Agr. Nat. Resour. 58 (2024) 453–462

AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

Estimation of population and threats of Northern White-cheeked Gibbon (*Nomascus leucogenys*) in Phou Khao Khouay National Biodiversity Conservation Area, Lao PDR

Phansamai Phommexay[a,b], Aingorn Chaiyes[c], Prateep Duengkae[d], Chantip Chuaynkern[a], Yodchaiy Chuaynkern[a,*]

[a] *Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand*

[b] *Faculty of Forest Science, National University of Laos, Dongdok Campus, Vientiane Capital 7322, Lao PDR*

[c] *School of Agriculture and Cooperatives, Sukhothai Thammathirat Open University, Nonthaburi 11120, Thailand*

[d] *Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand*

Article Info

Article history:
Received 28 February 2024
Revised 14 June 2024
Accepted 8 July 2024
Available online 30 August 2024

Keywords:
Listening post,
Nomascus leucogenys,
Phou Khao Khouay,
Population,
Threat

Abstract

Importance of the work: The northern white-cheeked gibbon (*Nomascus leucogenys*) is classified as Critically Endangered on the IUCN red list, urgent species conservation is required. However, there remains a notable lack of information regarding gibbon population sizes, distribution and conservation efforts, particularly in regions within Lao PDR.
Objectives: To estimate the population of *N. leucogenys* and to assess the status of threats to their existence within the Phou Khao Khouay National Biodiversity Conservation Area (PKK NBCA), Lao PDR.
Materials & Methods: Listening posts were utilized to enumerate the number of gibbon groups. Density estimates were calculated by dividing the total number of groups heard in the listening area by the effective listening area. Threat identification was conducted through interviews with local people and direct observations. Subsequently, a value scale of threats was established, which was then used to rank and prioritize the identified threats.
Results: The total population estimate was 23 *N. leucogenys* individuals within and around the PKK NBCA. These individuals were distributed among seven groups, categorized into four age classes, comprising 11 adult males, 8 adult females, 3 juveniles and 1 infant. The density of *N. leucogenys* was 2.33 groups/km^2. Habitat loss and hunting were identified as the two primary direct threats.
Main finding: The density of *N. leucogenys* derived from these findings was 2.33 groups/km^2, with habitat loss and hunting being the two primary direct threats and posing extreme danger to the species, necessitating urgent regulatory and conservation interventions.

* Corresponding author.
E-mail address: yodchaiy@kku.ac.th (Y. Chuaynkern)

https://doi.org/10.34044/j.anres.2024.58.4.05

Introduction

Gibbons, belonging to the family Hylobatidae within the order Primates, are primates widely distributed across the tropical rainforests of Southeast Asia, ranging from China to the Malay Peninsula, Myanmar and North Sumatra (Geissmann, 1995). Among the 16 recognized species, Lao PDR boasts the second highest species richness, hosting six gibbon species: *N. concolor, N. annamensis, N. leucogenys, N. siki, H. lar* and *H. pileatus*. However, the majority of these species are classified as Endangered on the IUCN Red List (Bleisch et al., 2008; Rawson et al., 2020), with *N. leucogenys* being designated as Critically Endangered. *N. leucogenys* is endemic to Southeast Asia, particularly Lao PDR, Vietnam and China (Harding, 2012; Syxaiyakhamthor et al., 2020), with Lao PDR boasting the largest distribution of this species.

Gibbons live in the canopies of tall trees of mixed semi-evergreen and coniferous species, in the upper mountains in both dry and wet evergreen forests (Coudrat et al., 2015). In Laos PDR, most gibbons are found in good quality forests; furthermore, they live in the middle level of the tropical forests (Phoutabounma, 2013). Gibbons are known for their early morning vocalizations, with sex-specific songs being a prominent feature (Geissmann, 2002). Typically, male gibbons produce solo calls, while females produce both solo and duet calls, often joining with their mates or subadult males (Brockelman and Ali, 1987; Brockelman and Srikosamatara, 1993). Unmated individuals generally do not engage in duetting. The distinctive gibbon calls serve as a valuable tool for estimating group density, a method frequently applied in research (Brockelman and Ali, 1987; Brockelman and Srikosamatara, 1993; Phoonjampa et al., 2011; Coudrat et al., 2015; Syxaiyakhamthor et al., 2020). Typically, a main listening post is established on a hill, with a distance of up to 1 km from another listening team located on a separate hill (Brockelman and Srikosamatara, 1993).

In the natural forests of Lao PDR, the once prominent calls of gibbons have become increasingly rare due to declining populations, with the main threats to gibbons resulting from various human activities, including hunting (Duckworth, 2008). Additionally, logging, human disturbance and collection of forest products exacerbate the situation (Lwin et al., 2022). These activities not only fragment the gibbon habitat but also produce easier access for hunters, posing major threats to the survival of gibbon populations (Duckworth, 2008; Fan, 2016; Fan and Bartlett, 2017)

However, there remains a notable lack of information regarding gibbon population sizes, distribution and conservation efforts, particularly in regions within Lao PDR. As *N. leucogenys* is classified as Critically Endangered on the IUCN red list, urgent species conservation is required. The ecological characteristics, taxonomy, vocalizations and population densities of *N. leucogenys* are poorly understood (Ruppell, 2013). Therefore, this study aimed to address these gaps by estimating the population of *N. leucogenys* and assessing their threat status within the Phou Khao Khouay National Biodiversity Conservation Area (PKK NBCA) in Lao PDR. The findings of this research should provide vital information to authorities and policymakers, aiding in conservation decision-making by identifying the population size and primary threats faced by *N. leucogenys*. Additionally, it should offer insights into the current status of these gibbons and enable future predictions regarding their conservation needs.

