A MARK-RECAPTURE POPULATION SIZE ESTIMATION OF SOUTHERN YELLOW-CHEEKED CRESTED GIBBON *Nomascus gabriellae* (Thomas, 1909) IN CHU YANG SIN NATIONAL PARK, VIETNAM

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ABSTRACT

The Southern Yellow-cheeked Crested Gibbon *Nomascus gabriellae* occurs in southern Vietnam and southeastern Cambodia and is an IUCN Red List Endangered species. The species occurs in Chu Yang Sin National Park (CYSNP), Vietnam, but quantitative data were lacking. We conducted an auditory point count survey in 2012 to estimate the number of gibbon groups. We analyzed the data using a mark-recapture framework in program MARK to adjust for variation in the gibbon daily calling probability. Twenty-eight gibbon groups were detected during the survey. The species inhabited only broadleaf evergreen forest, mixed forest with broadleaf and bamboo, mixed broadleaf and coniferous forest. On average, 87.5% of the gibbon groups were detected in the three survey days at each listening post. We estimated the number of gibbon groups in the surveyed area to be 32.25 (CI: 25.26–39.24) and the total number of gibbon groups in CYSNP to be 166 (CI: 135.04–203.84). Thus the estimated Southern Yellow-cheeked Crested Gibbon population of CYSNP is the largest known gibbon population in Vietnam and CYSNP is an important conservation area for the species.

Keywords: Chu Yang Sin, gibbon, mark-recapture, *Nomascus gabriellae*

INTRODUCTION

The Southern Yellow-cheeked Crested Gibbon *Nomascus gabriellae* (Thomas) occurs in southern Vietnam and southeastern Cambodia (Geissmann et al., 2000, Van et al., 2010). The species is threatened by habitat destruction, hunting, and wildlife trade (Geissmann et al., 2000) and is listed as Endangered on the IUCN Red List (Geissmann et al., 2008). The population sizes of the Southern Yellow-cheeked Crested Gibbon in Vietnam are relatively unknown. Although common in the central highlands of Vietnam, only a few rapid surveys have been conducted, with a focus on the status and distribution of the species (Geissmann et al., 2000). Additional, detailed surveys are needed for long-term gibbon-conservation planning.

Chu Yang Sin National Park (CYSNP) is located in the central highlands of Vietnam (12°52′37″N 108°26′17″E). It is one of the least disturbed and largest protected areas in Vietnam, covering an area of 59,531 ha (BirdLife International & FIPI, 2001). The forest in CYSNP is mostly intact, only slightly disturbed by humans, and is considered suitable gibbon habitat. Gibbons have been recorded in CYSNP (Le Trong Trai et al., 2008), and a brief survey recorded eight groups in a 2,500 ha area (BirdLife International, 2010), but few intensive surveys or recorded conservation actions had taken place. CYSNP is thus a potential site for conserving a viable population of the species.

As gibbon groups do not call daily, several survey days are needed to detect almost all gibbon groups (Brockelman & Ali, 1987). A recent advance to estimate gibbon density and population size is the application of a correction factor (Jiang et al., 2006), which requires estimating the daily calling probability. The calling probability can be estimated using two methods (Vu & Rawson, 2011). The first method uses long-term observations of calling behaviour of known groups. This method can lead to biased estimates of calling probability, because only a small number of gibbon groups can be followed, and how well this small number represents the entire population is uncertain. The second method relies upon data collected over multiple visits to listening posts (Jiang et al., 2006; Vu & Rawson, 2011). The calling probability estimated using this method is more representative of the entire population and does not require following known gibbon groups. This method assumes homogeneity in the calling probability among gibbon groups and occasions (days). Variation among groups (heterogeneity in calling probability), across occasions (time variation in calling probability), or due to the behaviour of surveyors (behavioural variation in detection probabilities) might occur for a number of reasons. Individual group heterogeneity in calling probability can be created by competition among groups (Raemaekers & Raemaekers, 1985). Variation in gibbon density within surveyed areas can also lead to variation in stimuli for gibbons to call (Vu & Dong, 2015) and group size can affect the calling probability (Phanchana & Gray, 2009; Vu & Dong, 2015). Additionally, variation in weather and spatial microclimate variation can lead to temporal variation in the calling probability; e.g., vocalizations of Southern Yellow-cheeked Crested Gibbon in Cambodia are less frequent in the rainy season (Rawson, 2004). Finally, surveyors are more likely to detect groups that have been detected before, resulting in a behavioural variability in detection probability. These sources of variation in detection of gibbon groups can lead to biased estimates, and should be accounted for when estimating the size of gibbon populations (Otis et al., 1978).

