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Cover: Cat Ba langur (*Trachypithecus poliocephalus*). Photo: T. Nadler.

# Ranging behavior of the southern yellow-cheeked gibbon (*Nomascus gabriellae*) in response to food resources and environmental variables

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**Key words:** Southern yellow-cheeked gibbon, *Nomascus gabriellae*, activity budget, Cat Tien National Park, Vietnam.

## Summary

Understanding animals' ranging behavior is critical for their management and conservation, especially for endangered and little-known species. In this study, one group of southern yellow-cheeked gibbons (*Nomascus gabriellae*), a highly threatened primate species distributed only in South Vietnam and Cambodia, was observed for one year in the lowland tropical rainforest of Cat Tien National Park in Vietnam. Data collection included the daily activities, the spatial location and movements of the group, and the location of food sources. The mean day range did not differ significantly between the dry season and the raining season ( $1.25 \pm 0.41$  vs.  $1.21 \pm 0.43$  km), but differed significantly among different months and seasons; the longest daily travel distance was 2.43 km in November and the shortest distance was 0.30 km in May, the monthly average being  $1.22 \pm 0.42$  km (mean  $\pm$  SD). There was a significant difference in the seasonal use of the home range between the two seasons. Travelling time was lowest in the fruit scarce and foliage rich dry season compared to the rainy season. The daily mean temperature, fruit and leave consumption were among those biotic and abiotic factors that were significantly and positively correlated with the day range and home range use. We conclude that the ranging behavior of the gibbons varies seasonally in response to the weather condition and food resource availability in this lowland tropical rainforest.

## Sự ảnh hưởng của nguồn thức ăn và yếu tố môi trường đến tập tính hoạt động của loài Vượn đen má vàng (*Nomascus gabriellae*)

### Tóm tắt

Sự hiểu biết về những tập tính phạm vi hoạt động của động vật là rất quan trọng đối với việc quản lý và bảo tồn chúng, đặc biệt là đối với các loài có nguy cơ tuyệt chủng và ít được biết đến. Cả hai yếu tố phi sinh học (môi trường) và các yếu tố sinh học có thể đóng góp tạo nên tập tính phạm vi hoạt động của động vật; về sau, sự thay đổi của thời gian và không gian của nó, chỉ có thể là yếu tố quan trọng đối với những động vật có bộ não lớn, trong khi nghiên cứu về điều đó là khá thiếu. Trong nghiên cứu này, một gia đình Vượn đen má vàng (*Nomascus gabriellae*), một loài linh trưởng bị đe dọa cao chỉ phân bố ở phía Nam Việt Nam và Campuchia, đã được quan sát trong vòng một năm tại khu rừng mưa nhiệt đới đất thấp của Vườn Quốc gia Cát Tiên ở Việt Nam. Quan sát bao gồm toàn bộ hoạt động hàng ngày, vị trí không gian, di chuyển và vị trí của các nguồn thức ăn. Chúng tôi đã tìm thấy có sự khác nhau đáng kể trong việc sử dụng phạm vi hoạt động giữa các mùa khác nhau. Quãng đường di chuyển trung bình hàng ngày là không có sự khác biệt đáng kể giữa mùa khô và mùa mưa ( $1,25 \pm 0,41$  so với  $1,21 \pm 0,43$  km), nhưng có khác biệt đáng kể giữa các tháng; khoảng cách di chuyển hàng ngày dài nhất là 2,43 km trong tháng 11 và khoảng cách ngắn nhất là 0,30 km trong tháng 5, trung bình hàng tháng là  $1,22 \pm 0,42$  km. Có sự khác biệt đáng kể trong việc sử dụng vùng hoạt động giữa hai mùa; từ 0,29 km<sup>2</sup> trong mùa mưa đến 0,43 km<sup>2</sup> trong mùa khô và phạm vi vùng hoạt động hàng

năm là 0,45 km<sup>2</sup>. Tương tự, tỷ lệ phân trăm thời gian được phân bổ cho các hoạt động khác nhau cũng thay đổi đáng kể qua các tháng. Nghỉ ngơi và các hoạt động xã hội cho thấy ít thay đổi hơn trong chu kỳ hàng năm so với hoạt động tìm kiếm thức ăn hoặc di chuyển. Thời gian sử dụng cho di chuyển thấp trong mùa có khan hiếm trái cây và nhiều lá non vào mùa mưa. Ngược lại, Vượn dành nhiều thời gian tìm kiếm thức ăn hơn trong mùa khô. Nhiệt độ trung bình hàng ngày, thời gian tiêu thụ trái cây và lá cây là một trong những yếu tố sinh học và phi sinh học có tương quan đáng kể và tích cực với quãng đường di chuyển hàng ngày và phạm vi hoạt động; 89,4% đối với biến nhiệt độ môi trường xung quanh và 44,4% biến thời gian tiêu thụ trái cây được giữ lại trong các mô hình tốt nhất cho chiều dài di chuyển hàng ngày, trong khi biến thời gian tiêu thụ lá cây 74,2% và biến thời gian tiêu thụ trái cây 44,8% được giữ lại trong các mô hình tốt nhất cho phạm vi hoạt động. Hơn nữa, hầu hết các điểm thay đổi hướng di chuyển hàng ngày (97,4%) có liên quan trực tiếp đến các hoạt động có ý nghĩa sinh học của chúng như kiếm ăn, di chuyển, đi ngủ... Nghiên cứu của chúng tôi cho thấy rằng tập tính sử dụng phạm vi hoạt động của Vượn biến động rất lớn theo mùa, có lẽ là để thích nghi với tính thời vụ của nguồn thức ăn sẵn có và điều kiện thời tiết ở khu rừng mưa nhiệt đới vùng thấp này.

## Introduction

The ranging patterns of arboreal frugivores, such as gibbons, are influenced by various ecological factors of their natural habitats; most of which are associated with the availability of food resources, daily activities and climate seasonality (Bartlett 2009; Coelho 1986; McConkey et al. 2003; Sarma & Kumar 2016). Diet often plays a critical role in determining home-range size regardless of taxonomic affinity (McNab 2002; McNeillage 2001; Robinson 1986). Fruit-eating species (frugivores) generally have large home-ranges (Robinson 1986), while leaf-eating species (folivores) inhabit smaller home-range areas (McNab 2002). For example, one of the folivorous gibbons, the siamang (*Symphalangus syndactylus*), has a smaller home range, shorter day range, and spends less time searching for food than other frugivorous gibbon species which have to invest more time travelling to scattered sites of fruit resources (Gittins & Raemaekers 1980; Palombit 1997).

Besides diet, several other factors may also affect the foraging strategies of social primates. Spatial and temporal patterns of resource availability, predation risk and navigation strategies have been found to affect animal foraging success (Bell 1990; Thums et al. 2011). A number of studies have examined the movement patterns of animal species to assess individual decision-making and potential travel-planning abilities using the change point test (CPT) and have revealed some of the mechanisms behind cognitive processes and foraging strategies (Asensio et al. 2011; Noser & Byrne 2014). For example, primates with larger cranial capacity and complex social systems are particularly good at planning their travel (Noser & Byrne 2014). Biologically relevant behavioral processes are more effectively detected along movement paths than in a random travel search (Noser & Byrne 2014; Schlägel & Lewis 2014; Suarez et al. 2014).

Maintaining energy balance is contingent upon food availability and the ability to exploit those food resources, which, in turn, is influenced by seasonal variation in climate (Stearns 1992). Numerous studies have documented seasonal variation in ranging patterns of primates associated with changes in the abundance, quality, or distribution of food resources (Di Fiore & Rodman 2001; Hanya 2004; Vasey 2005). Home range and diurnal activities also differ among primate populations of the same species living in different habitats. For example, the mountain gorilla (*Gorilla beringei*) was found to display different ranging patterns at different altitudes (Ganas & Robbins 2005; Nkurungiet et al. 2004). Additionally, the eastern lowland gorilla (*G. b. graueri*), also showed differences in travel distance as well as variety of foods consumed between lowland forests and forests at higher altitudes (Yamagiwa & Mwanza 1994). Clearly, more studies are needed to better understand the ranging behavior and foraging strategies of different primate species.

The southern yellow-cheeked gibbon represents a species for which there is only limited data on its behavioral ecology and no previous study of its ranging behavior. This highly threatened and regionally endemic species is distributed to the east of the Mekong River and south of the Srepok River in Cambodia, and south of the Ba River and Srepok River in Vietnam and lives exclusively



in undisturbed tropical forests and depends mostly on ripe fruits for food (Thanh et al. 2017). This gibbon species is currently categorized as endangered by the IUCN Red List (Rawson et al. 2020). It has been estimated that approximately 600 groups occur within protected areas in Vietnam (Hoang Minh Duc et al. 2015; Hoang Minh Duc et al. 2010; Rawson et al. 2011; Van Ngoc Thinh et al. 2009). At least 200 additional groups are estimated to occur in forest remnants outside protected areas (Hoang Minh Duc et al. 2015; Hoang Minh Duc et al. 2014). The Cat Tien National Park, the site for this study, is one of the strongholds for this species in Vietnam, with 149 groups recorded and an estimated density of 0.52 ( $\pm 0.47$ ) and 0.72 ( $\pm 0.08$ ) groups per square kilometer for the two different sectors of the park, Cat Loc and Nam Cat Tien (Kenyon 2008).

Based on existing knowledge about primates' range behavior, we generated the following hypotheses that were tested in this study:

1) Since the southern yellow-cheeked gibbon is highly frugivore, while fruit resources in this seasonal forest varied among different seasons (Thanh et al. 2017), their range behavior should vary among seasons: a smaller home range in fruit-rich season and a larger home range in fruit-scarce season;

2) The directional changes (changing points) of the gibbon will be associated with food resources or the gibbons mainly travel from food tree to food tree (Noser & Byrne 2014).

## Materials and methods

### Study site

This study was carried out at Cat Tien National Park (CTNP; 11°20'-11°50'N, 107°09'-107°35'E). This 71,350 ha park was designated as a protected area in 1978 and was upgraded to a national park in 1992. It is managed by the central government's Ministry of Agriculture and Rural Development. CTNP consists of two separate sections, Cat Loc in the north and Cat Tien in the south (Fig. 1).

This study focused on the southern Cat Tien sector which is one of the last remaining evergreen and semi-evergreen rain forests in Vietnam (FIPI, 1993). Cat Tien also forms a transitional zone between two major ecosystems in Vietnam: 1) the southern end of the Dalat Plateau and 2) the Mekong Delta (Polet & Ling 2004). Our study site consisted mostly of tall (> 40 m) low-land evergreen and semi-evergreen forests (130-300 m asl), in which most of the canopy trees were deciduous

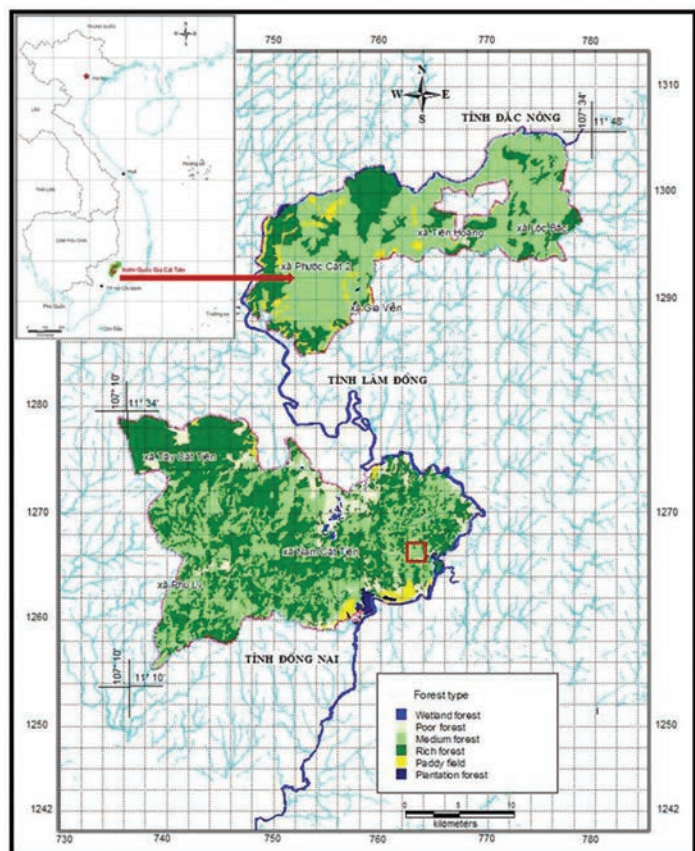


Fig.1. Location and study site of the studied gibbon group in Cat Tien National Park.

and most of the sub-canopy trees were evergreen (Fig. 2, 3). The climate is tropical with annual monsoon and there are two distinct seasons: a wet season from May to October, and a dry season from November to April (Fig. 4). The average annual temperature is 26.5° C and the average annual humidity is 82%. The monthly rainfall varies seasonally with most of the precipitation falling during the rainy season. The mean annual precipitation is 2200 mm.