Materials and Methods

Study site

PKK NBCA is one of six designated conservation areas in Lao PDR (18º14'–18º 32' N 102º 38'–102º 59' E), as shown in Fig. 1. PKK NBCA is nestled in the Bolikhamxay province of central-eastern Lao PDR and is bordered by four neighboring provinces: Bolikhamxay, Vientiane Capital, Vientiane and Xaisomboon and encompasses six districts: Hom, Keo Udom, Long Xan, Pak Ngum, Thaphabath and Thulakhom. PKK NBCA spans approximately 1,942 km^2 with an additional 24,031 ha in Xaisomboun province. Initially, the Conservation Area was established as a National Protected Area in 1993 through Prime Minister's Decree No. 164/PM (29 October 1993); later (30 December 2021), it was re-designated as a National Biodiversity Conservation Area by Prime Minister's Decree No. 733/PM (National Embassy of Laos, 2021), aiming to safeguard indigenous forests and wildlife. Despite a decade-long government ban on logging, much of forest within PKK NBCA has experienced degradation over the years. The areas boast diverse forest types, including mixed deciduous, dry evergreen dipterocarp and monodominant coniferous forests at higher elevations, with elevations in the range ≤100–nearly 1,700 m. There is a stark contrast between rainfall patterns, with the rainy season (May–October) recording an average of 3,369 mm, whereas the dry season (November–April) has a much reduced average rainfall of only 265 mm (Satdichanh et al., 2015).

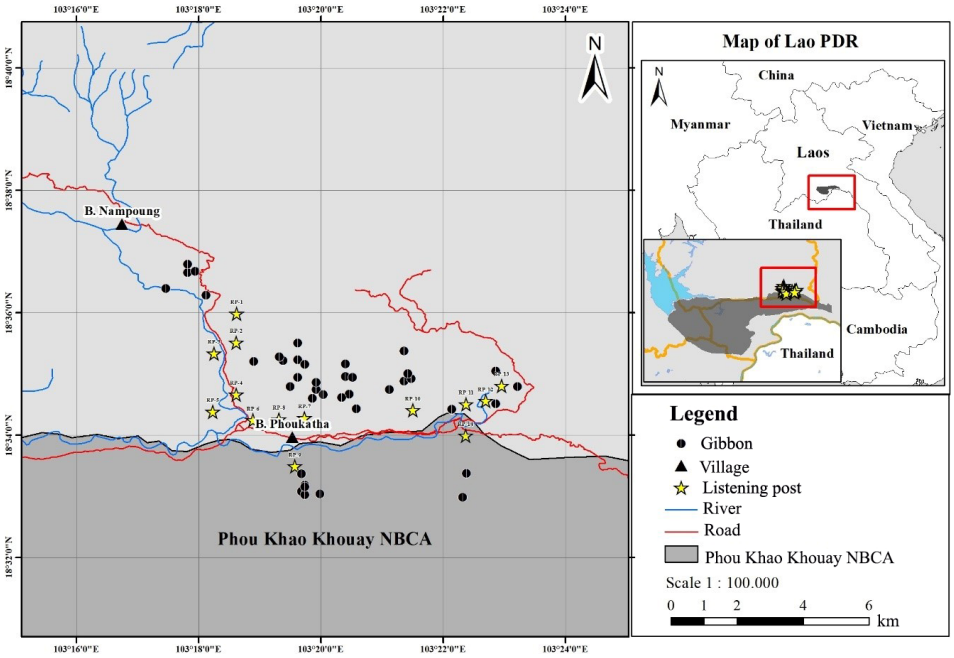

Fig. 1 Geographical location of study site within Pho Khao Khouay National Biodiversity Conservation Area (PKK NBCA) and surrounding area

Permission to carry out research in the Conservation Area

Formal approval was given by the District Agriculture and Forestry Office (DAFO; reference number 0101/DAFO) on 10 March 2021. Stakeholder engagement encompassed collaboration with educators and students from the Faculty of Forestry Science at the National University of Laos, local village authorities and personnel from DAFO affiliated with the Provincial Agriculture and Forestry Office of the Ministry of Agriculture and Forestry. Animal ethics approval (reference number 660201.2.11/466 (108)/2021) was granted by the Northern Laboratory Animal Center at Khon Kaen University, Thailand.

Data collection

Population estimation

The study included a survey to assess the gibbon population, recording various parameters for each gibbon vocalization encounter, including song bout, distance from observer, compass bearing, start time, end time, song type (solo or duet), group size and age-sex categories of individuals (Table 1). Listening areas were strategically chosen at high altitudes on mountain ridges or hilltops to maximize the detection range, typically spanning at least 2 km under favorable conditions (Brockelman and Ali, 1987). Field surveys commenced between 05:00 hours and 10:00 hours, continuing until the cessation of vocalizations.

Table 1 Summary of family composition, age class and group density estimates for *N. leucogenys* observed during current study

Group No.	Composition				Total	Density (group/km^2)
	Adult male	Adult female	Juvenile	Infant		
G1	1	1	-	-	2	-
G2	1	1	-	-	2	-
G3*	4	2	2	1	9	-
G4*	2	1	1	-	4	-
G5	1	1	-	-	2	-
G6	1	1	-	-	2	-
G7	1	1	-	-	2	-
Total	11	8	3	1	23	2.33

* Groups based on field obsrvations.

Each listening post team was stationed within a radius of 1 km to allow estimation and triangulation techniques to be utilized (Brockelman and Ali, 1987; Nongkael and Thong-aree, 2007; Phoutabounma, 2013; Coudrat et al., 2015; Syxaiyakhamthor et al., 2020). Two separate teams conducted simultaneous surveys, each operating at different listening points (Fig. 2), with rotations occurring every 2–3 d. Gibbon locations were determined using triangulation techniques based on the angles and timing of duet bouts (Brockelman and Ali, 1987; Lwin et al., 2022), with song locations spaced 500 m apart on the triangulation map, assuming that overlapping time of song bouts indicated distinct groups. Ground surveys were conducted for large groups with more than two duet bouts to confirm group compositions. Gibbons were classified into four categories based on age and sex: adult males, adult females, juveniles and infants. A group was defined as comprising at least one female great call and one male coda, indicative of a family group (Cheyne et al., 2016). Field observations were made on 92 d at 12 listening post stations, involving 168 listening times that covered an area of 60 km^2. Gibbon density estimates were calculated by dividing the total number of groups heard in the listening areas by the effective listening areas, according to equation 1 (Brockelman and Srikosamatara, 1993; Cheyne et al., 2008):

$$D = \frac{n}{E} \quad (1)$$

where D is the density, n represents the cumulative total number of groups heard in the listening areas and E denotes the effective listening areas.