Our objective was to assess the population status and distribution of Southern Yellow-cheeked Crested Gibbon in CYSNP. This is one of the few studies (see also Kidney et al. 2016) in which data from auditory point counts has been analyzed in a mark-recapture framework to estimate gibbon daily calling probability and gibbon population size.

METHODS

Field surveys

We relied upon a forest cover map of CYSNP (Vietnam Administration of Forestry, 2010) to conduct the field survey and data analysis. CYSNP has five main forest types: broadleaf evergreen, mixed broadleaf and bamboo, mixed broadleaf and coniferous, coniferous, and shrub (Vietnam Administration of Forestry, 2010). Broadleaf evergreen forest, the dominant habitat type in CYSNP, was further classified into rich forest (standing tree volume = >200m^3/ha), medium forest (standing tree volume = 100-200 m^3/ha), poor forest (standing tree volume = 10-100 m^3/ha, after selective logging), and regrowth forest (standing tree volume = 10-100 m^3/ha with regenerating trees; Fig. 1).

Gibbons usually live in the upper forest canopy and are sensitive to human presence. Therefore, seeing gibbons is difficult in the field, especially during short surveys. Gibbons can be detected by their loud and long song bouts (Geissmann, 1993; Geissmann & Orgelginger, 2000). Thus, an auditory point count method was used to assess gibbon population size and density (Brockelman & Ali, 1987). A total of 26 listening posts were selected randomly (Fig. 1). Each group of three posts was surveyed simultaneously (Fig. 2) for three consecutive mornings (05:00–09:00 h) from April to July 2012. Surveyors recorded compass bearing and estimated distance to the calling group, start and end time of song bouts, and song type (duet or solo). Gibbon groups were differentiated by their locations and were considered to be separate if more than >500m apart (Brockelman & Ali, 1987). Gibbon calls can be heard at a maximum of 2 km in this mountainous region of the Central Highlands of Vietnam (Vu & Dong, 2015) and we restricted our detections to a radius of 2 km around each listening post (Fig. 1 and 2).

Data analysis

The overlap of listening posts allowed us to use MapInfo 10.0 (Pitney Bowes Business Insight, New York, US) to triangulate gibbon groups using the angle and distance data recorded by surveyors (Fig. 2). We used the Pledger models (Pledger, 2000) in MARK (White & Burnham, 1999) to estimate the number of gibbon groups in the sampled area (the area within which a gibbon could be heard) while also correcting for variation in calling probability of gibbon groups as well as time and behavioural variation. Since detection probability of a gibbon group was a combination of daily calling probability of a group (group heterogeneity), weather (time variation) and listening ability of the

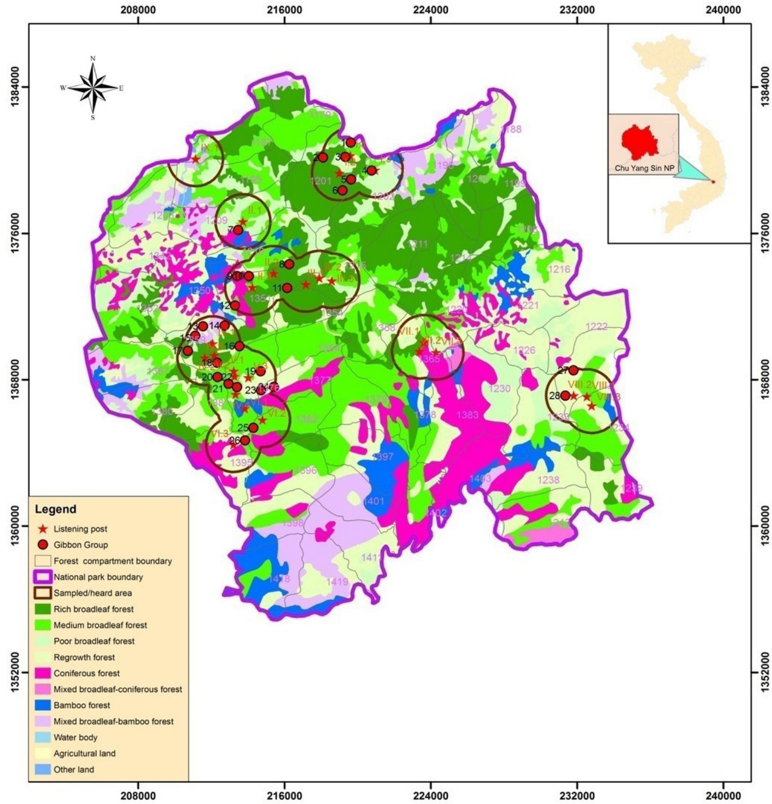

Fig. 1. Listening posts, gibbon groups, and sampling areas in Chu Yang Sin National Park in 2012.

