CONSERVATION ACTION PLAN FOR THE CAO VIT GIBBON (*NOMASCUS NASUTUS*) 2021 – 2030 WITH A VISION TO 2050

Report from a hybrid online and face-to-face workshop held on 17-19th March 2021, with physical meeting spaces in Hanoi, Vietnam and Guangxi, China

FAUNA & FLORA INTERNATIONAL

IUCN SSC Species Survival Commission

CONSERVATION PLANNING SPECIALIST GROUP
Changing the Future for Wildlife

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Front cover: © Nguyen Duc Tho / FFI. A young cao vit gibbon belonging to group 'AB'.
Background: © Oliver Wearn / FFI. Limestone in the cao vit gibbon's habitat.

Back cover: © Ryan Deboodt. A female cao vit gibbon in Vietnam.

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A PDF of this report can be downloaded at:
http://cpsg.org/content/cao-vit-gibbon-action-plan

Full translations of this report in Vietnamese and Mandarin have also been produced and disseminated to local conservation actors; these are available upon request.

Condensed versions of this Action Plan have also been formally approved by the governments in Vietnam (Cao Bang Province) and China (Baise City, Guangxi).

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Cao vit gibbons (*Nomascus nasutus*) in Bangliang NNR, China. Image © Zhao Chao.

PREFACE

Opening remarks by Hoang Phuong Vy, Vice-Director of the Cao Bang Provincial Forest Protection Department

Dear guests, comrades and colleagues!

The conservation of nature in general and the conservation of forest ecosystems and forest wildlife in particular are the shared responsibility of all people, all disciplines and countries in the world. However, conflicts always arise as we try to effectively conserve [natural resources] while ensuring socio-economic development. In order to resolve the conflicts and ensure the harmonization of interests between conservation and socio-economic development, we need to develop a gibbon Conservation Plan in Vietnam, in China and in the Vietnam-China border area.

Dear delegates at the Workshop!

The conservation of gibbons and our ecological environment in the 2015-2020 period achieved very positive results: the number of gibbons has increased and the forest ecosystem on the limestone mountains of the Reserve is sustainably preserved, in particular:

- Raising the people and communities' awareness of gibbon conservation
- Improving people's lives by supporting their livelihoods
- Attracting an increasing number of scientists to the reserve for research
- The number of gibbons is 20 groups, with 121 to 123 individuals; The diversity of forest animals in the nature reserve increases significantly
- Effectively zoning forests with additional planting of native trees, maintaining the limestone forest ecosystem to keep the gibbon habitat stable over the long term

The above results are attributed to the efforts of the Forest Protection Department staff of the protected area, the Forest Rangers of Trung Khanh and the financial and technical support of Fauna & Flora International (FFI).

In addition to the results achieved, the following issues remain:

- The results of scientific research on gibbons, livelihood support for local people, silviculture measures affecting forest enrichment have yet to be evaluated, summarised and publicised
- No research on the limestone mountain ecosystem, forest fauna and flora species in the Reserve has been conducted, and their impacts on the growth and development of gibbons remain unknown
- The exchange of information between the two sides of the border was at times held up

To solve the problems above and ensure the resolution of conflicts when implementing gibbon conservation, we will continue to effectively implement the Memorandum of Understanding dated March 22nd, 2019 between Cao Bang province (Vietnam) and Baise City of Guangxi province (China) on cooperation in cao vit gibbon and gibbon habitat protection, and study more carefully the ecological characteristics and habitat of the gibbon, which will serve as the

basis for the expansion of the Nature Reserve. The development of a conservation action plan for the cao vit gibbon is necessary.

With these reasons, I would like to announce the opening of the International Workshop on developing the Cao vit gibbon conservation action plan for the 2021 - 2030 period with a vision to 2050.

Thank you very much for listening and I wish the Workshop a great success!

Opening remarks by Xie Junzhu, Deputy Secretary-general, Baise City People's Government

Dear leaders, experts and representatives of China and Vietnam:

Good morning to all participants!

Today the China-Vietnam transboundary cooperation and protection online exchange meeting is held. I am deeply honoured to participate in this meeting on behalf of the People's Government of Baise City, Guangxi, China. I take this opportunity to extend a warm welcome to the leaders and comrades of China and Vietnam who are participating in this meeting!

The two protected areas, Bangliang and Trung Khanh, are connected by mountains and rivers, and are the only places in the world where the cao vit gibbon population is distributed. The cao vit gibbon is a Critically Endangered species globally. The two protected areas work together to protect the cao vit gibbon. It is of great significance. It is also the shared responsibility of China and Vietnam. Since the discovery of the cao vit gibbon on the Sino-Vietnamese border, the Chinese and Vietnamese governments and departments have attached great importance to the protection of this species. The two governments have successively established gibbon sanctuaries and have given strong support in terms of providing funding, human resources, and project [approvals]. In 2011, the Guangxi Forestry Department of China and the Department of Agriculture and Rural Development of Cao Bang Province, Vietnam signed the Cao Vit Gibbon Transboundary Cooperation Memorandum "Memorandum of Understanding (Revised in 2017)". In 2019, Baise City, Guangxi, China and Cao Bang Province, Vietnam signed the "Cooperation Document in Cao vit gibbon and Habitat Conservation," establishing an institutional framework for normalized transboundary cooperation in protected areas between the two countries. Under the guidance of the spirit of the memorandum, Bangliang Nature Reserve and Trung Khanh Nature Reserve are actively cooperating for gibbon protection. This important species has made efforts and contributions.

To protect this species well, the joint efforts of the protected areas of the two countries have been central. In the past ten years, in the spirit of the cooperation memorandum, the two sides have actively carried out transboundary cooperative protection activities, and the protection work has achieved remarkable results. In the past ten years, there has not been a forest fire in the two protected areas; logging, poaching and charcoal burning by the border residents of the two countries have basically been eliminated. Similar to the occurrence of illegal activities, smuggling of wildlife products on the border passages has basically been curbed. Through the

strengthening of the propaganda about the protection areas between the two countries, the environmental protection awareness of the people of the two countries will be further enhanced and they will consciously participate in protection actions. In China, the security of natural resources in the border protection areas of the two countries has been strongly guaranteed, ensuring the integrity of the transboundary cao vit gibbon habitat, while the size of the gibbon population has continued to grow. Here, I would like to express my high respect to the comrades in the protected areas of the two countries who have made positive contributions to the cause of conservation!

I believe that through regular meetings and exchanges, the friendship between the two peoples will be further enhanced, and the level of transboundary cooperation and protection in the protected areas of the two countries will be further improved. I hope that the governments and departments of the two countries will continue to support and guide Bangliang and Trung Khanh. These protected areas carry out transboundary cooperation, deepen cooperation areas, further improve cooperation methods and mechanisms, and in-depth advance cooperation and exchanges in the new year, and make greater contributions to the protection of the world's Critically Endangered species, cao vit gibbon!

I wish you all success in your work and good health!

Thank you!

March 17th, 2021

ABBREVIATIONS USED

ANR – Assisted Natural Regeneration

CCT – Community Conservation Team

CCD – Center for Nature Conservation and Development

CPC – Commune People's Committee (Vietnam)

CVG – Cao vit gibbon (*Nomascus nasutus*)

CPSG – IUCN SSC Conservation Planning Specialist Group

DARD – Department of Agriculture and Rural Development (Province level)

FFI – Fauna & Flora International

FPD – Forest Protection Department

IUCN – International Union for Conservation of Nature

LiDAR – Light Detection and Ranging

MAC – Management Advisory Committee

MB – Management Board

MoU – Memorandum of Understanding

NDVI – Normalised Difference Vegetation Index

NNR – National Nature Reserve

NR – Nature Reserve

NTFPs – Non-timber Forest Products

PA – Protected Area

PC – People's Committee (Vietnam)

PPC – Provincial People's Committee

PRCF – People Resources and Conservation Foundation

PVA – Population Viability Analysis

SHCA – Species and Habitat Conservation Area

SMART – Spatial Monitoring and Reporting Tool

SSA – IUCN SSC Primate Specialist Group Section on Small Apes

SSC – Species Survival Commission

ToC – Theory of Change

VNFOREST – Vietnam Administration of Forestry

EXECUTIVE SUMMARY

1. In the early 2000's, the cao vit gibbon was raised from the dead, when a small population of the species was found to be persisting in a limestone forest straddling the Vietnam-China border. The re-discovery of the species set in motion two decades of concerted work from partners in both Vietnam and China, including the established of two new protected areas to save the species. Recent surveys have estimated that the population consists of 20 family groups (approximately 120 individuals) and is apparently stable over time.

2. With the species saved from immediate extinction, the time was ripe for a new conservation Action Plan for the species, which would consider a bold, ambitious vision for the future, including consideration of what it might mean to not just *save* the species, but *recover* it in parts of its historical range.

3. On the 17-19th March 2021, a hybrid online and face-to-face workshop was held, with physical meetings held simultaneously in Hanoi, Vietnam and Guangxi, China. Government representatives, conservationists and researchers gathered together to: craft a long-term (2050) vision for the species; identify the major conservation issues the species faces, and define the near-term objectives and actions that will be undertaken between 2021 and 2030.

4. A Population Viability Analysis (PVA) was undertaken prior to the workshop, in consultation with gibbon experts, and was presented to participants at the workshop for further refinement. The headline results of the PVA modelling were that: (i) the cao vit gibbon is extremely unlikely to go extinct due to chance (i.e. due to demographic or environmental stochasticity), but is likely to be gradually losing genetic diversity over time; (ii) the population is likely to be robust to extinction from unforeseen catastrophes, unless the genetic health of the population is in a poorer state than expected, or catastrophes are especially severe and-or occur frequently; (iii) restoration of the Trung Khanh – Bangliang forest block is likely to substantially reduce the vulnerability of the species to threats, including catastrophes and inbreeding, and (iv) establishment of a second population of the species is theoretically possible without impacting the current population, but it would likely necessitate a long-term (20+ years) effort. Moreover, the significant practical challenges of safely translocating gibbons in limestone habitat would need to be overcome.

5. The vision for the cao vit gibbon produced by workshop participants was the following:

> *By 2050, the cao vit gibbon lives in a restored and well-connected habitat in the Trung Khanh – Bangliang forest and has a population large enough to be robust to any future challenges. The protected areas are a model of highly effective transboundary collaborative management, using high-technology and working in harmony with, and providing benefits to, local communities. The cao vit gibbon's song is heard by local villagers once again, and people across Vietnam, China and the world consider it a high-profile 'star' species. After in-depth research, a new population has been established and the species is on a path to broader recovery.*

6. Twelve *issues* affecting the cao vit gibbon were identified during the workshop, which were (in order of their ranked importance, from highest to lowest): the single small population; low

awareness and apathy about the species; knowledge gaps; livestock grazing; natural disasters and climate change; forest fires; fuelwood collection; exploitation of forest products; disease; hunting, and illegal logging. The twelve issue, which was not considered a direct threat to the species but important nonetheless, was transboundary collaboration.

7. Each of these Issues was defined and assigned between 1 and 3 objectives for the period 2021-2030, each with associated *actions.* This led to the creation of a total of 70 distinct Actions that need to be undertaken over the next decade for the conservation of the species.

8. Actions were categorised based on their priority and their urgency, of which 32 were deemed to be of high importance and high urgency. We highlight these actions in the Plan, because they were considered to be most impactful for the cao vit gibbon, and cannot be delayed. We grouped these 32 Actions under coherent work packages, consisting of the following:

1) Enhance patrol effort and effectiveness in the PAs

2) Restore the cao vit gibbon's habitat

3) Conduct a scoping study of potential translocation sites

4) Build local awareness and pride in the cao vit gibbon

5) Establish an education fund for local communities

6) Fill critical knowledge gaps about the gibbon for informing management

7) Fill the knowledge gaps about awareness, attitudes and values in relation to gibbons

8) Improve the sustainability of livestock management systems

9) Increase awareness in local communities about PA laws

10) Develop an emergency response plan for the cao vit gibbon

11) Maintain an effective system for the prevention, detection and control of forest fire

12) Reduce the demand for fuelwood around the PAs

13) Targeted reduction in the collection and trade of orchids

14) Maintain cooperation between the two protected areas in Vietnam and China

9. As with all Action Plans, there is an ever-present danger of an 'implementation gap' between the expectation and the reality on the ground. A number of proposals have been put forward to guard against this, including the formation of an Implementation Committee to drive the realisation of the plan and-or periodic reviews of progress, for example as an agenda item on the periodic transboundary meetings between the protected areas in Vietnam and China.

10. This Action Plan defines a new Chapter for the species, full of optimism and hope. By 2030, the cao vit gibbon should be safer and more valued that it is today, with the bold realisation of broader recovery of the species just on the horizon.

Dusk over Phong Nam valley, Trung Khanh District, Vietnam. Image © Hoang Van Tuan / FFI.

WORKSHOP & ACTION PLAN RATIONALE

In the early 2000's, a small remnant population of the cao vit gibbon (*Nomascus nasutus*) was rediscovered in a limestone forest straddling the Vietnam-China border. The species – likely to have been historically widespread across northern Vietnam and southern China – was teetering on the edge of extinction. The governments of Vietnam and China, with support from NGOs, set to work on preventing the extinction of this Critically Endangered primate in its last stand on Earth. This conservation work has been sustained now for nearly two decades, with considerable success in averting the immediate extinction of the species.

In order to focus and coordinate the actions needed to save the cao vit gibbon, a series of workshops at the village, district and provincial levels were held in 2014-2015 on both sides of the Vietnam-China border. In June 2015, this culminated in a transboundary action planning workshop convened by the governments of Vietnam and China (in partnership with FFI), in Nanning, Guangxi, China. This led to the first transboundary conservation Action Plan for the cao vit gibbon, for the period 2016-2020. This action plan – in the process of expiring – urgently needs updating to reflect improvements in our knowledge about the species over the last 5 years, the latest information on the threats it faces, and the current priorities of stakeholders.

An opportunity also now exists to define a new era in the conservation of the cao vit gibbon, focusing not only on the critical actions needed to safeguard the last remaining population, but also to consider for the first time what *recovery* of the species might look like in parts of its previous historical range. Understandably, given the urgency of the threats that the cao vit gibbon faced, past action planning processes have been geographically constrained, focusing entirely on the two protected areas which today host the remnant population of the species. The existing action plans, therefore, are implicitly plans for the two protected areas, and not for the species as a whole. This restricted focus has meant that plans have not been able to effectively address the existential threat that has always been in the background for the species: that it exists in a single, isolated population. It has also meant that a bold vision for the species, perhaps including its recovery in the forests of northern Vietnam and southern China, has not been able to be considered by stakeholders.

The intention with this updated Action Plan is for it to truly be an action plan for the species as a whole. The aim is that this global action plan will then inform the site-specific management planning in the Cao Vit Gibbon SHCA and Bangliang NNR. The plan will also act as a blueprint for the activities of relevant NGOs, help to prioritize research efforts both nationally and internationally, and assist donors in directing funding to where it is most needed.

THE PLANNING PROCESS

Pre-workshop meeting in Vietnam

A stakeholder consultation meeting was conducted at the district level in Trung Khanh, Cao Bang Province, Vietnam. A total of 32 participants attended, representing the Management Advisory Committee (MAC), the Cao Vit Gibbon SHCA, district-level Forest Protection Department (FPD) and People's Committee (PC), the provincial Cao Bang FPD, and village and commune leaders. Staff members from Fauna & Flora International – Vietnam Programme (FFI) facilitated this meeting in a participatory manner, following the steps outlined in the IUCN conservation planning 'cycle' (IUCN – SSC Species Conservation Planning Sub-Committee, 2017). A Vision for the species in 2050 was co-developed first, followed by discussion of the local scale threats to the cao vit gibbon population in Vietnam. Once the major threats were identified, corresponding Objectives and Actions were developed to address each threat. The results of this meeting were compiled and presented during the Actions discussions of the international workshop.

International workshop

The international species conservation planning workshop for the cao vit gibbon was held between 17-19th March 2021. Given restrictions due to the Covid-19 pandemic, the workshop was conducted in a hybrid online-offline format over the three days. In addition to the online discussions on Zoom, physical meetings were held simultaneously in Hanoi, Vietnam and Guangxi, China (**Plate 1**). All discussions during the workshop were in either Chinese, Vietnamese, or English with simultaneous translation support provided for both online and offline participants. The workshop was organised by FFI, in collaboration with Cao Bang FPD (Vietnam), Bangliang NNR (Guangxi, China), Daji Nature and facilitated by the IUCN SSC Conservation Planning Specialist Group (CPSG).

The objective of the workshop was to facilitate the collaborative development of a comprehensive species conservation plan for the cao vit gibbon, by diverse communities of stakeholders who were willing and able to act for the species. 85 participants including gibbon experts, multi-level government representatives including protected area managers, international experts and NGOs working in primate conservation participated.

The workshop began with a quick introduction of all participants. This was to help everyone get familiar with all the people that they would be working with on discussions and development of the action plan over the three days. The first step of the workshop was to share all currently available information about the cao vit gibbon with all participants through a series of presentations (**Table 1**). These covered the topics of: population status and dynamics; past and present habitat status; ecological insights based on focal group monitoring; ongoing restoration work and protected area management in both Vietnam and China. The introductory scene-setting presentations also covered: the findings from a population viability study of the cao vit gibbon population in its current habitat; learnings from Hainan gibbon on the importance of population genetics in small populations; and learnings from the release and tracking of gibbons. This was followed by a presentation on current transboundary activities under a MoU between Cao Bang Province and Baise City and how they pertain to cao vit gibbon conservation. The purpose of these presentations at the start of the workshop was to set a

common understanding amongst all participants on the status, ongoing conservation efforts and threats being currently faced by the cao vit gibbon. This would be essential for the following planning elements of Vision, Goals, Objectives and Actions.

The workshop continued with participants breaking out into three working groups to develop a vision statement for the cao vit gibbon in 2050. Participants first articulated their personal visions for the gibbon, which was shared amongst all members within their working group, and followed by a plenary discussion with all three working groups coming together to combine and create a common vision statement. Subsequently a small drafting group worked on a consensus vision statement that was shared twice with all workshops participants for feedback and editing before being finalised.

A group brainstorming session followed, in which participants identified potential threats, challenges or issues of concern that were thought to impact the cao vit gibbon population viability and conservation, and that could impede realisation of the vision. This was done using an online Mural board and all issues raised were captured in all three languages – Chinese, Vietnamese and English. Creating a theory of change using all these issues and their link to the vision in three languages simultaneously on Mural was challenging during the workshop. However, this was done after the workshop by the core organising team, capturing all the points raised by participants in this brainstorming session, as well as the subsequent working group sessions.

Table 1. Presentations given at the cao vit gibbon action planning workshop, 17-19th March, 2021.

No.	Title	Presenter
1	*Status of the cao vit gibbon (*Nomascus nasutus*)*	Trinh Dinh Hoang (Independent)
2	*Cao Vit Gibbon Species and Habitat Conservation Area, Trung Khanh District*	Nong Van Tao (FPD)
3	*Enhancing cao vit gibbon conservation through nature reserve management and cooperation*	Yang Jiang (Bangliang NNR)
4	*Population Viability Analysis for the cao vit gibbon*	Oliver Wearn (FFI)
5	*Habitat quality and utilization pattern of cao vit gibbon*	Pengfei Fan (Sun Yat-sen University)
6	*Habitat recovery in the Cao Vit Gibbon SHCA*	Oliver Wearn (FFI)
7	*Demography monitoring of cao vit gibbons in Bangliang NNR*	Changyong Ma (Guangxi Normal University)
8	*Trung Khanh Gibbon Monitoring Team: Results to date*	Oliver Wearn (FFI)
9	*Conservation genetics of tiny gibbon populations: Lessons from the Hainan gibbon*	Samuel Turvey (Zoological Society of London)
10	*Learnings from the release and tracking of* Nomascus *gibbons: Implications for translocations*	Marina Kenyon (Dao Tien Primate Species Centre)
11	*Restoration and expansion critical habitat in the Cao Vit Gibbon Conservation Area, Trung Khanh District, Cao Bang*	Le Anh Tu (PRCF)
12	*Habitat restoration at Bangliang NNR*	Huiying Wu (Daji Nature)

The participants then worked in two working groups for the rest of the workshop. The working groups divided up the 12 identified issues and further defined them and their impact on the cao vit gibbons. Objectives were developed to address each threat, and management and research actions were recommended as steps to help achieve those objectives. Each action was categorised based on priority and urgency. Timelines and responsible parties/collaborators for each action were also identified. Plenary reporting sessions allowed all workshop participants to provide relevant expertise and feedback for all issues, objectives and actions. Designated and volunteer translators provided essential translation between Chinese, Vietnamese and English for the plenary and working group sessions, both oral and written as needed.

The result is this conservation Action Plan for the cao vit gibbon 2021 – 2030 with a vision to 2050.

Plate 1. Group photos for the 'offline' workshop attendees in Vietnam and China.

Typical habitat of the cao vit gibbon (Nam and Lang valleys, Cao Vit Gibbon SHCA). Image © Le Khac Quyet / FFI.

BACKGROUND: AN UPDATED KNOWLEDGE-BASE FOR THE CAO VIT GIBBON

Unlike most other *Nomascus* gibbon species, the cao vit gibbon has been relatively well studied, in particular due to the efforts of Prof. Pengfei Fan and colleagues (Fan et al., 2010, 2011, 2013, 2015; Fei et al., 2012; Feng et al., 2014; C. Ma et al., 2017; H. Ma et al., 2020). In this section, we provide background information on the species relevant to conservation planning, focusing in particular on where our knowledge-base for the species has substantially altered in recent years. During the workshop process, we also identified where substantial knowledge gaps remain for the species (see *Knowledge Gaps*).

For additional information on the phylogeny, morphology and behaviour of the cao vit gibbon see Roos et al. (2007), Van Ngoc Thinh et al. (2010), Rawson et al. (2011), Mootnick & Fan (2011), Fan et al. (2013, 2016) and Fei et al. (2015).

Population size and distribution

When the cao vit gibbon was re-discovered in the early 2000's on both sides of the Vietnam-China border (La Quang Trung & Trinh Dinh Hoang, 2002; Chan, Tan, & Tan, 2008), it was already confined to a single, small, isolated population. However, on the basis of specimens and written accounts, the species appears to have had a much larger distribution historically, stretching across northern Vietnam and southern China (Yunnan and Guanxi Provinces) east of the Red River (Rawson et al., 2011). Today's distribution of the cao vit gibbon can in fact be understood as the 'long tail' of a protracted range contraction that has been ongoing for at least the last several hundred years. Given the long history of agriculture (particularly, rice farming) in the region, the species was likely already severely impacted by human activities by the turn of the 19th Century, and was persisting in a dwindling number of small, isolated populations by that time. Very few large and contiguous areas of occupied habitat had survived into the 20th Century (notably, the Tam Dao and Dong Trieu mountain ranges, in Vinh Phuc and Quang Ninh provinces, respectively).

By the time conservationists in Vietnam began to search for the cao vit gibbon in the late 1990s, only a handful of forest areas likely still retained the species and it was a race against time to find the species at all. It was thought to have become extirpated from Tam Dao NP and Dong Son-Ky Thuong NR just a decade or two earlier (in the 1970/80s; Trinh Dinh Hoang, 2021), and its status was apparently very precarious in a collection of other sites, including Tay Con Linh NR, Than Sa-Phuong Hoang NR, Huu Lien NR, and the area around Thang Hen lake (Trinh Dinh Hoang, 2021; **Fig. 1**). By the turn of the 21st Century, the species was likely only present in two forest blocks: in the Trung Khanh – Bangliang forest block (spread across the Cao Vit Gibbon SHCA and Bangliang NNR) and in Kim Hy NR (Trinh Dinh Hoang, 2021; Trinh Dinh & Tuan Anh et al., 2021), although the latter was never confirmed by researchers (Thomas Geissmann et al., 2009). Today's population in the Trung Khanh – Bangliang forest likely became the last population of the cao vit gibbon on Earth sometime between 2000 and 2006.