Effective listening areas (E) were defined as the regions within which groups could be heard singing from up to 1 km away from two or more listening posts (Cheyne et al., 2008). Groups needed to be audible from at least three listening posts to ensure accurate mapping and inclusion within the listening areas.

Identifying threats

Throughout the study period, interviews were conducted with local residents and field observations were carried out. Initially, consultations were held at the village level, involving discussion with village leaders, elders, community organizations and residents to identify primary direct and indirect threats leading to the decline in gibbon populations. In addition, household-level interviews were conducted using a random sampling method to choose 25% (44 families) from the total of 174 families (Akakoon, 2007). Points made by respondents and recurring threats were noted and

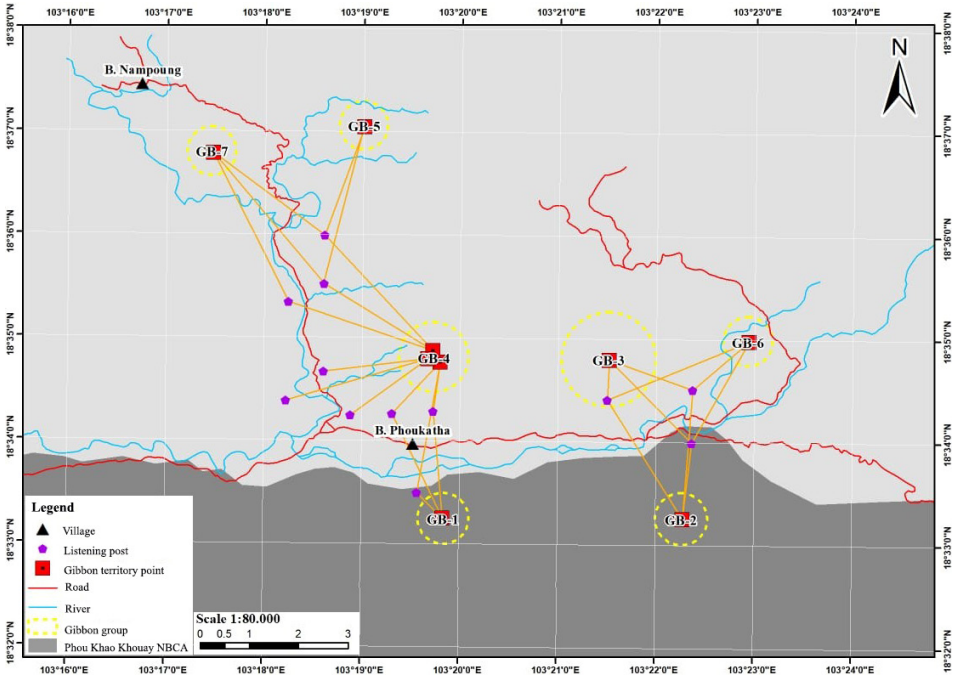

Fig. 2 Locations of listening post stations and directional movements of *N. leucogenys* groups (GB-1 to GB-7) at study sites in Pho Khao Khouay National Biodiversity Conservation Area (PKK NBCA) and surrounding area

the main threats were ranked and categorized based on the mean value of threat scale lengths ranging from 1 to 5, representing the likelihood from 'not at all likely' to 'extremely likely' (see Table 2). The Likert rating scale (Likert, 1932) was used to evaluate threats, with the mean scale value being classified as shown in Table 2.

Table 2 Definitions of threat ranking scale

Scale level	Mean value	Definition
1	1.60–1.80	Not at all likely
2	1.81–2.60	Not very likely
3	2.61–3.40	Somewhat likely
4	3.41–4.20	Very likely
5	4.21–5.00	Extremely likely

The threats result value scale levels were defined as: 1) not at all likely, indicating a species of low concern, considered appropriate to exclude from protection and conservation planning; 2) not very likely, suggesting a species of moderate importance for protection and conservation efforts; 3) somewhat likely, implying a species posing a potential threat and requiring immediate attention through regulatory measures and conservation actions; 4) very likely, indicating a major threat to the species, necessitating urgent regulatory interventions and conservation initiatives; and 5) extremely likely, signifying an imminent and severe danger to the species, demanding immediate regulatory action and intensive conservation efforts.

Filed observations were conducted through ground surveys, documenting location and the date and time of the various threats encountered during the study period. These threats included activities such as woodcutting, barking dogs, gunshots, land disturbance (including fires and land clearing), wildlife trapping and the collection of non-timber forest products (NTFPs). Then, the observed threats were categorized according to predefined definitions (Chuaynkern and Duengkae, 2014; Rowley and Stuart, 2014) as: 1) habitat destruction/habitat loss: logging, fires, agricultural expansion or mining; and 2) overharvesting: hunting, wildlife utilization, wildlife trapping, gunshots and collection of NTFPs; and 3) wildlife trade.

The quantification of habitat destruction/habitat loss involved summing the occurrences of logging, forest fires, land degradation (such as shifting cultivation and rice fields) and mining observed during the survey (Table 3, Fig. 3). Overharvesting was quantified by tallying instances of hunting, barking dogs, gunshots, wildlife trapping, wildlife utilization (including the portions used and bone parts), wildlife sales (species, time and frequency) and NTFPs collection recorded during the study.

