gibbon groups are polygynous and usually include two breeding females (Fan et al., 2010, 2015; Guan et al., 2018; this study). The two adult females are generally nonaggressive towards each other and are commonly observed grooming (Fan et al., 2010). In addition, both females may breed at the same time (Fan et al., 2015). As a result, the mean group size of these bi-female groups was 6.3–6.4 individuals, which is comparable to bi-female groups of the western black crested gibbon *Nomascus concolor* (Fan et al., 2006) and Hainan gibbon (Zhou et al., 2005), and larger than monogamous gibbon groups (normally with four individuals, Bartlett, 2011).

During the 2016 survey we observed one group with three females, which is rare in any gibbon population. We observed two groups with three females during the long-term behavioural study on the Chinese side of the border. In the first group one female stayed in her natal group and replaced an old female that was not her mother, so temporarily there were three females in this group before the older female dispersed. The second group contained an old female who had not given birth since 2007 and lived in the group with a second adult female. In August 2016, we identified a third female, a young adult, in this group. We are not certain whether this young female was born in the group or immigrated into it. However, we have never observed a group with three adult females that all produced offspring.

We recorded a mean of 0.84–0.92 infants per group (0.39–0.52 infants per female) during our surveys. However, the long-term monitoring of the gibbon population on the Chinese side of the border indicates that females are breeding at a rate comparable to that reported in other gibbon species (0.77 infants per female; Fan et al., 2015). A possible reason for this discrepancy is that researchers may have misidentified older infants as small juveniles. As infants mature they spend more time travelling independently from their mothers (P.F. Fan & C.Y. Ma, unpubl. data), although they continue to nurse. Thus, during a short observation period, an older infant may be observed to travel independently and therefore be misidentified as a juvenile.

Groups containing more than one adult male have been recorded in lar gibbons *Hylobates lar* (Reichard et al., 2011) and siamangs *Symphalangus syndactylus* (Lappan, 2007), but are rare in *Nomascus* gibbons. During the 2007 and 2016 surveys we recorded few groups with more than one fully grown adult male. Because we did not know the genetic relationships and life history of males, subadult males that are fully grown but remained in their natal groups may have been wrongly recorded as adults. Given that there were two breeding females in most groups, one or both may have produced male offspring that could have been subadult during our relatively short survey period.

In rare situations, there could be three or even four adult-sized black individuals living in the same group. However, based on behavioural observations, only one male mates with adult females in cao vit gibbon groups. This contrasts with bi-male lar gibbon and siamang groups, in which both adult males copulate with resident females (Lappan, 2007).

## Transboundary conservation

Since the rediscovery of the cao vit gibbon in 2002 in Viet Nam and 2006 in China, no hunting of gibbons has been recorded in either country. The main threat to the species is habitat degradation caused by selective logging, charcoal making, fuel wood collection and farming (Fan et al., 2011). Since the establishment of the Trung Khanh Cao Vit Gibbon Species and Habitat Conservation Area in Viet Nam and the Bangliang Gibbon National Nature Reserve in China, the gibbons and their habitat are legally protected. Logging, charcoal making, fuel wood collection and farming have been eliminated in the protected areas. Livestock grazing is completely prohibited in the protected area in Viet Nam, but still occurs inside the protected area in China.

Since the rediscovery of the cao vit gibbon population, conservation awareness education has been conducted annually with local communities in both Viet Nam and China. In addition, programmes that improved the livelihoods of the local people were implemented by local government and international NGOs, such as growing grass for livestock, planting trees for firewood, expanding the use of biogas, and the Community Seed Fund pilot programme (FFI, 2016).

The governments of Viet Nam and China permit international NGOs to conduct conservation projects in this area and facilitate transboundary conservation of the cao vit gibbon. A memorandum of understanding between China and Viet Nam for cooperative conservation of the cao vit gibbon was signed by the Department of Forestry of Guangxi Zhuang Autonomous Region and the Department of Agriculture and Rural Development of Cao Bang Province in 2011. The two sides reached agreement on mechanisms of bilateral exchanges, collaborative approaches to counter wildlife hunting, and emergency measures such as forest fire protection. Both countries take turns to host a joint meeting every 2 years, to exchange experience on monitoring, programme management, public education, law enforcement and other aspects of daily administration. In addition, the two protected areas have held informal meetings on the border twice per year since 2014. Participants from both countries did not need to apply for visas to travel to the other country, which makes transboundary conservation flexible and cost-effective. A transboundary species conservation action plan 2016–2020 was developed for the cao vit gibbon. This includes plans to expand the

conservation area, gibbon population and habitat monitoring, community development, publicity and education, scientific research, and transboundary cooperation.

### Habitat restoration

Fan et al. (2013) evaluated habitat quality for the cao vit gibbon population in both countries and suggested that the remaining area of intact forest can support c. 20 groups. However, systematic habitat restoration in disturbed forests could increase suitable habitat to support 26 groups. The current population size of 20–22 groups is approaching the estimated habitat carrying capacity. In saturated habitat with a high density of gibbon groups, transitory individuals are expected to replace resident individuals rather than establish new breeding groups (Brockelman et al., 1998). Two cases of male replacement and one case of female replacement were recorded in two cao vit gibbon groups on the Chinese side of the border, suggesting that this population is approaching habitat carrying capacity (C.Y. Ma, unpubl. data).

To promote population recovery, Fan et al. (2013) suggested habitat restoration. Three transboundary symposiums on habitat restoration for the cao vit gibbon were conducted, in 2010, 2011 and 2012, with the support of FFI and the People Resources and Conservation Foundation. A framework for transboundary restoration of cao vit gibbon habitat was published in English in 2013 and Chinese in 2014 (FFI, 2016). Pilot habitat rehabilitation actions under this framework have been implemented at four sites, covering 1.3 ha in China. Food trees for the gibbon have been planted in abandoned fields (32.3 ha in six valleys) in the protected area in Viet Nam (Uong Sy Hung, People Resources and Conservation Foundation, pers. comm., 2016). Despite these initial successes, the situation remains challenging because habitat restoration requires time and continued funding. Progress and effectiveness of habitat restoration and reforestation programmes need to be systematically evaluated. Livestock grazing continues inside protected reserves in China, and future research should examine the potentially adverse effects of grazing on habitat restoration and gibbon recovery.

In summary, our results from two transboundary surveys of the only known population of the Critically Endangered cao vit gibbon indicate that previous surveys conducted separately in Viet Nam and China have underestimated the global population of this species. According to the latest survey (2016), this population is increasing slowly and has 20–22 remaining groups containing c. 107–136 individuals. The gibbon population and its habitat in both countries are legally protected and hunting and charcoal making have been eliminated in the past decade. As habitat carrying capacity is a limiting factor, habitat restoration needs to be expanded, but lack of sufficient funding remains a major challenge.

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**Conflicts of interest** None.

**Ethical standards** This research abided by the *Oryx* guidelines on ethical standards. The research did not involve human subjects, experimentation with animals and/or collection of specimens.

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