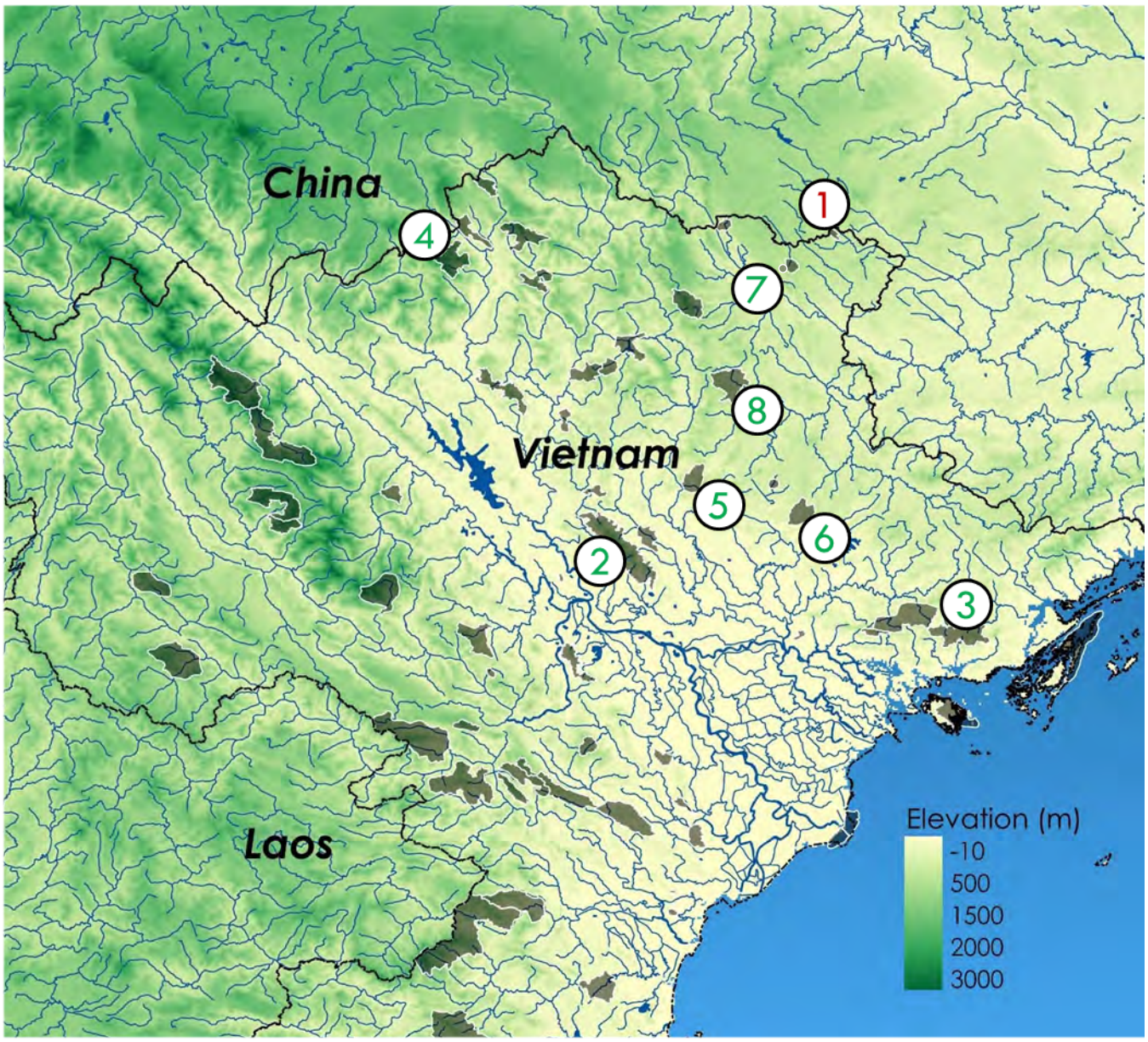

Figure 1. Map of protected areas in northern Vietnam, showing the location of the last cao vit gibbon population on Earth (1), on the border between Vietnam and China. Other locations mentioned in the text are indicated: (2) Tam Dao NP, (3) Dong Son-Ky Thuong NR, (4) Tay Con Linh NR, (5) Than Sa-Phuong Hoang NR, (6) Huu Lien NR, (7) Thang Hen lake and (8) Kim Hy NR.

The last remaining population of the cao vit gibbon was originally reported to be just a few dozen individuals in the early population surveys between 2002 and 2006, with estimates ranging between 17 and 37 individuals (summarised in Le Trong Dat & Le Huu Oanh, 2007). However, the survey coverage across the Trung Khanh – Bangliang forest block is likely to have been insufficient to cover all groups, and these early estimates were therefore likely negatively biased.

More recent population surveys of the species – in 2007, 2012, 2016 and 2018 – have explicitly attempted to systematically 'census' the population, i.e. to visit all occupied areas of habitat

and count all individuals (Le Trong Dat & Le Huu Oanh, 2007; Nguyen The Cuong et al., 2012; Trinh Dinh Hoang et al., 2016, 2018). However, an inescapable feature of all gibbon population surveys is that not all individuals in all groups can easily be counted, and therefore an extrapolation from a subset of the total population is still necessary. Specifically, the total population size is the product of the average group size of the subset of groups that were observed and the total number of groups detected (whether by sight or by sound). For each survey year, this extrapolation provides our 'best estimate' of the population size and the uncertainty around this estimate (i.e. the confidence interval; **Table 2**)**.** The uncertainty is inherent to any population survey method and is largely unavoidable (though, by increasing the effort and cost of surveys, we can reduce the amount of uncertainty).

Table 2. Summary of cao vit gibbon population survey data for the Trung Khanh – Bangliang forest from 2007 to 2018. The estimated number of gibbons for each survey was calculated as: total population size = average group size of observed groups x number of groups recorded. Confidence intervals were calculated using the upper and lower confidence intervals of average group size (= estimate ± 1.96 x SD), assuming for simplicity that group size is approximately normally distributed. Note, where there was uncertainty about the total recorded number of groups, we have taken the minimum number, in order to be precautionary about the status of the population.

Year	Type of estimate	Groups	Total individuals	Observed group size	SD of group size
2007	Total recorded	18	106	6.31	2.02
	Fully-observed	16	101		
	Estimated (95% CI)	18	**114 (106-122)**		
2012	Total recorded	24	129	5.71	1.55
	Fully-observed	21	120		
	Estimated (95% CI)	24	**137 (128-163)**		
2016	Total recorded	20 groups + 3 lone males + 1 lone female	107	6.36	1.50
	Fully-observed	14	89		
	Estimated (95% CI)	20	**131 (114-149)**		
2018	Total recorded	20 groups + 1 lone male	84	5.42	1.38
	Fully-observed	12	65		
	Estimated (95% CI)	20	**109 (88-131)**		

Population surveys between 2007 and 2018 have shown that the population has oscillated around approximately 20 groups and 120 individuals, and is apparently showing a stable trend (**Fig. 2**). Importantly, though, the uncertainty around the estimates means that we cannot be sure of the exact number of cao vit gibbons at any point in time. Given the uncertainty, we also cannot be sure whether the population has increased or decreased by a small amount across the studied period of 2007-2018 (the confidence intervals for these two time points overlap; **Fig. 2**); we can only say certainly that it has not undergone a major change.

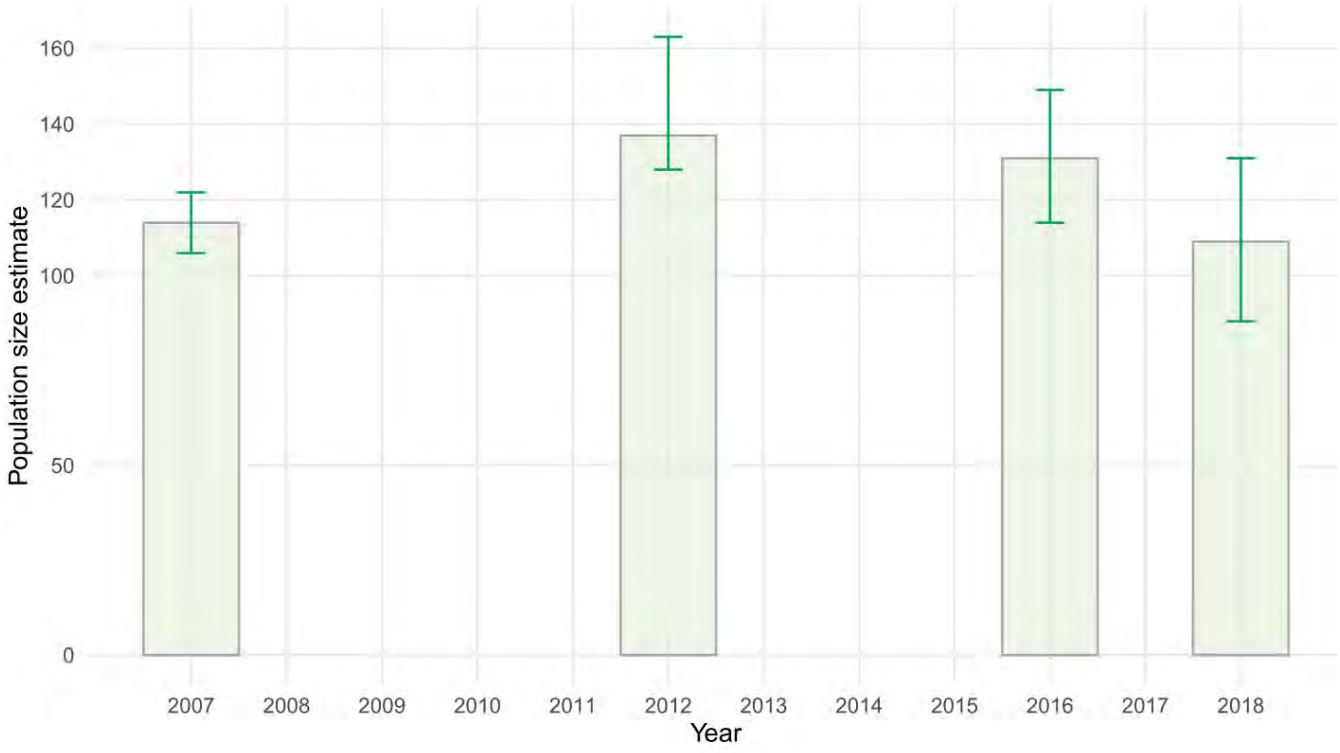

Figure 2. Cao vit gibbon population size over time, based on transboundary population surveys in the Cao Vit Gibbon SHCA and Bangliang NNR.

At least three important caveats for the population survey methods, as employed to date, are worth noting when interpreting the data. These caveats likely impart, to a greater-or-less degree each year, an unquantified bias in the population size estimates.

(1) Existing methods do not adjust for unseen groups, only for unseen individuals. This means that, with poor weather or insufficient survey effort (temporally and-or spatially), the number of groups (and therefore the total population size) can be underestimated.

(2) Population estimates are subject to errors in counting the number of individuals in detected groups. These estimates of group size are critical for extrapolating from the number of groups to the number of individuals in the population. If individuals in detected groups are undercounted, for example, then the total population size might be underestimated. This is suspected to have happened in the 2018 survey (Trinh Dinh Hoang, pers. comm.), which might explain the surprisingly low estimate in that year.

(3) Thirdly, it is sometimes difficult to ascertain if songs heard at different times, but in similar locations, are the same gibbon group or not, and different surveyors may come to different conclusions (Rawson, 2010). This subjectivity may cause either positive or negative bias in the estimated number of groups. In future, acoustic data could be used to help distinguish groups.

It is also evident that our uncertainty in the population estimates has increased over time. This is caused by the underlying uncertainty in our estimate of average groups size, which in turn has been caused by decreasing sample size; in 2007, survey teams were able to directly observe and count the individuals in 16 of 18 groups, whilst in 2018 only 12 of 20 groups could be observed. We can express this in terms of the probability that a group is directly observed during the survey (= # groups observed / # groups in total). When we do that, we can see it has particularly declined in the 2016 and 2018 surveys (**Fig. 3**). This declining probability of observing groups is attributed to habitat changes, specifically an increase in the canopy height and vertical complexity of the forest, which means that gibbon groups can more easily remain hidden in sub-canopy layers of the forest (Trinh Dinh Hoang and Pengfei Fan, pers. comm.). In future surveys, this increasing difficulty in observing the gibbons using traditional methods (i.e. using binoculars and scopes) will need to be counteracted with new technologies (e.g. drone-mounted thermal cameras and thermal scopes).

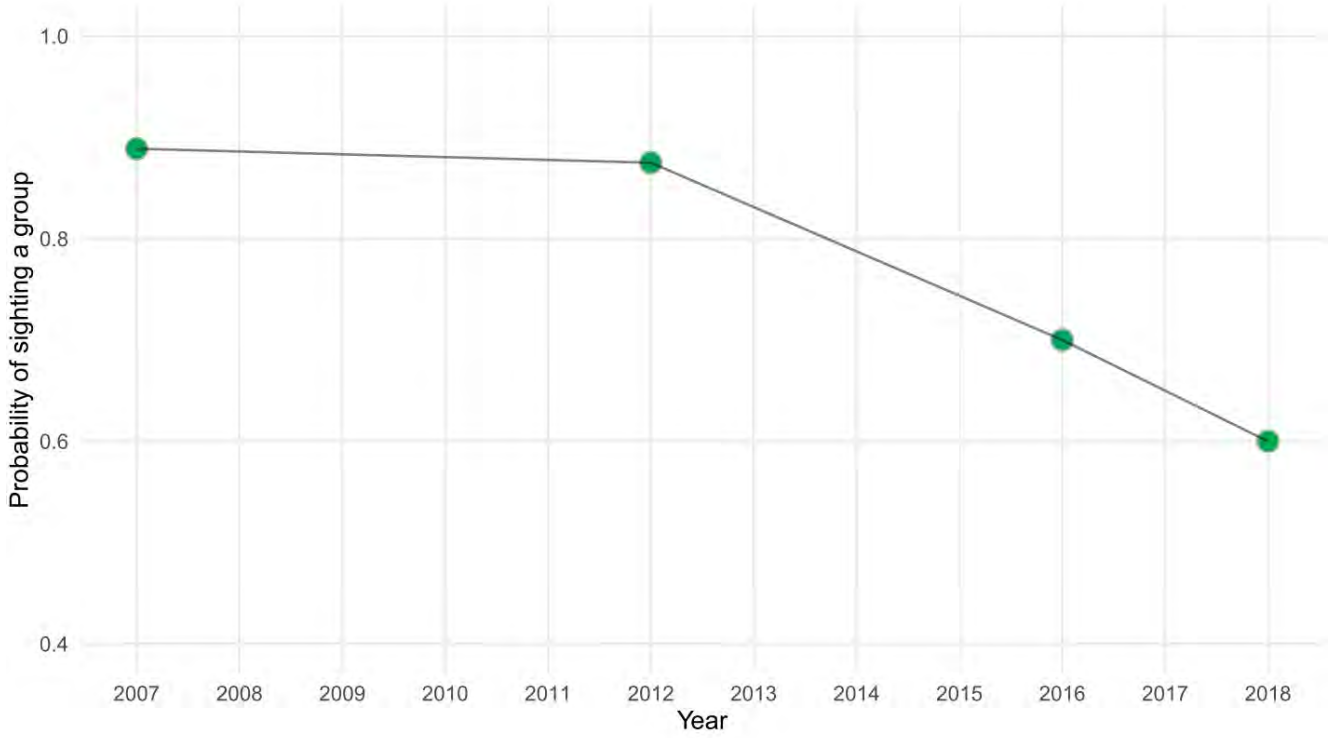

Figure 3. Probability that a cao vit gibbon group is directly observed over time. This has declined noticeably in the two most recent surveys, which has been attributed to an increase in the canopy height and vertical complexity of the forest in the Trung Khanh – Bangliang block.

Population demographics from focal group monitoring

An understanding of the demographics of the last remaining cao vit gibbon population – including birth, death and dispersal rates – is critical to assessing the viability of the population over the medium- to long-term. Monitoring of population size, whilst very important, only tells us the static state of the population at particular instances in time, and it may be too late to

address fundamental issues with the population if we wait for clear declines in population size. Monitoring of demographic rates allows us to make predictions about the *trajectory* of the population in good time, and also gives us better information on the *causes* of changes in population size (e.g. perhaps adults have a high death rate, or perhaps females are breeding very infrequently). An understanding of the demographics of the Trung Khanh – Bangliang population will also be an important baseline against which to measure the demographic 'health' of any newly-established populations elsewhere.

It is impractical to monitor the demographics across the entire cao vit gibbon population, even though this would provide the most complete data. Instead, the approach has been to focus resources on monitoring a small number of (hopefully representative) groups, from which broader inferences can be made about the whole population. To date, this focal group monitoring has taken place almost exclusively in China, with follows of three main groups having been conducted since 2007 (H. Ma et al., 2020). Two additional groups were formed in 2015 and 2017 in China (in an area not previously known to support gibbons) and these were added to the long-term monitoring, meaning that five groups are now being followed in China (**Fig. 4**). Since the beginning of 2020, a single group in Vietnam has also been followed intensively for the first time.

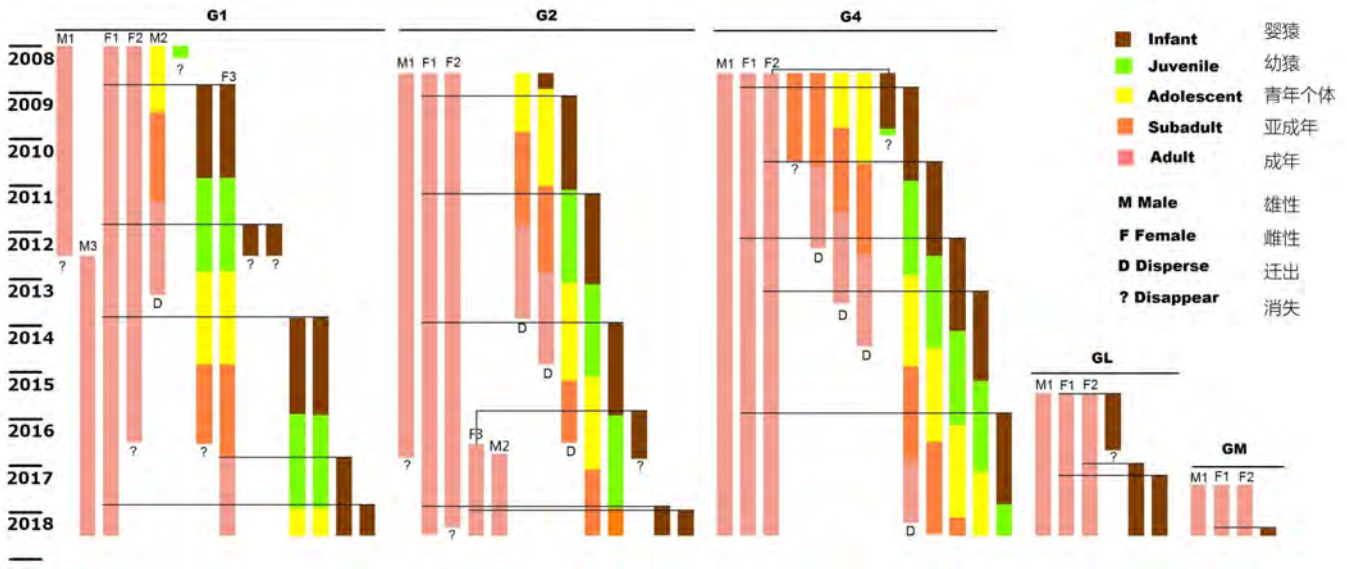

Figure 4. Demographics of five cao vit gibbon groups that have been the focus of long-term focal monitoring in China (Changyong Ma & Pengfei Fan, unpublished data).

This focal monitoring has provided us with a picture of typical birth and death rates, as well as other important aspects of the population biology of the cao vit gibbon (not to mention habitat-use, detailed below). Average birth rate across females was 0.26 infants per year in the period 2008-2020 (n = 10 females), i.e. a breeding rate of once every 3.8 years (Ma & Fan, 2021, unpublished data). This is a substantially slower breeding rate compared to the closely-related Hainan gibbon, where females are reported to breed approximately every 2 years in

Bawangling NNR (Turvey et al., 2015). This might reflect the fact that the two populations exist at very different densities in the respective habitat blocks, with the cao vit gibbon population in Trung Khanh – Bangliang perhaps being at or close to the carrying capacity of the habitat. It might also reflect differences in habitat quality – specifically, food availability – between Trung Khanh – Bangliang and Bawangling NNR. The latter hypothesis could be investigated with a detailed botanical and phenological comparison of the two sites.

Death rates have apparently been low in the monitored cao vit gibbon groups, with just 4 of 25 infants (16%) dying during the period 2008-2020, and 2 of 19 juveniles (11%)(Ma & Fan, 2021, unpublished data). Mortality in later age groups – sub-adults and adults – has thus far not been observed, but is also concomitantly much harder to confirm, because disappearances might also represent dispersal rather than death. If we assume, pessimistically, that the disappearances among adults in the studied groups actually represent deaths, this would give an annual death rate of 3% (3 disappearances across a total of 103 monitored years of adulthood; **Fig. 4**). We do not have any information on adults living outside a family group, where death rates might be expected to be higher. The main proximate causes of death are different depending on the age class: for infants, male takeovers (occurring approximately once every 15 years) and subsequent infanticide is perhaps the main cause of death whilst, for juveniles, periods of harsh weather have been implicated as a main cause of death (Fan et al., 2010; C. Ma et al., 2019). The ultimate causes of these deaths, however, are likely to be a lack of available habitat (exacerbating 'normal' rates of infanticide) and stochasticity in climatic conditions (causing especially cold winters).

Cao vit gibbons are unusual among the Hylobatidae in that most groups contain two adult females, rather than the single adult female which is more common in the majority of other gibbon species (Fan et al., 2015). Moreover, these bi-female groups are stable over the long-term, at least across the 12 years of monitoring so far. The western black crested gibbon and Hainan gibbon also exhibit this group structure, and it may be due to the relatively more folivorous diets of these gibbon species, living as they do in much more seasonal forests than their tropical counterparts. The increased reliance on leaves in their diet may reduce competition among individuals in a group, allowing larger groups (of up to 9 individuals) to form (Fan et al., 2015). Phylogenetic analysis of mating systems across the Hylobatidae support the idea that polygyny (and large group size) is a 'natural' condition for the western black crested gibbon, Hainan gibbon and cao vit gibbon, rather than being an anthropogenic 'crowding effect' caused by reduced habitat availability (Bryant et al., 2015).

The polygynous mating system of the cao vit gibbon makes females the 'limiting resource' in terms of population growth for the cao vit gibbon, much more so than males, assuming there is a pool of unmated 'floating' males in the population ready to take-over a group. Indeed, floating males have twice been observed to take-over groups, albeit in those cases when the resident male was still present (Fan et al., 2015). Nonetheless, these observed take-overs suggest that the loss of a male from a group will not necessarily lead to its disbandment.

Habitat requirements

Our understanding of the cao vit gibbon's habitat requirements remains incomplete. At least in part, this is because of insufficient research attention, but it is also due to the inescapable fact

that the species occurs in just a single site, likely offering a very narrow view of what the species prefers and can adapt to. Moreover, across the current and historical range of the cao vit gibbon, there is no habitat remaining that can be considered intact, making it difficult to study the 'natural' habitat preferences of the species in the absence of human impacts. Historical baseline data from these areas is also absent.

Nonetheless, filling in this knowledge gap for the species remains critical for understanding the current carrying capacity of the Trung Khanh – Bangliang forest block, and for determining how the population might respond to future changes in habitat, especially under restoration (whether passively or actively). A thorough understanding of what cao vit gibbon groups need is also critical for determining whether any potential site is suitable or not for establishing a second population of the species.

For habitat to be suitable for the cao vit gibbon, it likely needs to satisfy a number of requirements. These different requirements can be thought of as different components of suitability which, when combined, determine how suitable a habitat patch is. For a given patch of forest, we can therefore pose a series of questions to assess its suitability in terms of each of these components:

1. Does the forest have sufficient **canopy cover** and **contiguity** to allow for the movement of gibbons from one food tree to the next?
2. Are there sufficient **food** resources for survival and reproduction?
3. Does the habitat contain '**key resources**' such as suitable sleeping and singing trees?
4. Is **human disturbance and hunting** sufficiently low?
5. Can gibbons reach the habitat patch by natural dispersal along a **habitat corridor** (or will translocation be needed)?
6. Is the habitat **large enough** to sustain not just a family group, but a population?