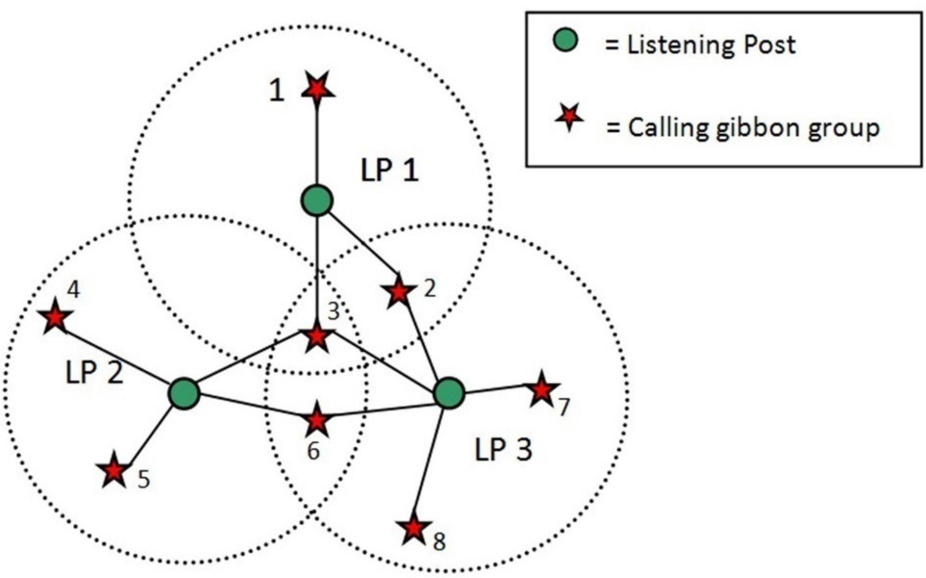

Fig. 2. Arrangement of listening posts for gibbon surveys in Chu Yang Sin National Park in 2012.

surveyors (behaviour variation), we estimated detection probability p, and redetection probability (c) of gibbon groups from the daily calling surveys by developing the following five models that incorporated these three variabilities in detection probabilities (detection probability can be considered capture probability under a mark-recapture framework):

a) $p = c$ where detection probability on day one for a group, p, is equal to the redetection probability (c) on subsequent days. Gibbon groups were not partitioned into mixtures (groups of animal with relatively homogeneous capture probabilities). This model assumes no variation in heterogeneity, time, or behaviour i.e., probability of calling is constant across gibbon groups, days, and surveyor.

b) p # c: This model considers detection affecting the probability of subsequent detection. Gibbon groups were not partitioned into mixtures. This model allows variation due to observer behaviour only.

c) $p = c$, mixture: Same as (a), but gibbon groups were partitioned into two mixtures that have homogeneous calling probabilities. This model allows variation due to heterogeneity between gibbon groups only.

d) p # c, mixture: Same as (b), but gibbon groups were partitioned into two mixtures that have homogeneous calling probabilities. This model allows variation due to heterogeneity between gibbon groups and surveyor behaviour.

e) $p = c$, time: Same as (a) with time variation; gibbon groups were not partitioned into mixtures. The model allows for variation in detection probability by survey occasion (day) only.

We evaluated and ranked the models using AICc (Akaike's information criterion adjusted for small samples), ΔAICc, AICc weight (w_i), and cumulative AICc weights (Σw_i) (Burnham & Anderson, 2002). Parameters of interest were model-averaged across the entire model set. The number of gibbon groups in CYSNP was then extrapolated based on density and the amount of suitable habitat.

RESULTS

Gibbon groups detected

Twenty-eight gibbon groups were detected during the survey: 16 groups were detected on the first day, 17 groups on the second day, and 13 on the third day (Table 1). Gibbons were only detected at 16 of 26 listening posts (61%). The areas where gibbons were detected are dominated by rich or medium broadleaf forests. Only Groups 11, 15, 22, and 24 were detected on all three days (Table 1). Ten groups were detected calling on two days and 14 groups were detected on only one day.