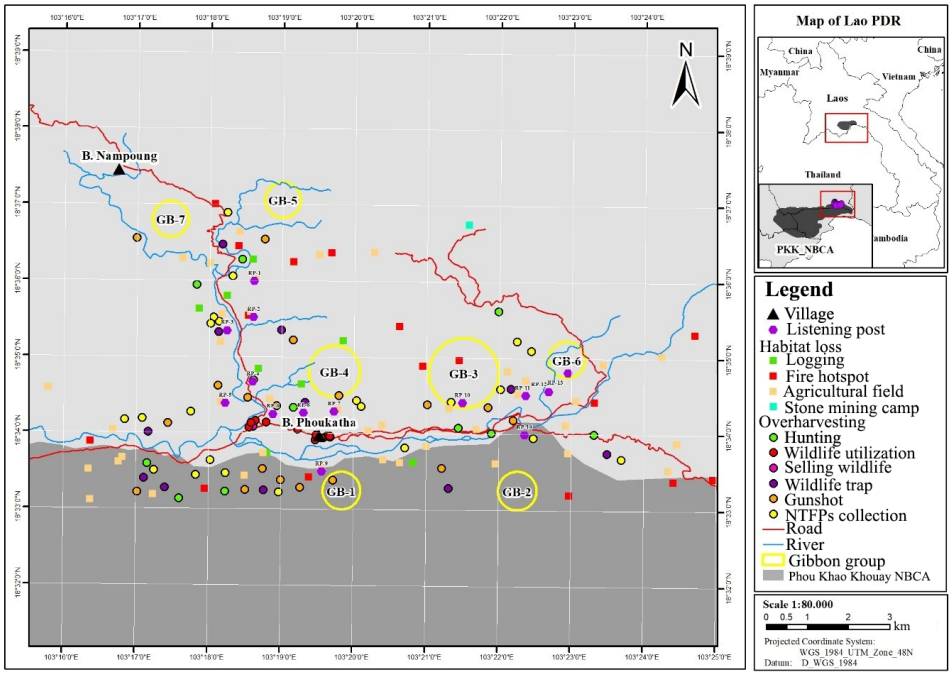

Fig. 3 Spatial distribution of habitat loss and overharvesting threat realtive to groups of *N. leucogenys* (GB-1 to GB-7) at study sites in Pho Khao Khouay National Biodiversity Conservation Area (PKK NBCA) and surrounding area

Table 3 Percentage of field observations of threats during dry and rainy seasons (November 2021–October 2022)

Threat	Frequency	%	1	2	3	4	5	6	7	8	9	10	11	12
Habitat loss										⊗				
1 Logging	7	1.2		⊗				⊗	⊗	⊗	⊗			⊗
2 Fire	25	4.2					⊗	⊗	⊗	⊗	⊗			
3 Agriculture field	49	8.3						⊗	⊗	⊗	⊗	⊗		
4 NTFPs collection	22	3.7					⊗			⊗				
5 Mining	32	5.4						⊗	⊗	⊗	⊗	⊗		
Overharvesting							⊗							
1 Hunting	17	2.9					⊗							
2 Wildlife utilization	35	5.9				⊗	⊗	⊗	⊗	⊗	⊗	⊗		
3 Gunshots	404	68.4					⊗	⊗			⊗	⊗		
Total	591	100		Present data					⊗	Absent data				

NTFPs = non timber forest product.

Table 4 Summary of mean threat ranking scores and their definitions from field interviews

Threat	Mean value	Definition
Hunting	4.52	Extremely likely
Logging	4.36	Extremely likely
Gunshots	3.36	Somewhat likely
Fire	3.04	Somewhat likely
Mining	2.66	Somewhat likely
Agriculture activity	2.20	Not very likely
Wildlife trade	2.18	Not very likely
NTFP collection	1.48	Not at all likely
Total	2.98	Somewhat likely

NTFPs = non timber forest product.

Results and Discussion

Population estimation

Based on the field research findings using the observed song bouts from the gibbon group sightings (Table 1), the estimated total population of *N. leucogenys* within and surrounding PKK NBCA was 23 individuals. These individuals were distributed among seven groups, classified into four age compositions: 11 adult males, 8 adult females, 3 juveniles and 1 infant. The calculated density of *N. leucogenys* based on these findings was 2.33 groups/km^2 (Table 1). The mean group size of *N. leucogenys* was 3.28 individuals. Among these groups, only two, labeled G1 and G2, were located within PKK NBCA, specifically in the Phou Kong Khao and Pho Ho mountains. Both groups had the same population size and age compositions, consisting of one adult male and one female. The remaining five *N. leucogenys* groups were found roosting outside PKK NBCA, within the National Protection Forest and National Production Forest. Most of these five groups consisted of mating pairs (one adult male and one female), such as G5, G6 and G7. G5 and G6 were roosting in the area surrounding the Phoukatha mountain base, at a moderate elevation of up to 2,000 m above mean sea level, with mainly rocky terrain and sparse vegetation at the mountain top that was possibly unsuitable for roosting. Song bouts from G7 were heard from the base of Phoumee to Phoubaikhor Mountains, near the border between Phoukatha and Nam Poung Village, albeit with slightly lower audibility due to the greater distance from the listening point. G3 and G4 contained the largest group numbers of *N. leucogenys*. G4 comprises four gibbons, including two adult males, an adult female and one juvenile, roosting at the top of Phouloun mountain trail. The largest group of G3, consisted of nine gibbons spanning four age classes: four adult males, two adult females, two juveniles and an infant. This group was located near the approach to Phouloun mountain, leading to Phoukatha village.