**Fig.2.** Evergreen forest during the wet season. Photo: Bach Thanh Hai.



**Fig.3.** Semi-evergreen forest during the dry season. Photo: Bach Thanh Hai.

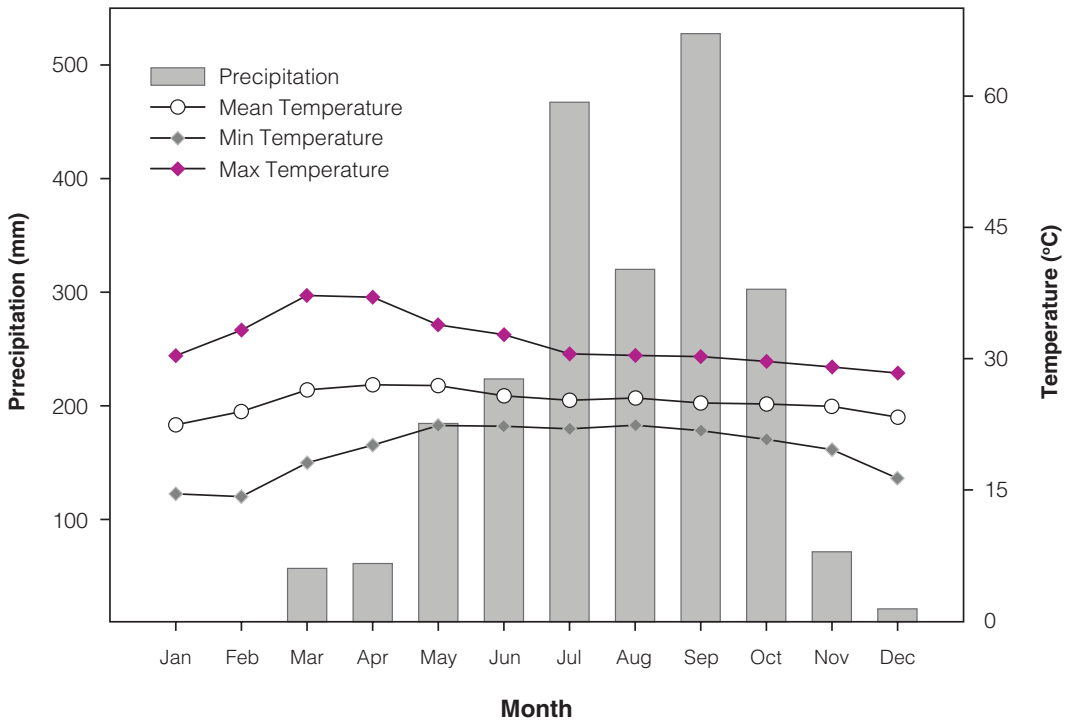


Fig.4. Monthly precipitation and temperature ranges at Cat Tien National Park, Vietnam, from November 2014 to September 2015.

### Study group

For the purpose of this study, one family group of southern yellow-cheeked gibbons had been habituated to the observers for 6 months prior to the actual study period. This study group consisted of three individuals, one adult male, one adult female, and their single offspring were monitored from the moment the group left the sleeping site in the morning (approximately 5:30 am) to the moment they settled down at a sleeping site for the evening (approximately 6:00 pm) for 10-12 days per month for 12 consecutive months, from 1<sup>st</sup> October 2014 to 30<sup>th</sup> September 2015. We collected observations for a total of 1391 hrs during 168 days, including 124 complete and 44 incomplete days. For some days the observations were interrupted due to the intergroup fighting, heavy rain or disappearance of the group in dense vegetation. Whenever possible, the observers followed the gibbon family at a distance from 15 to 30 m and observed the behavior with binoculars. All field data were collected by BTH and two experienced field assistants.

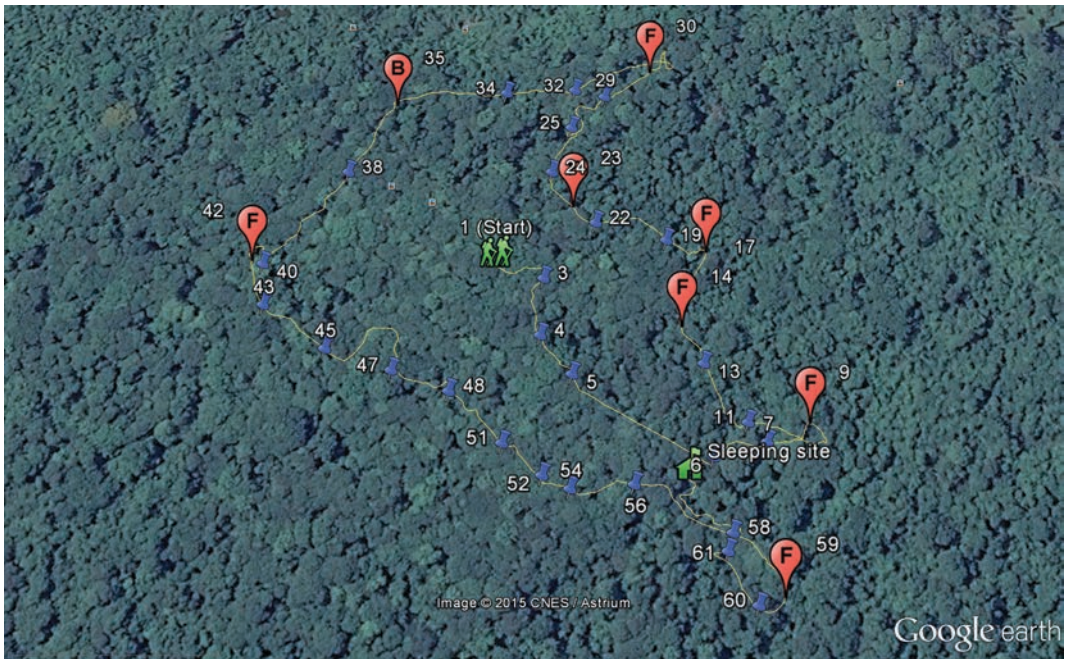
### Collection of behavioral data

The behavioral activities of the gibbons were recorded by scan sampling at 5 min intervals for 12–13 hours per day (Altmann 1974). A total of 79,900 scan samples were recorded. We recorded activities as resting, travelling, foraging, playing and other socializing and several specific activities as drinking, defecating and urinating. Resting included any inactive posture (sitting, lying, leaning, hanging and sleeping); travelling comprised movement (bipedal walking, quadrupedal climbing, brachiating, leaping, bridging and walking with occasional use of the arms). Foraging included searching, eating or swallowing food, whereas playing referred to grabbing, pulling, wrestling, manipulating other gibbon, chasing another gibbon, auto-playing, playing with branch or objects and moving through the trees with no obvious purpose like feeding or travelling. Other socializing included grooming, auto-grooming, calling (including solo, duet and alarm calls), conflict and fighting with other groups, mating, clinging to the mother and nursing the offspring. We also recorded the time and the location for each activity by each individual gibbon in order to calculate the total time invested on each activity.



### Day range and home-range calculation

Movement data were collected at 5 min intervals by transcribing the movements of the observed family with reference to a detailed route map. We did not include incomplete days in the calculation of the daily travel length as the group might have travelled after we stopped observing. The day range were digitized and measured by MapInfo Professional 12.0 software and then visualized on the Google Earth Pro software (Fig. 5). We calculated home range size by combining all the observed travel routes using the minimum convex polygon method (Linnell et al. 2001). The outline of the minimum convex polygon was digitized in MapInfo Professional 12.0 software and then converted to areas to calculate the actual home-range size.



**Fig.5.** Example of daily movements recorded on 8<sup>th</sup> April 2015: blue pins represent observed gibbon locations at 5 minute intervals; red pins represent change points; F CP relevant to feeding, B CP relevant to branches; yellow line represents gibbons route.

### Travel change-point detection

We applied the change-point test (CPT) (Byrne et al. 2009) in order to determine at which points the gibbons significantly changed their travel direction. The CPT examines routes composed of short linear segments (vectors) to detect points at which the direction of these vectors changes significantly, these are, 'change-points' in otherwise more uniform or undirected travel (Byrne et al. 2009). Accordingly, we applied the CPT to 124 daily travel paths of the complete observation days by calculating travel segments starting from the gibbons' last sleeping tree location of a given day until a change-point was discovered. This location then became the starting point for applying the CPT until the next change-point was found and so on, until no further change-points were detected for a daily path. We examined the activities observed at the change-points in order to assess whether the change-points reflect specific activities or activity patterns. In this study we used the data from instantaneous sampling at fixed intervals of 5 minutes, at variant level  $q = 6$  and with an alpha level of  $P < 0.01$  (for further details of level detection and detailed description of the CPT please see Byrne et al. (2009) and Asensio et al. (2011)).

### Data analysis

All statistical analyses were conducted in R studio 3.0 (R Core Team 2013). The amount of time dedicated to each activity was taken into a percentage to analyze diurnal and seasonal variation.



Kruskal-Wallis test was used to test the differences of time budgets between the hours of the day and between the months. The relationship between behavior activity (dependent variables) and ecological variables (independent variables) was tested using Pearson's partial correlation tests after visual inspection of residuals which indicated that assumptions for parametric statistics were not violated. When residuals did not fit the assumptions for parametric tests, we ran non-parametric Spearman rank correlations. Generalized Linear Models (GLM) with "BMA" package were run to simultaneously evaluate the possible influences of temperature, rainfall and diet on daily travel paths and home-range use concurrently. Code in R for performing the change-point test is available from <http://www.mcs.st-andrews.ac.uk/wpej/CPT.html>.

## Results

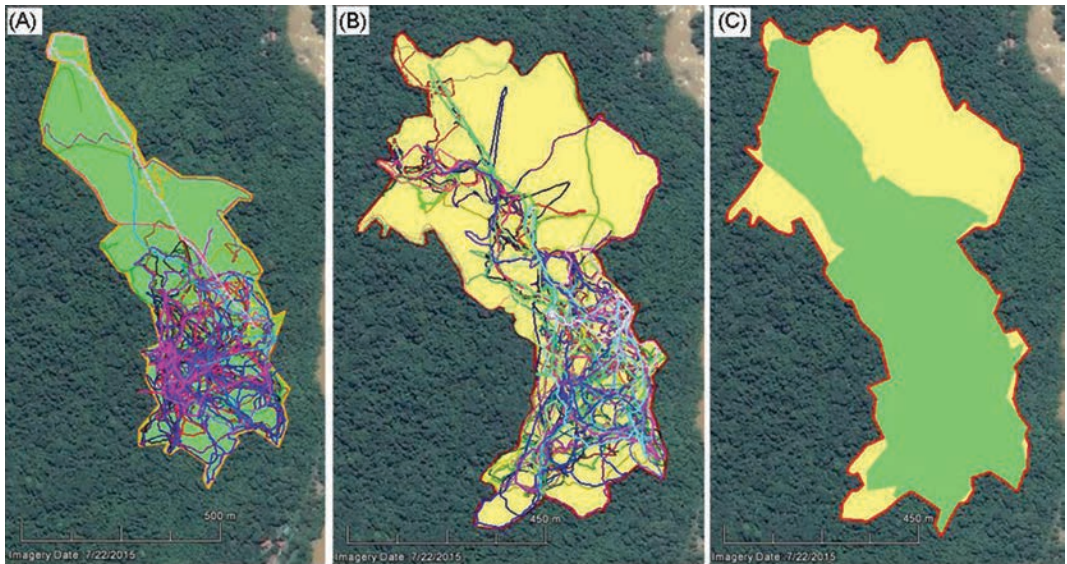
### Ranging pattern

During the 124 complete day observation periods, the study group travelled a total distance of 150 km. The mean daily travel distance was  $1.22 \pm 0.42$  km; the longest daily travel distance was 2.43 km in November (dry season) and the shortest daily travel distance was 0.30 km in May (wet season). The mean daily distance did not differ significantly between the seasons ( $1.23 \pm 0.42$  vs.  $1.21 \pm 0.43$  km), but the monthly mean travel length varied significantly (ANOVA;  $df = 11, 112$ ;  $F = 6.61$ ,  $P < 0.001$ ) (Table 1).

**Table 1.** Monthly variation in mean day range and home range use.

Season/Months	Total day range (m)	Mean $\pm$ SD (m)	Home range (ha)
<b>Rainy season</b>	<b>67,861</b>	<b>1,212 <math>\pm</math> 428</b>	<b>30.5</b>
May	8,523	947 $\pm$ 409	7.3
June	10,207	1,021 $\pm$ 279	8.3
July	14,455	1,446 $\pm$ 343	10.6
August	17,438	1,585 $\pm$ 392	13.2
September	8,887	1,270 $\pm$ 406	8.1
October	8,351	928 $\pm$ 195	11.1
<b>Dry season</b>	<b>82,512</b>	<b>1,232 <math>\pm</math> 423</b>	<b>42.7</b>
November	15,102	1,079 $\pm$ 448	15.6
December	9,963	996 $\pm$ 185	15.8
January	15,304	1,177 $\pm$ 285	12.1
February	5,880	1,470 $\pm$ 272	19.4
March	16,861	1,405 $\pm$ 340	26.8
April	19,402	1,617 $\pm$ 403	18.4
<b>Total</b>	<b>150,373</b>	<b>1,223 <math>\pm</math> 424</b>	<b>45.4</b>

The average home-range size was calculated to be 0.45 km<sup>2</sup>. The home-range use varied monthly (Mann-Whitney Rank Sum Test  $N = 12$ ,  $t = 3.69$ ,  $P < 0.001$ ) (Table 1) and seasonally. The gibbons used the smallest daily home range in the rainy season (0.30 km<sup>2</sup>) and largest daily home range in the dry season (0.43 km<sup>2</sup>) (Fig. 6). The monthly home range was the largest in March (26.8 ha) and the smallest in May (7.3 ha).



**Fig.6.** Day range and seasonal home range size of the female gibbon. A: wet season home range (green area) and daily travel tracks; B: dry season home range (yellow area) and daily travel tracks; C: superimposed home ranges for the dry and wet seasons (colored lines represent daily travel tracks for 124 days).