Distribution of gibbons

Distribution in relation to habitat

Gibbons were only detected in broadleaf evergreen forest, mixed broadleaf and bamboo forest, mixed broadleaf and coniferous forest, which are considered suitable habitat types (total suitable habitat in CYSNP = 48,535 ha; Table 2). The 26 listening posts were within these five habitat types (Fig. 1, Table 3). The total area sampled/heard around all listening posts was 10,634.8 ha, including 9,422.4 ha of suitable habitat for gibbons. Twenty-six of the 28 gibbon groups surveyed inhabited evergreen broadleaf forest, with only two groups detected in mixed broadleaf and coniferous forests (Fig. 3). Sixteen groups (57.2%) were detected in the most suitable habitat types, the closed canopies of the rich and medium broadleaf forest (eight groups in each).

Spatial distribution

The survey recorded six gibbon groups in the northern part of CYSNP, in Forest Compartments 1201 and 1202 (Vietnam Administration of Forestry, 2010). Twenty gibbon groups were detected in the centre of CYSNP in Forest Compartments 1209, 1351, 1259, 1376, 1381 and 1382. In addition, two groups were recorded in the southeast of CYSNP in Forest Compartments 1227 and 1233 (Fig. 1).

Population size estimation

The model with no variation in gibbon daily calling probability (Model a) ranked highest and suggested a detection probability of 0.48. Models that considered no difference in detection (p) vs redetection (c) probability (Models a, b, c) had more AICc weight (0.91) than models (d and e) that coded for a difference in detection and redetection probability (Table 4). We found little evidence for mixture or time effects. The estimates of the number of groups, N, in the listening area from the five models were similar and ranged from 31.02 to 33.19 groups (Table 4). Our best estimate of N, based on model-averaging and accounting for model uncertainty, was 32.25 (CI: 25.26–39.24). The estimated area of suitable habitat in the listening area was 9,422.4 ha (Fig. 1), and in CYSNP was 48,535.3 ha (19.41% of suitable habitat in the CYSNP

Table 1. Yellow-cheeked Crested Gibbon (*Nomascus gabriellae*) groups detected during the survey in Chu Yang Sin National Park in 2012.

Group ID	Order of day at LP			Forest compartment	Listening post
	First day	Second day	Third day		
1	0	0	1	1209	II.1
2	1	1	0	1351	II.3
3	1	0	0	1351	II.3
4	1	0	0	1210	II.2
5	0	0	1	1351, 1354	II.2
6	1	1	0	1351	II.3
7	1	0	0	1359	IV.2
8	0	1	1	1359	IV.2
9	1	0	0	1359	IV.2
10	0	0	1	1359	IV.1
11	1	1	1	1376	IV.2
12	1	0	0	1376	V.2
13	0	1	0	1376	VI.1
14	0	0	1	1381	VI.2
15	1	1	1	1381	IV.2
16	1	1	0	1376	VI.3
17	0	0	1	1376	VI.3, VI.2, V.1
18	0	1	1	1376	VI.3, VI.2
19	0	1	0	1382	VI.3
20	0	1	0	1382	VI.3
21	1	1	0	1201	I.2
22	1	1	1	1201	I.2
23	0	1	1	1201	I.1
24	1	1	1	1202	I.1
25	1	1	0	1201	I.2
26	1	1	0	1201	I.2, I.3
27	1	0	1	1227	VIII.2, VIII.3
28	0	1	0	1233	VIII.2, VIII.3
Total	**16**	**17**	**13**	**12**	**16**

1: Detected during the survey day
0: Not detected during the survey day

Table 2. Main habitat types in Chu Yang Sin National Park (2012).

No	Habitat	Area (ha)
I	Broadleaf evergreen forest	43,499
1.1	Rich forest	10,679
1.2	Medium forest	12,603
1.3	Poor forest	7,034
1.4	Regrowth forest	13,183
II	Mixed broadleaf and bamboo forest	4,470
III	Mixed broadleaf and coniferous forest	565
IV	Coniferous, shrub land and others (non-suitable habitat for gibbon)	10,996
Total		**59,531**

Table 3. Coverage of Yellow-cheeked Crested Gibbon call records by habitat type in Chu Yang Sin National Park in 2012.