Based on these results, the total estimated population of 23 individuals of *N. leucogenys* within and around PKK NBCA were distributed across seven groups. The calculated density of *N. leucogenys* based on these findings was 2.33 groups/km^2 (Table 1). In comparison, other studies have reported lower densities for *N. leucogenys* in different regions, such as 0.4 group/km^2 in Nam Et-Phou Louey, northern Laos (Syxaiyakhamthor et al., 2020), 0.21 group/km^2 in the Nam Kading National Protected Area, central Laos (Hallam et al., 2016) and 0.16 group/km^2 in Pu Mat National Park, Vietnam (Bach and Rawson, 2011). In contrast, higher densities have been observed for other gibbon species, such as 1.02 group/km^2 for *H. lar* in Khao Yai, National Park, Thailand (Phoonjampa et al., 2011) and 0.71 group/km^2 for *N. gabriellae* in Seima, Cambodia (Rawson et al., 2009). However, other findings aligned closely with the current study, such as a density of 2.68 group/km^2 for *N. siki* in Nakai Nam Thuen National Park Area, Laos (Nanthavong, 2013) and 2.59 group/km^2

for *N. albibarbis* in Central Kalimantan, Indonesia (Cheyne et al., 2008). Nonetheless, certain studies have reported even higher densities, in the approximate range of 4–5 groups/km^2 (Brockelman et al., 2009).

These findings indicated a relatively high density of this species in Nam Et-Phou Louey, northern Laos (Syxaiyakhamthor et al., 2020), the Nam Kading National Protected Area, central Laos (Hallam et al., 2016) and Pu Mat National Park, Vietnam (Rawson et al., 2009). According to Brockelman and Srikosamatara (1993), with a density of gibbon groups lower than 2 groups/km^2 representing a low density. Thus, the current results (2.33 groups/km^2) indicated that the density of *N. leucogenys* in PPK NBCA exceeded this threshold. However, the density of *N. leucogenys* may be influenced by various threats. For example, in Nam Et-Phou Louey, northern Laos, habitat quality and high threats, such as logging, are likely factors (Syxaiyakhamthor et al., 2020), contrasting with the current study. In Phoukatha, where the population consists predominantly of Hmong ethnic groups engaged in farming and heavily reliant on natural resources, wildlife hunting for sustenance is common; however, gibbons are respected and protected. Similarly, in the Nam Kading National Protected Area, central Laos, distance from roads and human resettlement may influence gibbon densities compared to the current study site. For example, Phoukatha village lacks proper roads, especially during the rainy season and transportation is hindered by large rivers such as Nam Pa, Nam Xaikhao, Huaytamkhao and Huay Yakwai rivers. Notably, the *N. leucogenys* distribution in Laos from the north to the central regions (Duckworth, 2008; Phommexay et al. 2024), suggests that the central part, including PKK NBCA, could harbor the largest distribution. However, while the density is promising, the low number of adult females, juvenile and infants in terms of family composition raises concerns. Based on the current results, the limited presence of younger age classes could jeopardize population survival in the future (O'Brien et al., 2004), especially considering the long birth interval and low birth rate of this species, which contribute to its conservation challenges (Duckworth, 2008).

There was a notably higher density of *N. leucogenys* in the current study area compared to the populations observed in Nam Et-Phou Louey, the Nam Kading National Protected Area in Laos and Pu Mat in Vietnam. This difference in density could be attributed to the selection effects of the listening areas (Syxaiyakhamthor et al., 2020) and the favorable conditions for listening (Brockelman and Ali, 1987). Specifically, a major proportion of the *N. leucogenys* groups in the current study were situated outside the border of NBCA (Phommexay et al., 2024), contrasting with previous research conducted within national parks. Therefore, the influence of listening areas on density estimation may have been relatively diminished in the current study. Additionally, the calculation of density estimates encompasses agricultural areas or areas undergoing disturbance such as gardens, plantations and fire-prone zones. These current results underscored that gibbons inhabit specific sites characterized by high-quality forests, with tree size typically exceeding 40 cm diameter at breast height over bark (Phoutabounma, 2013) and ample food availability within the area (Ruppel, 2013).

Identifying threats

The results obtained from consultations with villagers and household interviews revealed eight primary threats contributing to declines in the population and density of *N. leucogenys* within and around PKK NBCA (Fig. 3). These threats consisted of: hunting, logging, gunshots, fires, mining, agricultural activities, wildlife trade and the collection of non-timber forest products (NTFPs), as shown in Table 3. These findings can be classified into three categories based on their threat levels. First, the highest threat levels, classified as extremely likely, contained hunting (score: 4.52; range: 3–5) and logging (score: 4.36; range: 3–5) (Table 3). Second, the threats classified as somewhat likely were: gunshots (score: 3.36: range: 1–4), fires (score: 3.04; range: 2–4) and mining (score: 2.66; range: 1–3). Third, threats categorized as not very likely consisted of: agricultural activities (score: 2.20; range: 1–3) and wildlife trade (score: 2.28; range: 1–3), while collection of NTFPs (score: 1.48; range: 1–3) was classified as not at all likely. The overall mean average threat level contributing to the decline in *N. leucogenys* population was deemed somewhat likely (2.98). In addition, the local interviews highlighted that most threats were either considered extremely likely, posing an intermediate and severe danger to the species, or somewhat likely, indicating the importance of addressing these threats urgently regulatory and conservation measures.

The field observations yielded a total of 591 instances of threats (Table 3). These threats were classified into two main groups: habitat loss and overharvesting. Habitat loss threats accounted for 22.8% of the total, encompassing activities such as logging (1.2%), fires (4.2%), agricultural encroachment (8.3%), collection of NTFPs (3.7%) and mining (5.4%), as shown in Fig. 4. In contrast, overharvesting threats

constituted a larger proportion, totaling 77.2%. This category included gunshots (68.4%), wildlife utilization (5.9%) and hunting (2.9%), as shown in Table 3 and Fig. 4. Analysis of occurrence data across different time periods revealed that both the dry and rainy seasons experienced major levels of threats throughout the year (Table 3). Furthermore, habitat loss and overharvesting threats were consistently prevalent across all periods, indicating ongoing challenges in addressing these issues.