Canopy cover and contiguity: We have a relatively good understanding of the structural requirements of suitable forest for the cao vit gibbon in terms of canopy cover and contiguity, at least in part due to relevant research on other gibbon species. Gibbons are highly specialised arboreal locomotors (Michilsens et al., 2009), using a mixture of brachiation, climbing and leaping to move through the mid- and upper-level of the forest canopy, and they almost never come down to the ground (Gittins, 1983). This locomotory behaviour requires near-continuous canopy cover, with only short gaps between trees of no more than 12 m in the worst-case (Cheyne et al., 2013). The cao vit gibbon is no exception to this, even though the habitat that it today occupies has a much lower canopy height compared to other studied gibbon species (Fan et al., 2011, 2013; Fei et al., 2015). Individuals have been observed exploiting the forest understorey, down to 2 m off the ground (Nguyen Duc Tho, pers. obs.), but never coming down to the ground itself (Fan et al., 2013). The only exception to this is when individuals are crossing exposed mountain ridges, in which case they may in rare cases use the limestone rocks in order to cross the gap in the canopy. In Vietnam, for example, an adult female was filmed briefly clambering over the limestone when crossing a ridge (FFI - Vietnam Programme, 2020, unpublished data), whilst in China another adult female was photographed sitting on exposed rocks (Haigang Ma, 2021, pers. obs.). Importantly, there are no observations of gibbons crossing the degraded grassland and shrubland areas found in valley bottoms.

In terms of thresholds of canopy cover that can be considered suitable for the cao vit gibbon, modelling of the 2007 population survey data led Fan et al. (2013) to suggest that > 80% canopy cover (as measured using global 30 m resolution data from remote-sensing) is highly suitable habitat for the species, whilst 60-80% is moderately suitable. Now that gibbon location data are available from long-term monitoring of followed groups, there is an opportunity to refine these thresholds of canopy cover, ideally using high-resolution satellite or drone-based imagery, and-or LiDAR data. Other metrics of forest structure could also be included in these analyses.

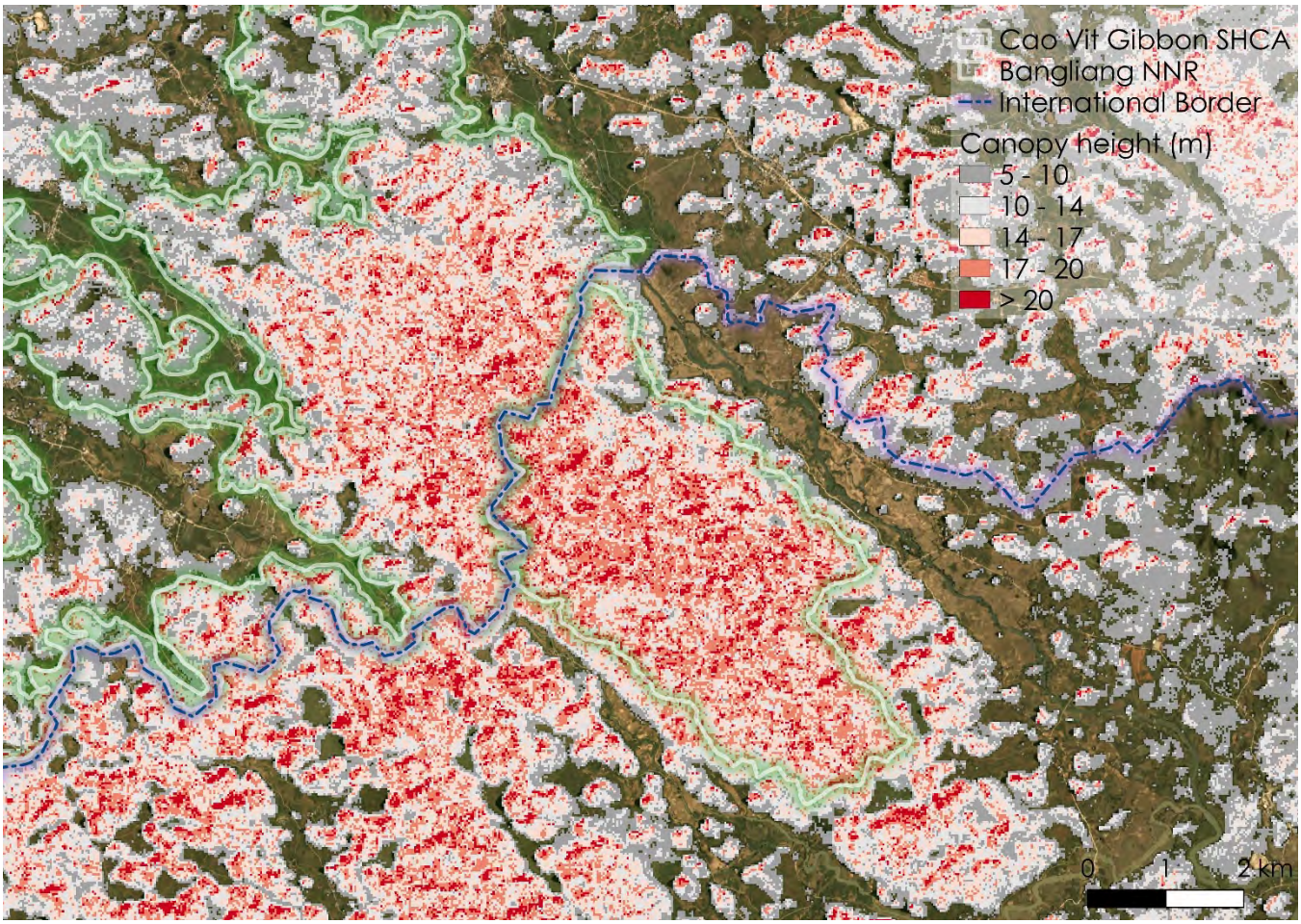

Figure 5. Canopy height across the Trung Khanh – Bangliang forest block, according to remotely-sensed data (Potapov et al., 2021). Vegetation < 5 m is shown transparent. Underlying basemap for 2020 © Planet Labs.

The habitat in the Trung Khanh – Bangliang forest block is thought to be structurally very degraded in its current state, with a canopy height of just 11 m in the core area occupied by gibbons (Fan et al., 2011; Vu Quang Nam & Phung Van Phe, 2021)). Importantly, however, the habitat is likely in a recovering state, and was previously *even more degraded*. Since the establishment of the two protected areas, grazing, logging, charcoal production and NTFP collection have all decreased, allowing the habitat to undergo natural restoration over the last

15 years. According to the testimony of researchers, the forest in the core area occupied by gibbons has consequently become denser and taller since the first surveys began there in the early 2000s (Trinh Dinh Hoang, pers. comm.). This is also corroborated by the fact that the gibbons have become more difficult to observe over time (**Fig. 3**). Fixed-point photography, although not done systematically, also gives us anecdotal information on habitat succession following agricultural abandonment in a few select valleys (**Fig. 6**).

Figure 6. Fixed-point photographs for Lung Day valley, in the core of the Cao Vit Gibbon SHCA (Left: 2008; Right: 2020). This valley was used by local people for growing maize and other crops but was abandoned shortly before the protected area was formally gazetted in 2007. The valley is slowly undergoing succession and a patchy canopy has naturally established itself. The outcomes in other valleys are less dramatic and some valleys are still dominated by *Microstegium ciliatum* grass.

Although no long-term and consistently-collected field data on the recovery of the habitat are available, it is possible to validate this anecdotal information using remote-sensing data. Using the Landsat archive (Landsat 5 to 8), 602 relatively cloud-free images of the Trung Khang – Bangliang forest are available, spanning 1986-2020 (Wearn, 2020). For each image, the Normalised Difference Vegetation Index (NDVI) was calculated for each pixel and then averaged over the area occupied by gibbons in the present day (Wearn, 2020). This showed that NDVI – which has been shown to correlate well with aspects of vegetation structure, such as canopy height, canopy cover and vegetation composition – has been increasing recently, especially since the gazettement of the protected areas in 2007 and 2009 in Vietnam and China, respectively (**Fig. 7**). The NDVI data indicate that the habitat was in a much poorer state in the past than it is today, especially before 2000. The NDVI data and anecdotal information together suggest a very broad tolerance to habitat structure for the cao vit gibbon, at least in terms of its ability to persist in a site. It is not known, however, if the historically poor state of the habitat constrained the population size and-or was associated with lower rates of breeding or survival.

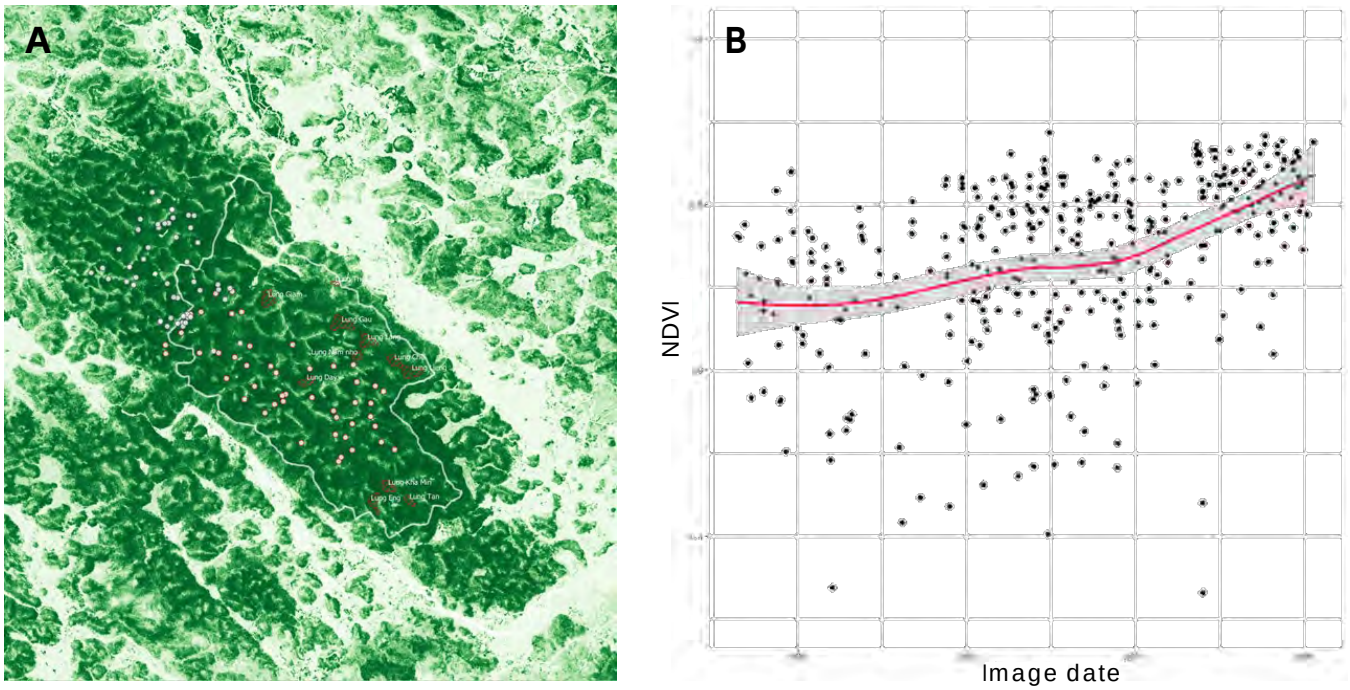

Figure 7. NDVI across the Trung Khanh – Bangliang forest block, according to Planet Labs data for April 2020 (**A**), and the NDVI trend across time (1986-2020) within the area currently occupied by gibbons, extracted from Landsat imagery (**B**).

Food resources: Research in China has provided a wealth of information on the diet of the focal groups, and how this varies over the seasons. For example, the cao vit gibbon is known to feed on a wide diversity of plants, including 89 species for the groups in China alone (Fan et al., 2011, 2012). This diversity is all the more surprising given that it comes from the study of the species in a single site; the species likely has a much wider dietary breadth than we can currently observe, as seen for example in *Nomascus concolor* across sites (Ni et al., 2014). This dietary information can be combined with vegetation data (e.g. from standardised plots), thereby allowing for the assessment of food availability in a given patch of forest. This is a critical first step in assessing whether a site could theoretically support gibbons, and this process has indeed already been started for the proposed extension area of the Cao Vit Gibbon SHCA, to the west of the current boundary. Preliminary results suggest that, compared to the core of the existing SHCA, this extension area does indeed have a similar diversity of food plants, although the total abundance appears to be lower (Vu Quang Nam & Phung Van Phe, 2021). More research in other sites within the historical range of the species are needed for comparative purposes.

The focal monitoring has also provided us with information on how large an area is required to provide the food resources for a family group, i.e. the home-range size of the species. In China, the average home-range of the two main focal groups (G1 and G4) was 101 ha for the period 2008-2016 (Fan, 2021). In Vietnam, the preliminary home-range size for the main focal group ('AB') was 82 ha for the period 2020-2021 (FFI – Vietnam Programme, unpublished data; **Fig. 8**). These home-range sizes are large compared to other gibbon species, and might be related to the comparatively large group sizes seen in the species (Fan et al., 2015).

Despite the large home-ranges, it seems unlikely that this is due to low population density, as might be the case for the Hainan gibbon (Bryant et al., 2015). On the contrary, gibbons in the core of the Trung Khanh – Bangliang forest block are already living at high density and there are indications that within-group feeding competition is already operating (Fan et al., 2015), suggesting little scope for further compression of home-range sizes. However, this is not to say that future improvements in habitat quality at the *margins* of the current core habitat could not allow for new groups to form, as for example has been observed in China already, with the formation of two new groups in 2015 and 2017 in previously unoccupied areas of habitat.

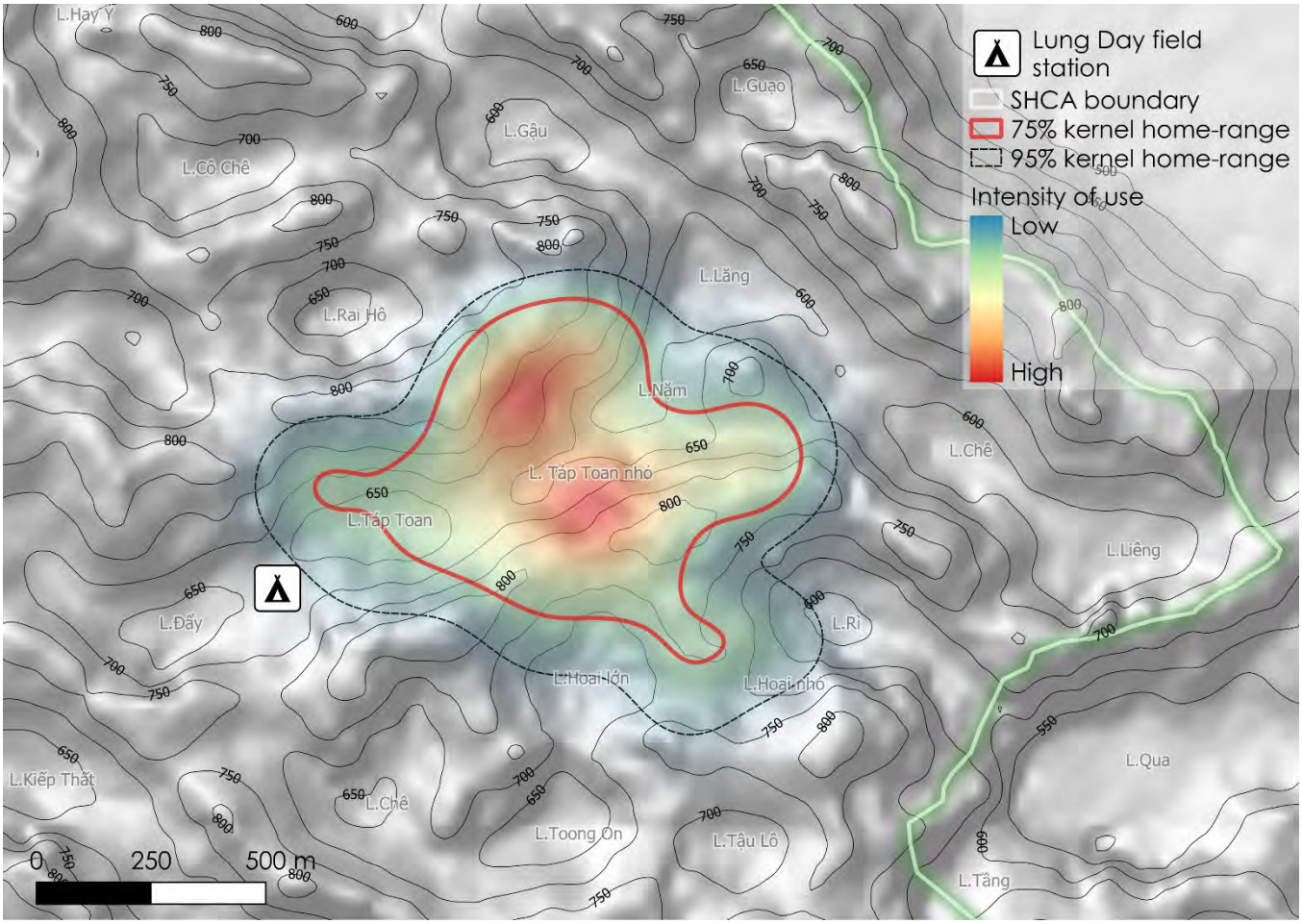

Figure 8. Home-range for group 'AB' in the Cao Vit Gibbon SHCA, Vietnam. Over the 13 month monitoring period (2020-2021), the group most intensively used the slopes of the Tap Toan 'Small' valley. The preliminary home-range size is 82 ha (95% kernel density estimate).

Key resources: Beyond food plants, there are likely a few key resources that cao vit gibbons require in order to survive and breed successfully. Cao vit gibbons, like all gibbons, often sing loudly in the morning hours, in order to defend their territory and cement their family bonds (Geissmann, 2000). This is a defining life history characteristic of gibbons and, in turn, it might make the trees that gibbons choose to sing from a key resource. Similarly, sleeping trees may

also be a key resource, providing safe places for resting during the night. In other gibbon species, it has been found that large, emergent trees are preferentially chosen as the platforms to sing from (Whitten, 1982), as well as for sleeping in (Fan & Jiang, 2008; Cheyne et al., 2013). The singing tree preferences of the cao vit gibbon have not yet been characterised, but it seems likely that they also prefer tall trees, and anecdotal observations support this. However, the complex karst terrain of the cao vit gibbon's habitat means that the tallest trees may not always be the best places to sing from, if for example they are in locations where sound transmission will be occluded, such as in valleys. This explains the finding that cao vit gibbons prefer to sing from higher elevation areas within their home-range (H. Ma et al., 2020). For the sleeping tree preferences of the species, one study in China found that emergent trees without lianas, situated towards ridge-tops, were most often used (Fei et al., 2012).

It has also been shown that monitored cao vit gibbon groups selectively use the lower-lying areas (at an elevation < 750 m) of their home-range much more than the higher-elevation areas (Fan, 2021). These areas are primarily valley-bottom areas and, given the strong preferences for using these areas shown by monitored groups, might be considered an important, if not key, resource.

Climate change may cause changes in the community composition of the forests Trung Khanh – Bangliang forest over the coming century, affecting both the availability of food and key resources for the cao vit gibbon. Although no down-scaled predictions for the current and potential range of the cao vit gibbon currently exist, predictions for the East Asian region indicate that temperatures will greatly increase, frost days will decrease and rainfall will become more extreme, with more drought and more torrential rain periods (Gutiérrez et al., 2021). How this will affect the habitat of the cao vit gibbon is not known.

Human disturbance and hunting: No cao vit gibbons are known to have been hunted at least in the past 20 years and, whilst the threat of this re-emerging is ever-present, hunting does not exert control over the cao vit population today. On the other hand, *disturbance* by humans may be a significant factor in explaining the current distribution of the population. The hypothesis is that disturbance, primarily from the noise of people's voices or from carrying out activities in the forest (e.g. cutting trees), creates a 'landscape of fear' (Laundre et al., 2010) for the gibbons and makes certain parts of the Trung Khanh – Bangliang forest either partly or completely uninhabitable. For dispersing gibbons, these disturbed areas may be perceived as unsuitable habitat, forcing them either to oust an existing group from its territory or remain as unmated 'floating' individuals. For established groups that experience disturbance in their home-range, this is likely to cause temporary emigration from the affected areas. For example, lar gibbons (*Hylobates lar*) in Malaysia were observed to temporarily change their home-range use during the noise and disturbance of selective logging operations, reoccupying their original home-ranges once logging had ceased (Johns, 1985). If disturbance is sustained over the long-term, however, the alterations in home-ranging may affect the foraging success, and therefore survival, of individuals.

The cao vit gibbon occupies just 30% of the 3,698 ha of the Trung Khanh – Bangliang forest block (area estimated from a Landsat-derived land cover map; FFI – Vietnam Programme, unpublished data), and groups have never been recorded < 400 m from the edge of the forest

(**Fig. 9**). This 'edge effect' may be due to multiple factors, including the more degraded state of the habitat, but it is also consistent with the idea that the gibbons avoid areas with frequent human presence. In practice, it is difficult to disentangle the effects of human disturbance and habitat quality in Trung Khanh - Bangliang because they are very closely correlated. To overcome this, a series of coordinated experiments (involving controlled disturbance to the population) would be needed, although this is not readily defensible from an ethical standpoint given the stress that this would cause to groups and the very high endangerment status species. A 'natural experiment' of this sort did, however, reportedly occur during the 2018 transboundary population survey, when > 50 people entered the forest and the gibbons temporarily experienced more noise than they would have heard for several years prior (Trinh Dinh Hoang, pers. comm.). Group 'AB', which occupies an area close to the Lung Day Ranger Station in the Cao Vit Gibbon SHCA, did not call at all during the 5 days of the survey and may have temporarily modified its ranging behaviour in response to the disturbance.

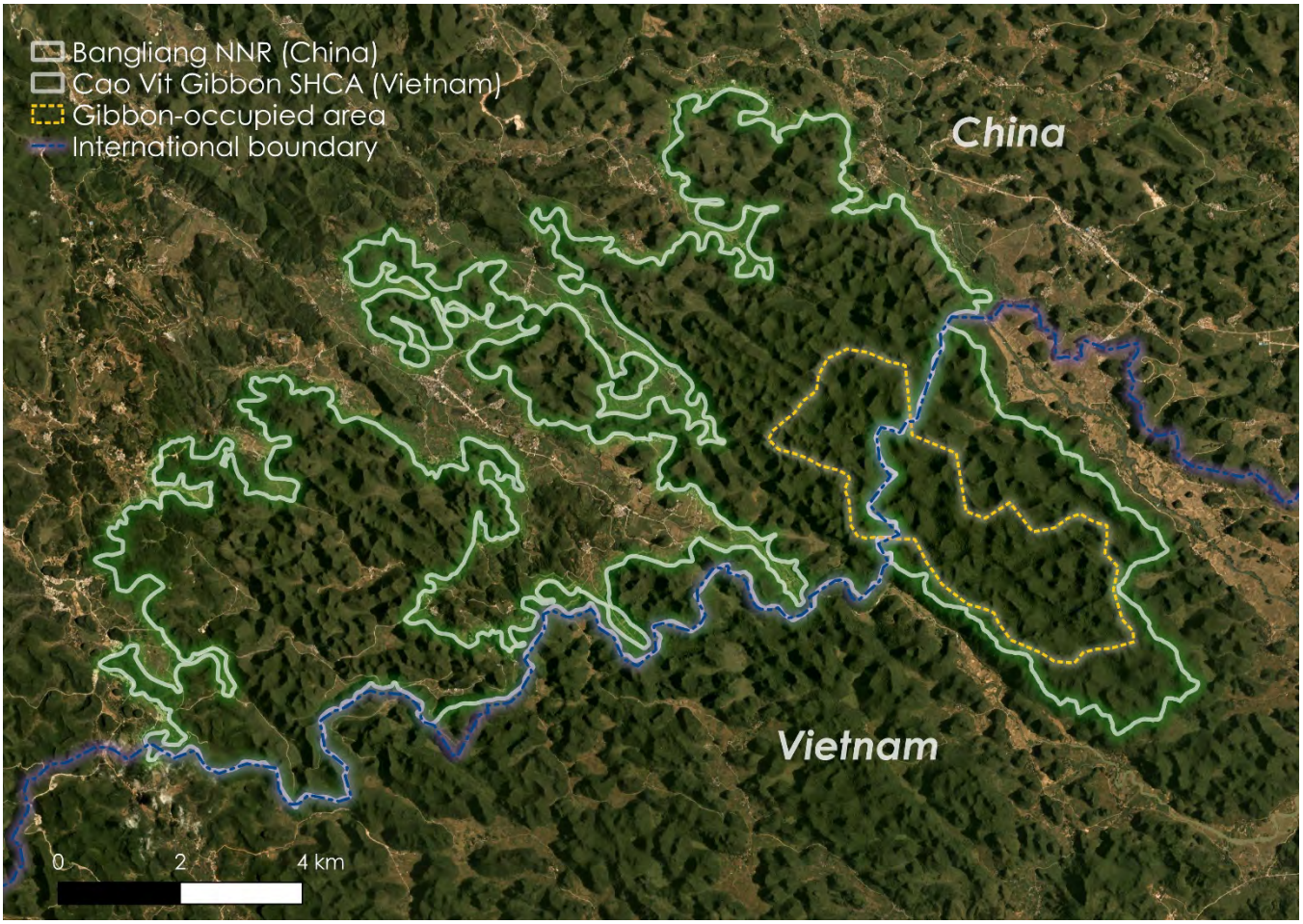

Figure 9. The area currently occupied by the cao vit gibbon within the two protected areas in Vietnam and China, the Cao Vit Gibbon SHCA and Bangliang NNR, respectively. Basemap for 2020 © Planet Labs.