### Travel change point

During the 124 days, when we were able to follow the gibbons the entire day, we detected a total of 351 travel change points (CP) (Appendix 1). Most CP (97.4 %) were directly associated with biologically meaningful gibbon activities. Only 2.6% CP were not associated with any behavior. A total of 182 (51.9%) CP were related to foraging; 85 (24.2%) related to travelling, such as encountering forest gaps; 77 (21.9%) of them involved resting activities such as resting, napping and sleeping places and 7 (2.0%) were connected with social activities such as duet calls, fighting and intergroup encounters. In most cases of foraging associated CPs (178 out of 182, 97.8%), the changes in the gibbons' travel direction coincided with food sources, of which 87 cases were fruit (48.9 %), 58 cases were leaves (32.6 %), 22 cases were flowers (12.3 %) and 11 cases were other food sources (6.2 %). There were significant differences between the categories of behavior associated with CPs (ANOVA;  $df = 3, 348; F = 37.8; P < 0.001$ ). There were significant differences between the CPs related to foraging with travelling (Tukey test,  $q = 4.08, P < 0.05$ ), foraging with resting (Tukey test,  $q = 4.25, P < 0.05$ ) and foraging with socializing (Tukey test,  $q = 8.66, P < 0.05$ ).

### Relationship between daily activity budgets and ranging patterns

Over the course of the year, the study group spent 45% of their time foraging, 31.9% resting, 14.1% travelling and 9.0% on social activities. Daily travel distances were correlated significantly and positively with the travelling time budget, but were correlated negatively with the foraging time budget (Table 2).

**Table 2.** Spearman Rank correlation between percentage of time allocated to different daily activities and day range (N=124 days) and home range use (N=12 months).

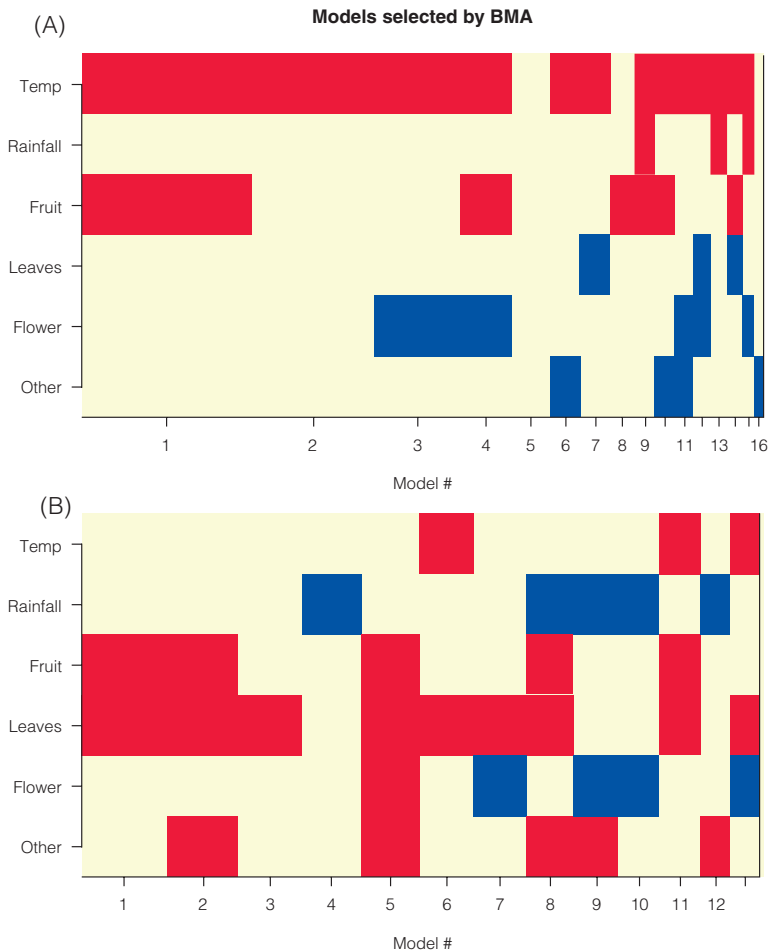
Dependent variable	Foraging		Traveling		Resting		Socializing	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
Day range	-0.206	0.022 *	0.324	0.000**	-0.067	0.460	-0.016	0.863
Home range	0.699	0.010 **	0.685	0.013 *	0.035	0.904	-0.441	0.143

\* Correlation is significant at  $P \leq 0.05$ ; \*\* Correlation is significant at  $P \leq 0.01$

The home range of gibbons was strongly influenced by foraging and time budget (Table 2). Results revealed that when the gibbon group spent more time on travelling, they also covered a greater distance; but when they spent more time on feeding, they had shorter daily travel distance.

### Factors affecting ranging pattern

During the study period, we recorded a total of 69 plant species in 35 families consumed by gibbons. Fruits were the most common food item eaten (43.3%), followed by leaves (38.4%), flowers (11.6%) and other plant parts (buds, petioles, shoots, and roots) (6%). Insects and bird eggs contributed only 0.5% to the overall diet. The GLM analysis showed that the day range of the gibbons was affected by ambient temperature and the percentage of fruit and leaves in their diet (Fig. 7).



**Fig.7.** The influences of dietary, ambient temperature and precipitation on A: day range, and B: monthly home range of gibbons. Red color indicates positive influences and blue color indicates negative influences.

The day range of the gibbons was correlated strongly and positively with temperature and fruit availability; 89.4% of ambient temperature variable was retained in the best models and 44.4% for fruit consumption variable. Further, home-range use was positively correlated with fruit and leaves consumption that retained 44.8% and 74.2%, respectively, in the best models (Table 3). Rainfall negatively affected monthly home-range use with 32.8% frequency. Whereas leaves, fruits and other parts in their diet positively influenced home-range use with occurrence frequency in the best models were 74.2%, 44.8% and 37.1%, respectively.

**Table 3.** The three best models were selected by BMA for the influences of ambient temperature, rainfall and diet on day range (N = 124 days) and home range use (N = 12 months).

Dependent variable	Source	p!=0	SD	3 models were selected by BMA			
				model 1	model 2	model 3	
Day range (m)	Intercept	100.0	744.79	-579.94	-471.48	-683.00	
	Temperature	89.4	29.17	64.65	69.73	71.63	
	Rainfall	7.0	1.03	-	-	-	
	Fruit	44.4	3.76	6.76	-	5.70	
	Leaves	9.0	1.19	-	-	-	
	Flower	27.0	8.06	-	-16.51	-12.77	
	Other	11.6	4.35	-	-	-	
	nVar			2	2	3	
	r <sup>2</sup>			0.10	0.09	0.12	
	BIC			-3.00	-1.64	-0.61	
	post prob			0.25	0.13	0.08	
	Home range (ha)	Intercept	100.0	41.29	-23.27	-40.75	17.40
		Temperature	18.2	0.69	-	-	-
Rainfall		32.8	0.011	-	-	-0.02	
Fruit		44.8	0.38	0.31	0.48	-	
Leaves		74.2	0.48	0.62	0.80	-	
Flower		33.4	0.28	-	-	-	
Other		37.1	0.52	-	0.60	-	
nVar				2	3	1	
r <sup>2</sup>				0.52	0.60	0.37	
BIC				-3.80	-3.39	-3.03	
post prob				0.13	0.10	0.09	

These results indicated that the gibbons travelled abundantly when they ate more fruit. In addition, the gibbons travelled longer distances during the warmer days than colder days. GLMs analyses also indicated that the monthly home-range use of the gibbon group was affected by rainfall and the percentage of fruits and leaves in their diet (Fig. 4).

**Discussion**

Resource availability can affect diet, ranging patterns, and overall behavior of primates (Hemingway & Bynum 2005). The amount of time spent traveling and the distances travelled can vary according to the foraging strategy of the species (Nagy-Reis & Setz 2016). Seasonality in resource production also leads to the evolution of morphological, behavioral, and physiological adaptations in consumers (van Schaik et al. 1993) as they alter their foraging strategies according to temporal food fluctuations and adopt a low-cost/low-yield strategy (Nagy-Reis & Setz 2016). We designed this study to examine the ranging behavior of the southern yellow-cheeked gibbon at different seasons



and various levels of the resource availability in a lowland tropical rainforest of Cat Tien National Park, Vietnam.

We acknowledge at the outset, that our study focused on a single group of gibbons. As such, we are limited in our ability to generalize the results to the entire population/species. We do believe however, at a time when primate biodiversity is in critical decline (Estrada et al. 2017), and there is a call to increase our study and understanding of a broader range of species (Bezanson & McNamara 2019), this study provides important and useful baseline data on a threaten species for which there is very limited information.

Our results demonstrate that for our study group of southern yellow-cheeked gibbons, their ranging behavior was strongly influenced by the availability of food resources and daily activities, and was shaped by the seasonality of the climate. The daily travel distance of the gibbons varied considerably over the course of the year and the main influencing factors were the spatial distribution and abundance of preferred resources (fruits) as well as daily average temperature. The gibbons travelled more frequently and shorter distances when ripe fruit was abundant (rainy season), but less frequently and further when ripe fruit was scarce (dry season). This indicated that the gibbons spent more energy travelling but in return were able to obtain better food with high energy. A low density of fruit trees in their home range forces them to alter their diet pattern and switch to food sources of inferior quality such as young leaves, buds or shoots.

Shifting to lower-quality food also has been reported in the frugivorous white-handed gibbon (*Hylobates lar*) in Khao Yai National Park, Thailand (Bartlett 2009). The highly flexible feeding behavior of gibbons has often been discussed as they appear to eat whatever is available in their habitat. For example, the western black gibbon (*Nomascus concolor*) living in the highly seasonal habitat in Wuliang Mountain in Yunnan, China, is nearly entirely folivorous (Fan & Jiang 2008). Many primates adjust their ranging behavior in response to seasonal variation in food availability and distribution (Bartlett 2009; Di Bitetti 2001; Di Fiore 2003; Fan & Jiang 2008; Zhang et al. 2013). and this is more often the case for frugivorous primates than for folivorous primates (Glutton-Brock & Harvey 1977) because of the higher spatial and seasonal variance in the availability of fruit compared to leaves (Janson & Chapman 1999).

In our study, the gibbon group's travel routes were associated with biologically relevant activities and largely goal oriented, especially in finding preferred food resources. About half of all travel change-points were linked to feeding, particularly on fruit. Studies have shown that primates, including gibbons, have developed efficient strategies that allow them to discover and remember the locations of out-of-sight food resources (Noser & Byrne 2007). Two such strategies include an understanding of the reproductive phenology of preferred food plant species (i.e. temporal mechanism) and a better knowledge of resource organization and habitat structure (i.e. spatial mechanism). However, gibbons are more efficient than other primates in planning their travel because of their coordinated social organization, relatively small groups and overlapping home ranges (Bartlett 2009; Di Fiore & Suarez 2007; Savini et al. 2008). Though our results provide strong support that locating food resources was the decisive factor for the daily travel directions of the gibbons, the other travel change points may constitute locations where gibbons made critical decisions about where to travel next. Furthermore, these change points might constitute locations where gibbons deviated from their planned path due to constraints in the landscape (e.g. gaps in the canopy), where they escaped predation or where they encountered competing groups of gibbons (Asensio et al. 2011). This phenomenon is also well recognized in other primates like baboons (Noser & Byrne 2007).

The annual home-range use of the southern yellow-cheeked crested gibbon group was smaller than of other more folivorous *Nomascus* gibbons (45.5 ha vs. more than 150 ha reported for other species), and was more similar in size to the home range of *Hylobates* gibbons in less-seasonal forests (Table 2). The home ranges of frugivores usually tend to be bigger than those of folivores (Ruppell 2013), and they also often correlate with the body size of primates. The siamang (*Symphalangus syndactylus*) is to more than 50% folivorous and has a smaller home range than the frugivorous

white-handed gibbon (Milton & May 1976), although it is twice the size of the white-handed gibbon. However, as noted above, we studied only one group of gibbons, and can therefore not evaluate the relationship between body size and home range use. The smaller home ranges of folivores have been attributed to the high availability of leaves compared to fruit. Fruit is usually widely dispersed and a less temporally predictable resource.

The southern yellow-cheeked gibbon is a frugivore, however their diet is flexible. They search for fruit and might travel long distances to locate them, but they rely on leaves and other items only during periods of low fruit availability. Hence, the availability of fruit appeared to be the main driver of their ranging ecology. A converse pattern of decreased ranging resulting in smaller home ranges during periods of abundant food availability has been observed in many other folivorous and frugivores primates such as sifaka (*Propithecus*) (Richard 1978), woolly spider monkey (*Brachyteles*) (de Carvalho et al. 2004), gorilla (*Gorilla*) (McNeillage 2001), colobine monkey (Colobinae) (Davies & Oates 1994), white-cheeked gibbon (*Nomascus leucogenys*) (Ruppell 2013) and eastern hoolock gibbon (*Hoolock leuconedys*) (Sarma & Kumar 2016). This consistency among species indicates that ranging patterns of primates are also an adaptation to highly seasonal environments, in which small home ranges would pose a greater risk during times of extreme weather events and low food availability. Alternatively, larger home ranges could buffer them in case of extreme climate and food scarcity (Fan & Jiang 2008).