Habitat type	Survey Area (ha)	Total Area in CYSNP (ha)	% Area Surveyed
Rich broadleaf forest	2,368.3	10,679.2	22.2
Medium broadleaf forest	3,192.1	12,602.9	25.3
Poor broadleaf forest	1,471	7,034.4	20.9
Regrowth broadleaf forest	2,090.7	13,182.9	15.9
Mixed broadleaf and bamboo forest	1,96.6	4,470.1	4.4
Mixed broadleaf and coniferous forest	1,03.7	565.8	18.3
Total	**9,422.4**	**48,535.3**	

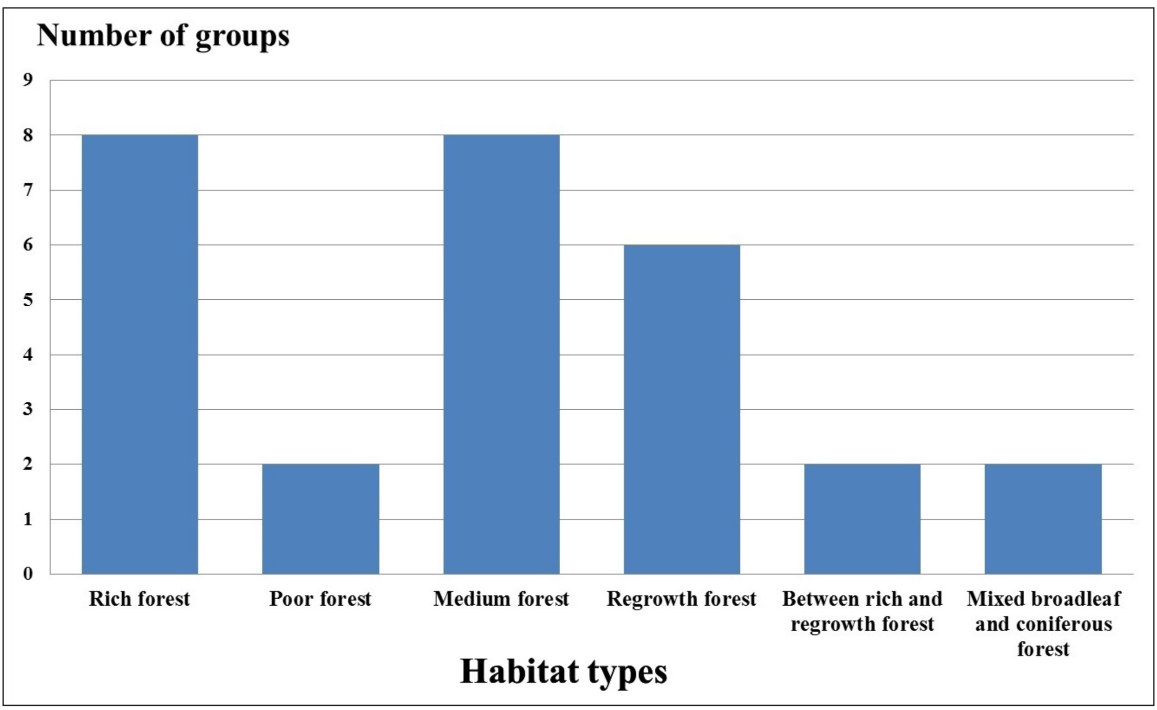

Fig. 3. Distribution of gibbon groups detected in relation to habitat types in Chu Yang Sin National Park in 2012.

Table 4. Model selection results.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	N* (group)	Standard Error
a) p = c	-19.70	0.00	0.58	1.00	2	32.18	3.20
b) p=c, mixture	-17.74	1.96	0.22	0.38	3	33.11	4.31
c) p=c, time	-16.43	3.27	0.11	0.19	4	32.03	3.14
d) p#c	-15.47	4.22	0.07	0.12	4	31.02	3.73
e) p#c, mixture	-13.46	6.24	0.02	0.04	5	31.06	3.92

*Estimated number of groups

was surveyed). Thus, our extrapolated estimate of the number of gibbon groups in CYSNP is 166 (CI: 135.04–203.84).