Patch connectivity and habitat corridors: As noted above, there are large areas of the Trung Khanh – Bangliang forest block, in particular in the peripheral areas, that are unoccupied by the cao vit gibbon. In part this may be due to human disturbance (see above), but it is likely also due to the poor state of the habitat (caused by grazing, logging and agriculture) and the poor connectivity with the core forest area. The poor connectivity of the habitat may mean that areas that could otherwise be suitable for the gibbon cannot easily be accessed by dispersing gibbons. This may be the case for at least three habitat patches: i) a ~320 ha area to the south of the current Cao Vit Gibbon SHCA (and likely to be included in the SHCA in future), ii) a ~70 ha area just inside the eastern boundary of the SHCA, and iii) a 120 ha area outside the eastern boundary of the SHCA. On the basis of visual assessment of satellite imagery and tree cover data, these three main patches contain areas of habitat with satisfactory canopy cover (> 60%) and appear to be connected to the occupied forest in the core of the SHCA by eight narrow habitat 'corridors' (Trinh Dinh Hoang, 2020). Substantial uncertainties remain for these putative corridors, in particular how wide they should be for gibbons to use them, the quality of the habitat required (both in the corridor and in the 'sink' habitat), and if human disturbance precludes their use in any case. In addition, it is unclear how cost-effective an approach which protects and restores these corridors would be versus an approach which restores degraded areas at the immediate periphery of the existing occupied area. The former will potentially unlock areas of currently inaccessible habitat for the gibbon, whilst the latter is likely to encourage an expansion in occupancy at the edge of the current range of the species, as has already been observed in China.

The Trung Khanh – Bangliang forest block is now almost completely isolated from surrounding forest blocks, so prospects for much broader, landscape-scale corridors are now very limited. The exception to this is the putative corridor to the forest area in Phong Nam and Ngoc Chung districts (currently mostly designated as a Protection Forest), to the west of the Cao Vit Gibbon SHCA. Near the village of Da Be, there is minimal structural connectivity (**Fig. 10**), with degraded and secondary forest providing a putative dispersal route. However, for gibbons, this likely does not represent functional connectivity, and significant restoration of this putative corridor would likely be needed.

Habitat patch size: Finally, a habitat patch must be large enough to sustain not just a single gibbon, or even a single family group, but a self-sustaining and healthy *population* of gibbons. An understanding of minimum viable population sizes will be critical not just for understanding the viability of the current population in Trung Khanh – Bangliang, but also for estimating the viability of any newly-established populations. In the absence of being able to study multiple populations of cao vit gibbon, the only way to usefully approach this question is to run simulations of populations in a computer (see section on *Population Viability Analysis*, below).

Genetic status of the remaining population

The cao vit gibbon population in the Trung Khanh - Bangliang forest block has persisted in a small and isolated state for probably a long time. The lowland forest that would have originally connected the various limestone blocks together in the surrounding landscape was likely cleared for agriculture hundreds of years ago, given the long history of people in the region. Moreover, given that the habitat in the Trung Khanh – Bangliang block was in a much poorer

state in the past (due to logging, grazing and charcoal production), and that the population was subject to hunting offtake, the population size was likely to have been smaller than today's population historically, i.e. surely less than 100 individuals, and perhaps less than 50 individuals.

Figure 10. In the western part of the Trung Khanh – Bangliang forest block, there is a tenuous connection near the Vietnam-China border to adjacent forest areas (currently designated primarily as Protection Forest) in Phong Nam and Ngoc Chung communes. Although there is a river on this western margin of the SHCA (**A**), this becomes narrow and eventually goes underground. The arboreal connectivity (**B**) is mostly very poor (small trees, with many breaks in contiguity) and would likely need substantial restoration in order to provide functional connectivity for the cao vit gibbon. Images © Hoang Van Tuan / FFI.

Isolated populations which persist at such low numbers inevitably are subject to loss of their genetic diversity over time through genetic drift. This can cause the fixation of harmful alleles which reduce individual fitness, for example by increasing susceptibility to disease. It can also reduce the ability of a population to adapt to future changes, e.g. under climate change. The rate of loss is dependent on various factors, including the population size, dispersal ecology (i.e. how far individuals go to find a mate), the mating system (e.g. strongly polygynous systems will, all else being equal, lose their diversity faster than monogamous systems), and the starting frequencies of alleles. Currently, the genetic diversity of the cao vit gibbon population, and the rate of loss, remains unknown and it is a key knowledge gap for the species. In the Hainan gibbon (*Nomascus hainanus*) – a relatively closely-related species to the cao vit gibbon which is also now found in only a single site – the genetic diversity is today extremely low compared to other studied species, and the effective population size is just 2.2 individuals (Bryant et al., 2016). The remnant Hainan gibbon population is much smaller than the remnant cao vit gibbon population (approximately 30 individuals, compared to 120), which means it has likely lost its diversity more quickly, but it serves to highlight the extent of loss that is possible in the extreme case. Certainly, the cao vit gibbon population has lost genetic diversity, and will continue to, but we do not yet know how extensive this loss has been.

Looking at the cao vit gibbon as a species with a previously relatively wide distribution across northern Vietnam and southern China, it is also clear that the species has now been forced

through a very narrow population bottleneck. As populations were lost, for example in Tam Dao in the 1970/80s or in Kim Hy in the 2000s, it is highly likely that unique alleles that were never found in the Trung Khanh - Bangliang population were also lost. This means that, even if recovery of the species were achieved, with a second or even third population established, it may still take a very long time for the species to recover its original genetic diversity, and therefore also its adaptability to future change. This means that intensive measures to manage the population genetically may be required. Research into the population genetics of the Hainan gibbon also uncovered population bottlenecks in this species (Bryant et al., 2016), which might be mirrored in the cao vit gibbon. Specifically, the Hainan gibbon is thought to have undergone dramatic pre-20th Century declines in its population size and distribution, as well as a more recent decline (likely since the 1980s). A comparison of present-day genetics of the last remaining cao vit gibbon population with the genetics of historical museum specimens is needed, and may uncover a similar story.

Small populations such as the cao vit gibbon's last remaining population are also at risk of inbreeding, i.e. the mating of closely-related individuals. This increases the chances that offspring inherit two copies of deleterious or even lethal alleles, resulting in 'inbreeding depression' in the population. This can manifest itself in various ways: high infant mortality, a skewed sex-ratio, reduced adult survival, increased health problems, and infertility. Inbreeding is also exacerbated by the loss of diversity under genetic drift, so the two processes can reinforce each other. We do not yet know the patterns of relatedness in the last remaining cao vit gibbon population, but the case of the Hainan gibbon is a stark warning of what is possible: in this population, so much genetic diversity has been lost that individuals in different groups were found to be related at the level of siblings or half siblings (Bryant et al., 2016). There are now no individuals left in the population that are not closely related. Fortunately, extreme effects of inbreeding depression have not yet been observed (an initial concern that the sex-ratio was male-biased was not confirmed by the genetics), but focal group follows will be essential in order to continually monitor this threat. This may also be applicable in the case of the cao vit gibbon.

Smallholder livestock farming in Trung Khanh District, Vietnam. Image © Hoang Van Tuan / FFI.

EXISTING MANAGEMENT PRACTICES IN VIETNAM AND CHINA

In Vietnam, the Cao Vit Gibbon Species and Habitat Conservation Area (SHCA) in Trung Khanh, Cao Bang was established in 2007 with a total area of 1,656.8 ha. It is currently under the management of the Cao Vit Gibbon SHCA Forest Protection Station (FPS). In China, the Bangliang Nature Reserve (NR) has an area of 6,530 ha and was established as a provincial reserve in 2009. It was subsequently upgraded to a National Nature Reserve (NNR) in 2013. These two protected areas (PAs) cover the entire global distribution of the cao vit gibbon.

Research and population monitoring

Scientific understanding of the gibbon's population dynamic and ecology provides an important basis for conservation actions. In Vietnam, several population surveys have been conducted by experts from FFI. In early 2020, a Gibbon Monitoring Team dedicated to gibbon research was established for the first time. This team, consisting of 6 members, collects ecological and behavioural data from focal gibbon groups for 10 continuous days per month. The home-range and movement data this has produced has led to an improved understanding of gibbon habitat needs in Vietnam. Over the long-term, this monitoring will allow for demographic rates (births and deaths) to be estimated, complementing the well-established monitoring work done in China. Over 2020 and 2021, FFI also carried out research to assess the availability of food for gibbons in different areas, in particular comparing currently occupied areas with areas that remain unoccupied (Vu Quang Nam & Phung Van Phe, 2021).

In China, since as early as 2007, the Bangliang NNR has maintained strong collaborations with research universities (Dali University and Sun Yat-sen University) to conduct research and monitoring of cao vit gibbon, generating a wealthy of valuable information on the species' ecology and behaviour; this work underpins much of the knowledge-base for the species to date (as detailed in the previous section).

Transboundary population surveys by research teams on both sides of the border have been conducted on two occasions (2007 and 2016), with an updated survey planned for 2021.

Law enforcement

Rangers of the two PAs conduct regular patrols to deter and handle violations of the protected area regulations, including logging, timber and non-timber product harvest and other human activities that disturb the gibbon and its habitat. In Vietnam, FPD staff coordinate with commune police, civil militia, and border guards to organize patrols of hotspots in the conservation area. Two FFI-supported Community Conservation Teams (CCT), each consisting of 2-3 members recruited from local ethnic minorities, work 15 days per month and patrolled a total of 4,412 km in 2020. All data are now collected in SMART Mobile using rugged smartphone devices (**Plate 2**), which is then uploaded to the cloud using SMART Connect, allowing rapid and timely inspection of the data by managers. Monthly meetings are also held, in which a summary report is presented and violations are discussed in further detail by the local members of the CCT and the FPD staff. The introduction of SMART to the CVG SHCA in 2013, and then the shift from paper-based to smartphone-based data collection in 2019, are thought to be two key milestones that led to improvements in the quality and quantity of the patrol efforts.

In China, three ranger teams of 5-6 members each patrol along fixed routes for at least 8-10 days per month, covering an area of approximately 4,000 ha. Rangers consist of both PA employees and part-time community rangers. On several occasions, rangers on two sides of the border have conducted joint patrols.

Plate 2. A member of the Community Conservation Team in the Cao Vit Gibbon SHCA removes traps from the forest and enters the data into SMART Mobile. Image © Hoang Van Tuan.

Outreach

With the aim of improving local awareness, signboards (**Plate 3**) and murals have been installed and publicity materials about forest protection and gibbon conservation have been distributed in both Vietnam and China. Among a range of outreach initiatives targeted at young people, the two PAs conduct classroom events, as well as host field trips where students can cultivate an appreciation of local biodiversity. In Vietnam, a series of Cao Vit Gibbon Festivals is underway in three communes bordering the SHCA to promote cao vit gibbon as a local icon and source of pride (**Plate 4**). PA managers also hold village meetings to raise local awareness about forestry

law and activities prohibited in the SHCA. In China, messages about gibbon conservation also reach the wider public via radio, TV, newspaper and social media.

Plate 3. Signboard to raise awareness about the cao vit gibbon, installed December 2017. Image © Hoang Van Tuan.

A 2021 questionnaire-based survey of 298 households, stratified across 15 villages surrounding the Cao Vit Gibbon SHCA, revealed strong support for conservation among local people (FFI unpublished data, 2021). Almost everyone thought that the forest was 'important' or 'very important' to protect (98% of respondents) and that the cao vit gibbon specifically should be protected (97%). Many people would like to be involved in upcoming conservation activities (57%) and most people think that local communities have an important responsibility in conserving the forest and the gibbon (83%).

Plate 4. Festivals were held in villages surrounding the Cao Vit Gibbon SHCA, to celebrate the gibbon and its forest habitat. Images © Ho Hai Yen (April 2021).

Co-management and livelihood support

The management of the CVG SHCA in Vietnam is supported by a Management Advisory Committee (MAC), consisting of stakeholders at the district level (including FPD, Agriculture and Rural Development Office, Natural Resources and Environment Office, Agricultural Service Centre and Border Army) and representatives from three surrounding communes. This model was pioneered by FFI across various sites in north Vietnam, and is considered a vehicle for co-management of protected areas within the context of Vietnam. The MAC provides advice to the PA in biannual meetings, primarily on matters concerned with law enforcement and community development. In China, Bangliang NRR is also advised by a co-management committee, which operates at three different levels (at the PA level, at the community level, and at the broader municipal level) and meets annually.

Livelihood solutions implemented by the CVG SHCA in Trung Khanh (in collaboration with FFI) and Bangliang NNR aim to reduce human impacts on the forest by promoting alternatives to high-impact human activities such as cattle grazing and fuelwood collection. Credit loans in Vietnam and a Community Development Fund in China have been set up to help communities to shift towards more sustainable livelihoods. The Community Development Fund has benefited 340 households across 5 villages surrounding Bangliang NRR. In Vietnam, the CVG SHCA in Trung Khanh implements tree planting, distributes eco-stoves, and provides households with metal water-wheel frames (as a replacement for traditional wooden wheels) to reduce the domestic fuelwood demand. In addition, local people around the SHCA have been supported to grow elephant grass as cattle feed, instead of grazing their cows inside the forest area, and were subsidised to relocate their goats away from the PA. In addition, households suffering from crop damage by wildlife are provided with financial compensation to reduce retaliation. Local residents are also given permanent employment in community-based conservation and research teams, as well as temporary employment as guides, porters and cooks. In China, the Bangliang NNR employs temporary rangers and labourers from surrounding communities, promoting conservation as an opportunity for job creation and income enhancement. As for Vietnam, FFI supported the distribution of eco-stoves to reduce fuelwood demand, and the

reserve subsidises the relocation and removal of goats from the NNR. Local communities have also been provided with technical advice on agriculture and livestock breeding, with the aim of making practices more sustainable.

Habitat restoration

In both Vietnam and China, a range of restoration activities have been implemented since the two protected areas were established, with the aim of improving forest cover and restoring gibbon habitat. Over 2011 and 2012, a series of workshops were held across both countries to assess the restoration efforts to date and formulate a framework for future restoration (Insua-Cao et al., 2012). This framework, which has now underpinned a decade of restoration work, consists of Assisted Natural Regeneration (ANR) and forest enrichment activities, with the aim of recovering degraded areas of former gibbon habitat. ANR consists of activities – such as grass clearing, vine cutting and 'ring weeding' – that aim to accelerate and enhance the natural succession processes happening in heavily-degraded areas. For forest enrichment, seeds and-or wildlings (seedlings and saplings) are taken and grown in community-based nurseries under ideal conditions, with the aim of improving their growth and survival (**Plate 5**). The resulting saplings, once large enough, are then transported back to the forest and planted. A range of gibbon food trees have been used for enrichment, particularly *Bischofia javanica* (bishop wood), *Choerospondias axillaris* (hog plum) and *Cephalomappa sinensis*, all with the aim of enhancing not only the extent but also the quality and connectivity of the cao vit gibbon's habitat. Species selection has been based on a review of gibbon food species, completed in 2012 (Tran Duc Thien & Michael Dine, 2012).

In Vietnam, after piloting ANR on 8.5 ha in four valleys between 2011 and 2014, the CVG SHCA Forest Protection Station partnered with the People Resources and Conservation Foundation (PRCF) to implement and maintain ANR on 32.4 ha in seven valleys (2014-2020). From 2011 to 2020, approximately 6,000 trees were also planted in six different valleys, across a total of 13.6 ha. In China, tree planting was implemented on 18.3 ha and ANR on 14.7 ha between 2012 and 2020.

In 2020, FFI reviewed the restoration work done in Vietnam, producing important recommendations for improvement, including on species selection, nursery maintenance, and criteria for identifying suitable saplings for planting (Tran Viet Ha & Phung Van Phe, 2020). This will help define a new period of restoration activities from 2021 to 2024. Meanwhile, the Bangliang NNR in China aims to restore a total of 80 ha of gibbon habitat over the period of the current management plan, i.e. 2018-2022. Lessons have been learnt over the first 9 years of restoration work in China, for example on the best season to plant different species and on aspects of the maintenance and monitoring protocols for restoration sites that can be improved.

Plate 5. Growing seedlings in nurseries as part of restoration efforts in the Cao Vit Gibbon SHCA, including *Choerospondias axillaris* (right-hand image). Images © PRCF.

Transboundary cooperation

Since the Memorandum of Understanding (MoU) on transboundary cao vit gibbon conservation was signed in 2011 by Cao Bang Provincial People's Committee (Vietnam) and the government of Baise city (Guangxi, China), it has provided an official framework for collaboration between the two PAs in gibbon and habitat conservation. In addition to joint gibbon population surveys and patrols (mentioned above), regular meetings between patrol teams and the PA managers ensure timely response and continuous cooperation. Workshops at the provincial level are organised every one to three years to exchange longer-term conservation lessons (**Plate 6**).

Plate 6. Transboundary meeting between Trung Khanh FPD (CVG SHCA) and Bangliang NNR, July 2017.

Young male cao vit gibbon in Bangliang NNR, China. Image © Huang Tao.

POPULATION VIABILITY OF THE CAO VIT GIBBON

Background and approach

In order to inform the conservation planning for the cao vit gibbon, a quantitative assessment of the viability of the last remaining population was undertaken, specifically to estimate its: probability of extinction, future population size, and genetic health. The assessment was grounded in real data (from demographic monitoring) and expert opinion, and sensitivity testing was done around key uncertainties in the model.

In addition to estimating the likely future state of a population under current conditions, i.e. the baseline scenario, it is also possible to run virtual 'experiments' on the population, in which specific conservation interventions are made. The effectiveness of these interventions can be assessed by comparing the results with and without the intervention. For the cao vit gibbon, the two conservation interventions that were applied were *forest restoration* and *translocation.* In addition, we investigated a scenario in which the population is subject to *natural catastrophes*, in order to test the population's vulnerability to this particular type of random, infrequent threat. This kind of virtual experimentation with a population, or *scenario modelling*, is often a more useful and informative way to approach the quantitative assessment of viability than attempting to accurately predict the future *per se*, especially when knowledge of a species is incomplete (as is the case for the cao vit gibbon, and in fact most threatened species globally). This is because it is much more feasible to assess the relative difference in population outcomes between two scenarios than it is to accurately predict the absolute state of a population.

This kind of quantitative approach is commonly called *Population Viability Analysis* (PVA) and is associated with a set of tools and approaches that have been widely used and refined around the world for several decades (Pe'Er et al., 2013). Specifically, we used the computer program *Vortex* v.10.5.4 (Lacy, 2000; Lacy & Pollak, 2021), which allows for the running of many repeated simulations of a given population and monitors the outcomes (extinction, population size, and genetics) in each case. Birth and death rates of individuals are a lottery process in these simulations (even though the long-term average is set based on our knowledge of the species), so the outcomes of each simulation are slightly different. PVA is invaluable for conservation planning because it allows for safe experimentation with a population (entirely within a computer) in order to answer questions that would not otherwise be tractable, especially when just a single population of a species remains.

We asked four main questions about the cao vit gibbon population in order to inform planning for the species, namely:

1. What is the viability of the current cao vit gibbon population?

2. How is this conclusion altered when we consider the possibility of unforeseen catastrophes?

3. What effect will forest restoration in the Trung Khanh – Bangliang block have on viability?

4. How might we feasibly begin to recover the species by re-establishing a second population?

We applied a *parsimonious* approach to the modelling, making the models as simple as we could justify, but no simpler. In other words, we did not overly complicate the population model with additional processes if we did not have reasonable evidence (theoretical or empirical) to include them. For example, we included a simple form of density dependence in the model, given the strong theoretical and empirical justification for it in general in any wild population (albeit no evidence, in particular, for the cao vit gibbon), but we only modelled it as having an effect on breeding rates (the default in *Vortex*), and not on mortality, because we had no strong evidence for the latter (neither in general nor specifically for the cao vit gibbon). We also applied a *precautionary* approach to the modelling; if we were not sure about a particular aspect of the model (e.g. whether a process should be included, or the value of a particular parameter), we made the models slightly more pessimistic than optimistic about population outcomes. This is a reasonable approach given the precarious situation the cao vit gibbon is in, occurring as it does in just a single population.

Data and assumptions

Data to inform the PVA included: the population size and age-structure from the recent population survey in 2018 (Trinh Dinh et al., 2018); demographic rates from long-term monitoring of groups in China between 2007 and 2020 (Changyong Ma & Pengfei Fan, 2021, unpublished data), and current understanding of the social structure and life history of the species (including, for example, the preponderance of bi-female family groups and the two years of infant dependence on their mothers). The assumptions we made included: an initially low level of relatedness among individuals in 2018; a weak effect of inbreeding depression when closely-related individuals breed together; weak density-dependence (i.e. if the population in a simulation declines for any reason, then remaining females can access more resources and breed marginally faster than normal), and that the population is approximately at carrying capacity in today's habitat (consistent with the fact that the population shows no statistically significant increase over the last 11 years of surveys). Full information on the parameters used in the models is provided in **Appendix II**, ensuring reproducibility of the findings (Morrison et al., 2016).

Results I: What is the viability of the current population?

The baseline PVA scenario, i.e. the viability of the current population under the *status quo* (no changes in threats, habitat or management), indicates that the population is robust to extinction in the absence of changes: it experiences some quite large changes in size over short periods of time, but overall is very unlikely to go extinct due to chance variation (**Fig. 11**). However, the population does not perform optimally in the baseline and, by the end of 200 years (approximately 10 generations), it is smaller (by 4%) than it is today and is depressed below the habitat carrying capacity (by 15%). This slight downward trajectory is due to the gradual loss of genetic diversity predicted by the model.