Gibbons and their habitat in Vietnam have faced continuous threats over the past ten years. Hunting for subsistence or larger international markets, habitat disturbance and forest fragmentation are the major threats to gibbons' survival. Resources for species conservation in the country are very limited. Our study provides essential information on the ecology of gibbons and will be helpful to develop urgently required conservation measures to safeguard the remaining populations of endangered gibbons from extinction. Conservation managers should consider the effects of food resource availability and habitat quality on gibbon ranging behavior when developing corridors, selecting sites for relocation or reintroduction programs, and designating and managing protected areas and primate rescue centers.

### Authors' Contributions

BTH and JC designed the research and BTH conducted the field study. BTH, LK and AT analyzed the data and prepared the manuscript. All authors read and approved the final version of the manuscript.

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**Appendix 1.** Location and information of 351 change points were created by gibbons during 124 days following in Cat Tien National Park, 2015.

No	Change point's name	Date	Season	Time	Weather	Location (X,Y) UTM-WGS84	Activity
1	14	6, Jan	Dry	10:05	Sunny	764809, 1264372	Foraging
2	21	6, Jan	Dry	11:25	Sunny	764968, 1264328	Foraging
3	32	6, Jan	Dry	14:05	Sunny	764918, 1264687	Foraging
4	12	7, Jan	Dry	8:20	Sunny	764797, 1264824	Foraging
5	28	7, Jan	Dry	11:55	Sunny	764990, 1264580	Traveling
6	32	7, Jan	Dry	12:20	Sunny	764971, 1264540	Resting
7	34	7, Jan	Dry	12:35	Sunny	764903, 1264531	Traveling
8	40	7, Jan	Dry	14:20	Sunny	764891, 1264655	Traveling
9	12	8, Jan	Dry	7:50	Sunny	764926, 1264681	Resting
10	19	8, Jan	Dry	10:00	Sunny	764796, 1264625	Foraging
11	23	8, Jan	Dry	12:05	Sunny	764791, 1264716	Foraging
12	27	8, Jan	Dry	13:30	Sunny	764926, 1264682	Foraging
13	8	9, Jan	Dry	8:35	Sunny	764904, 1264691	Foraging
14	11	9, Jan	Dry	9:35	Sunny	764758, 1264664	Foraging
15	11	13, Jan	Dry	8:25	Sunny	765000, 1264281	Traveling
16	25	13, Jan	Dry	14:10	Sunny	764860, 1264467	Foraging
17	8	15, Jan	Dry	8:40	Sunny	764867, 1264663	Resting
18	15	15, Jan	Dry	11:05	Sunny	764990, 1264323	Foraging
19	14	20, Jan	Dry	8:25	Sunny	764557, 1264851	Foraging
20	20	20, Jan	Dry	11:20	Sunny	764625, 1264934	Foraging
21	17	21, Jan	Dry	12:10	Sunny	764712, 1264904	Resting
22	23	21, Jan	Dry	13:15	Sunny	764726, 1264790	Foraging
23	27	21, Jan	Dry	14:00	Sunny	764782, 1264807	Resting
24	11	22, Jan	Dry	11:15	Sunny	764783, 1264558	Foraging
25	17	22, Jan	Dry	12:10	Sunny	764855, 1264391	Foraging
26	9	27, Jan	Dry	11:25	Sunny	764907, 1264396	Foraging
27	15	27, Jan	Dry	13:40	Sunny	764924, 1264464	Resting
28	20	28, Jan	Dry	12:15	Sunny	764889, 1264729	Foraging
29	9	29, Jan	Dry	7:50	Sunny	764776, 1264604	Foraging
30	24	29, Jan	Dry	10:05	Sunny	764524, 1264987	Foraging
31	35	29, Jan	Dry	14:20	Sunny	764369, 1264945	Resting
32	9	3, Feb	Dry	10:45	Sunny	764520, 1264986	Resting
33	12	4, Feb	Dry	10:00	Sunny	764741, 1264306	Resting
34	22	4, Feb	Dry	14:00	Sunny	764723, 1264575	Traveling
35	16	5, Feb	Dry	10:45	Sunny	764710, 1264243	Foraging
36	24	5, Feb	Dry	13:15	Sunny	764778, 1264264	Traveling
37	32	5, Feb	Dry	14:10	Sunny	764830, 1264414	Foraging
38	8	5, Mar	Dry	7:30	Sunny	764971, 1264948	Traveling
39	12	5, Mar	Dry	7:50	Sunny	764797, 1264807	Foraging
40	21	5, Mar	Dry	13:50	Sunny	764880, 1264699	Traveling
41	8	6, Mar	Dry	7:05	Sunny	764933, 1264380	Traveling

42	11	6, Mar	Dry	7:30	Sunny	764742, 1264353	Traveling
43	23	6, Mar	Dry	10:35	Sunny	764749, 1264623	Foraging
44	29	6, Mar	Dry	15:10	Sunny	764783, 1264555	Resting
45	34	6, Mar	Dry	15:45	Sunny	764806, 1264777	Traveling
46	14	7, Mar	Dry	8:10	Sunny	764695, 1264255	Resting
47	26	7, Mar	Dry	10:30	Sunny	764770, 1264561	Resting
48	28	7, Mar	Dry	11:55	Sunny	764745, 1264619	Resting
49	33	7, Mar	Dry	13:05	Sunny	764771, 1264488	Foraging
50	39	7, Mar	Dry	14:45	Sunny	764902, 1264543	Foraging
51	10	12, Mar	Dry	8:20	Sunny	765005, 1264335	Traveling
52	23	12, Mar	Dry	11:45	Sunny	764688, 1264364	Foraging
53	29	12, Mar	Dry	13:35	Sunny	764719, 1264247	Foraging
54	38	12, Mar	Dry	15:45	Sunny	764755, 1264462	Resting
55	9	13, Mar	Dry	7:45	Sunny	764820, 1264719	Traveling
56	10	13, Mar	Dry	7:50	Sunny	764825, 1264671	Resting
57	14	14, Mar	Dry	8:25	Sunny	764666, 1264722	Traveling
58	21	14, Mar	Dry	10:30	Sunny	764997, 1264559	Foraging
59	25	14, Mar	Dry	14:05	Sunny	764964, 1264502	Traveling
60	11	19, Mar	Dry	9:15	Sunny	764759, 1264451	Foraging
61	20	19, Mar	Dry	13:25	Sunny	764816, 1264593	Resting
62	24	19, Mar	Dry	14:50	Sunny	764925, 1264551	Foraging
63	13	20, Mar	Dry	10:00	Sunny	764742, 1264426	Foraging
64	19	20, Mar	Dry	14:45	Sunny	764798, 1264511	Traveling
65	8	21, Mar	Dry	7:40	Sunny	764738, 1264543	Foraging
66	21	21, Mar	Dry	11:30	Sunny	764732, 1264344	Foraging
67	16	25, Mar	Dry	8:25	Sunny	764733, 1264243	Resting
68	12	26, Mar	Dry	7:10	Sunny	764671, 1264635	Foraging
69	18	26, Mar	Dry	9:00	Sunny	764729, 1264714	Resting
70	30	26, Mar	Dry	11:20	Sunny	764409, 1264996	Foraging
71	35	26, Mar	Dry	13:10	Sunny	764378, 1265064	Resting
72	38	26, Mar	Dry	13:30	Sunny	764413, 1265111	Traveling
73	42	26, Mar	Dry	13:50	Sunny	764458, 1265122	Foraging
74	48	26, Mar	Dry	14:50	Sunny	764485, 1265244	Foraging
75	50	26, Mar	Dry	15:00	Sunny	764545, 1265288	Resting
76	12	28, Mar	Dry	10:10	Sunny	764963, 1264509	Traveling
77	17	28, Mar	Dry	12:00	Sunny	764954, 1264409	Foraging
78	10	1, Apr	Dry	7:15	Sunny	764710, 1264313	Traveling
79	12	1, Apr	Dry	8:00	Sunny	764731, 1264236	Foraging
80	14	1, Apr	Dry	10:15	Sunny	764793, 1264416	Resting
81	16	1, Apr	Dry	10:30	Sunny	764771, 1264469	Foraging
82	18	1, Apr	Dry	10:40	Sunny	764778, 1264487	Resting
83	10	2, Apr	Dry	6:45	Sunny	764812, 1264471	Foraging
84	13	2, Apr	Dry	7:00	Sunny	764775, 1264466	Resting
85	20	2, Apr	Dry	7:45	Sunny	764843, 1264513	Foraging
86	30	2, Apr	Dry	8:50	Sunny	764819, 1264688	Resting

87	34	2, Apr	Dry	9:45	Sunny	764802, 1264769	Resting
88	43	2, Apr	Dry	13:00	Sunny	764905, 1264685	Foraging
89	49	2, Apr	Dry	14:35	Sunny	764863, 1264584	Traveling
90	55	2, Apr	Dry	15:15	Sunny	764958, 1264400	Foraging
91	8	4, Apr	Dry	9:15	Sunny	764723, 1264431	Foraging
92	20	4, Apr	Dry	13:25	Sunny	764738, 1264251	Foraging
93	9	8, Apr	Dry	6:40	Sunny	764734, 1264242	Foraging
94	14	8, Apr	Dry	7:15	Sunny	764800, 1264318	Foraging
95	17	8, Apr	Dry	7:30	Sunny	764851, 1264298	Foraging
96	23	8, Apr	Dry	8:00	Sunny	764885, 1264385	Foraging
97	30	8, Apr	Dry	8:55	Sunny	764984, 1264325	Foraging
98	35	8, Apr	Dry	10:05	Sunny	764969, 1264501	Traveling
99	42	8, Apr	Dry	11:30	Sunny	764856, 1264595	Foraging
100	59	8, Apr	Dry	14:30	Sunny	764628, 1264269	Foraging
101	8	9, Apr	Dry	7:50	Sunny	764670, 1264317	Traveling
102	33	9, Apr	Dry	11:25	Sunny	764850, 1264792	Foraging
103	43	9, Apr	Dry	13:00	Sunny	764504, 1264925	Traveling
104	47	9, Apr	Dry	13:45	Sunny	764488, 1265013	Traveling
105	52	9, Apr	Dry	14:10	Sunny	764461, 1264905	Foraging
106	9	10, Apr	Dry	8:55	Sunny	764473, 1264919	Traveling
107	14	10, Apr	Dry	9:30	Sunny	764606, 1264993	Foraging
108	27	10, Apr	Dry	14:30	Sunny	764781, 1264647	Traveling
109	8	11, Apr	Dry	6:40	Sunny	764735, 1264242	Foraging
110	12	11, Apr	Dry	7:20	Sunny	764599, 1264272	Foraging
111	19	11, Apr	Dry	8:00	Sunny	764748, 1264448	Resting
112	25	11, Apr	Dry	8:45	Sunny	764888, 1264399	Foraging
113	27	11, Apr	Dry	9:00	Sunny	764908, 1264431	Foraging
114	46	11, Apr	Dry	13:10	Sunny	764701, 1264813	Foraging
115	8	16, Apr	Dry	6:40	Sunny	764769, 1264724	Traveling
116	22	16, Apr	Dry	8:20	Sunny	764855, 1264386	Traveling
117	31	16, Apr	Dry	12:40	Sunny	764684, 1264185	Traveling
118	43	16, Apr	Dry	14:20	Sunny	764778, 1264427	Traveling
119	45	16, Apr	Dry	14:35	Sunny	764767, 1264465	Resting
120	8	17, Apr	Dry	7:00	Sunny	764768, 1264396	Foraging
121	18	17, Apr	Dry	8:55	Sunny	764711, 1264241	Foraging
122	26	17, Apr	Dry	14:15	Sunny	764870, 1264202	Traveling
123	33	17, Apr	Dry	15:05	Sunny	764927, 1264437	Foraging
124	21	22, Apr	Dry	8:05	Sunny	764603, 1264749	Foraging
125	45	22, Apr	Dry	13:10	Sunny	764774, 1264518	Resting
126	8	23, Apr	Dry	6:50	Sunny	764773, 1264492	Traveling
127	18	23, Apr	Dry	7:55	Sunny	764597, 1264167	Foraging
128	29	23, Apr	Dry	9:10	Sunny	764846, 1264403	Foraging
129	35	23, Apr	Dry	11:05	Sunny	764829, 1264520	Socializing
130	42	23, Apr	Dry	12:05	Sunny	764934, 1264619	Resting
131	56	23, Apr	Dry	14:55	Sunny	764720, 1264806	Traveling