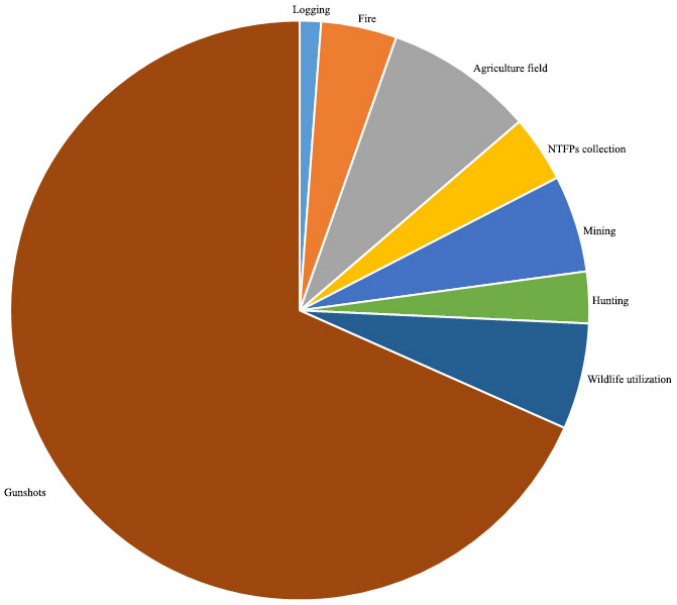

Fig. 4 Percentage distribution of threat occurrences for habitat loss (logging, fire, agriculture, NTFPs collection and mining) and overharvesting (hunting, wildlife utilization and gunshots)

Based on the results from the interviews and observations, it was evident that both habitat loss and hunting were the outstanding primary threats contributing to the decline in the *N. leucogenys* population. These threats categories were consistent with findings from various research studies worldwide, where hunting and habitat loss have been identified as major factors leading to species decline (Schmiegel and Monkkonen, 2002; Jiang et al., 2006). Indeed, these threats have led to the extinction of some gibbon populations in China (Fan, 2016), while also posing substantial challenges to the pileated gibbon (*Hylobates pileatus*) in Thailand (Phoonjampa et al., 2008), *Hoolock leuconedys* in Myanmar (Lwin et al., 2022) and *N. siki* in Vietnam (Tran et al., 2023). In Lao PDR, widespread illegal hunting and habitat loss, particularly affecting the *N. leucogenys* population, have been highlighted as major concerns (Duckworth, 2008). The low density of *N. leucogenys* in Nam Et-Phou Louey National Park Area, northern Laos, has been attributed to long-term logging activities (Syxaiyakhamthor et al., 2020). Gibbons are highly selective in their habitat preferences, favoring areas with tall trees with a height range of 10–25 m (Phoutabounma, 2013; Ruppell, 2013), large trees with a diameter over bark exceeding 40 cm (Phoonjampa et al., 2011), in addition to having a low birth rate (Jolly, 1972; Duckworth, 2008). The phenomenon of habitat loss and fragmentation represents a major global threat to biodiversity, impacting not only *N. leucogenys* but numerous other species as well (Gray et al., 2010). The results from the current study underscored hunting and habitat loss as the primary direct threats contributing to the decline in the studied *N. leucogenys* population. Notably, the percentage of overharvesting threats (77.2%) outweighed that of habitat loss (22.8%), highlighting the prominence of overharvesting as the leading threat to species decline.

However, certain threats reported in the literature did not directly correspond to the conditions observed in the current study, such as proximity to roads, villages and rivers (Hallam et al., 2016). While some studies suggested that threats, such as mining activities and the collection of NTFPs could contribute to human disturbances (Gaynor et al., 2018), the current findings suggested that these threats have a comparatively less negative impact compared to other research studies. Nevertheless, disagreements exist regarding the relative ranking of biodiversity threats (Bellard et al., 2022) and some differences may have resulted from the choice of testing methodologies (Antonak and Livneh, 1995). Despite this, some research endeavors have successfully applied threat-ranking methodologies to study amphibian biodiversity (Cavasos et al., 2023) and the impacts of climate change on protected areas (Lemieux and Scott, 2011; Phommexay et al., 2024), although such studies remain relatively uncommon within the social context research domain. Therefore, the current results should offer valuable insights into the prevailing threats in the study area, albeit with certain limitations.

Based on the research findings presented above, it was concluded that the population estimate of *N. leucogenys* in and around PKK NBCA was 23 individuals distributed among seven groups, classified into four age categories, comprising calculated density of *N. leucogenys* based on these results was approximately 2.33 groups/km^2. This density was greater than that observed in comparable areas such as Nam Et-Phou Louey, the Nam Kading National Protected Area and Pu Mat in Vietnam, possibly due to variations in selection methodologies and the environmental conditions conductive to listening.

Furthermore, the current study identified habitat loss and hunting as the two primary direct threats to the decline of *N. leucogenys* populations. These threats could be characterized by their extreme likelihood levels and high percentage scores, providing strong support for urgent regulatory and conservation measures to address the imminent danger posed to the species. Based on the current study, some urgent actions can be suggested for protecting the population of *N. leucogenys* in and around PKK NBCA: 1) protecting the remnant gibbons from hunting; 2) reviewing and developing rules and regulations between NBCA authorities and the communities; 3) including agreement on utilization of the forest and forest resources for sustainability; 4) allocating specific areas for land use and land management due to their limited availability, as determined by local authorities, especially at the village level, particularly in Phou loun, Phou mee, Phou kongkhao, Phou ho, Phoukatha, Nam Poung and Nam Thuay villages in Hom district; 5) promoting reforestation and trees or crop plantations that can be food sources for *N. leucogenys;* and 6) promoting and increasing local awareness of *N. leucogenys* conservation that offers substantial shared benefits for local communities and district and provincial authorities.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgements

The staff at PKK NBCA, as well as the staff and students from the Faculty of Forest Science at National University of Laos and the local community, provided valued assistance during field surveys. The Hom District Agriculture and Forest Office granted permits to conduct the research. The leaders of Phoukatha village offered invaluable support in facilitating the study. Financial support was provided by SSHEP-ADB and the Ministry of Education and Sports, Lao PDR. This research and innovation activity was funded by the National Research Council of Thailand (NRCT) (N34E670115) and the Centre of Excellence on Biodiversity (MHESI) (BDC-PG1-167003).