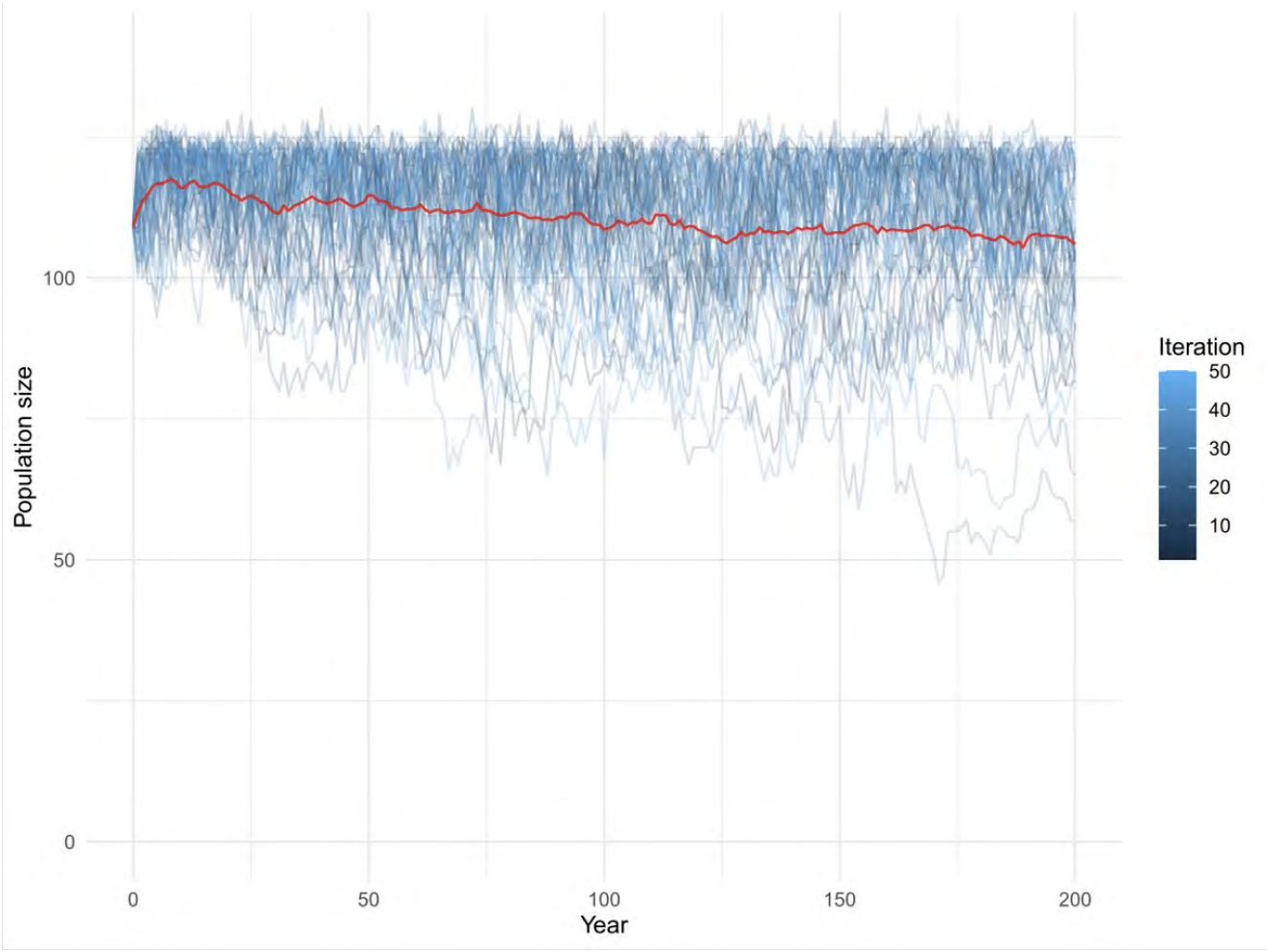

Figure 11. Mean expected population size (red line) over the next 200 years (approximately 10 generations) for the cao vit gibbon, under a baseline scenario (no changes in threat, habitat or management). The first 50 of 1000 simulations are shown (blue lines) to demonstrate the variability across the simulations. Overall, the population is expected to be slightly smaller after 200 years and to be on a gradual downward trajectory.

This outcome under the baseline is subject to strong caveats, due to three major knowledge gaps that exist for the species. Firstly, in the baseline we assumed weak density dependence. This means that when the population size declines it is rescued somewhat by a small boost in the breeding rates of females. If the population shows extremely weak or non-existence density-dependence, then the baseline scenario will be too optimistic. It is considered unlikely on theoretical grounds that the population will not be affected by density-dependence. Indeed, the current female breeding rate of once every 3.8 years is much slower than the rate of every 2 years for the Hainan gibbon, which lives at a much lower population density; this might suggest that breeding rates in cao vit gibbon females have the capacity to increase dramatically.

The second caveat is that individuals in today's population might be very closely related, which may mean the individuals are subject to inbreeding depression. Initial relatedness was set to a

non-zero (but low) value, to account for the fact that the population has likely been relatively small and isolated for a long time, but relatedness might be much higher than estimated if the population has also been through a narrow bottleneck (e.g. of < 30 individuals).

Thirdly, the strength of inbreeding depression (i.e. the increase in infant mortality that occurs when parents are closely related) was assumed to be low, but is currently unknown. Patterns of inbreeding depression across taxa are difficult to predict – similar species can have markedly different inbreeding effects – and so there is no shortcut to detailed monitoring of a species in the wild. This is a key knowledge gap for the species and, if individuals are related and inbreeding depression is strong, then we might see a sudden and unforeseen decline in the population. For example, if inbreeding depression is worse than expected (i.e. it is moderate rather than weak), we'd expect a 25% population decline after 10 generations in the baseline scenario. No obvious signs of inbreeding effects have been noted from the focal group monitoring – neither in China nor Vietnam – but this does not mean that effects will not materialise in the near future. The uncertainty in our information about the relatedness among individuals and inbreeding depression suggests that an assessment of population genetic health is an urgent research priority for the species.

Modelling conclusion**:** The cao vit gibbon is **extremely unlikely to go extinct due to chance** (i.e. due to demographic or environmental stochasticity), but is likely to be **gradually losing genetic diversity** over time, which might in turn lead to increasing effects of inbreeding and a reduced ability for the population to adapt to new challenges.

Results II: What is the viability of the population if it suffers from catastrophes?

Two types of unforeseen catastrophe were considered: human-induced and natural. The human-induced catastrophe scenario explored the potential effects of hunting on the population. No hunting of the cao vit gibbon has been reported over the last 20 years, though we know the species was hunted historically. The assumption is that, if hunting resumes, it is unlikely to be a consistent pressure on the population given the protection that the population receives today. Instead, a re-emergence of hunting as a threat is likely to be opportunistic and unpredictable. We considered a scenario in which opportunistic hunting occurs once every 2 generations (i.e. 40 years), and results in the death of 20% of the population in total (e.g. 3-4 adult pairs and their offspring). This results in an expected population decline of 14% by the end of 10 generations, but never leads to the extinction of the population. However, when hunting is combined with a moderate strength of inbreeding depression (including moderate levels of initial relatedness), the population has a 19% probability of extinction and is expected to be 63% lower on average than it is today after 10 generations (**Fig. 12**).

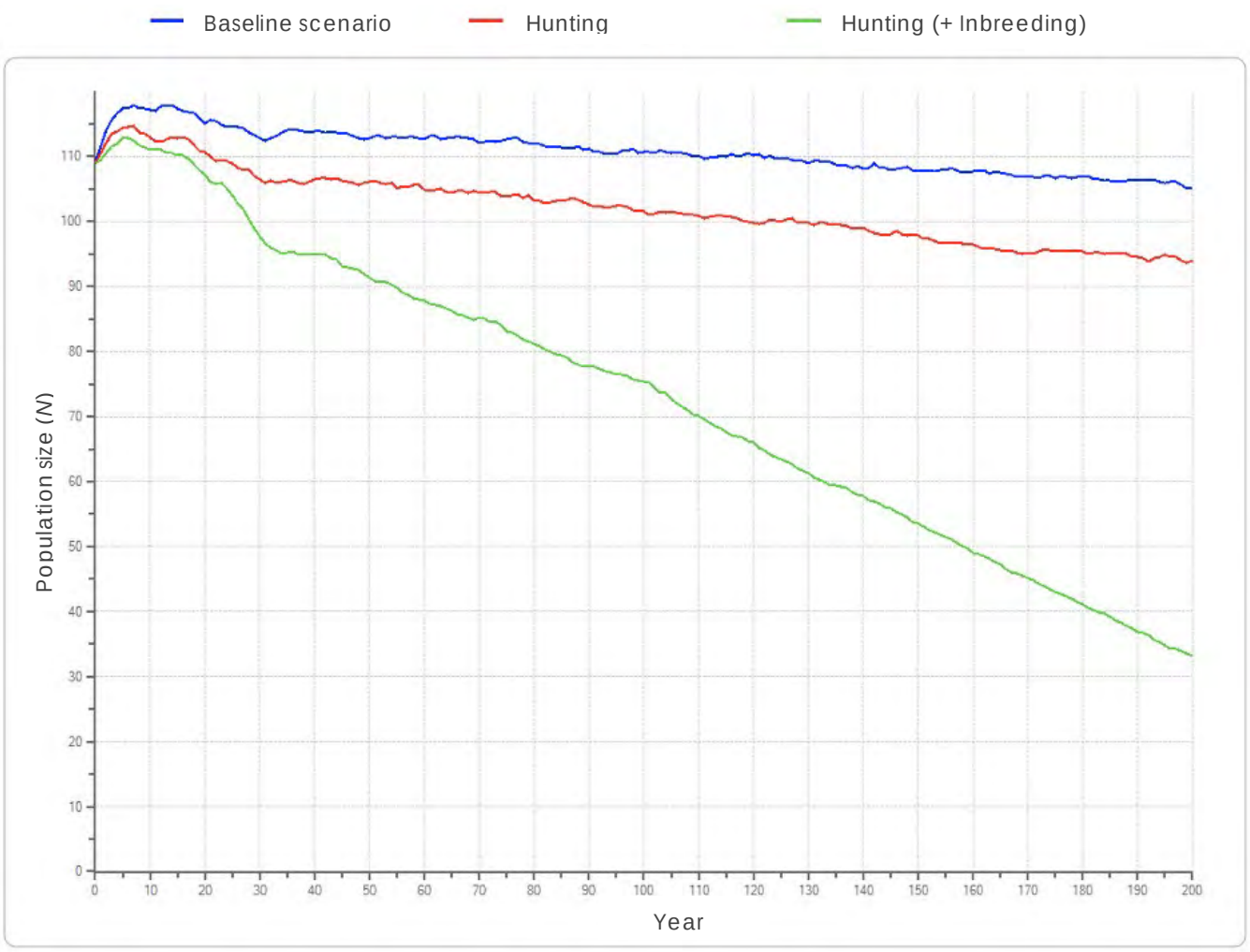

Figure 12. Mean expected size of the cao vit gibbon population under human-induced catastrophes, i.e. opportunistic hunting, as compared to the baseline scenario (blue line). With catastrophes, the population is expected to be 14% smaller than today after 200 years (red line), as compared to 4% smaller under the baseline. With more pessimistic assumptions about the genetic health of today's population, the population is 63% smaller after 200 years (green line). Variation across simulations (as shown in Fig. 11) are not shown here for clarity.

Wild populations that have been studied around the world typically experience natural catastrophes on average approximately once every 7 generations (Reed et al. 2003), which for the cao vit gibbon equates to a 0.7% chance per year. It is very difficult to predict when and how a natural catastrophe will materialise, but examples include disease, extreme weather and fire. Arguably, under climate change, natural catastrophes may become more prominent over time. We assumed that a natural catastrophe of this sort would kill 50% of the population. The results under natural catastrophes are similar to those under hunting (and are therefore not shown here): the population was robust to outright extinction, but was not performing optimally after 10 generations, with a population that is 18% smaller than today. In combination with more pessimistic assumptions about the cao vit gibbon's genetic health, the population is expected to be 61% smaller than today, with a 25% chance of extinction.

Note that, due to the inherent unpredictability of catastrophes, the mean expected population sizes under catastrophes have large uncertainty associated with them. It may be the case that the cao vit gibbon experiences no catastrophes in the next 200 years, or it may experience several. The most important thing to note is that, if the genetic health of the population is poorer than we have estimated, there is between a 1:5 and 1:4 chance of the species going extinct in 10 generations under a scenario with catastrophes.

Modelling conclusion**:** The current cao vit gibbon population is likely to be **robust to extinction from catastrophes**, both human-induced and natural, **unless the genetic health of the population is in a poorer state than expected, or catastrophes are more severe and-or more frequent than expected**.

Results III: Population viability under habitat restoration

Based on anecdotal information and the analysis of NDVI trends, it appears that the habitat for the cao vit gibbon's last remaining population has been gradually improving naturally, especially since PA gazettement in the late 2000's. NDVI has increased by approximately 1.4% per year since 2010 (Wearn, unpublished analysis) and, simplistically, this rate was used to build a scenario of habitat recovery in the Trung Khanh – Bangliang forest block. The current area occupied by gibbons, and therefore the area assumed to be currently available for gibbons, was 1121 ha. This is a smaller area of gibbon habitat than was estimated in Fan et al. (2013), because we took the observed area occupied, rather than estimating it based on a tree cover index. Assuming a 1.4% recovery rate, after 85 years the entirety of the main forest block inside the Cao Vit Gibbon SHCA and Bangliang NNR (at 3,698 ha) will have fully recovered. Given a constant percentage rate, in absolute terms this means that the area that is assumed to recover each year increases over time, from approximately 16-20 ha to > 60 ha per year. This increase in the absolute area recovering each year might be expected based on the increasing size of the source population of seeds, more effective dispersal (due to the recovery of animal dispersers), and decreasing human-induced pressures over time.

Under this scenario of habitat restoration, the cao vit gibbon population is expected to increase dramatically (by 2.2 times), reaching a peak of approximately 245 individuals after 5 generations, i.e. 100 years (**Fig. 13**). This assumes that the gibbon density observed in the occupied areas today is maintained through time. This larger population size shows much reduced rates of genetic diversity loss and therefore no appreciable downward trend after 200 years, unlike in the baseline scenario. When catastrophes (either human-induced or natural) are included in concert with restoration, we find that the population is also much more robust to this threat than in the baseline scenario, showing only a 4% decline from a peak of > 220 individuals. With more pessimistic assumptions about the genetic health of the population, however, population growth is significantly stunted, with a peak of 195 individuals reached after 6 generations (120 years). Thereafter, the population begins to slowly decline from the peak (by 8% after 10 generations) due to the increasing effects of inbreeding depression.

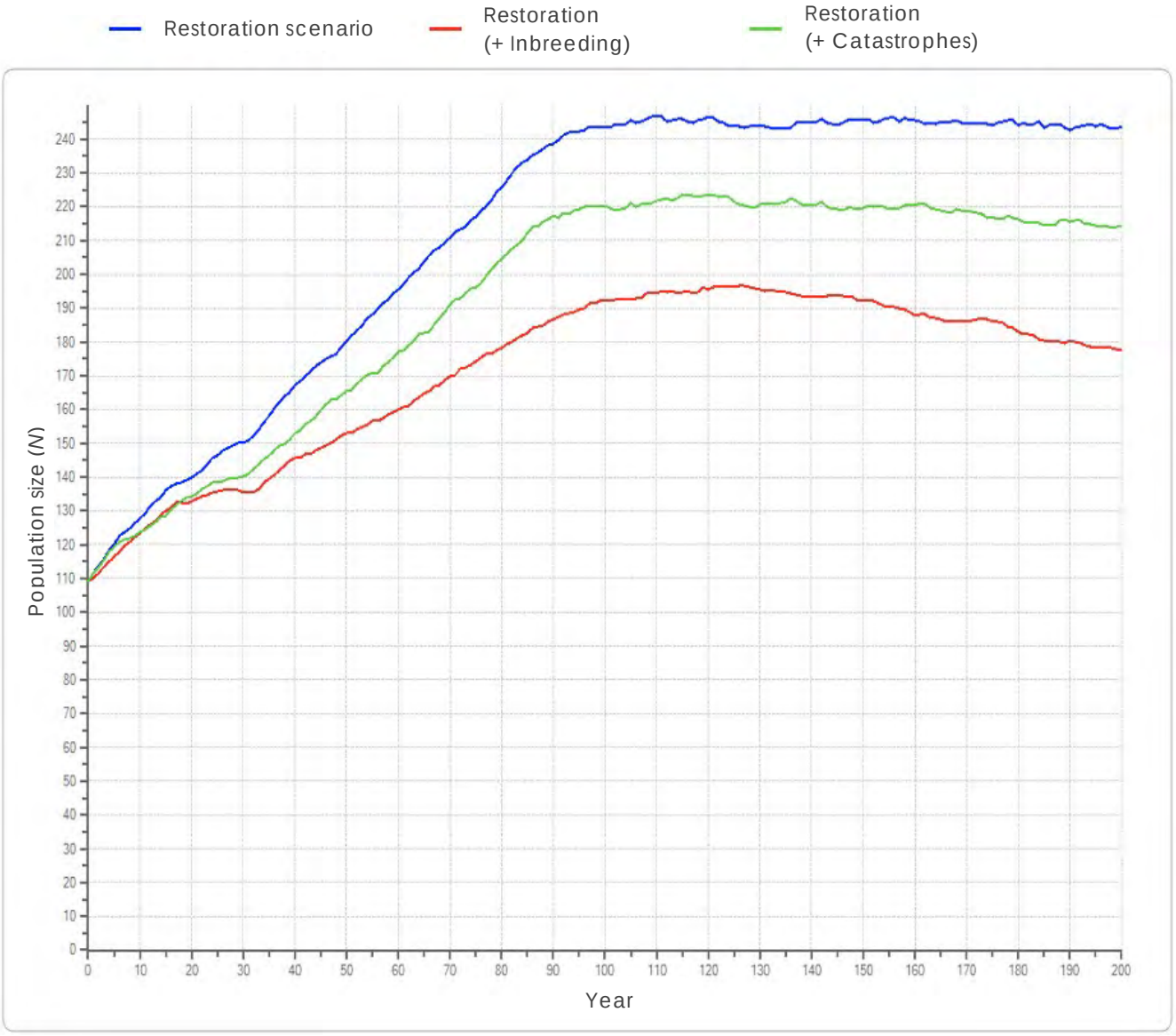

Figure 13. Mean expected size of the cao vit gibbon population under habitat restoration. Under restoration, the population size peaks at 2.2 times its current size after 100 years, and is stable thereafter (blue line). With catastrophes, the population peaks at a lower size and slightly declines thereafter (by 4%), but is robust to extinction over the 200-year timeline (green line). With more pessimistic assumptions about the population's genetic health, the growth of the population under restoration is substantially stunted, but it is also robust to extinction after 200 years (red line). Variation across simulations (as shown in Fig. 11) are not shown here for clarity.

Two very important caveats exist for this restoration scenario. Firstly, gibbons may not be able to reach restored habitat immediately if recovery occurs patchily across the Trung Khanh – Bangliang forest block. Dispersing individuals looking to set up new territories in recovered habitat may be blocked from moving out of the core occupied habitat by intervening areas of poor habitat. In this case, population size will not track the absolute availability of habitat, and population growth will proceed with a (potentially severe) lag. Secondly, natural habitat recovery may provide habitat quantity but not necessarily *quality* (in terms of food availability

and other key resources). If this is the case, targeted enrichment planting in areas of low food availability may be required to accelerate habitat recovery, as well as assisted natural regeneration in areas where succession is blocked by grasses (e.g. in some valleys).

These caveats may explain why significant population growth has not been seen over the last 10+ years, when the evidence supports the idea that the habitat has indeed been recovering. The alternative explanation is simply that the population growth has not yet been large enough to be detectable in the population size estimates, with their associated uncertainty. Indeed, two additional gibbon territories were observed forming in 2015 and 2017 in China, but this represents a small increase relative to the confidence intervals on the population size estimates (see **Table 2** and **Fig. 2**). The true underlying population trend will become clear over the long-term.

Modelling conclusion**:** Restoration of the Trung Khanh – Bangliang forest block is likely to **substantially reduce the vulnerability of the cao vit gibbon population to threats**, including catastrophes and inbreeding.

Results IV: Establishing a second population by translocation

Given that the last remaining population appears vulnerable to loss of genetic diversity over time, a larger global population size is desirable. In addition to increasing the carrying capacity of the habitat in the Trung Khanh – Bangliang forest block, another way of achieving this is to establish one or more additional populations in other forest blocks. The Trung Khanh – Bangliang forest is functionally isolated from other forests, with only a very tenuous connection with neighbouring forests to the west in Phong Nam and Ngoc Chung districts (see **Fig. 10**), and so the only feasible way to achieve this in the short- to medium-term would be by translocating individuals. Establishing multiple independent populations, i.e. 'insurance populations', would also be a way to reduce the risk to the species of unforeseen catastrophes, assuming that catastrophes are uncorrelated across the populations. Finally, re-establishing populations in parts of the former range of the species, and allowing it once again to fulfil its ecological function across a broader area, must form part of a recovery vision for the species.

Conservation translocations should never be considered lightly, and building the knowledge, expertise and support (both locally and from government) necessary to undertake translocations for any species is a long process. Gibbon translocations present particular challenges, due to their mobility and arboreality, and these challenges are accentuated in the limestone habitat of the cao vit gibbon. Nonetheless, as an initial step towards evaluating the feasibility of such a strategy for the cao vit gibbon, a translocation scenario was considered using PVA.

The translocation scenario involved periodically removing individuals from the main Trung Khanh – Bangliang population and releasing them into a separate, isolated habitat with similar characteristics as the main habitat block (and therefore with similar demographic rates and population density). The only difference was that the secondary habitat block was half the size of the Trung Khanh – Bangliang block, reflecting the relative scarcity of large blocks of remnant forest in the cao vit gibbon's historical range. The focus here was on wild-to-wild translocations, rather than captive-to-wild translocation, as the latter scenario would require substantial expertise and resources to build and maintain a breeding facility, successfully breed the species

(which has never been done) from a sufficiently large founder population, and establish protocols to educate the captive gibbons for life in the wild (Campbell et al., 2015). The wild-to-wild option was considered here to be a substantially more cost-effective and feasible option.

Adults were preferentially selected for translocation over sub-adults in the translocation scenario, according to a hypothesis that adult survival rates might be higher than sub-adults in the novel (and potentially challenging) environment of the release site. It was initially assumed that removing adult individuals from the cao vit gibbon population might lead to population declines. However, initial testing using Vortex showed that, given the observed mortality and breeding rates, the current population appears to be quite robust to adult removal (sub-adults are available to recruit into the adult class and take up vacant territories, and breeding rates of remaining females are temporarily boosted due to the reduced competition for resources). It was further assumed that adult pairs plus dependent offspring would be selected for translocation. To minimise impacts on the source population, small family groups of one male, one female and one infant were assumed to be the target for translocation. This had further benefits: i) if pairs have an infant, they are more likely to stay together post-release (Marina Kenyon pers. comm., Dao Tien Wildlife Rescue Centre), increasing their likelihood of survival due to the benefits of group-living, and ii) if the pair are already bonded they therefore might more quickly reproduce than if unpaired sub-adults were translocated.

It was also assumed that translocations would be as frequent as is feasible and involve as many individuals as possible, in order to quickly establish the new population with sufficient founders and reduce the effects of inbreeding. Given the likely practical and logistical constraints on capture, it was assumed that a maximum of two small family groups (each consisting of one female, one male and one infant) could be translocated every three years. Capture, translocation and release was expected to be stressful for gibbons and subject to unforeseen problems, and therefore survival across the process was pessimistically assumed to be just 50%.

The translocation programme was considered a 'success' if i) it did not impact upon the viability of the main population in Trung Khanh – Bangliang, and ii) the newly-established population has a more than 90% probability of survival over 10 generations (i.e. 200 years).

The results suggest that short-term translocation programmes, involving three or five translocation events, produce a very vulnerable second population with an unacceptably high extinction probability (**Table 3**). More than eight translocation events, perhaps taking more than 20 years to accomplish, would likely be needed for a successful outcome. This rate of adult removal from the main Trung Khanh – Bangliang population does not apparently reduce its viability to any appreciable extent.

Table 3. Outcomes of translocation programmes for the cao vit gibbon of varying lengths, assuming that the maximum rate at which translocations could be sustained would be two gibbon groups every three years. These results suggest that a minimum of eight translocations, involving at least 16 groups over 21 years, would need to be undertaken in order to establish a second population with an acceptable (> 90%) probability of persistence.

Number of translocations	Number of groups translocated	Duration of programme (years)	Probability of persistence for 2nd population (after 10 generations)
3 (= 6 groups)	6	6	38%
5 (= 10 groups)	10	12	75%
7 (= 14 groups)	14	18	89%
8 (= 16 groups)	16	21	93%
9 (= 18 groups)	18	24	93%

These results are best considered as broadly indicative of the magnitude of effort (time and funding) that might be required in order to establish a second population. The exact details of such a translocation programme are inevitably highly speculative at this early stage, in particular in terms of the number of individuals it might be possible to capture and translocate and over what timeframe, as well as the survival and breeding rates in the new habitat block. Nonetheless, the modelling approach here could easily be adjusted to the specifics of the translocation programme as it materialised in reality.