132	16	24, Apr	Dry	7:45	Sunny	764942, 1264462	Traveling
133	21	24, Apr	Dry	9:40	Sunny	765009, 1264328	Foraging
134	28	24, Apr	Dry	11:30	Sunny	764752, 1264359	Traveling
135	31	24, Apr	Dry	12:30	Sunny	764697, 1264247	Foraging
136	8	6, Apr	Wet	6:50	Sunny	764813, 1264581	Foraging
137	23	6, Apr	Wet	10:00	Sunny	764719, 1264252	Foraging
138	10	7, May	Wet	6:25	Sunny	764694, 1264318	Traveling
139	13	7, May	Wet	6:50	Sunny	764736, 1264459	Foraging
140	20	7, May	Wet	7:45	Sunny	764968, 1264412	Foraging
141	25	7, May	Wet	8:45	Sunny	764968, 1264525	Foraging
142	33	7, May	Wet	11:00	Sunny	764823, 1264581	Traveling
143	8	12, May	Wet	9:40	Sunny	764744, 1264330	Traveling
144	16	12, May	Wet	10:30	Sunny	764874, 1264393	Foraging
145	19	12, May	Wet	11:25	Sunny	764981, 1264319	Foraging
146	12	13, May	Wet	9:00	Sunny	764808, 1264496	Foraging
147	17	13, May	Wet	9:45	Sunny	764737, 1264481	Foraging
148	23	13, May	Wet	10:25	Sunny	764710, 1264572	Traveling
149	31	13, May	Wet	13:10	Sunny	764996, 1264559	Foraging
150	11	14, May	Wet	7:30	Sunny	764749, 1264452	Foraging
151	8	21, May	Wet	7:05	Sunny	764744, 1264337	Foraging
152	11	21, May	Wet	7:30	Sunny	764764, 1264303	Foraging
153	25	21, May	Wet	10:10	Sunny	764863, 1264396	Foraging
154	28	21, May	Wet	11:10	Sunny	764969, 1264361	Traveling
155	41	29, May	Wet	13:30	light rain	764731, 1264264	Foraging
156	9	31, May	Wet	8:40	Sunny	764703, 1264429	Socializing
157	16	31, May	Wet	9:20	Sunny	764714, 1264323	Foraging
158	21	31, May	Wet	11:05	Sunny	764645, 1264236	Traveling
159	11	1, Jun	Wet	9:35	Sunny	764721, 1264235	Foraging
160	14	1, Jun	Wet	10:10	Sunny	764650, 1264239	Foraging
161	17	3, Jun	Wet	8:20	Sunny	764764, 1264397	Foraging
162	22	3, Jun	Wet	12:30	Sunny	764810, 1264483	Traveling
163	28	3, Jun	Wet	14:15	Sunny	764833, 1264400	Foraging
164	30	3, Jun	Wet	14:55	Sunny	764826, 1264366	Traveling
165	9	4, Jun	Wet	6:35	Sunny	764898, 1264489	Traveling
166	20	4, Jun	Wet	8:35	Sunny	764762, 1264459	Foraging
167	27	4, Jun	Wet	9:50	Sunny	764724, 1264364	Foraging
168	40	4, Jun	Wet	13:50	Sunny	764921, 1264622	Traveling
169	18	7, Jun	Wet	8:20	Sunny	764968, 1264338	Foraging
170	39	7, Jun	Wet	13:00	Sunny	764845, 1264572	Foraging
171	51	7, Jun	Wet	14:35	Sunny	764669, 1264583	Foraging
172	9	13, Jun	Wet	8:50	Sunny	764737, 1264342	Resting
173	22	13, Jun	Wet	11:40	Sunny	764906, 1264399	Foraging
174	30	13, Jun	Wet	14:45	Sunny	764991, 1264337	Traveling
175	10	14, Jun	Wet	6:30	Sunny	764704, 1264316	Resting
176	17	14, Jun	Wet	7:30	Sunny	764723, 1264462	Traveling



177	30	14, Jun	Wet	12:30	Sunny	764739, 1264234	Foraging
178	36	14, Jun	Wet	13:40	Sunny	764761, 1264341	Foraging
179	41	14, Jun	Wet	14:55	Sunny	764711, 1264373	Resting
180	29	22, Jun	Wet	13:00	Rain	764952, 1264369	Foraging
181	35	22, Jun	Wet	14:30	Rain	764875, 1264383	Traveling
182	12	24, Jun	Wet	9:35	Sunny	764944, 1264383	Foraging
183	20	24, Jun	Wet	12:40	Sunny	764965, 1264528	Resting
184	22	30, Jun	Wet	12:15	Sunny	764757, 1264454	Resting
185	26	30, Jun	Wet	13:05	Sunny	764730, 1264448	Traveling
186	32	30, Jun	Wet	13:55	Sunny	764817, 1264497	Foraging
187	35	30, Jun	Wet	13:40	Sunny	764910, 1264463	Traveling
188	13	1, Jul	Wet	6:50	Sunny	764741, 1264566	Resting
189	17	1, Jul	Wet	7:35	Sunny	764730, 1264507	Foraging
190	24	1, Jul	Wet	9:15	Sunny	764639, 1264693	Traveling
191	30	1, Jul	Wet	10:15	Sunny	764699, 1264611	Foraging
192	43	1, Jul	Wet	12:45	Sunny	764688, 1264399	Resting
193	50	1, Jul	Wet	14:00	Rain	764791, 1264433	Traveling
194	58	1, Jul	Wet	15:20	Rain	764956, 1264379	Traveling
195	10	2, Jul	Wet	8:45	Sunny	764809, 1264362	Traveling
196	19	2, Jul	Wet	11:20	Sunny	764801, 1264496	Foraging
197	11	6, Jul	Wet	7:35	Sunny	764876, 1264268	Traveling
198	15	6, Jul	Wet	8:35	Sunny	764994, 1264284	Traveling
199	33	6, Jul	Wet	10:55	light rain	764861, 1264458	Resting
200	41	6, Jul	Wet	11:45	light rain	764745, 1264465	Traveling
201	43	6, Jul	Wet	12:10	Cloudy	764725, 1264502	Resting
202	46	6, Jul	Wet	12:40	Cloudy	764702, 1264484	Traveling
203	52	6, Jul	Wet	14:05	Rain	764691, 1264544	Resting
204	8	14, Jul	Wet	6:45	Sunny	764829, 1264514	Traveling
205	26	14, Jul	Wet	10:00	light rain	764847, 1264199	Traveling
206	29	14, Jul	Wet	10:15	light rain	764808, 1264131	Foraging
207	44	14, Jul	Wet	12:40	Sunny	764891, 1264338	Traveling
208	46	14, Jul	Wet	12:50	Sunny	764949, 1264371	Foraging
209	11	15, Jul	Wet	8:30	Sunny	764800, 1264473	Foraging
210	18	15, Jul	Wet	9:30	Sunny	764833, 1264351	Foraging
211	24	15, Jul	Wet	10:15	Sunny	764970, 1264249	Traveling
212	12	21, Jul	Wet	9:05	Sunny	764912, 1264395	Resting
213	21	21, Jul	Wet	10:40	Sunny	764750, 1264324	Foraging
214	11	22, Jul	Wet	12:05	Sunny	764708, 1264669	Traveling
215	22	22, Jul	Wet	13:05	Sunny	764707, 1264470	Foraging
216	26	22, Jul	Wet	13:50	Sunny	764658, 1264458	Resting
217	9	23, Jul	Wet	7:00	Sunny	764705, 1264488	Foraging
218	16	23, Jul	Wet	8:55	Sunny	764737, 1264324	Traveling
219	25	23, Jul	Wet	10:05	Sunny	764714, 1264562	Foraging
220	29	23, Jul	Wet	10:45	Sunny	764810, 1264650	Resting
221	40	23, Jul	Wet	11:55	Sunny	764762, 1264464	Resting

222	51	23, Jul	Wet	13:10	Sunny	764706, 1264351	Resting
223	13	24, Jul	Wet	8:00	Sunny	764710, 1264484	Traveling
224	24	24, Jul	Wet	9:50	Sunny	764741, 1264311	Socializing
225	37	24, Jul	Wet	12:05	Sunny	764936, 1264388	Traveling
226	45	24, Jul	Wet	13:35	Sunny	764787, 1264434	Traveling
227	19	31, Jul	Wet	10:15	Sunny	764684, 1264419	Socializing
228	32	31, Jul	Wet	14:20	Sunny	764890, 1264663	Foraging
229	8	1, Aug	Wet	7:00	Sunny	764665, 1264454	Resting
230	16	1, Aug	Wet	8:15	Sunny	764686, 1264281	Socializing
231	24	1, Aug	Wet	9:00	Sunny	764792, 1264195	Foraging
232	26	1, Aug	Wet	9:10	Sunny	764824, 1264186	Foraging
233	36	1, Aug	Wet	10:25	Sunny	764743, 1264356	Resting
234	39	1, Aug	Wet	10:40	Sunny	764707, 1264363	Traveling
235	51	1, Aug	Wet	12:45	Sunny	764718, 1264572	Foraging
236	14	8, Aug	Wet	9:50	Rain	764699, 1264698	Foraging
237	24	8, Aug	Wet	11:30	Rain	764913, 1264601	Foraging
238	11	10, Aug	Wet	7:00	Cloudy	764762, 1264333	Resting
239	18	10, Aug	Wet	7:45	Sunny	764706, 1264391	Traveling
240	24	10, Aug	Wet	8:15	Sunny	764757, 1264468	Resting
241	30	10, Aug	Wet	9:10	Sunny	764812, 1264427	Traveling
242	48	10, Aug	Wet	10:50	Sunny	764632, 1264690	Foraging
243	8	16, Aug	Wet	6:10	Sunny	764719, 1264599	Foraging
244	37	16, Aug	Wet	9:50	Sunny	764721, 1264234	Resting
245	46	16, Aug	Wet	10:50	Sunny	764981, 1264277	Foraging
246	59	16, Aug	Wet	12:30	Sunny	764823, 1264411	Resting
247	61	16, Aug	Wet	12:50	Sunny	764765, 1264396	Foraging
248	9	19, Aug	Wet	6:25	Sunny	764701, 1264597	Foraging
249	11	19, Aug	Wet	7:00	Sunny	764724, 1264624	Foraging
250	17	19, Aug	Wet	8:25	Sunny	764663, 1264610	Traveling
251	28	19, Aug	Wet	12:10	Sunny	764897, 1264396	Foraging
252	11	20, Aug	Wet	7:30	Sunny	764694, 1264604	Resting
253	16	20, Aug	Wet	8:30	Sunny	764708, 1264516	Foraging
254	21	20, Aug	Wet	9:35	Sunny	764657, 1264458	Traveling
255	33	20, Aug	Wet	11:25	Sunny	764707, 1264591	Traveling
256	44	20, Aug	Wet	13:55	Sunny	764892, 1264693	Foraging
257	52	20, Aug	Wet	14:45	Sunny	764799, 1264547	Foraging
258	13	21, Aug	Wet	7:40	Sunny	764633, 1264684	Resting
259	25	21, Aug	Wet	10:10	Sunny	764772, 1264635	Resting
260	29	21, Aug	Wet	10:55	Sunny	764750, 1264683	Foraging
261	45	21, Aug	Wet	13:45	Sunny	764746, 1264329	Traveling
262	50	21, Aug	Wet	14:20	Sunny	764912, 1264284	Foraging
263	14	22, Aug	Wet	7:50	Sunny	764687, 1264799	Socializing
264	25	22, Aug	Wet	9:50	Sunny	764790, 1264540	Resting
265	38	22, Aug	Wet	12:05	Sunny	764726, 1264363	Socializing
266	8	29, Aug	Wet	7:05	Sunny	764761, 1264555	Resting

267	10	29, Aug	Wet	7:15	Sunny	764793, 1264570	Traveling
268	13	29, Aug	Wet	7:30	Sunny	764799, 1264528	Traveling
269	23	29, Aug	Wet	9:30	Sunny	764702, 1264589	Resting
270	34	29, Aug	Wet	11:00	Sunny	764776, 1264717	Resting
271	28	31, Aug	Wet	11:30	Sunny	764978, 1264387	Foraging
272	31	31, Aug	Wet	11:45	Sunny	764994, 1264284	Foraging
273	10	5, Sep	Wet	9:20	Sunny	764903, 1264640	Foraging
274	16	5, Sep	Wet	10:30	Sunny	764753, 1264465	Foraging
275	23	5, Sep	Wet	13:10	Sunny	764931, 1264392	Foraging
276	12	6, Sep	Wet	8:25	Sunny	764730, 1264427	Foraging
277	19	6, Sep	Wet	10:00	Sunny	764884, 1264386	Resting
278	11	7, Sep	Wet	7:45	Sunny	764729, 1264506	Foraging
279	18	7, Sep	Wet	10:25	Sunny	764762, 1264680	Foraging
280	22	7, Sep	Wet	11:15	Sunny	764900, 1264628	Foraging
281	11	13, Sep	Wet	8:10	Sunny	764750, 1264342	Foraging
282	15	13, Sep	Wet	10:00	Sunny	764713, 1264576	Foraging
283	8	16, Sep	Wet	7:10	Sunny	764973, 1264386	Foraging
284	12	16, Sep	Wet	9:05	Sunny	764942, 1264364	Resting
285	11	30, Sep	Wet	9:20	Sunny	764970, 1264341	Traveling
286	20	9, Oct	Wet	10:55	Sunny	764906, 1264673	Traveling
287	23	9, Oct	Wet	11:30	Sunny	764940, 1264669	Foraging
288	27	9, Oct	Wet	12:20	Sunny	764871, 1264738	Resting
289	13	10, Oct	Wet	8:00	Sunny	764854, 1264895	Traveling
290	8	17, Oct	Wet	7:35	Sunny	764959, 1264543	Resting
291	16	17, Oct	Wet	9:55	Sunny	764904, 1264288	Foraging
292	26	17, Oct	Wet	13:20	Sunny	764712, 1264348	Foraging
293	21	18, Oct	Wet	12:25	Sunny	764921, 1264624	Traveling
294	26	18, Oct	Wet	13:45	Sunny	764937, 1264532	Foraging
295	7	19, Oct	Wet	7:50	Sunny	764901, 1264555	Foraging
296	10	26, Oct	Wet	7:55	Sunny	764977, 1264351	Resting
297	13	26, Oct	Wet	8:50	Sunny	764939, 1264313	Foraging
298	22	26, Oct	Wet	11:05	Sunny	764806, 1264382	Resting
299	27	26, Oct	Wet	12:25	Sunny	764723, 1264340	Foraging
300	11	27, Oct	Wet	8:30	Sunny	764914, 1264571	Foraging
301	23	27, Oct	Wet	12:00	Sunny	764622, 1264899	Resting
302	13	28, Oct	Wet	11:30	Sunny	764391, 1265023	Resting
303	10	30, Oct	Wet	10:25	Sunny	764416, 1265266	Resting
304	17	30, Oct	Wet	12:00	Sunny	764402, 1265210	Foraging
305	22	30, Oct	Wet	13:10	Sunny	764470, 1265192	Traveling
306	8	4, Nov	Dry	7:50	Sunny	764726, 1264707	Foraging
307	11	5, Nov	Dry	9:25	Sunny	764486, 1265076	Resting
308	16	5, Nov	Dry	12:45	Sunny	764465, 1265198	Resting
309	9	6, Nov	Dry	8:25	Sunny	764419, 1265301	Foraging
310	17	6, Nov	Dry	11:15	Sunny	764419, 1265207	Resting
311	22	6, Nov	Dry	12:30	Sunny	764539, 1265108	Foraging