DISCUSSION

Detection

We found little evidence for variation in detection probability (Table 4) with an average probability of 0.48, leading to a correction factor of approximately 0.875 (correction factor = 1- $[1-p]^3$) which is similar to results from other studies (Hoang et al., 2010; Ha et al., 2011; Luu & Rawson, 2011). Greater variability in detection might be expected over larger spatial and temporal scales; e.g. weather alone would be more variable across longer time scales. With the exception of mixed broadleaf and bamboo forest, and regrowth broadleaf forest, the proportion of habitat areas we surveyed is uniform among habitat types (Table 3). We surveyed a higher proportion of mixed broadleaf and bamboo forest, and regrowth broadleaf because these types represent a small portion of the national park. Future surveys could stratify based on area of forest type, but this might be risky because of small areas for some forest types.

Population size

We estimated 166 gibbon groups inhabiting CYSNP, with gibbon density being highest in the mixed broadleaf and coniferous forest (two gibbon groups detected in 104 ha). However, this habitat type might not be the most suitable habitat for gibbons. The area of this type of forest is very small and forest units of different types border each other. Therefore some error might have occurred in determining the habitat where gibbon groups were detected. Evergreen broadleaf forest provides abundant and year-round food resources because of its high diversity in tree species. Additionally, broadleaf forest, especially with high canopy closure, is suitable for gibbon movement (Pham, 2002). Forest Compartments 1201, 1202, 1209, 1351, 1259, 1376, 1381, 1382, 1227 and 1233 are dominated mainly by rich and medium broadleaf forest and we believe they should be a high priority for patrolling and monitoring efforts. CYSNP is large with steep terrain. Hence, patrolling efforts should focus on the more accessible areas with high biodiversity.

With an estimated total of 166 gibbon groups, CYSNP apparently supports the largest number of Southern Yellow-cheeked Crested Gibbon in Vietnam. Populations of the species in Bu Gia Map National Park and Nam Cat Tien National Park were previously considered the largest in Vietnam (Rawson et al., 2011), but are apparently smaller than CYSNP (Table 5). The Southern Yellow-cheeked Crested Gibbon population of CYSNP is comparable to the populations of the protected areas in Cambodia (Channa & Gray, 2009) and our results suggest the global importance of CYSNP in the conservation of the Southern Yellow-cheeked Crested Gibbon across its range.

There are six gibbon species in the genus *Nomascus* in Vietnam, and a comparison across the genus shows that the number of *Nomascus* gibbon groups is also highest at CYSNP (Table 6). CYSNP appears to hold the largest *Nomascus* gibbon population in Vietnam. This is likely because of its large area (59,531 ha, of which 81.5% is considered suitable habitat). Additionally, the difficult terrain and the lack of human inhabitants limit the anthropogenic pressures on the species survival, and underline the importance of CYSNP to the conservation and survival of the Southern Yellow-cheeked Crested Gibbon.

Table 5. Population size of *N. gabriellae* in Vietnam.

Protected area	Area (ha)	Number of groups	Source
Bu Gia Map National Park	25,926	124	Rawson et al., 2011
Cat Tien National Park	73,878	149	Rawson et al., 2011
Chu Yang Sin National Park	59,531	166	This study
Bi Dup-Nui Ba National Park	63,938	≥25	Rawson et al., 2011
Phuoc Binh Nature Reserve	19,814	≥4	Rawson et al., 2011
Ninh Son Protected Forest	30,332	≥6	Rawson et al., 2011
Nam Nung Nature Reserve	10,499	30	Rawson et al., 2011
Ta Dung Nature Reserve	18,893	12-18	Hoang et al., 2010
Vinh Cuu Protected Forest	100,303	15	Rawson et al., 2011

Table 6. Population size of *Nomascus* species in Vietnam.

No	Species	Scientific name	Protected area	Area (ha)	Number of groups	Source
1	Western Black Gibbon	*N. concolor*	Mu Cang Chai Nature Reserve	20,293	> 14	Le & Le, 2010
2	Eastern Black Gibbon	*N. nasutus*	Trung Khanh Nature Reserve	1,656	18	Rawson et al., 2011
3	White-cheeked Gibbon	*N. leucogenys*	Pu Mat National Park	91,113	130	Luu & Rawson, 2011
4	Siki Gibbon	*N. siki*	Phong Nha - Ke Bang National Park	85,754	37	Le et al., 2009
5	Northern Yellow-cheeked Crested Gibbon	*N. annamensis*	Dak Rong Nature Reserve	37,640	56	Rawson et al., 2011
6	Southern Yellow-cheeked Crested Gibbon	*N. gabriellae*	Chu Yang Sin National Park	59,531	166	This study

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