Modelling conclusion**:** Establishment of a second population might be feasible **without impacting the current population in Trung Khanh – Bangliang**, but it would likely necessitate a **concerted, long-term (20+ years) effort**.

Conclusions from the PVA modelling

- The current gibbon population is surprisingly robust to extinction due to chance variation in demography or the environment, assuming the demographic rates observed in China apply across the whole population; monitoring data from Vietnam is urgently needed, and from a larger sampled number of groups, to verify this

- Model conclusions are highly dependent on the population genetic health of the population, for which a reasonable expert guess was made; no empirical data are currently available for the cao vit gibbon and this represents a major knowledge gap

- The population appears robust to single stressors, such as very isolated incidents of hunting or extreme weather, but if these combine (and especially if they combine synergistically with poor population genetic health), then the cao vit gibbon could become at risk of extinction in the short-term (< 10 generations)

- Restoration of the habitat block in Trung Khanh – Bangliang – which is currently only 30% occupied – will greatly increase the robustness of the cao vit gibbon population to catastrophes and make it much more secure over long time-frames

- If the population currently has a poor genetic health (this remains a knowledge gap), restoration is even more urgently required, in order to increase the total population size and therefore reduce the rate of genetic diversity loss over time

- The modelling suggests that it is theoretically feasible to translocate a small number of adult individuals from the current population without measurably harming its viability, but establishing a second population with an acceptable probability of persistence will require committing to a long-term translocation programme that will likely need to be sustained over at least two decades

- It may be possible to establish a second population over a shorter timeline if: the target habitat for translocation is better quality than Trung Khanh – Bangliang (this seems unlikely); survival of individuals during the translocation process is very high, and-or if a faster rate of capture and translocation than 2 family groups every 3 years can be achieved

Co Ma village, Trung Khanh District, Vietnam. Image © Hoang Van Tuan / FFI.

VISION STATEMENT

By 2050, the cao vit gibbon lives in a restored and well-connected habitat in the Trung Khanh – Bangliang forest and has a population large enough to be robust to any future challenges. The protected areas are a model of highly effective transboundary collaborative management, using high-technology and working in harmony with, and providing benefits to, local communities. The cao vit gibbon's song is heard by local villagers once again, and people across Vietnam, China and the world consider it a high-profile 'star' species. After in-depth research, a new population has been established and the species is on a path to broader recovery.

ANALYSIS OF THREATS & CHALLENGES: A THEORY OF CHANGE FOR THE CAO VIT GIBBON

Using the threats and challenges (i.e. *Issues*) identified during the brainstorming in the workshop, a Theory of Change (ToC) was developed by FFI and revised based on input from experts (**Fig. 14**). We present it here, before the Issues, because it provides a high-level overview of the many interconnected challenges facing the species, and indeed the many possible pathways to conservation impact.

The ToC established that the **loss of suitable habitat** and the fact that all remaining cao vit gibbons exist in **one single population** are the proximate threats to the survival of the species. However, these are ultimately driven by: a lack of alternatives to forest resources; low awareness and apathy (at local, national and international levels); insufficient protected area capacity; natural disaster risks, and knowledge gaps. The Objectives and Actions identified at the workshop (described in the next sections) were targeted at addressing these proximate and ultimate threats to the cao vit gibbon.

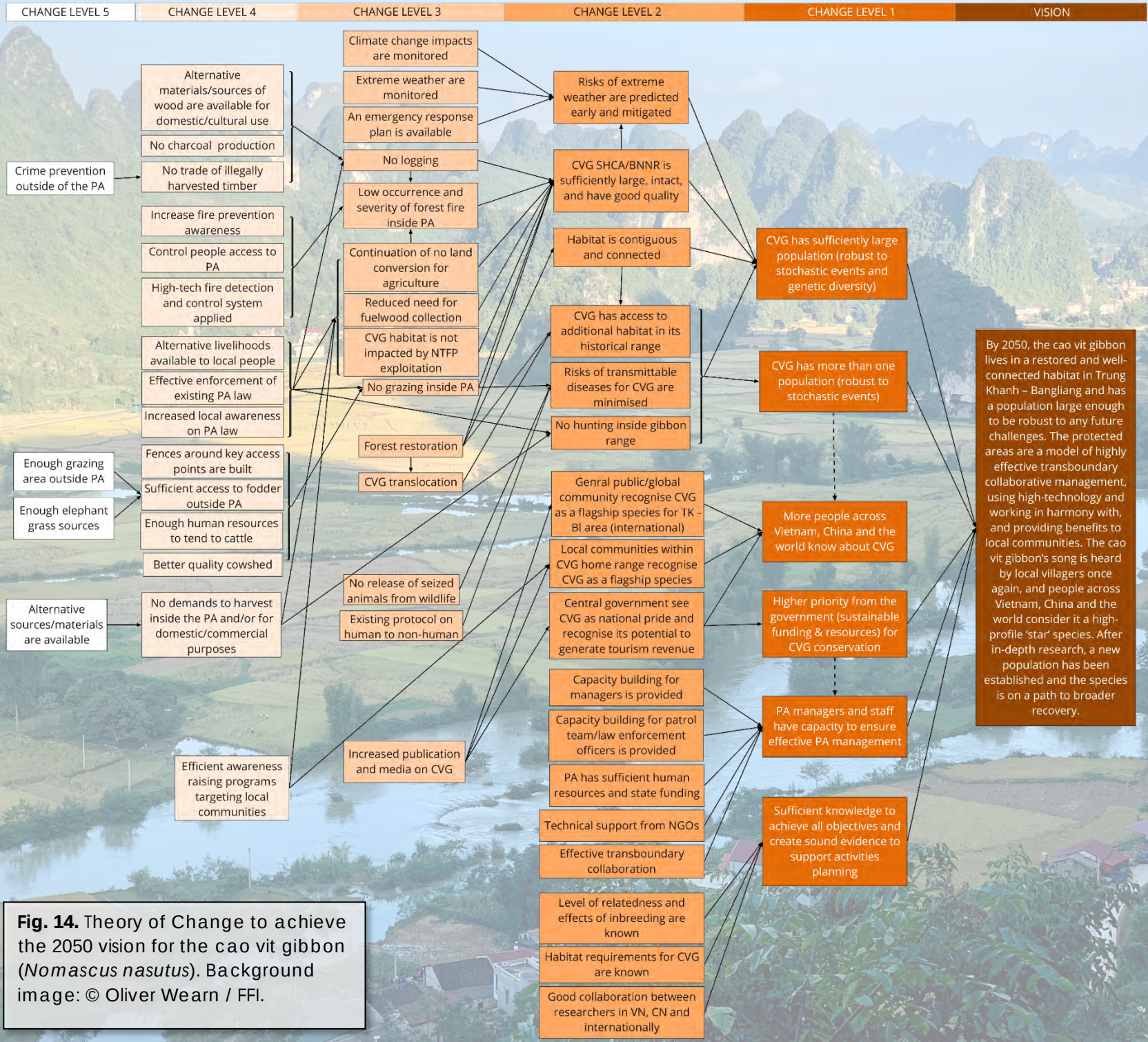

Fig. 14. Theory of Change to achieve the 2050 vision for the cao vit gibbon (*Nomascus nasutus*). Background image: © Oliver Wearn / FFI.

ISSUES, OBJECTIVES AND ACTIONS

Twelve *Issues* for the cao vit gibbon were identified during the brainstorming session by all workshop participants. Their impact on cao vit gibbon conservation was evaluated in a plenary session (**Table 4**). These Issues were taken forward by two working groups, who were tasked with producing a succinct description of each Issue, and formulating Objectives designed specifically to address each Issue. Individual Actions for each Objective were also recommended by the working groups (see **Table 5**). The outputs from the working groups was then presented to all participants, who had a further opportunity to change and refine the Issue descriptions, Objectives and Actions. The results of this process are presented here.

Note that *Transboundary collaboration* was not considered a core Issue affecting the cao vit gibbon (and was therefore not voted on), but nonetheless was thought to be an important political dimension to conservation efforts. Workshop participants agreed that it required specific Objectives and Actions and it was therefore included in the working group discussions, alongside the core Issues.

Table 4. Issue voting results.

Issue[a]	High	Med	Low	Total	Weighted Importance Score[b]	Normalised Importance Score (0 to 100 range)
Single / small population	16	12	3	31	241.94	100.00
Low awareness & apathy	5	24	0	29	217.24	82.60
Knowledge gaps	2	25	4	31	193.55	65.91
Livestock grazing	5	13	10	28	182.14	57.87
Natural disasters & climate change	2	14	15	31	158.06	40.91
Forest fire	4	4	23	31	138.71	27.27
Fuelwood collection	1	7	19	27	133.33	23.48
Exploitation of forest products	0	9	18	27	133.33	23.48
Disease	0	8	21	29	127.59	19.44
Hunting	0	2	28	30	106.67	4.70
Illegal logging	0	0	29	29	100.00	0.00

[a]Transboundary collaboration was not voted on because it was not considered a core Issue affecting the cao vit gibbon
[b]High = 3 votes; Med = 2 votes; Low = 1 vote

A note on the Covid-19 pandemic: Workshop participants reported that some of the identified Issues had become more intense during the pandemic, approximately since March 2020, namely *Fuelwood collection*, *Exploitation of forest products*, and *Grazing.* Local livelihoods were thought to be negatively impacted by the reduced national and international trade in goods (especially trade with China), which in turn was causing people to extract resources from the protected areas in an attempt to make up the shortfall. The pandemic has also caused the closure of international borders, which has hindered transboundary efforts.

In the following sections, we provide the Issue statements and Objectives created by the workshop participants. Issues are presented in order of their ranked importance. Objectives that specifically apply to Vietnam ('VN') and-or China ('CN') are noted.

Single small population

The cao vit gibbon population is < 150 individuals and is in a single, isolated site, which means it is especially vulnerable to inbreeding and stochastic events, in particular unforeseen catastrophes (disease, extreme weather/storms, fire). Periodic catastrophes may cause the extinction of the species, but are also predicted to cause a gradual decline in the population. The forest block is completely isolated from nearby habitats, so natural (re-)colonisation of new sites is not possible. The population also straddles the China-Vietnam border and its persistence is also entangled with the politic relations between these two countries.

Objective 1: Gibbon occupancy in the Trung Khanh-Bangliang forest block (currently about 30%) is expanded (VN + CN).

Objective 2: All preparatory steps towards establishing a second population are completed (VN).

Note for *Single small population*: workshop participants in both Vietnam and China agreed that expanding the range of the existing population is an immediate priority. However, participants in China saw translocation as a lower priority than participants in Vietnam, likely because a large area of unoccupied habitat for population expansion still exists in Bangliang NRR (a comparatively smaller area is available in the CVG SHCA), and because there are fewer potential translocation sites on the Chinese side of the border.

Low awareness and apathy

The low levels of awareness on the importance of the gibbon leads to unintentional harm caused by official visitors to the PAs (e.g. community patrol groups, researchers, tourists), as well as local villagers. This harm consists of habitat degradation and human disturbance. At the national level, the species is not recognised as important by both official (government) and general public, due to a general apathy towards the species (rather than a lack of awareness *per se*). This apathy leads to lower priority being given to legislative protection and resource allocation for the species and its habitat. At the international level, there is a lack of awareness about the species, which reduces access to funding for its conservation and also reduces the possibility of exploring potential revenues from tourism to help conserve the species.

Objective 1: Local people are aware of, and engaged with, the gibbon's plight and benefit from its conservation (VN + CN).

Objective 2: There is a demonstrable improvement in decision-making at the national level in relation to the cao vit gibbon (VN + CN).

Objective 3: More priority is given to gibbons by international donors, researchers and potential eco-tourists (VN + CN).

Knowledge gaps

Although research conducted by Sun Yat-sen University in China and FFI in Vietnam provide a strong foundation for *in situ* conservation actions of the cao vit gibbon, significant gaps remain in the scientific understanding of cao vit gibbon population genetics, habitat recovery and public perception, among others. These result from the small population size of the gibbons, limited capacity and the challenging terrain that hinders field research efforts. These knowledge gaps hinder our ability to design effective conservation interventions and prioritise different actions.

Objective 1: Levels of genetic relatedness among individuals and levels of inbreeding are assessed (VN + CN).

Note for *Knowledge gaps*: various knowledge gaps were also identified under other Issues, with specific Objectives and Actions to address those (see *Lack of awareness, Single small population, Natural disasters & climate change* and *Disease*). The knowledge gap for population genetics was considered sufficiently large and distinct to warrant a specific Objective here under *Knowledge gaps*.

Livestock grazing

Uncontrolled grazing by domestic cattle in the PAs destroys the natural vegetation and, where grazing is intense, prevents plant regeneration through overgrazing and trampling effects. Grazing inside the PA is driven by a lack of pasture for cattle raising, still a major livelihood activity in this area. It can lead to degradation and loss of gibbon habitat, as well as hinder restoration efforts. Human and cattle presence in or near areas occupied by gibbons can also impact the habitat-use patterns of the gibbons.

Objective 1: There is no grazing within the PA and buffer zone (CN)

Objective 2: Areas for grazing are properly zoned and known by local people (VN)

Objective 3: Overgrazed areas in both the core gibbon habitat and buffer zone undergo restoration, in order to address the historical effects of grazing (CN).

Note for *Livestock grazing*: this Issue was considered to be much more important by workshop participants in the meeting room in China, compared to those in Vietnam. This seems to be driven by higher grazing pressure in and near to the gibbon habitats in China compared to in Vietnam.

Natural disasters & climate change

Although the current range of the gibbon is not necessarily exposed to many natural disasters, extreme cold weather could be a risk to infants and weak individuals. Cold weather is also linked to periods of drought and associated increased risk of forest fires, the synergistic impact of which can reduce the extent of available habitat or alter its composition. There has been some evidence of the effect of extreme weather events on the gibbon population and habitat in the last 5 years.

Objective 1: Address knowledge gaps about the frequency and severity of natural disasters (VN + CN).

Objective 2: Mitigate the risks of natural disasters & climate change (VN + CN).

Forest fire

Forest fires are occasional events where the forest vegetation is burnt down. Fires result in the loss of gibbon individuals and large areas of habitat, which in turn leads to increased intra- and inter-specific competition for resources. Causes of forest fires include human activities in the forest (for hunting, grazing, fuelwood and NTFP collection, shifting cultivation and ritual practices) as well as natural phenomena (such as lightning).

Objective 1: All fire incidents are prevented (VN + CN).

Objective 2: In case of fire, control measures are in place and effective (CN).

Note for *Forest fire*: this Issue was considered to be much more important by workshop participants in the meeting room in China, compared to those in Vietnam. It is not known if this is driven by higher fire incidence in China. In Vietnam, no major fire outbreaks are known to have occurred since the PA was established.

Fuelwood collection

Residents in communes surrounding the PAs collect fuelwood for household use (cooking, warming and alcohol production) as well as for sale at local markets. At high collection intensities, this activity contributes to forest degradation. Human presence inside the forest may also disturb the gibbons.

Objective 1: Fuelwood needs are reduced (50% in VN and 100% in CN).

Objective 2: Affected areas in both the core gibbon habitat and buffer zone undergo restoration, to address the historical effects of fuelwood collection (CN).

Exploitation of forest products

Villagers living near the PAs enter the forest to collect non-forest timber products (NFTPs) such as medicinal plants and orchids. These activities, though of low intensity, can degrade natural vegetation and reduce biodiversity, as well as cause human disturbance to the gibbons. The exploitation of forest products will continue to be a threat as long as villagers remain dependent on the forest for additional sources of income and external demand for high-value orchids and medicinal herbs remains high.

Objective 1: Exploitation of NFTPs is reduced (VN + CN).

Objective 2: There is no orchid collection (VN + CN).

Objective 3: Medicinal plant collection is reduced by 50% (VN + CN).

Disease

Inappropriate release of animals that have been confiscated from the illegal wildlife trade without following appropriate quarantine and disease screening processes can lead to spread of diseases (e.g. tuberculosis) to the gibbons. Increased human presence in the gibbon range for various activities (research, hunting, potential tourism) could also potentially transmit disease. The risk from transmission of diseases from cows, goats or dogs that may enter the gibbon range

is minimal (as gibbons are arboreal) but could theoretically occur. It is believed that disease transmission from other native primates might be ongoing but, as a part of the natural balance, is not considered a target for any intervention. Overall, disease outbreak should be considered a low probability – high impact threat to the species.

Objective 1: No new diseases are introduced to the gibbon population from humans or introduced animals (VN + CN).

Note for *Disease*: In theory it might be possible to monitor the incidence of disease in the population, and detect the arrival of new diseases, using samples taken from the gibbons, but this was considered to be too challenging at the current time, both practically in terms of obtaining samples, and in terms of resources (capacity and funding) needed for the storage, transport and analysis of samples.

Hunting

Although there is currently no known threat to the species from gibbon-targeted hunting (no gibbons are known to have been hunted since the PAs were established), this could suddenly and unpredictably change, with potentially catastrophic impacts on the gibbon population. As for disease outbreak, gibbon hunting should be considered a low probability – high impact threat. Other species within the gibbon's habitat are still hunted relatively frequently (for subsistence, recreation or use in traditional medicine) and this may cause human disturbance to the gibbons. In particular, the use of guns may affect the movements of gibbon groups, and cause stress to individual gibbons (impacting upon their health).

Objective 1: There is no hunting (including shooting and trapping) of any species inside the gibbon's habitat (VN + CN).

Illegal logging

The cutting and removal of timber from gibbon habitat negatively effects the availability of resources (food and availability of singing and sleeping trees) for the cao vit gibbon. However, it was determined that illegal logging of timber is no longer an important issue for the gibbon in both China and Vietnam, since the establishment of the PAs. Workshop participants recognised that this was due to continual protection efforts that have been effective in deterring logging, and it was agreed that these efforts should be maintained.

Objective 1: There are no illegal logging incidents (VN + CN).

Transboundary collaboration

Transboundary collaboration between PA managers in China and Vietnam has been established at the official level and mechanisms are in place for effective communication. However, Covid-19 has disrupted collaborative activities between the two sides. There is an opportunity to further strengthen the collaboration, share learning and promote effective management practices for the conservation of the transboundary cao vit gibbon population.

Objective 1: Communication between the two PAs is strengthened (VN + CN).

Objective 2: Mechanisms for cooperation in monitoring and research between the two PAs are improved (VN + CN).

Table 5. Table of Actions identified by workshop participants. Actions are ordered first by the ranked importance of the Issue that they relate to (from high to low importance scores), and then by priority (*High*, *Medium*, *Low*). Actions with an *Immediate* start date are scheduled to begin with the first 12 months of the Action Plan, whilst *Short-term* actions are scheduled to begin in years 2-5 and *Long-term* actions are scheduled to begin in years 5+. Note that some Actions were identified under multiple Issues, and are here grouped under the Issue they correspond to with highest ranked importance. Abbreviations used: *VN* = Actions that apply to Vietnam only; *CN* = Actions that apply to China only; *FPD* = Trung Khanh District Forest Protection Department. Background image: © Nguyen Van Truong / FFI.

Action	**Indicator of achievement**	**Priority**	**Start Date**	**Action Period**	**Leads (Partners)**	**Issue (Objective)**
Actions to address *Single small population*:						
1. Reduce human disturbance in areas of habitat that are currently unoccupied by gibbons	Very low levels of human noise both inside the core occupied habitat and in the peripheral habitats that gibbons could expand into	High	Immediate	Continuous	FPD Bangliang NNR (FFI)	Single small population (Objective 1)
2. Enrichment planting of gibbon food trees to improve forest quality and connectivity in the Trung Khanh – Bangliang forest block	Important food trees are planted, surviving, and growing well in degraded, unoccupied habitat The density of food trees in unoccupied habitat improves relative to the baseline (spatial or temporal control) Ground- and satellite-based imagery shows evidence of improvements over time Note: workshop participants agreed that: i) over the long-term, this may also help to mitigate the risks of natural disasters, by boosting the availability of food resources	High	Immediate (ongoing)	Continuous	FPD Bangliang NNR (FFI) (PRCF)	Single small population (Objective 1) Natural disasters (Objective 2) Forest fire (Objective 1) Grazing (Objective 3) Fuelwood collection (Objective 2)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
	for gibbons; ii) it may reduce the risk of fire, by improving water retention and humidity, and iii) it will help to address historical habitat degradation, in particular from grazing and fuelwood collection					
3a. Conduct a habitat scoping study for potential CVG translocation sites (VN)	Comprehensive scoping study produced, including site-by-site details on habitat, threats, management, capacity and institutional will	High	Immediate	End date - 2022	FPD (FFI)	Single small population (Objective 2) Natural disasters (Objective 2)
3b. Obtain approval from provincial and central authorities for gibbon translocation (VN)	Approval obtained from PPC and VNFOREST	High	Short-term	End date - 2025	FPD (FFI)	Single small population (Objective 2) Natural disasters (Objective 2)
3c. Eliminate threats (hunting and disturbance) in selected translocation site(s) (VN)	Very low human presence in translocation area (as confirmed by SMART patrolling)	High	Long-term	Continuous	FPD	Single small population (Objective 2) Natural disasters (Objective 2)
3d. Develop capture and translocation protocols for CVG based on IUCN guidelines (VN)	Protocols developed after wide consultation Risk assessment completed	High	Short-term	End date - 2026	FFI (IUCN SSA)	Single small population (Objective 2)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
						Natural disasters (Objective 2)
3e. Develop post-release monitoring protocols for CVG (VN)	Protocols developed based on experience and learning from other species (e.g. GPS collaring of gibbons)	High	Short-term	End date - 2026	FFI (IUCN SSA)	Single small population (Objective 2) Natural disasters (Objective 2)
3f. Establish a baseline of "normal" gibbon behaviour for comparison with translocated gibbons	Baseline established from long-term monitoring in the Trung Khanh – Bangliang forest, including: - home-range size & overlap - daily path lengths - activity budgets	Medium	Immediate	End date – 2026 (ongoing)	Sun Yat-sen University Guangxi Normal University FFI	Single small population (Objective 2) Natural disasters (Objective 2)
3g. Improve habitat quality in selected translocation site(s), through enrichment planting, ANR and protection (VN)	Habitat quality, including food availability, is improved and is comparable to occupied habitat in the Trung Khanh – Bangliang forest Satellite data indicates that forest structure (e.g. canopy cover and canopy height) in selected translocation site(s) is sufficiently restored	Medium	Long-term	Continuous	FPD (FFI)	Single small population (Objective 2) Natural disasters (Objective 2)
4. Secure provincial permission & PA support for tree planting inside the core zone of the CVG SHCA (VN)	Formal or informal support is obtained	Low	Short-term	End date - 2022	FFI (PRCF)	Single small population (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
Actions to address *Low awareness and apathy*:						
5. Collaborate with schools to organise events that raise interest and pride in the gibbon among children living near to the PAs (district and provincial level)	Interest and pride among children can be assessed qualitatively using interactive sessions (e.g. art or writing contests and games)	High	Immediate	Continuous (school and local events)	FFI Zoological Society of London Bangliang NNR	Low awareness (Objective 1)
6. Collaborate with regional tourism authorities and agencies to spread the message that the gibbon is a regional mascot and part of the natural heritage	Partnerships with tourism authorities and agencies are established and at least 500 tourists per year are exposed to information about the cao vit gibbon (through tour information, talks and leaflets)	High	Short-term	End date – 2024	FFI Provincial Tourism Dept (VN) Bangliang NNR	Low awareness (Objectives 2 and 3)
7. Create a fund to support local people to pursue higher education degrees in environmental studies or wildlife conservation	Education fund is established and 10-20 scholarships are disbursed	High	Immediate	End date - 2026	FFI Zoological Society of London Bangliang NNR	Low awareness (Objective 1)
8. Have gibbons and other threatened wildlife featured in the national curricula in both countries	Gibbons and other wildlife are featured in the National Curriculum of Vietnam and China Note: participants highlighted that it may prove difficult to influence the national-level curricula.	High	Long-term	End date – 2028	Bangliang NNR FFI	Low awareness (Objective 2)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
9. Create and maintain a website to publicise information about CVG conservation	Website is created and updated regularly with recent activities Engagement with the website will be assessed using page view and sharing metrics	High	Short-term	Continuous – website created by 2022	FPD Bangliang NNR (FFI) (IUCN SSA)	Low awareness (Objectives 2 and 3)
10. Organise events around International Gibbon Day (Oct 24th)	1-3 gibbon-themed events are organised around International Gibbon Day each year	Medium	Immediate	Continuous	IUCN SSA FFI Bangliang NNR	Low awareness (Objectives 2 and 3)
11. Develop personality profiles for gibbons in each of the focal groups and use these in awareness-raising events	Personality profiles are developed for 1 gibbon group each, in Vietnam and China, based on the long-term monitoring data, and these profiles are used in events (e.g. during school events, festivals or social media posts)	Medium	Short-term	End date – 2023	FFI Bangliang NNR	Low awareness (Objectives 2 and 3)
12. Run a national awareness-raising campaign to raise the profile of the CVG	A targeted campaign on CVG and its habitat is designed and run at the national level, using TV or radio	Medium	Short-term	End date - 2024	FFI Bangliang NNR (IUCN SSA)	Low awareness (Objective 2)
13. Publish CVG research in international scientific journals and share findings with scientific community	1-3 journal articles in peer-reviewed international journals per year 1-3 seminars (online or offline) given on CVG research per year	Medium	Short-term	Continuous	Sun Yat-sen University Guangxi Normal University FFI CCD	Low awareness (Objective 3)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
14. Present CVG research and conservation at conferences, nationally and internationally	1-3 presentations and-or posters given at conferences/symposia	Medium	Short-term	Continuous	Sun Yat-sen University Guangxi Normal University FFI	Low awareness (Objective 3)
15. Share and-or co-produce communications materials on gibbons	Online cloud repository is created for sharing communications materials across the two countries	Low	Immediate (ongoing)	Continuous	Bangliang NNR FPD (FFI)	Low awareness (Objective 2)
Actions to address *Knowledge gaps*:						
16. Fill knowledge gaps on CVG population genetics (genetic diversity and extent of inbreeding)	Research projects completed on: - The genetic diversity of the population (compared to a reference) - Relatedness of individuals within and among groups Note: samples may also be used to study CVG phylogenetics, placing the species into the gibbon evolutionary tree (CN)	High	Immediate	End date - 2024	FFI Sun Yat-sen University Guangxi Normal University	Knowledge gaps (Objective 1) Single small population
17. Fill knowledge gaps on habitat requirements of CVG	Research projects completed on: - The influence of forest structure and food tree distribution on habitat-use - Singing tree preferences - Effects of human disturbance on ranging behaviour	High	Immediate	End date - 2025	Sun Yat-sen University Guangxi Normal University FFI	Single small population (Objective 1) Knowledge gaps