312	26	6, Nov	Dry	13:05	Sunny	764480, 1265025	Resting
313	16	7, Nov	Dry	9:10	Sunny	764967, 1264526	Foraging
314	21	7, Nov	Dry	10:30	Sunny	764756, 1264393	Resting
315	23	7, Nov	Dry	11:35	Sunny	764700, 1264419	Resting
316	8	11, Nov	Dry	7:00	Sunny	764884, 1264388	Foraging
317	12	11, Nov	Dry	7:55	Sunny	764968, 1264350	Resting
318	24	11, Nov	Dry	11:10	Sunny	764799, 1264270	Foraging
319	28	11, Nov	Dry	12:55	Sunny	764753, 1264317	Resting
320	8	12, Nov	Dry	7:30	Sunny	764866, 1264560	Foraging
321	16	12, Nov	Dry	8:55	Sunny	764954, 1264367	Traveling
322	20	12, Nov	Dry	11:35	Sunny	764903, 1264373	Foraging
323	8	13, Nov	Dry	8:35	Sunny	764965, 1264372	Foraging
324	18	13, Nov	Dry	10:55	Sunny	764692, 1264374	Traveling
325	8	14, Nov	Dry	7:35	Sunny	764840, 1264481	Foraging
326	10	14, Nov	Dry	8:25	Sunny	764875, 1264562	Foraging
327	13	14, Nov	Dry	8:45	Sunny	764950, 1264547	Foraging
328	8	19, Nov	Dry	7:25	Sunny	764939, 1264570	Traveling
329	26	19, Nov	Dry	11:40	Sunny	764741, 1264787	Foraging
330	9	20, Nov	Dry	8:40	Sunny	764936, 1264379	Foraging
331	16	20, Nov	Dry	10:35	Sunny	764774, 1264400	Foraging
332	16	22, Nov	Dry	12:10	Sunny	764858, 1264590	Resting
333	8	25, Nov	Dry	9:35	Sunny	764436, 1265277	Foraging
334	15	25, Nov	Dry	12:05	Sunny	764645, 1265260	Foraging
335	16	27, Nov	Dry	9:10	Sunny	764964, 1264541	Foraging
336	13	28, Nov	Dry	8:55	Sunny	764840, 1264263	Foraging
337	16	28, Nov	Dry	10:00	Sunny	764896, 1264274	Foraging
338	23	28, Nov	Dry	11:15	Sunny	764869, 1264332	Foraging
339	12	1, Dec	Dry	10:50	Sunny	764433, 1264979	Foraging
340	16	1, Dec	Dry	12:25	Sunny	764384, 1265053	Foraging
341	9	7, Dec	Dry	10:00	Sunny	764939, 1264675	Foraging
342	11	9, Dec	Dry	12:05	Sunny	764532, 1265013	Foraging
343	18	15, Dec	Dry	13:40	Sunny	764882, 1264875	Resting
344	8	17, Dec	Dry	10:00	Sunny	764717, 1264810	Foraging
345	9	21, Dec	Dry	8:20	Sunny	764580, 1265002	Foraging
346	17	21, Dec	Dry	13:05	Sunny	764391, 1265010	Foraging
347	8	22, Dec	Dry	8:30	Sunny	764540, 1264964	Resting
348	16	22, Dec	Dry	11:05	Sunny	764372, 1265012	Foraging
349	12	23, Dec	Dry	8:55	Sunny	764638, 1264816	Traveling
350	11	24, Dec	Dry	11:10	Sunny	764554, 1264726	Foraging
351	14	24, Dec	Dry	11:35	Sunny	764701, 1264720	Foraging

## The development of pelage coloration in Cat Ba langurs (*Trachypithecus poliocephalus*)

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**Key words:** Cat Ba langur, *Trachypithecus poliocephalus*, development pelage coloration

### Summary

Cat Ba langurs are endemic to Vietnam and occur only on Cat Ba Island in Halong Bay in northern Vietnam. With currently only about 60 individuals they represent the world's rarest colobine species.

Description and photographic documentation of the development of the pelage coloration from the natal coat to the coat of infants, juveniles and adults can be a helpful tool to assess the age of individuals in field studies and helps to estimate the age of individuals, confiscated from the illegal trade. The documentation of the development of pelage coloration recorded on a number of captive individuals at the Endangered Primate Rescue Center, and also the pelage coloration development recorded of representatives of the wild population on Cat Ba Island show significant differences in the speed of pelage coloration development. This makes an exact determination of the age impossible. The differences between fast and slow development of the pelage coloration become clearer with the age of the individuals.

Cat Ba langurs are born with uniformly light orange fur, which over a period of about one to one and a half years changes to a coloration similar to those of adult individuals. Subadults differ from adults in a somewhat smaller body size and by some individuals only in slightly extended yellow hairs on the shoulders.

## Sự phát triển màu sắc lông ở loài Voọc Cát Bà (*Trachypithecus poliocephalus*)

### Tóm tắt

Voọc Cát Bà là loài đặc hữu của Việt Nam, loài chỉ phân bố ở đảo Cát Bà trong Vịnh Hạ Long, miền Bắc Việt Nam. Hiện nay chỉ có khoảng 60 cá thể còn tồn tại nên được xem là loài khiếm hiếm nhất trên thế giới. Việc mô tả và tài liệu hóa bằng hình ảnh sự thay đổi hình thái màu sắc bộ lông của loài trong các giai đoạn phát triển là hết sức cần thiết. Đây có thể là một công cụ hữu ích để đánh giá độ tuổi các cá thể trong nghiên cứu thực địa và giúp ước lượng độ tuổi các cá thể được tịch thu từ hoạt động buôn bán động vật hoang dã. Việc nghiên cứu và tổng hợp sự thay đổi màu sắc lông qua các giai đoạn phát triển của loài đã được thực hiện trên các cá thể được nuôi tại Trung tâm Cứu hộ Linh trưởng Nguy cấp. Khi so sánh sự thay đổi màu sắc bộ lông trên các cá thể ngoài tự nhiên tại đảo Cát Bà, chúng tôi đã phát hiện ra sự khác biệt đáng kể ở tốc độ thay đổi màu sắc lông giữa hai nhóm. Điều này đã khiến cho việc xác định độ tuổi của các cá thể một cách chính xác là không thể, nếu chỉ thông qua màu sắc lông. Khác biệt giữa tốc độ thay đổi nhanh hay chậm màu sắc lông chỉ có thể nói rõ khi độ tuổi của cá thể được xác định. Voọc Cát Bà được sinh ra với màu sắc lông vàng cam nhạt, sau khoảng một năm đến một năm rưỡi thì đổi sang màu sắc lông của cá thể trưởng thành. Nhưng cá thể bán trưởng thành chỉ khác cá thể trưởng thành ở kích thước cơ thể chứ không phải màu sắc lông.

### Introduction

The Cat Ba langur is amongst the world's rarest and most endangered primates. The species is listed as 'Critically Endangered' (IUCN) and also as one of the 'The World's 25 Most Endangered Primates' (Schwitzer et al. 2019)



Cat Ba langurs occur only on Cat Ba Island in Ha Long Bay in northern Vietnam, an island with a total surface of 285 km<sup>2</sup>. In the past the distribution area was roughly identical with the land area of the Cat Ba National Park comprising 98 km<sup>2</sup> (Tordoff et al. 2004), but it decreased with the dramatic decline of the langur population during the last decades. Since the first comprehensive surveys in 1999 and 2000 (Nadler & Ha Thang Long 2000; Nadler & Brockman 2014), which estimated the population between 104 and 135 individuals, the population has shrunk dramatically. And while in 2015 the population consisted of an estimated 70 individuals (Leonard & Raffel 2015) it counts currently only about 60 individuals (Cat Ba National Park, pers.comm.).

Over the years ten individuals have been kept at the Endangered Primate Rescue Center (EPRC), Cuc Phuong National Park, Vietnam, including five individuals which were born here and grew up here, and another one born at 2020. These six individuals are the only ones born in captivity. The founders of the small captive population at the EPRC are two animals confiscated from poachers on Cat Ba Island.

Hendershott et al. (2019) gives the first description on pelage coloration development in Cat Ba langurs based on field observations. Our studies are conducted in captivity and on several individuals and give a more detailed insight and show also individual differences.

Such detailed descriptions of pelage development are helpful to identify the age of individuals in the field, assess the age of confiscated individuals and provides an interesting source for taxonomic comparisons.

## Material and Methods

The development of pelage and skin coloration of six Cat Ba langurs born at the EPRC (Table 1) was recorded. Photos and notes were taken every one to two weeks from birth until the age of three months and later on every two to three weeks. Additional information on the pelage coloration and its development of four new born individuals was collected during surveys on Cat Ba Island in 1999 and 2000.

**Table 1.** Cat Ba langurs born at the Endangered Primate Rescue Center, Vietnam.

<b>EPRC Studbook No.</b>	<b>sex</b>	<b>born</b>
15-04	male	2.6.2003
15-06	male	1.3.2010
15-07	female	25.6.2012
15-08	male	2.8.2014
15-09	male	8.2.2018
15-10	female	10.7.2020

## Results

### New born animals

Cat Ba langurs are born with uniformly light yellow-orange pelage (Fig.1), sometimes already with a brownish tinge on the back. The fur on the distal half of the tail might in newborns already be intermingled with brown hairs and has a dark brown tip (Fig 2). On the crest of the head there might be a few brown hairs, also in individuals with an otherwise uniformly yellow-orange pelage. The skin of the face, ears, fingers, toes and ischial callosities is light and not pigmented. The eyebrows are sparsely but some hairs are very long (up to 3 cm; Fig. 1). The growth direction of the hair at the back of the head points upward and even in the newborn forms a very small crest on the top of the head. There are no sexual differences in pelage coloration of new born individuals.



**Fig.1.** Cat Ba langur 21 days old (EPRC, male 15-06) with the typical bright orange natal coat. All Photos: Tilo Nadler.



**Fig.2.** New born Cat Ba langur – first day (EPRC, male 15-04). New born individuals can show already a brownish tinge on the back and a darker coloration of the tail with a dark brown tip.

### First month (1 – 30 days)

During the first month there is no change of the pelage coloration and the hairless skin of face, fingers and toes is unpigmented (Fig. 3).



**Fig.3.** Cat Ba langur 21 days old (EPRC, male 15-06). During the first month are no remarkable color changes of the pelage and the naked parts. Face, ears fingers and toe are flesh-colored.

### Second month (31 – 60 days)

At the beginning of the second month the hairless skin areas of face, ears, fingers and toes start to darken and get a grayish tinge (Fig. 4). The hair on the distal half of the tail starts to grow and begins to form a thin tassel (Fig. 5).



**Fig.4.** Cat Ba langur 42 days old (EPRC, female 15-07). The naked parts, face, ears and fingers start to darken and get a grayish tinge.



**Fig.5.** Cat Ba langur 42 days old (EPRC, female 15-07). The hairs on the distal half of the tail are growing and form a thin tassel.

### Third month (61 – 90 days)

With two and a half month face and ears get darker gray, the fingers and the back of the hands and feet get dark brown and turn black towards the end of the month. The black hair on the back of the hand is then mixed with silvery grey hairs. Grey hairs extend to the wrists and to the ankles (Fig. 6). A thin line of dark greyish hair reaches from the hands on the outer forearm to the elbow. The back starts to darken from the shoulder girdle to the root of the tail and the yellow-orange natal coat changes to very light brown. A small part at the base of the tail darkens and by end of the third month forms a dark brown band around the base of the tail. The color of the ischial callosities changes to grey (Fig. 7).



**Fig.6.** Cat Ba langur 76 days old (EPRC, female 15-07). Face and ears become darker greyish; the fingers to the dorsum of the hand are dark brown and turn during the month to blackish, mixed with silvery grey hairs.



**Fig.7.** Cat Ba langur 76 days old (EPRC, female 15-07). The back starts to darken from the shoulder girdle to the root of the tail. A small part of the base of the tail darkens as a ring. The color of the ischial callosities changes to grey.

### Fourth month (91 – 120 days)

With increasing age the speed of the pelage change shows individual, but not sex specific differences. In some animals the coloration of the back from below the shoulders to the base of the tail changes to brown already, with the yellow-orange baby fur still shining through (Fig. 8). Sparse silvery hairs mark the triangle over the lower back and the line on the thighs. The brownish parts on the legs extend along the outside of the thighs and form a brownish stripe from the back to the ankle. The inside of the thighs and the knees are still light brown to yellow-orange. A patch around the elbow starts to darken and is connected with a thin darker line along the outside of the forearm to the little

finger (Fig. 9). The fur on hands and feet is no longer uniformly black but there are grey hairs growing on the toes and the proximal phalanges of the fingers. The face gets darker and the ears are already almost black (Fig. 10). This phase of the coloration change was also observed in infants of the wild langurs on Cat Ba Island (Nadler, pers. obs.). These described changes are the ones observed in most infant Cat Ba langurs, however one animal at the EPRC (male 15-06) showed a much slower change in the pelage coloration (Fig. 11). A photo by Hendershott et al. (2019; Fig 5b) also shows a slow coloration change; it shows an infant, which is 119-122 old and still has the nearly complete orange-yellow natal color.