References

Akakoon, T. 2007. Research and Methodology in Behavioral Science and Social Science. Ubon Ratchathani Rajabhat University. Ubon Ratchathani, Thailand. [in Thai]

Antonak, R.F., Livneh, H. 1995. Direct and indirect methods to measure attitudes toward persons with disabilities, with an exegesis of the error-choice test method. Rehabil. Psychol. 40: 3–24. doi.org/10.1037/0090-5550.40.1.3

Bach, L.T., Rawson, B. 2011. Population Assessment of the Northern Whithe-Cheeced Crested Gibbon (*Nomascus leucogenys)* in Pu Mat National Park, Nghe An Province. Fauna & Flora International. Hanoi, Vietnam.

Bellard, C., Marino, C., Courchamp, F. 2022. Ranking threats to biodiversity and why it doesn't matter. Nat. Commun. 13: 2616. doi.org/10.1038/s41467-022-30339-y

Bleisch, B., Geissmann,T., Manh Ha, N., Rawson, B., Timmins, R.J. 2008. *Nomascus leucogenys*. The IUCN Red List of Threatened Species 2008: e.T39895A10272040. dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T39895A10272040.en

Brockelman, W.Y., Ali., R. 1987. Methods of surveying and sampling forest primate populations. In: Marsh, C.W., Mittermeier, R.A. (Eds.). Primate Conservation in Tropical Rain Forest. Alan R. Liss, Inc. New York, NY, USA, pp. 23–62.

Brockelman, W.Y., Naing, H., Saw, C., Moe, A., Linn, Z., Moe, T.K., Win, Z. 2009. Census of eastern hoolock gibbons (*Hoolock leuconedys*) in Mahamyaing Wildlife Sanctuary, Sagaing Division, Myanmar. In: Lappan, S., Whittaker, D. (Eds.). The Gibbons. Springer. New York, NY, USA. pp. 435–451.

Brockelman, W.Y., Srikosamatara, S. 1993. Estimation of density of gibbon groups by use of loud songs. Am. J. Primatol. 29: 93–108. doi.org/10.1002/ajp.1350290203

Cavasos, K., Poudyal, N.C., Brunner, J.L., et al. 2023. Attitudes and behavioral intentions of pet amphibian owners. EcoHealth 20: 194–207. doi.org/10.1007/s10393-023-01645-8

Cheyne, S.M., Gilhooly, L.J., Hamard, M.C., et al. 2016. Population mapping of gibbons in Kalimantan, Indonesia: Correlates of gibbon density and vegetation across the species' range. Endang. Species Res. 30: 133–143. doi.org/10.3354/esr00734

Cheyne, S.M., Thompson, C.J.H., Phillips, A.C., Hill, R.M.C., Limin, S.H. 2008. Density and population estimation of gibbons (*Hylobates albibarbis*) in the Sabangau catchment, Central Kalimantan, Indonesia. Primates 49: 50–56. doi.org/10.1007/s10329-007-0063-0

Chuaynkern, Y., Duengkae, P. 2014. Decline of amphibians in Thailand. In: Heatwole, H., Das, I. (Eds.). Conservation Biology of Amphibians of Asia. Status of Conservation and Decline of Amphibians: Eastern Hemisphere. Natural History Publications. Borneo, Indonesia, pp. 233–263.

Coudrat, C.N.Z., Nanthavong, C., Ngoprasert, D., Suwanwaree, P., Savini, T. 2015. Singing patterns of White-cheeked gibbons (*Nomascus* sp.) in the Annamite Mountains of Laos. Int. J. Primatol. 36: 691–706. doi.org/10.1007/s10764-015-9849-x

Duckworth, J.W. 2008. Preliminary gibbon status review for Lao PDR 2008. Unpublished report. Flora International. Maharashtra, India.

Fan, P. 2016. The past, present, and future of gibbons in China. Biol. Conserv. 210: 29–39. doi.org/10.1016/j.biocon.2016.02.024

Fan, P., Bartlett, T.Q. 2017. Overlooked small apes need more attention! Am. J. Primatol. 79: e22658. doi.org/10.1002/ajp.22658

Gaynor, K.M., Hojnowki, C.E., Carter, N.H., Brashares, J.S. 2018. The influence of human disturbance on wildlife nocturnality. Science 360: 1232–1235. doi:10.1126/science.aar7121

Geissmann, T. 1995. Captive management and conservation of gibbons in China and Vietnam, with special reference to crested gibbons (*Hylobates concolor* group). Primate Rep. 42: 29–41.

Geissmann, T. 2002. Duet-splitting and the evolution of gibbon songs. Biol. Rev. Camb. Philos. Soc. 77: 57–76. doi.org/10.1017/S1464793101005826

Gray, T.N.E., Phan, C., Long, B. 2010. Modelling species distribution at multiple spatial scales: Gibbon habitat preferences in a fragmented landscape. Anim. Conserv. 13: 324–332. doi.org/10.1111/j.1469-1795.2010.00351.x

Hallam, D.C., Johson, A., Hannah, O.K., Seateun, S., Thamsathit, T., O' Brien, G.T., Strindberg, S. 2016. Using occupancy-based surveys and multi-model inference to estimate abundance and distribution of crested gibbons (*Nomascus* spp.) in Central Laos. Am. J. Primatol. 78: 462–472. doi.org/10.1002/ajp.22508

Harding, L.E. 2012. *Nomascus leucogenys* (Primates: Hylobatidae). Mamm. Species 44: 1–15. doi.org/10.1644/890.1

Jiang, X., Luo, Z., Zhao, S., Li, R., Liu, C. 2006. Status and distribution pattern of black crested gibbon (*Nonascus concolor jingdongenis*) in Wuliang Mountains, Yunan, China: Implication for conservation. Primates 47: 264–271. doi.org/10.1007/s10329-005-0175-3

Jolly, A. 1972. The Evolution of Primate Behavior. MacMillan Phulishing Co., Inc. New York, NY, USA.