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
18. Improve understanding of local-level awareness, attitudes and values in relation to gibbons and conservation (VN)	FFI's existing Knowledge-Attitudes-Behaviour questionnaire approach is reviewed, improved, and implemented in 3 communes around the CVG SHCA The questionnaires are supplemented with semi-structured interviews, and a deeper understanding of local values and attitudes is gained	High	Immediate	End date – 2021	FFI Zoological Society of London	Low awareness (Objective 1) Knowledge gaps
19. Assess national-level awareness, attitudes and values in relation to the CVG	An online questionnaire is administered, focussing on urban-dwelling adults in Vietnam and China	High	Short-term	End date – 2023	FFI Zoological Society of London Bangliang NNR	Low awareness (Objective 2) Knowledge gaps
20. Fill knowledge gap on dispersal behaviour of CVG	Research project completed on gibbon dispersal (in particular sub-adults), including - Habitat preferences during dispersal - Factors encouraging the use of habitat corridors	Medium	Short-term	End date - 2028	Sun Yat-sen University FFI	Single small population (Objective 1) Knowledge gaps
21. Fill knowledge gap on health of individual gibbons	Research project completed on gibbon gut microbiome and individual gibbon health (especially between replaced male & new male) from faecal samples	Medium	Short-term	End date - 2024	Sun Yat-sen University	Knowledge gaps

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
	Note: the methodology developed may also be useful for post-release monitoring of translocated gibbons					
22. Trial potential methods for screening wild gibbons for disease	Scoping study to develop a method for screening wild gibbons for 'natural' and introduced diseases	Low	Long-term	End date - 2023*	FFI CCD	Disease (Objective 1) Knowledge gaps
Actions to address *Livestock grazing*:						
23. Grow food to feed livestock (VN)	An area of at least 15 ha is allocated by local communities for growing livestock feed (e.g. corn and elephant grass)	High	Immediate	End date - 2024	FPD (FFI)	Grazing (Objective 1)
24. Establish zones for livestock grazing in each village (VN)	100% of the villages surrounding the SHCA have a defined area for livestock grazing	High	Immediate	End date - 2025	FPD (FFI)	Grazing (Objective 1)
25. Improve the current livestock enclosure system (VN)	100% of local people who rear livestock have access to suitable cattle sheds (upgrade existing cattle sheds and-or build new ones)	High	Immediate	End date - 2025	FPD (FFI)	Grazing (Objective 1)
26. Raise awareness on PA laws concerning grazing in the SHCA and NNR	100% of local people surrounding the PAs are aware that it is illegal to graze inside the boundary of the PAs and the consequences of violation	High	Immediate (ongoing)	End date - 2023	FPD Bangliang NRR (FFI)	Grazing (Objective 1) Low awareness (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
27. Fence off restoration areas to prevent damage from livestock (VN)	All restoration areas are fenced-off with barbed wire	Medium	Short-term	End date - 2022	FPD (FFI)	Grazing (Objective 1)
28. Encourage local people to find work in nearby towns/cities and-or adopt alternative livelihoods (CN)	70% of the labour force in communities surrounding the NNR find work outside the local area	Medium	Long-term	Continuous	National government (CN) Bangliang NNR	Grazing (Objective 1) Fuelwood collection (Objective 1) Exploitation of forest products (Objective 1)
29. People living inside the NNR are encouraged to migrate outside (CN)	The settled population in the NNR decreases by 10%	Low	Long-term	Depends on government	National government (CN)	Grazing (Objective 1) Fuelwood collection (Objective 1) Exploitation of forest products (Objective 1)
Actions to address *Natural disasters & climate change*:						
30. Develop an emergency response plan in case of natural disasters affecting the gibbons (including disease, fire, extreme weather and other emergencies)	A plan in case of natural disasters is developed with expert input and approved by both PAs, including an ex-situ component in case the wild population looks likely to go extinct	High	Immediate (ongoing)	End date - 2022	CCD FPD Bangliang NNR (FFI)	Natural disasters (Objective 2)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
31. A subset of the population is monitored over the long-term, providing an 'early-warning system' on impending disasters	A monitoring programme covering several focal groups is in place, allowing for any new threats to be documented as soon as they emerge Note: this monitoring will also provide a baseline of gibbon survival rates in 'normal' years, which can be compared in future to any translocated gibbons	Medium	Immediate (ongoing)	Continuous	FFI Bangliang NNR (Sun Yat-sen University) (Guangxi Normal University)	Natural disasters (Objective 2)
32. Collect testimony from interviews with local people on historical disasters, to help inform preparedness for future disasters	A baseline is established on the type and frequency of threats that have occurred in the past	Medium	Short-term	End Date - 2025	FFI CCD	Natural disasters (Objective 1)
33. The phenological patterns of important gibbon food trees is monitored over the long-term	A monitoring programme covering 15-20 important gibbon food species is in place, alongside climatic monitoring	Medium	Short-term	Continuous	FFI CCD Bangliang NNR	Natural disasters (Objective 1)
Actions to address *Forest fire*:						
34. Maintain current forest fire detection system and fire prevention teams (VN)	Ensure that 7-10 members of each village are trained on forest fire prevention and control Provide fire prevention teams with all necessary equipment	High	Immediate (ongoing)	Continuous	FPD	Forest fire (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
35. Update the forest fire prevention protocol annually (VN)	Forest fire prevention protocol is reviewed annually and any changed are approved by relevant government agency	High	Immediate	Continuous	FPD	Forest fire (Objective 1)
36. Strictly limit access to the forest during the dry season (Nov – Apr) (VN)	Ranger and community patrols are intensified during the dry season (as evidenced by SMART data)	High	Immediate	Continuous	FPD (FFI)	Forest fire (Objective 1)
37. Increase awareness levels on fire prevention among local people and all visitors to the PAs	Local communities, as well as all visitors to the PA, are aware of: - potential fire hazards (both natural and anthropogenic) - behaviours to avoid which might lead to fire - actions to take in case of fire	High	Immediate	Continuous	Bangliang NNR FPD (FFI)	Forest fire (Objective 1) Low awareness (Objective 1)
38. Carry out fire practice in key communes (VN)	At least 1 forest fire practice exercise per year	High	Immediate	Continuous	FPD (FFI)	Forest fire (Objective 2)
39. Equip all field camps in the NNR with fire extinguishing equipment (CN)	Each camp in the NNR is equipped with 5-8 dry powder fire extinguishers	High	Immediate	End date - 2024	Bangliang NNR	Forest fire (Objective 2)
40. Improved cooperation between the emergency management bureau, Fire Prevention Office and other related departments (CN)	Cooperation agreement is created and signed Annual meetings to improve communication among relevant departments	High	Short-term	Continuous	Baise Forestry Bureau	Forest fire (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
41. Establish a high-technology 'early-warning' monitoring system for fire in and around the NNR (CN)	A technology-based monitoring system is setup in and around the NRR (including in villages), with recordings of environmental conditions (humidity and temperature) used to identify fire risk hotspots in near real-time Note: this monitoring system and protocol will replace the current 'Fire Emergency Plan'	High	Short-term (2024)	End date - 2026	Bangliang NNR	Forest fire (Objective 1)
42. Prepare access to helicopters for rapid and effective fire control (CN)	Fire brigade maintains communications with a helicopter crew who can be mobilised in the event of a fire	Medium	Long-term	Continuous	Bangliang NNR Jingxi Fire Station	Forest fire (Objective 2)
43. Apply artificial rainfall during the dry season (CN)	When a high fire risk is detected, apply to the Meteorological Bureau for 1-2 artificial rainfall treatments in the NNR	Low	Long-term	Continuous	Bangliang NNR	Forest fire (Objective 1)
44. Identify potential fire breaks (CN)	Potential fire breaks are identified in advance and can be established rapidly in the event of a fire	Low	Long-term	Continuous	Bangliang NNR	Forest fire (Objective 2)
Actions to address *Fuelwood collection*:						
45. Provide fuel-efficient eco-stoves in order to reduce fuelwood needs (VN)	100% of households who depend on fuelwood have eco-stoves and agree to stop using traditional stoves	High	Immediate (on-going)	End date - 2022	FFI (FPD)	Fuelwood collection (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
46. Plant fast-growing trees to meet fuelwood needs (VN)	At least 10,000 'dispersal trees' (directly translated from Vietnamese) planted annually in hedgerows, field margins and gardens (e.g. *Delavaya toxocarpa* or *Choerospondias axillaris*) Note: local communities will decide what they will plant and where, including trees for both fuelwood and timber	High	Immediate	Continuous	FPD (FFI)	Fuelwood collection (Objective 1)
47. Raise awareness on PA laws concerning fuelwood and forest product collection	100% of people surrounding the PAs are aware of laws pertaining to fuelwood and forest product collection	High	Immediate (ongoing)	Continuous	FPD Bangliang NNR (CPC) (FFI)	Fuelwood collection (Objective 1) Exploitation of forest products (Objectives 1, 2 and 3) Low awareness (Objective 1)
48. Increase the frequency of patrolling in known hotspots of fuelwood and forest product collection (VN)	Community patrols (accompanied by rangers and-or border army guards) cover all hotspots within a reporting cycle (e.g. quarterly) Incidences of illegal fuelwood and forest product collection are halved within 5 years	High	Immediate	Continuous (with milestone target to be achieved by 2026)	FPD (FFI)	Fuelwood collection (Objective 1) Exploitation of forest products (Objectives 1, 2 and 3)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
49. Fast and consistent handling of all detected cases of illegal fuelwood / forest product collection and logging (VN)	100% of violation cases are resolved according to the law within a short period of time (to be defined), as evidenced by an annual report on cases	High	Immediate	Continuous	FPD Police CPC (FFI)	Fuelwood collection (Objective 1) Exploitation of forest products (Objectives 1, 2 and 3) Illegal logging (Objective 1)
50. Encourage the use of electricity and gas for cooking instead of wood	Majority of households have electric or gas stove for daily cooking	Medium	Immediate	End date - June 2022	FPD Bangliang NNR (FFI)	Fuelwood collection (Objective 1)
Actions to address *Exploitation of forest products*:						
51. Set up additional signboards at forest entry points (VN)	10 additional signboards set up, detailing forest laws and consequences of violation Note: laws pertaining to logging inside the PA could also be added to the signboards	High	Immediate	End date - 2021	FPD (CPC) (FFI)	Exploitation of forest products (Objectives 1, 2 and 3) Illegal logging (Objective 1)
52a. Identify orchid traders and shops (VN)	The people and places involved in local orchid trade are identified	High	Immediate	End date - 2021	FPD (CPC) (Police)	Exploitation of forest products (Objective 2)
52b. Obtain formal commitments from orchid traders / shops that they will not handle wild orchids (VN)	Majority of orchid traders / shops are compliant with the law	High	Immediate	End date - 2022	FPD CPC	Exploitation of forest products (Objective 2)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
53a. Survey local supply chain of medicinal plants (VN)	A better understanding is gained of the volume and types of medicinal plants being traded, as well as the source of traded items	Medium	Short-term	End date - 2022	FFI District Agricultural Service Centre	Exploitation of forest products (Objective 3)
53b. Build pilot nurseries to grow medicinal plants (VN)	3 nurseries are built and a pilot study on growing medicinal plant species is completed	Medium	Short-term	End date - 2022	FPD CPC (FFI)	Exploitation of forest products (Objective 3)
53c. Local people are supported to grow medicinal plants and a market is developed (VN)	An area is maintained under cultivation, medicinal plants are produced with high yield, and 100% of the yield is able to be sold	Medium	Long-term	End date - 2026	FPD (FFI) (DARD) (Inter-sector authorities)	Exploitation of forest products (Objective 3)
Actions to address *Disease*:						
54. Ensure no wildlife from the illegal trade is released into CVG habitat without proper screening	Proper screening protocols (*cf.* IUCN best-practice standards) are integrated into PA regulations	Medium	Immediate	Continuous	FPD Bangliang NNR (FFI)	Disease (Objective 1)
55. Support nation-wide efforts reduce wildlife consumption	PAs coordinate with relevant agencies to support enforcement of wildlife hunting and trade laws 100% of local people are aware of the laws on hunting/trade and are willing to consume less wild meat	Low	Immediate (ongoing)	Continuous	FPD Bangliang NNR (FFI)	Disease (Objective 1) Low awareness (Objectives 1 and 2)
56. Livestock grazing is prevented inside CVG habitat	Monthly patrol reports from rangers/community groups (e.g. using SMART data) show that grazing no longer occurs in gibbon habitat	Low	Immediate (ongoing)	Continuous	FPD Bangliang NNR (FFI)	Disease (Objective 1) Grazing (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
57. Establish a Code of Conduct for people working in the PAs	A Code of Conduct is established with measures to reduce the risk of: - disease introduction - fire - human disturbance The Code is promoted and followed by all, including rangers, community patrol groups and researchers	Low	Immediate	End date – 2022	FPD Bangliang NNR (FFI)	Disease (Objective 1) Fire (Objective 1) Single small population (Objective 1)
Actions to address *Hunting*:						
58. Community-based patrols are highly effective at deterring and preventing hunting (VN)	Patrols are well planned, achieve patrol targets (e.g. on spatial coverage) and evidence is quickly acted upon (as verified by SMART data and reports) Border army guards and rangers join community patrols, to enable strong enforcement of laws Illegal cases are properly investigated and lead to prosecutions	High	Immediate (ongoing)	Continuous	FFI FPD	Hunting (Objective 1) Grazing (Objective 1) Exploitation of forest products (Objectives 1, 2 and 3) Illegal logging (Objective 1)
59. Upgrade the SHCA to a Nature Reserve with a ranger force (will require expanding the area of the PA to > 5000 ha) (VN)	Provincial decision on gazettement is made, and rangers are recruited and trained	High	Short-term	End date - 2023	FPD (FFI) (PRCF) (CCD)	Hunting (Objective 1) Grazing (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
						Exploitation of forest products (Objectives 1, 2 and 3) Illegal logging (Objective 1)
60. Raise awareness on hunting laws and the effects of hunting on wildlife	100% of local people are aware of the laws on hunting and are aware of the gibbon (including its threatened and protected status) Extracurricular programmes are organised for local school students with the topic of hunting and its effects	Medium	Immediate (ongoing)	Continuous	FFI Bangliang NNR (FFI)	Hunting (Objective 1) Low awareness (Objective 1)
Actions to address *Illegal logging*:						
61. Raise awareness on PA laws concerning logging and trade of illegal timber (VN)	100% of local people are aware of the laws surrounding timber extraction and trade The number of illegal logging incidents remains very low	High	Immediate	Continuous	FPD (FFI)	Illegal logging (Objective 1) Low awareness (Objective 1)
62. Stop the production of chopping boards made of illegally-harvested wood (CN)	100% of local people surrounding the NNR agree to stop making chopping boards from illegally-harvested wood (CN)	High	Immediate	End date - 2023	Bangliang NNR	Logging

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
63. Increase the frequency of patrolling in known hotspots of logging (VN)	Community patrols (accompanied by rangers and-or border army guards) cover all logging hotspots within a reporting cycle (e.g. quarterly)	Medium	Immediate	Continuous	FPD (FFI)	Illegal logging (Objective 1)
64. Support local community in repairing metal waterwheels (previously made of timber) (VN)	100% of the metal waterwheels in need of maintenance are repaired, reducing the need for local people to cut timber	Low	Short-term	End date - 2023	FFI	Illegal logging (Objective 1)
Actions to address *Transboundary collaboration*:						
65. Maintain one official communication channel between the two PAs	Each PA management creates and monitors a single email address for effective and timely communication Zalo and-or Wechat accounts are created for urgent communication needs	High	Immediate	Continuous	FPD Bangliang NNR	Transboundary collaboration (Objective 1)
66. Periodic review of the MoU between Baise City and Cao Bang Province	Progress towards the collaboration outlined in the MoU is reviewed biennially, and the content of the MoU is revised if necessary	High	Immediate	Continuous	FPD Bangliang NNR	Transboundary collaboration (Objective 1)
67. Transboundary 'focal points' are established in both PAs, consisting of staff members who are proficient in the language of the other country	The two PAs recruit (or identify amongst existing staff) at least one staff member who is multi-lingual (Mandarin and Vietnamese) and who can freely exchange information with, and learn from, the PA in the other country.	High	Short-term	Continuous	Bangliang NNR FPD	Transboundary collaboration (Objective 1)

Action	Indicator of achievement	Priority	Start Date	Action Period	Leads (Partners)	Issue (Objective)
68. Organise language exchange trips for key staff	At least one exchange trip (lasting at least one month) is organised each year for key staff members of the two PAs	High	Long-term	Continuous	FPD Bangliang NNR (FFI)	Transboundary collaboration (Objective 1)
69. Results from monitoring work are shared with both PA management boards to inform decision-making	One common platform is established to share results and insights from monitoring work, including monitoring of the CVG population and habitat restoration. All reports detailing monitoring work are shared with both PAs	High	Immediate	Continuous	FPD Bangliang NNR (Sun Yat-sen University) (Guangxi Normal University) (FFI)	Transboundary collaboration (Objective 2)
70. Establish an expert Cao Vit Gibbon Advisory Group to provide technical advice to the PAs and carry out relevant research to inform management efforts	An expert Advisory Group is formed, communicates regularly, and has a shared research agenda	Medium	Immediate	Continuous	Sun Yat-sen University Guangxi Normal University FFI CCD PRCF	Transboundary collaboration (Objective 2)

HIGH-PRIORITY, URGENT ACTIONS IDENTIFIED IN THE WORKSHOP

In the following section, we highlight the 32 Actions that were identified as being a high priority for cao vit gibbon conservation and for which work must start urgently (i.e. Priority = *High* and Start Date = *Immediate*; **Table 5**). They have been grouped under 14 *work packages* consisting of between 1 and 6 coherent Actions. Work packages are listed in order of the ranked importance of the main Issue that they address (see **Table 4**).

I. Enhance patrol effort and effectiveness in the PAs (Actions 1, 36, 48, 49, 58)

Description: Protected area patrols will be enhanced, in order to reduce human disturbance (noise and habitat degradation) which may be acting to constrain habitat occupancy by the gibbons. Patrols will also aim to deter and prevent hunting of all species, which is still ongoing in the PAs and is a key 'pull-factor' for people entering the PAs. Patrol efforts will also become more targeted, focussing particularly on hotspots for logging and the collection of fuelwood and non-timber forest products. Both the FPD and Bangliang NNR Management Office will continue to employ, and build the capacity of, community-based patrol forces. This will not only better engage local communities in conservation actions but also bolster PA law enforcement capacity. In Vietnam, patrol teams will also help to control access in the forest during the dry season (November – April) as a way to reduce forest fire risks. A financial mechanism will also be developed to sustainably maintain the Cao Vit Gibbon SHCA's Community-based Conservation Team (CCT).

Indicators of success:

- Patrol targets on coverage of hotspots are met (as evidenced by SMART data)
- Border Army guards and rangers join community patrols, leading to an increase in arrests and prosecutions
- Incidences of illegal fuelwood and forest product collection are halved within 5 years

Leading organisations: FPD (VN), Bangliang NNR (CN)

Supporting organisations: FFI

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

II. Restore the cao vit gibbon's habitat (Action 2)

Description: The Cao Vit Gibbon SHCA and Bangliang NNR will continue restoration efforts, with a focus on enhancing the quality, extent and connectivity of the gibbon's habitat. Restoration will primarily involve enrichment planting using gibbon food tree species, but will also use Assisted Natural Regeneration where conditions allow. These efforts will also help to address the historical effects of human activities, including fuelwood collection and grazing, and will provide improved ecosystem resistance to fire (by increasing water retention and humidity). Improved habitat quality may also help to mitigate risks associated with natural disasters (e.g. extreme

weather and disease outbreak) by boosting the background availability of resources for the gibbon population. Restoration efforts in Vietnam and China will focus on areas that are currently unoccupied by gibbons. It may also be necessary to seek additional permissions in Vietnam in order to undertake tree planting close to the areas occupied by gibbons, i.e. areas inside the 'core zone' of the SHCA.

Indicators of success:

- Gibbon food tree density in unoccupied habitat improves relative to the baseline (spatial or temporal control)
- Ground- and satellite-based imagery shows evidence of improvement over time
- Area-based targets for restoration by 2030 are met

Leading organisations: FPD (VN), Bangliang NNR (CN)

Supporting organisations: FFI, PRCF

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

III. Conduct a scoping study of potential translocation sites (Vietnam) (Action 3a)

Description: The CVG SHCA will conduct a habitat scoping study for potential sites in northern Vietnam that could receive translocated cao vit gibbon's in future. Primatologists and conservation experts will be enlisted to identify potential sites and assess if they are able to support a translocated gibbon population in terms of habitat quality, threats, and management factors on the ground. This is among the first steps towards establishing a second population of the cao vit gibbon and addressing the threat of extinction from unforeseen catastrophes and other stochastic events that can eliminate single small populations.

Indicators of success: Comprehensive scoping study produced

Leading organisations: FPD

Supporting organisations: FFI

Timeline: 2021-2022

Source of funding: FFI

IV. Build local awareness and pride in the cao vit gibbon (Action 5)

Description: Working in partnership with schools, both immediately adjacent to the PAs and further afield in Trung Khanh and Jingxi, extra-curricular events will be organised to raise interest and pride among school children. These events will be both classroom and field-based and designed specifically so that children remember key messages about the cao vit gibbon and its forest home, which children will then spread to their families. Related to this, the PAs will

collaborate with the local Tourism Departments to promote materials featuring cao vit gibbon in tourism activities. With the combination of school- and tourism-based awareness-raising, a substantially larger number of people will be reached with cao vit gibbon conservation messages than has been possible before. This will help to encourage the idea that the gibbon is a valuable piece of natural heritage in northern Vietnam and southern China, alongside other cultural and natural heritage treasures.