**Fig.8.** Cat Ba langur 113 days old (EPRC, female 15-07). During the fourth month the back beneath the shoulders to the proximal part of the tail changed to brown.



**Fig.9.** Cat Ba langur 113 days old (EPRC, female 15-07). Few silvery hairs mark already the triangle over the lower back and the line on the thighs.





**Fig.10.** Cat Ba langur 113 days old (EPRC, female 15-07). The face becomes darker and the ears are already nearly black. The fur on hands and feet is not completely black, on the toe and proximal phalanges growing grey hairs.



**Fig.11.** Cat Ba langur 110 days old (EPRC, male 15-06). This individual shows a slow change of the pelage coloration. The dark brown ring at the root of the tail appears mostly already end of the third month and on the back start to grow brown fur (cf. Fig. 9).

### Fifth month (121 – 150 days)

During this month the back becomes darker and the yellow-orange natal pelage disappears. More silvery hairs grow on the triangle over the base of the tail. The legs darken and the lower legs are already predominantly brown (Fig. 12; 13). Animals with a slow coloration change still maintain a large area of yellow-orange hair on the back and yellow-orange hair on the lower legs (Fig 14). The color change of the hairless skin parts also differs between animals with slow and those with fast coloration change. The face of the first ones can still be light grey, whilst in the latter ones it is almost black (Fig. 15, 16).



**Fig.12.** Cat Ba langur 139 days old (EPRC, female 15-07). The back becomes darker and the yellow-orange baby pelage disappears.



**Fig.13.** Cat Ba langur 140 days old (EPRC, male 15-04). This male has a similar development to the female 15-07 (cf. Fig. 12).



**Fig.14.** Cat Ba langur 150 days old (EPRC, male 15-06). This male with a slower development has still a large yellow part on the back and yellow lower legs.



**Fig.15.** Cat Ba langur 136 days old (EPRC, male 15-06). Individuals with slower development of pelage change show also a slower color change of the naked parts. The face can be already nearly black (cf. Fig. 16).



**Fig.16.** Cat Ba langur 142 days old (EPRC, male 15-08), with a nearly black face.

#### Sixth to seventh month (150 – 210 days)

The pelage overall darkens, but at this age individual coloration can differ notably and some animals undergo certain coloration changes two months earlier than others. Individuals with fast coloration change have already a dark brown back, brown legs and nearly completely brown arms (Fig. 17). An animal photographed by Hendershott et al. (2019; Fig. 6b, and likely the same individual pictured on Fig. 5b) identified to be between 180-211 days old appears to be an example of slow coloration change.



**Fig.17.** Cat Ba langur 150 days old (EPRC, male 15-04). The individual shows a fast coloration change. Back and legs are already dark brown. Animals about a half year old can show a markable difference in the development of the pelage coloration (cf. Fig. 14).

### Eighth to tenth month (210 – 300 days)

Individuals with faster pelage coloration development changes now rapidly; more silvery-grey hairs grow on the lower back, and the back, legs and proximal part of the tail gets dark brown. Simultaneously the yellow-orange fur on the distal part of the tail thickens to form a tassel (Fig. 18). In individuals with slow coloration change the yellow-orange fur still reaches from the shoulder to the middle of the back and the fur on the lower back is intermingled with yellow hairs. In these individuals arms and lower legs are still light brown and about three quarter of the distal part of the tail is still yellow to light brown (Fig. 19).



**Fig.18.** Cat Ba langur 228 days old (EPRC, female 15-07). Back and thigh and the proximal half of the tail are preponderant already dark brown. On the distal part of the tail grow the orange hair to thicken the tassel.



**Fig.14.** Cat Ba langur 221 days old (EPRC, male 15-06). The individual shows a slower coloration change. On the back is still a rest of the yellow natal fur visible. Arms and lower legs are still yellow to light brown and the tail just starts to darken.

### Eleventh month to one year (300 – 360 days)

Differences in the pace of pelage coloration might become even more apparent. Animals with fast pelage coloration change are almost completely brown besides the yellow-orange head and shoulders and the brown distal part of the tail. Animals with a slow coloration change might still have extensive yellow-orange pelage areas. There can be as much as a three months coloration development difference between individuals of the same age.



### One year to one and a half year (360 days – 550 days)

At the age of one individual with fast coloration development reach almost adult pelage coloration, only the fur of back and tail might be intermingled with very sparse yellow brown hairs. The pelage coloration of these individuals closely resembles the one of the adults only on the fur on the back and tail is intermingled with sparsely light hair. The yellow-light brownish tassel on the tail has now disappeared. The yellow fur area around the shoulders is still broader than in adults, and the silvery band from the thighs to the middle of the back, typical for adults is visible (Fig. 20). Individuals with a slow coloration change have at this age still extensive areas of yellow-light brown fur (Fig. 21).



**Fig.20.** Cat Ba langur 485 days old (EPRC, male 15-06). Animals with a slower reach coloration similar to adult also with less than one and a half year. The yellow part around the shoulders is broader than in adults.



**Fig.21.** Cat Ba langur 399 days old (EPRC, male 15-06). With the slow color change there are still larger parts in change from yellow to brown.

### Sub adult and adult animals

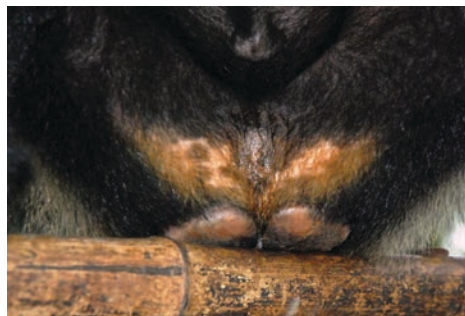
Sub adult individuals can be recognized by a smaller body size and an area of yellow fur around the shoulders which is more extensive than in older individuals. With about three years the animals have the final coloration of an adult. The fur is dark chocolate-brown; the head and neck down to shoulders are bright golden-brown. The coloration on the head in older males tends to be light almost ivory colored. The hair on the top head form a crest and central hairs of this crest are often brown tipped. A silvery band runs from the thighs to middle of the back and the base of the tail and forms an upside down V-shape with the tip on the lower back. The hairs forming this V are dark brown at the base and only the distal 5-10 mm of the hairs are bright silvery grey, giving the band a frosted appearance.

The dorsal sides of feet and hands have small individually differently sized light patches of the same color as shoulders. The bare skin of face, ears, hands and feet is black. The tail is dark brown like the back. In animals above 15 years grey to white hairs might appear on the distal half of the tail (Fig 22) and then resembles the tail of the closely related white-headed langur, which is brown in the proximal and white in the distal part.



**Fig.22.** Cat Ba langur female (EPRC 15-01) 14 years old shows in the distal half of the tail intermingled whitish and grey hairs which resembles to the white headed langurs which have the distal half of the tail completely white.

There is no major difference between the pelage of adult males and females other than the pubic patch characteristic for all female Vietnamese “limestone langurs” which has individually characteristic irregular pigmentation, and pale white to yellowish hairs (Fig. 23). Form and pigmentation of this patch can be used for individual identification, though it might be difficult in the wild to get a close enough look to exactly assess the patch. However since there is no other sexual dimorphism the presence of a pubic patch allows to identify the sex of the individuals in a group during field observations, in particular on photographs which show the rear view of walking or jumping animals (Fig. 24).



**Fig.23.** Pubic patch of an adult Cat Ba langur female. Form and extent are individually different.



Fig.24a,b,c,d. During field observation females are to identify from behind on the whitish hairs on the pubic patch.

## Discussion

The coloration of young Cat Ba langurs can be helpful to determine the age, but there is a rather large difference in the timing of the various pelage coloration changes. The differences in the timing of the changes in pelage coloration increase with age and become apparent at three to four months. At the age of one year the pelage coloration difference between animals with a slow and those with a fast pelage coloration development can amount several months. This means that an individual with slow pelage coloration change has at the age of one year a similar pelage coloration as an individual with fast pelage coloration change has already at the age of ten months. The observations suggest that the speed of the coloration development is genetically fixed. Animals which are born with a brown tinge on their back and tail will later show a fast pelage coloration development.

Hendershott et al. (2019) observed a difference in the timing of color change between Cat Ba and Francois' langurs (*Trachypithecus francoisi*) and suggested it to be related to infanticide avoidance. Though this is an interesting consideration, but it is to point out that it could also originate in the different coloration of the adults of the species in question - a darker species change the natal coat faster. Adult limestone langurs show subtle differences in the dark parts of the pelage, which are almost impossible to recognize in the field. The fur of these species – Francois' langurs, Hatinh langurs, Cat Ba langurs, white-headed langurs, Delacour's langurs and Lao langurs (*Trachypithecus francoisi*, *hatinhensis*, *poliocephalus*, *leucocephalus*, *delacouri* and *laotum*) - is commonly described as black. But only Francois' and Delacour's langurs actually have a glossy deep black fur. The fur of the Hatinh and Lao langurs is black but has a brown tinge and the fur of the Cat Ba and white-headed langurs is dark-chocolate brown.

The differences in coloration of new born animals and also the different speed of the coloration changes are also typical for other limestone langurs. Within the captive populations at the EPRC more than 20 Delacour's langurs and more than 100 Hatinh langurs were born. Both species belong to the 'limestone langurs' and their offspring are born with a yellow-orange natal coat. But within the captive born Hatinh langurs a great variation in the coloration of new born individuals is to observe - from complete yellow-orange individuals over animals with a partly dark back and tail to animals with an almost black back and a completely black tail. Observations at the EPRC show that the coloration of the natal coat and the pelage coloration development is genetically provoked as all animals at

the EPRC experience the same environmental conditions. Habitat quality, resource availability or social pressure, suggested by Hendershott et al. (2009) as essential drivers for the timing of the coloration change, can be excluded and more likely only affect an already existing disposition. It is also not clear if group size has an influence of the development of the pelage coloration change as observed by Borries et al. (2008) or is a result of the genetic structure of a group. In limestone langurs the females in one group are often sisters and they mate almost solely with the alpha male of the group. Borries et al. (2008) already pointed out the small sample size and cautioned against her own findings.

All limestone langur groups show the same social structure. Therefore the conclusion of a relation between infanticide and the speed of the coloration change (Hendershott et al. 2019) should be treated with utmost caution taking into consideration the individually and genetically fixed differences in coloration change.

Victims of infanticide in langurs are mostly infants less than one year of age (Davies & Oates 1994; Sommer 1996; Qing Zhao et al. 2001; Nadler pers. obs.) (Fig. 25, 26). During this time the animals change the pelage coloration, but more importantly in this respect is that with increasing age increases also the distance of the immature individuals to their mother or to other females, nonmaternal group members, and thereby the chance for an attack through an intruder is higher. But observations on Delacour's langurs (two cases) and Hatinh langurs (one case) (Nadler pers. obs.) show that intruder males also attacked older juveniles aged about one and a half to two years. At this age Hatinh langurs have their completely adult pelage coloration and Delacour's langurs already grey hips, but not yet the typical white trousers. In the observed cases the juveniles were injured but not killed. The killing of younger individuals is probably much more frequent and more often recognized.



**Fig.25a,b.** Cat Ba langur as a victim of an infanticide. The animal is probably four months old. It died through a puncture to the brain and to the lungs from a canine of a male.

Based on the observed differences in the development of the coat coloration of Cat Ba langurs, which also show other limestone langurs, a hypothesis about their influence on infanticide is highly speculative and not tenable.

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# Delacour's langur (*Trachypithecus delacouri*) reintroduction program: A preliminary report on the trial release into the Trang An UNESCO World Heritage Site, Ninh Binh Province, Vietnam

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**Key words:** Delacour's langur, *Trachypithecus delacouri*, reintroduction

## Summary

At the present time, the Van Long Nature Reserve Ninh Binh Province is home to the only viable sub-population of the 'Critically Endangered' Delacour's langur (*Trachypithecus delacouri*). The reserve contains about 200 individuals. The next largest sub-population of about 80 individuals exists in neighboring Ha Nam Province, in a currently unprotected area. Such small and isolated populations have heightened vulnerability to internal and external threats to their survival. The establishment of further sub-populations in suitable, secure and sustainable locations, therefore, is a crucial step towards helping to safeguard the survival of this species. Until the late 1990's a small population is known to have existed in the Trang An limestone massif, Ninh Binh Province. In 2014 Trang An was inscribed as UNESCO World Heritage Site. With strict protection of the area now in place and the existing and excellent habitat that the massif offers for Delacour's langurs, the establishment of a new sub-population here was recommended soon after its inscription and is included in the "Urgent Action Plan for the Conservation of Primates in Vietnam until 2020, Vision 2030". The Endangered Primate Rescue Center (EPRC), located in Cuc Phuong National Park, started breeding programs for several species of highly endangered primates in 1993, with the goal of releasing captive born individuals to support depleted wild populations or to establish new populations where the species has been extirpated. In 2017 a collaborative venture between local, national and international stakeholders was initiated to set in motion a reintroduction program for Delacour's langurs in Trang An. In August 2020, a group of three captive-born Delacour's langurs was transferred to an island in the World Heritage Site as a first step towards a possible re-establishment of a sub-population in this area.