Lemieux, C.J., Scott, D.J. 2011. Changing climate, challenging choices: Identifying and evaluating climate change adaptation options for protected areas management in Ontario, Canada. Environ. Manage. 48: 675–690. doi.org/10.1007/s00267-011-9700-x

Likert, R. 1932. A technique for the measurement of attitudes. Arch. Psychol. 22: 55.

Lwin, N., Ngoprasert, D., Sukumal, N., Browne, S., Savini, T. 2022. Status and distribution of hoolock gibbon in the newly established Indawgyi Biosphere Reserve: Implication for protected area management. Glob. Ecol. Conserv. 38: e02209. doi.org/10.1016/j.gecco.2022.e02209

Nanthavong, C. 2013. Singing behavior and population estimates of the endangered southern white-cheeked gibbon (*Nomascus siki*) in Nakai-Nam Theun National Protected Area, Lao PDR. M.Sc. thesis, Institute of Science, Suranaree University of Technology. Nakhon Ratchasima, Thailand.

National Embassy of Laos. 2021. Law on Forest. The National Assembly office. Vientiane, Lao PDR.

Nongkael, S., Thong-aree, S. 2007. Distribution, population, and habitat characteristic of Agile gibbon (*Hylobates agilis* Cuvier, 1821) and Siaman (*Symphalangus syndactylus* Ruffle (1821) in Bala Forest, Hala-Bala Wildlife Sanctuary, Narathiwat. Research and Progress Report Year 2006. Wildlife Research Division, Department of National Parks, Wildlife and Plant Conservation. Bangkok, Thailand [in Thai]

O'Brien, T.G., Kinnaird, M.F., Nurcahyo, A., Iqbal M., Rusmanto, M. 2004. Abundance and distribution of sympatric gibbons in a threatened Sumatran rain forest. Int. J. Primatol. 25: 267–284. doi.org/10.1023/B:IJOP.0000019152.83883.1c

Phommexay, P., Chaiyes, A., Duengkae, P., Chuaynkern, C., Chuaynkern, Y. 2024. Current and suitable habitat of the critically endangered northern white-cheeked gibbon (*Nomascus leucogenys*) in Lao PDR. Ecol. Montenegrina 75: 103–118. doi.org/10.37828/em.2024.75.10

Phoonjampa, R., Koenig, A., Brockelman, W.Y., Borries, C., Gale, G.A., Carroll, J.P., Savini, T. 2008. Survey of pileatus gibbon *Hylobates pileatus* in Thailand: Populations threated by hunting and habitat dagredation. Fauna Flora Int. 42: 600–606. doi.org/10.1111/j.1744-7429.2010.00743.x

Phoonjampa, R., Koening, A., Brockelman, W.Y., Borries, C., Gale, G.A, Carrol, J.P., Savin, T. 2011. Pileated gibbon density in relation to habitat characteristics and post-logging forest recover. Biotropica 43: 619–627. doi.org/10.1111/j.1744-7429.2010.00743.x

Phoutabounma, S. 2013. Ecology of Northern White Cheeked-Gibbons (*Nomascus leucogenys*) in Namkading National Protected Area, Bolikhamxay Province. National University of Laos, Vientiane, Laos.

Rawson, B.M., Clements, T., Hor, N.M. 2009. Status and conservation of Yellow-cheeked crested gibbons (*Nomascus gabriellae*) in the Seima Biodiversity Conservation Area, Mondulkiri Province, Cambodia. In: Whittaker, D., Lappan, S. (Eds.). The Gibbons. Developments in Primatology: Progress and Prospects. Springer. New York, NY, USA, pp. 387–408. doi.org/10.1007/978-0-387-88604-6_18

Rawson, B.M., Nguyen, M.H., Coudrat, C.N.Z., Roos, C., Jiang, X., Duckworth, J.W. 2020. *Nomascus leucogenys*, The IUCN Red List of Threatened Species. dx.doi.org/10.2305/IUCN.UK.20202.RLTS.T39895A180816530.en

Rowley, J.J.L., Stuart, B.L. 2014. Amphibian conservation in Vietnam, Laos, and Cambodia. In: Heatwole, H., Das, I. (Eds.). Conservation Biology of Amphibians of Asia. Status of Conservation and Decline of Amphibians: Eastern Hemisphere. Natural History Publications. Borneo, Indonesia, pp. 264–280.

Ruppell, J.C. 2013. Ecology of white-cheeked crested gibbons in Laos. Ph.D. thesis, College of Liberal Arts and Sciences, Portland State University. Portland, OR, USA. https://pdxscholar.library.pdx.edu/open_access_etds

Satdichanh, M., Millet, J., Heinimann, A., Nanthavong, K., Harrison, R.D. 2015. Using plant functional traits and phylogenies to understand patterns of plant community assembly in a seasonal tropical forest in Lao PDR. PLoS One 10: e0130151. doi.org/10.1371/journal.pone.0130151

Schmiegel, F.K.A., Monkkonen, M. 2002. Habiat loss and fragmentation in dynamic landscapes: Avian perspectives from the boreal forest. Ecol. Appl. 12: 375–389. doi.org/10.1890/1051-0761(2002)012[0375:HLAFID]2.0.CO;2

Syxaiyakhamthor, K., Ngoprasert, D., Asensio, N., Savini, T. 2020. Identifying priority areas for the conservation of the Critically Endangered northern white-cheeked gibbon *Nomascus leucogenys* in northern Lao. Oryx 54: 767–775. doi.org/10.1017/S0030605318001515

Tran, V.D., Le, T.T., Vu, T.T., et al. 2023. A review on the status and modeling of suitable habitats of the southern white-cheeked gibbon. Primates 64: 227–237. doi.org/10.1007/s10329-022-01047-4