Indicators of success:

- All schools in communities surrounding the PAs have events focussing on the gibbon
- Interest and pride in the gibbon measurably increases among local children
- Partnerships with tourism authorities and agencies are established
- At least 500 tourists to the region per year are exposed to information about the gibbon and its conservation (through tour information, talks and leaflets)

Leading organisations: FFI (VN), Bangliang NNR (CN)

Supporting organisations: FPD, Zoological Society of London, provincial Tourism Departments

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

V. Establish an education fund for local communities (Action 7)

Description: Local students pursuing higher education degrees in environmental studies or wildlife conservation will be supported through an education fund. Awardees will also have the opportunity to participate in field research trips and community engagement activities organised by the PAs and supporting NGOs. It is expected that a number of them will return to the community and work on the site after graduation, thereby raising the local community's awareness of conservation issues as well as the local research and law enforcement capacity. As students are provided with educational and professional opportunities, wildlife conservation will also be promoted as a viable career path, and returning students will set an example that others are able to follow.

Indicators of success:

- Education fund established
- 10-20 scholarships awarded over 10 years

Leading organisations: FFI (VN), Bangliang NNR (CN)

Supporting organisations: FPD, Zoological Society of London

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

VI. Fill critical knowledge gaps about the cao vit gibbon for informing management (Actions 16, 17)

Description: Key gaps in our understanding of the cao vit gibbon's genetics and ecology remain, which are causing uncertainties about the best management approaches to use for the species. In particular, no information is available on the population's genetic health, including the extent of inbreeding that is occurring. This defines the urgency and timeline of the required restoration in order to increase the carrying capacity of the Trung Khanh – Bangliang forest. The genetics of the population will be studies using DNA extracted from faecal samples collected in the field. Feasible methods for locating faecal samples will need to be developed.

In addition, a set of knowledge gaps will be filled by long-term monitoring of focal gibbon groups. Most importantly, the habitat requirements of the species are incompletely known, which limits the effectiveness of habitat restoration efforts and precludes assessments of habitat suitability in potential translocation sites. Research on the habitat-use of the focal groups in China and Vietnam will reveal the structure and composition of forest required to support gibbon family groups, as well as any requirements for 'key resources', such as emergent trees for singing or sleeping in. This may require innovative techniques, such as LiDAR scanning of the forest, as well as the use of high-resolution satellite data. Monitoring of habitat-use will also lead to a better understanding of the influence of human disturbance on habitat suitability, which may be an important limiting factor on the expansion of the current population. Other Actions that were identified in the workshop will also be achieved by monitoring focal groups, including establishing baselines for behaviour and demographic rates, for comparison with any translocated gibbons, and creation of an 'early warning system' to detect emerging threats to the gibbons as quickly as possible.

Although management of the cao vit gibbon population is the responsibility of the SHCA and Bangliang NNR, researchers in China and Vietnam will support the PAs with the research capacity and resources to fill knowledge gaps about the species.

Indicators of success:

- Research projects to address the two main knowledge gaps (population genetics and habitat requirements) are completed
- Information is shared with the PAs and leads to an improved evidence-base for conservation management of the species

Leading organisations: FFI (VN), Sun Yat-sen University (CN)

Supporting organisations: FPD, Bangliang NNR

Timeline: 2021-2025

Source of funding: FFI (VN), universities including Sun Yat-sen and Guangxi (CN)

VII. Fill the knowledge gaps about awareness, attitudes and values in relation to gibbons (Action 18)

Description: In order to design communications activities that are relevant to local people and that are effective, a better understanding of current awareness and attitudes pertaining to the cao vit gibbon is needed. FFI and the FPD will continue to refine their use of Knowledge-Attitude-Behaviour (KAB) surveys for this purpose. This will in future be supplemented with semi-structured interviews in focus groups, in order to gain a deeper understanding from local people. Given the different cultural context around Bangliang NNR, comparable work in China would also be very beneficial. Meanwhile, at the national levels in Vietnam and China, for the first time, an online and-or in-person questionnaire (in Vietnamese and Mandarin) will be used to evaluate the awareness, attitudes and values associated with gibbons, focussing on the urbanised populations.

Indicators of success:

- A refined KAB survey methodology is implemented in 3 communes around the Cao Vit Gibbon SHCA, supplemented by semi-structured interviews
- A representative snapshot sample of urbanised populations in Vietnam and southern China is canvassed about gibbons
- Using the new insights, the relevance and effectiveness of communications programmes is improved, thereby better promoting local and national pride in gibbons

Leading organisations: FFI (VN), Bangliang NNR (CN)

Supporting organisations: FPD, Zoological Society of London

Timeline: 2021-2023

Source of funding: FFI (VN), Bangliang NNR (CN)

VIII. Improve the sustainability of livestock management systems (Vietnam) (Actions 23, 24, 25)

Description: Local communities will be assisted by the FPD to plan and allocate an area for growing crops for livestock, such as elephant grass and corn. The FPD will also work with each village in the area to set aside livestock grazing areas, liaising with the Department of Agriculture and Rural Development for formal recognition of these areas in land-use plans. These two initiatives will serve to decrease the impacts on gibbon habitat from uncontrolled grazing inside the SHCA, but will also help to support an important livelihood of local communities. As an additional support to livelihoods, livestock enclosures (in particular, cattle sheds) will be upgraded and-or built.

Indicators of success:

- At least 15 ha is allocated by local communities for growing livestock feed
- 100% of the surrounding villages have an area for livestock grazing
- 100% of local people who rear livestock have access to suitable cattle sheds

Leading organisations: FPD (VN)

Supporting organisations: FFI

Timeline: 2021-2025

Source of funding: FFI (VN)

IX. Increase awareness in local communities about PA laws (Actions 26, 37, 47, 51, 61, 62)

Description: Communications activities will be conducted in local communities surrounding the two PAs to convey messages about reducing the consumption of fuelwood and other forest products, and to raise awareness about prohibitions that exist on logging, grazing and hunting within the PAs. Awareness about fire risks and prevention will also be improved among local people, as well as all visitors to the PAs. In Vietnam, additional signboards that detail PA laws will also be installed at key forest entry points to the SHCA. Some of these activities are already in place in both Vietnam and China and will be enhanced based on improved understanding of local awareness and attitudes gained under work package VII (Action 18).

Indicators of success:

- 100% of local people surrounding the PAs are aware of prohibitions on: grazing; fuelwood and forest product collection; timber extraction and trade, and hunting
- Awareness on fire prevention is measurably improved among local communities and all visitors to the PAs
- 10 additional signboards are set up at entry points to the CVG SHCA
- 100% of people around Bangliang NNR agree to stop making chopping boards from illegal timber

Leading organisations: FPD (VN), Bangliang NNR (CN)

Supporting organisations: FFI

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

X. Develop an emergency response plan for the cao vit gibbon (Action 30)

Description: An emergency response plan is under development to prepare the Cao Vit Gibbon SHCA for emergency situations, including natural disasters and disease outbreaks. It is based on scenario modelling of different emergencies and includes measures such as captive breeding in case of drastic population decline. The use of this response plan is expected to enhance the SHCA's readiness in the face of emergencies.

Indicator of success: An emergency response plan is in place, with the input of primate experts and in consultation with staff from both PAs

Leading organisations: CCD

Supporting organisations: FPD, Bangliang NNR

Timeline: 2021-2022

Source of funding: CCD

XI. Maintain an effective system for the prevention, detection and control of forest fire (Actions 34, 35, 38, 39)

Description: Forest fire prevention is a major task already undertaken by the FPD in Vietnam and the NNR in China. In Vietnam, the existing fire prevention system will be reviewed and updated annually, to adjust for changes in fire risk over time. Village-level fire detection and prevention teams will be maintained, as long as there are no significant changes in forest fire risks, and fire drills will be carried out each year. In China, all camps inside the reserve will be supplied with fire extinguishing equipment. Development of a technology-based fire monitoring system is underway, which will identify fire risk hotspots in near real-time, improving the timeliness of responses.

Indicators of success:

- 7-10 members from each village around the SHCA are trained on forest fire prevention and control and provided with equipment
- Forest fire prevention protocol in Vietnam is reviewed annually
- At least one fire practice exercise is conducted by the FPD annually
- Each camp in the NNR is equipped with fire extinguishers
- A new high-technology fire monitoring system is operational around the NNR

Leading organisations: FPD (VN), Bangliang NNR (CN)

Supporting organisations: FFI

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

XII. Reduce the demand for fuelwood around the PAs (Actions 45, 46)

Description: Communities surrounding the PAs have extensive needs for fuelwood in everyday household uses, including for cooking and providing warmth during cold winter months. This puts pressure on surrounding forests, including the two PAs. To reduce this pressure in Vietnam, households will be supported in switching to tried-and-tested fuel-efficient stoves. In addition, communities will receive training and support for planting additional trees in the landscape ('dispersal trees'), for example in gardens or as live-fencing at the edge of fields. The tree species will be chosen by the communities and will include a mixture of fast-growing species for fuelwood, as well as some hardwood species for timber. In both countries, communities will also

be encouraged to switch to electricity and gas for cooking, where possible. In China, local people will be gradually encouraged to find work in nearby towns and cities over the long-term, which will reduce a host of pressures on the NNR, including grazing, fuelwood collection and the exploitation of forest products.

Indicators of success:

- 100% of households surrounding the SHCA agree to switch from traditional stoves to fuel-efficient eco-stoves
- At least 10,000 trees planted in local communities around the SHCA annually
- Majority of households have electric or gas stove for daily cooking

Leading organisations: FPD (VN), Bangliang NNR (CN)

Supporting organisations: FFI

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

XIII. Targeted reduction in the collection and trade of orchids (Vietnam) (Action 52)

Description: Orchid collection was identified in the workshop as a driver of human disturbance to gibbons in the SHCA, as well as degradation of biodiversity in the gibbon's habitat. As well as intensified patrolling in known hotspots of orchid collection (see work package I), key locations and people involved in the illegal trade of wild-collected orchids will also be identified and monitored periodically (with unscheduled visits from FPD officers). Orchid traders will also be asked to make a formal commitment to not selling products sourced from the wild. While it will be difficult to completely stop the burgeoning and lucrative trade in orchids, not least because of the challenge of tracking provenance, these initiatives will raise awareness among communities about the illegality of orchid collection and trade, and in the process will enhance PA capacity for tackling the illegal wildlife trade.

Indicators of success:

- Orchid trading locations are identified
- Majority of orchid traders comply with the law

Leading organisations: FPD (VN)

Supporting organisations: FFI, CPC

Timeline: 2021-2022

Source of funding: FFI (VN)

XIV. Maintain cooperation between the Cao Vit Gibbon SHCA and Bangliang NNR (Actions 65, 66, 69)

Description: The Cao Vit Gibbon SHCA FPD and Bangliang NNR will continue to follow Memorandums of Understanding (MoUs) signed by the respective governments, with periodic reviews on progress occurring biennially, or as necessary. This forms the official basis of effective cooperation between the two sides. In addition, improvements in more regular communications will be a key priority going forwards, for example by establishing a single channel for correspondence, and by identifying (or recruiting) staff with both Vietnamese and Mandarin language skills who can act as mediators or 'focal points' to improve the two-way flow of information. Monitoring results, both about the cao vit gibbon and its habitat, will also be shared between both PAs, helping to improve management decisions. A coordinated transboundary population survey of the gibbon is also planned for late 2021, which will be important for updating the status assessment of the species (the last full transboundary survey was in 2016; the survey in 2018 was a compilation of records taken at different times with different methods). Ultimately, cooperation will enhance the efficiency of conservation measures taken by each side and ensure that the cao vit gibbon population is consistently protected throughout its range.

Indicators of success:

- Progress towards the more effective cooperation is reviewed periodically
- An information sharing platform is established, in particular for sharing monitoring results
- A full population survey is co-produced by both sides in late 2021

Leading organisations: FPD (VN), Bangliang NNR (CN)

Supporting organisations: FFI

Timeline: 2021-2030

Source of funding: FFI (VN), Bangliang NNR (CN)

Cao Vit Gibbon SHCA, Vietnam. Image © Ryan Deboodt.

IMPLEMENTATION OF THE PLAN

Action plans are, by definition, *intentions* to save a species, but do not guarantee by themselves that anything will change on the ground. This difference between intention and reality is often called the 'implementation gap'.

In order to minimise the implementation gap, a number of strategies were proposed both during and after the workshop. These included the following (which are not mutually exclusive):

- Formation of an Implementation Committee, formed of government, NGO and community representatives, which is responsible for both monitoring progress towards achieving the Action Plan and driving the implementation forwards

- Adding a review of the Action Plan progress to the transboundary meetings between Trung Khanh FPD and Bangliang NNR (held approximately biennially)

- Formation of a Cao Vit Gibbon Advisory Group, which will be responsible for addressing, in particular, the research components of the Action Plan (see *Knowledge gaps*) and could also help to advise the Implementation Committee

- Commissioning an independent review or audit of the Action Plan's implementation, to be conducted at key milestones (mid- and end-term)

FFI remains committed to the conservation of the species, and continuing its long association with the Cao Vit Gibbon SHCA. It will therefore fully support the FPD in monitoring and driving the Action Plan in Vietnam, pending formal adoption of any of the proposals suggested above. In China, the Bangliang NNR will assume responsibility of the Action Plan, although actions will initially be aligned with, and subsumed under, their existing Management Plan (which runs to 2022).

CONCLUSION: A NEW CHAPTER FOR CAO VIT GIBBON CONSERVATION

The cao vit gibbon entered the turn of this century lost to science and presumed extinct. It has now been rescued from this obscurity, is saved from immediate extinction, and the conversation has now shifted towards recovery. This is quite an achievement in just 20 years, or a single gibbon generation.

This marks the end of one chapter for the cao vit gibbon and the beginning of a new one. Where there was uncertainty and danger in the previous chapter, there is now optimism and hope. The new Chapter will be kickstarted over the next 10 years with the actions outlined in this plan, and will continue to mid-century. Momentum is easily lost, and so it will be critical for this first period to set the tone for coming years, demonstrating the success of an evidence-based and collaborative approach to conserving the gibbon, as outlined in this Action Plan. By 2030, the cao vit gibbon should be on a much firmer footing than it is today, with the steps in place to consider broader recovery of the species. Thereafter, an exciting phase should hopefully be set in motion, with the establishment and management of more than one population on the horizon.

At the same time, of course, we must not become complacent about the threats facing the single remaining population of the species that we have now. Although the population is now large enough to avoid the worst effects of the 'extinction vortex', the population is likely to become genetically unhealthy through time, and threats of catastrophes, whether via a disease outbreak or the gun of a hunter, loom large. In other words, our work to vigorously protect and restore the forests in Trung Khanh and Bangliang must continue apace.

Participants at the workshop envisaged a rich and hopeful future for the cao vit gibbon. By 2050, the vision is that the gibbon will be thriving in a restored forest, is fulfilling its natural ecological function across more of its historical range and, crucially, is the pride of local communities. This is clearly ambitious, but achievable. Our collective task over the coming three decades is to do justice to this vision, both for the cao vit gibbon and the people of Vietnam and China who share its habitat.

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APPENDIX I: LIST OF PARTICIPANTS & WORKSHOP FEEDBACK

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Workshop feedback received

We received 25 responses to our survey sent to all participants in the workshop. All stated that they were satisfied with the workshop proceedings, information shared, and ability to partake in discussions. There was feedback from some participants on important published or unpublished information that was not shared prior to the workshop. Some individuals also highlighted additional stakeholders that could be involved in the implementation of this Action Plan. Feedback was almost unanimous that the workshop was successful in the identification of priority conservation Actions needed to protect and manage the species. Participants all highlighted that the process had also allowed for deeper collaboration between the diverse set of stakeholders involved in the conservation of the cao vit gibbon.

APPENDIX II: SUPPLEMENTARY METHODS FOR PVA MODELLING

Table S1. List of parameters used, and their justification, for the Baseline simulation of population viability in Vortex. In addition, three main alternative scenarios were constructed ('Catastrophes', 'Restoration' and 'Translocation'), which are described in the main text.

Parameter	Value	Justification
Number of simulated years	200	200 years is approximately 10 gibbon generations, which was thought to be a reasonable time-frame over which to assess population viability.
Extinction definition	Number of individuals less than 10	We used a more conservative definition of extinction, in which we considered the population irrevocable if it dropped below 10 individuals. This is consistent with a precautionary approach to the modelling.
Lethal equivalents (% due to recessive alleles)	6.29 (50%)	This is a measure of the severity of inbreeding depression (specifically, on recruitment rates). The default value in Vortex of 6.29 was used in the Baseline scenario. Alternative scenarios were also investigated, where inbreeding depression was removed from the model, or raised to a moderate level of 12.29 (O'Grady et al., 2006).
Initial level of relatedness among individuals	0.05	A small amount of initial relatedness was assumed, as would be expected given that the population has been small and isolated for at least 2-3 decades. It is not known if the population has gone through a bottleneck (e.g. < 30 individuals) or not. The value of 0.05 used in the Baseline scenario was chosen with reference to the value of 0.2 that was used for the Hainan gibbon (Turvey et al., 2015). This was raised to 0.1, i.e. a moderate level of relatedness, in an alternative scenario.
Type of breeding system	Long-term polygyny	This matches data from long-term monitoring. Male take-overs (including suspected infanticide) have been observed in the species, but incorporating this into the model was not expected to change the main results (e.g. infanticide is already included in the infant mortality rate).
Age of first offspring - Female	10	This approximate value was taken from Fan et al. (2013) and is based on knowledge of other gibbon species, as well as insights from long-term monitoring of the cao vit gibbon (Changyong Ma & Pengfei Fan, unpublished data). For example, females have been observed to disperse between 7.5 and 9.3 years of age (n = 4), with reproduction expected to occur with a lag after this, due to the time needed to find a mate and territory, copulate, gestate and give birth.
Age of first offspring - Male	12	As above, this value was taken from Fan et al. (2013). Males are expected to reach adulthood and disperse more slowly than females, in common with other gibbon species.
Maximum age of reproduction	30	This approximate value was taken from Fan et al. (2013), and is based on knowledge of gibbon life history in general. If individuals are able to breed for longer, then

		our predictions may be slightly pessimistic, which is consistent with a precautionary approach.
Maximum lifespan	35	To match the field observations of (presumably) older non-reproductive females, the maximum lifespan was raised to a slightly higher value than the maximum age of reproduction.
Offspring dependence period	2 years	Field observations of the species indicate that infants are heavily dependent on their mother for at least 2 years. The model assumed that if the mother dies during this critical period, the infant would also die.
% Adult females breeding	25 to 45% (density-dependent)	Breeding rate was assumed to be density-dependent in the Baseline scenario. Specifically, breeding rate was assumed to be 45% at low density, declining to 25% if the population approaches the habitat carrying capacity. A value of 1.5 was used for the 'steepness' parameter in Vortex ('B') in order to set a weak level of density-dependence. Using these parameter values, breeding rates rise above 30% once the population size dips below 100, and reach a peak (of 45%) if the population drops to just 20-25 individuals. This specific from of density-dependence is somewhat arbitrary and, given the lack of data, might be considered a parsimonious approach to the modelling (i.e. not adding strong effects for which we have no evidence). The lower and upper bounds on breeding rates (i.e. 25 and 45%) are informed by various sources: we know that the % of females with infants (0-2 years old) was on average 40% (2007-2018 surveys); Fan et al. (2013) estimated that 30% of females reproduce in a given year, and the most recent data from China indicates that breeding rate across 2008-2020 was on average 0.26 (SD=0.12 across females; range=0 to 0.4; Changyong Ma & Pengfei Fan, unpublished data). In addition, monitoring of the Hainan gibbon population, which was at low density (N=25), suggested that female breeding rate was 45-50% (Turvey et al., 2015). In alternative scenarios, density dependence was removed (setting breeding rates to a constant 30%), or the strength of density-dependence was increased to moderate or strong level (using steepness parameters of 3 and 6, respectively).
Environmental variation in % breeding	18.2%	This value was taken from Fan et al. (2013), and is informed by long-term monitoring of the species.
Mortality rates - Female	0 to 1 yrs: 9% 1 to 2 yrs: 8% 2 to 3 yrs: 4% 3 to 4 yrs: 3.5% 4 to 5 yrs: 3.5% 5 to 6 yrs: 3% 6 to 7 yrs: 2.5% 7 to 8 yrs: 2% 8 to 9 yrs: 3% 9 to 10 yrs: 4%	Mortality rates by age-class were informed by monitoring data from China (2008-2020; Changyong Ma & Pengfei Fan, unpublished data). A survivorship curve was used, to approximately match the annual mortality rates to the aggregated mortality rates provided by monitoring (e.g. 'infant mortality' and 'juvenile mortality'). Although no sub-adult deaths have been observed during monitoring, a slightly lower annual mortality rate compared to juveniles was assumed. Adult mortality was arbitrarily assumed to be 1% for females and males, except for a

	10 to 11 yrs: 5% 11 to 12 yrs: 4% 12 to 13 yrs: 3% 13 to 14 yrs: 2% 14 to 23 yrs: 1% 23 to 28 yrs: 2% 28 to 29 yrs: 3% 29 to 30 yrs: 5% 30 to 31 yrs: 15% 31 to 32 yrs: 30% 32 to 35 yrs: 50%	spike in mortality for the first 2 years of adulthood (when individuals are dispersing and finding a mate and territory), as well as a substantial spike in the post-reproductive years (30-35 years old) due to senescence.
Mortality rates - Male	0 to 1 yrs: 9% 1 to 2 yrs: 8% 2 to 3 yrs: 4% 3 to 4 yrs: 3.5% 4 to 5 yrs: 3.5% 5 to 6 yrs: 3% 6 to 7 yrs: 2.5% 7 to 8 yrs: 2% 8 to 9 yrs: 2% 9 to 10 yrs: 2% 10 to 11 yrs: 3% 11 to 12 yrs: 4% 12 to 13 yrs: 5% 13 to 14 yrs: 4% 14 to 15 yrs: 3% 15 to 16 yrs: 2% 16 to 23 yrs: 1% 23 to 28 yrs: 2% 28 to 29 yrs: 3% 29 to 30 yrs: 5% 30 to 31 yrs: 15% 31 to 32 yrs: 30% 32 to 35 yrs: 50%	As for females, male mortality rates by age-class were informed by monitoring data from China (2008-2020; Changyong Ma & Pengfei Fan, unpublished data). The difference between males and females is the later timing of natal dispersal in the former, which is reflected in the elevated mortality rates from years 11 to 14.
Variation in mortality rates (standard deviation)	50% of mortality rate	The standard deviation was arbitrarily assumed to be half the mortality rate, meaning that in extreme years mortality will range from 0 (in very 'good' years) to approximately double the background rate (in very 'bad' years). For adults, which were assumed to have a very low mortality rate (1%), the variation will be very small. The variation will be larger in young individuals, which is probably justifiable given the presumed susceptibility of this age-class to variation in winter temperatures (approx. every 3-7 years there is a very cold winter in northern Vietnam).
Carrying capacity	123	Given the lack of significant increase in the population over recent surveys (2007 to 2018), the population was assumed to currently be oscillating around the carrying capacity. The carrying capacity was therefore estimated as the mean population size over the recent surveys (=123).

Initial population size	109	This value was taken from the last cao vit gibbon population survey in 2018. Alternative scenarios were also run using the lower and upper confidence intervals of this estimate (88 and 131, respectively).
% males in breeding pool	52.6%	The degree of mate monopolisation was calculated by making the following assumptions: i) the number of females is easiest to count because they will be resident in groups and are conspicuous, ii) the number of males in the population will equal the number of females if mortality rates are similar (as assumed in the PVA currently), and iii) only 1 adult male per group is breeding. Therefore the % of males breeding = number of breeding males / total number of males = number of groups / total number of females.
Age distribution	Specified age distribution	A feasible proportional age structures was created based on the 2018 population survey data. The population in 2018 apparently had an 'excess' of infants and adult females, and relatively few juveniles. This meant that all population trajectories show an initial 'boom', followed by a 'bust' phase (as evident in Figs. 11-12), before settling down into the stable age distribution.

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