## Chương trình chuyển giao loài vọc mông trắng (*Trachypithecus delacouri*): Chương trình thử nghiệm tại Di sản Thế giới UNESCO Tràng An, tỉnh Ninh Bình, miền Bắc Việt Nam - báo cáo sơ bộ.

### Tóm tắt

Khu bảo tồn thiên nhiên đất ngập nước Vân Long, tỉnh Ninh Bình là nơi sinh sống của quần thể lớn nhất loài vọc mông trắng 'Cực kỳ nguy cấp' với khoảng 200 cá thể. Một quần thể khác đang tồn tại ở tỉnh Hà Nam, vùng lân cận trong một khu vực hiện chưa phải là khu bảo tồn với khoảng 80 cá thể. Những quần thể nhỏ và biệt lập như vậy luôn có nguy cơ bị ảnh hưởng bởi nhiều tác động tiêu cực có thể xảy ra. Việc thiết lập thêm một vài quần thể khác sẽ đảm bảo sự tồn tại lâu dài cho loài. Đến cuối những năm 1990 ở Tràng An, tỉnh Ninh Bình đã có một quần thể nhỏ loài này sinh sống. Năm 2014, danh lam thắng cảnh này đã được Tổ chức Giáo dục, Khoa học và Văn hóa của Liên hợp quốc (UNESCO) công nhận là Di sản Hỗn hợp Thế giới.

## Introduction

The Delacour's langur (*Trachypithecus delacourii*) is one of three primate species endemic to Vietnam that are also listed as 'Critically Endangered' (IUCN 2019) and was included in the list of "The World's 25 Most Endangered Primates" (Mittermeier et al. 2000; 2012; Schwitzer et al. 2015; 2017). In the Van Long area, Ninh Binh Province, a Delacour's langur population was discovered in the early 1990's, and in 2001 the area was gazetted as Van Long Nature Reserve. Special protection against the effects of habitat destruction and poaching that the Vietnam Primate Conservation Program has been able to afford this species in the Van Long Nature Reserve has had a significant impact on population numbers there. With the help of two pilot projects (in 2011 and 2012) to augment the existing population through the release of captive born individuals, this has led to an increase from c.50 individuals to a secure count of 176-184 individuals (Agmen, 2014; Elser 2013; Elser et al. 2015; Nadler 2012; Nguyen Van Linh et al. 2019). The next largest surviving sub-population, of about 80 individuals, exists in neighbouring Ha Nam Province, in a currently unprotected area (Kim Bang). The impact of deleterious genetic defects is likely to have limited effect as the course and speed of the current decline suggests that extirpation is more likely to have occurred as a consequence of other pressures before the inbreeding coefficient increases sufficiently to become a significant factor (Nadler et al. 2020). Other internal pressures, such as disease-load, will have a bearing, but it is external factors – loss of food staples to plant disease, habitat conversion or destruction, or direct exploitation as a result of poaching – that have had a devastating impact on population numbers in recent decades, and are likely to remain the principal source of risk to future survival. In this context ensuring sustainable, protected conditions for existing groups and establishing new sub-populations represent essential steps towards securing the continued existence of this species (Nadler 2015a; Nadler et al. 2020). In this report we document recent efforts that have been made towards reintroducing Delacour's langur into part of its former range; specifically, into a secure area of forested limestone tower karst in a protected area of Ninh Binh Province: the Trang An Landscape Complex World Heritage Site.

Previous surveys and anecdotal evidence indicates that a small sub-population of Delacour's langurs existed in Trang An until the late 1990's (Fig. 1). When Trang An was inscribed on the World Heritage List under Criteria (v) (vii) (viii) (World Heritage Committee 2014), this created an area of 6,226 ha (the property's 'core zone') that is managed and protected under stringent government and international regulations. By 2018, Trang An had developed into a national tourism highlight, attracting more than 2.9 million visitors, the majority of whom view the property from traditional sampans (Hayashi et al. 2019). With this area protected and with the suitable habitat it affords Delacour's langurs, the establishment of a new sub-population was recommended by Nadler (2015b). In 2017 collaboration between local, national and international stakeholders set in motion a trial reintroduction program in Trang An modelled on the successful program in the Van Long Nature Reserve. These efforts further represent a direct response to the Vietnamese Government's "Urgent Action Plan for the Conservation of Primates in Vietnam until 2020, Vision 2030" (Prime Minister of Government 2017); and accord closely to UN Sustainable Development Goals 12.8, 15.4, 15.5, 15c, 17.17, and Aichi Biodiversity Strategic Goal C (Target 12).



**Fig.1.** The impressive scenic landscape of Trang An World Heritage Site housed decades ago a population of Delacour's langurs. Photo: Trang An World Heritage Site.

## Methods

### Source of animals for a reintroduction program

In 1993, the Vietnam Primate Conservation Program started as a project of the Frankfurt Zoological Society. One part of the project was the establishment of the Endangered Primate Rescue Center (EPRC) in Cuc Phuong National Park. The aim of the center was then and remains: to house endangered primates confiscated from the illegal wildlife trade in order to support the rangers of the forest protection agencies throughout the country with the possibility of housing confiscated animals. This possibility improved the rangers' motivation to confiscate animals from the illegal wildlife trade and relieved the rangers of protracted animal care.

For several highly endangered primate species, confiscated animals were used as founders for breeding programs at the EPRC, with the aim of releasing captive born animals to support depleted wild sub-populations or to establish new ones in areas where the species extirpation had occurred. The Delacour's langur, as a Vietnamese endemic species, has been a focus of the EPRC's breeding program and has been running successfully, with more than 30 births in captivity at the Center. In addition to the EPRC's 50 cages (total area of >3000m<sup>2</sup>) the Center also has access to two adjacent semi-wild areas, 2 and 5 ha in area, which contain primary forest and can be used as a training ground for the langurs before release into the wild.

### Selection of a release site

When comprehensive surveys were undertaken during the 1990's, a total of 19 isolated sub-populations of the Delacour's langur were discovered (Nadler 1996). All of these sub-populations have decreased in an extremely short period particularly as a result of illegal hunting, with at least ten groups extirpated in the first decade of the 21<sup>st</sup> century (Nadler 2015a; 2015b). In addition to the provision of an appropriate area of habitat, the unconditional requirement for a primate reintroduction program is the elimination of poaching. The natural and legal provisions in Trang An met these requirements (Nadler 2015b).

Releasing primates in order to establish a new sub-population is a protracted process that

requires long-term financial and staffing commitments, detailed planning and preparation, and dedicated and sustained monitoring. A first step towards a final decision on reintroduction in Trang An has been the transfer of a small group of Delacour's langurs to an uninhabited forested island (20°25'N/105°90'E) 1.5 ha in area within the property's core zone (Fig. 2). The positive benefits to this transfer are as follows:



**Fig.2.** The "Ngoc Island" in Trang An World Heritage Site was selected as a semi-wild area for a group of Delacour's langurs. Photo: Trang An World Heritage Site.

- ❑ The visitor numbers to the Trang An UNESCO World Heritage Site are such that it is not only a tourist destination for Ninh Binh Province, but for the whole country. The opportunity to observe langurs in their natural environment in the wild contributes to raising public awareness of conservation issues and the status of this species in particular. This project and the need to protect the flora and fauna of Vietnam are also presented in an accompanying poster exhibition and documentary at the Trang An Visitor Center (Fig. 3). With more than 60 park staff trained in conservation practice ahead of the release, there is also a growing knowledge-base that can help provide informed guidance for visitors.
- ❑ The presence of one of the world's rarest primates is an additional significant attraction for this World Heritage Site, marking an economic boost as well as a boost to its conservation and biodiversity credentials.
- ❑ Observing a group of Delacour's langurs in their natural habitat under favorable conditions provides a good opportunity to study the species and collect biological information as a background for further reintroduction.
- ❑ The keeping of Delacour's langurs on an island in Trang An with easy but controlled access, allows the management of this group at any time – e.g. through a possible exchange of animals or for any necessary treatments.
- ❑ The transfer of the three individuals opens up space within the facilities of the EPRC, especially in the semi-wild areas, for animals currently kept in cages. This creates an opportunity for more animals to experience living under natural conditions.
- ❑ The transfer will reduce costs and workload at the EPRC by reducing the amount of food and care. Commensurately, it provides security and management staff within Trang An not only with first-hand experience but also information regarding logistical costs and revenue projections that can be incorporated into strategic planning.





# TRĂNG AN

**QUẦN THỂ DANH THẮNG TRĂNG AN LANDSCAPE COMPLEX**

**Di sản Văn hóa và Thiên nhiên Thế giới**  
 Năm 2014, Ủy ban Di sản Thế giới - Tổ chức Giáo dục, Khoa học, Văn hóa Liên Hợp Quốc - UNESCO đã ghi nhận Quần thể danh thắng Tràng An vào Di sản thế giới có tổng diện tích 12.54 ha.

Quần thể danh thắng Tràng An ngự tại một cảnh quan nơi đã và nay tiếp tục làm theo mùa, không chỉ có vẻ đẹp thiên nhiên mà còn là nơi sinh sống của các loài quý hiếm như loài báo hoa mai, hổ, hổ chúa và nhiều loài chim quý hiếm khác. Đây là nơi sinh sống của người dân bản địa hơn 30.000 năm, tạo nên một quá trình lịch sử và văn hóa lâu đời.

**World Cultural and Natural Heritage**  
 In 2014, the World Heritage Committee of the United Nations - UNESCO - inscribed Trang An Landscape Complex on the list of the World Heritage. With its buffer zone covers a total area of about 12 km<sup>2</sup>, Trang An exhibits an outstanding humid tropical limestone karst landscape which is not only considered to be of global geological significance but also of major ecological importance as it provides a home for an astonishing and unique diversity of fauna and flora. Furthermore, anthropological discoveries have shown that people have lived for more than 30,000 years in the area, reflecting a long cultural history.

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# TRĂNG AN

**ĐIỂM ĐẾN DU LỊCH ĐẶC SẮC A TOURISM HIGHLIGHT**

Hàng năm, Quần thể danh thắng Tràng An đón hàng triệu du khách Việt Nam và quốc tế từ thành phố, thường ngoạn phong cảnh sơn kỳ, thủy tú nơi đây.

Du khách sẽ được băng bèo trên những con thuyền nhỏ xuyên qua các hang động, thưởng ngoạn hoa mùa trong cảnh núi sông hùng vĩ, lan hương tỏa khắp khi thuyền rời, thuyền khết, tiếng chuông.

Nơi đây có cảnh quan thiên nhiên an toàn để bảo tồn di sản sinh học và duy trì môi trường sống cho các sinh vật bị đe dọa.

Tràng An là nơi có tiềm năng lớn về du lịch sinh thái ở Việt Nam.

Hundreds of thousands of Vietnamese and foreign tourists enjoy the fascination of Trang An's unique landscape every year.

The tour with small boats passes through caves and corners of the underground water system, conveying hereby an impressive experience about the majestic karst rock system.

The area provides a secure environment for the conservation of biodiversity and limestone habitats.

Trang An exemplifies the potential of an ecotourism destination in Vietnam.

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**LA MỘT TRONG NHỮNG LOÀI LINH TRƯỞNG** này hiện nay chỉ còn lại được số lượng danh sách "Cực kỳ Nguy cấp" trong Các loài bị đe dọa của IUCN. Báo cáo hiện nay của IUCN.

**The Delacour's langur is one of the world's rarest primates and is listed as "Critically Endangered" by the IUCN's Red List of Threatened Species.**

**Vào mùa trắng thì chỉ sinh sống ở** Việt Nam. Tổng số chỉ loài này còn trong tự nhiên khoảng gần 300 cá thể.

**Delacour's langur exists only in Vietnam, with a total of less than 300 individuals.**

**Chuyến giao phối đầu tiên trong lịch sử của loài này được thực hiện một vài tuần trước khi mùa trắng bắt đầu của loài.**

**The aim of the first reproduction initiative in Trang An is to release a small number of captive bred individuals into a specific area of Trang An.**

**Vào mùa trắng sống theo bầy đàn.** Một đàn thường có một con đực làm đàn đầu và vài con cái và các con của chúng.

**Delacour's langurs live in family groups. A group can comprise one male, several females, and their offspring.**

**Vào mùa khi mùa sinh và mùa vàng cam đồng ý, các một nam hoặc các một con cái sinh ra con trong có một không hai là màu đen và trắng.**

**Rabbits are born in bright yellow fur and change during one year to the unique black and white coloration.**

**Vào mùa trắng sống trong các khu vực rừng núi và đôi khi tìm tòi và thực hành trong những loại lá cây rừng chỉ thích.**

**Delacour's langurs live in rocky limestone areas and feed without exception only on leaves from selected trees.**

**SỰ TRỞ VỀ CỦA LOÀI BIỂU THƯỢNG THE RETURN OF A FLAGSHIP ANIMAL**

Đến giữa những năm 1990, Quần thể danh thắng Tràng An đã là nơi sinh sống của loài linh trưởng quý hiếm nhất thế giới - loài vượn màu trắng (*Rhathypithecus delacourii*), đang bị nạn săn bắn hủy diệt hàng triệu cá thể mỗi năm.

Vào mùa trắng chỉ có thể được tìm thấy duy nhất ở Việt Nam. Trung tâm Cứu hộ loài linh trưởng Nguyễn CẬP, Viện Khoa học và Công nghệ Sinh học Việt Nam này. Một đàn vượn màu trắng ở Trang An sẽ được chuyển giao vào Quần thể danh thắng Tràng An - sự trở về và phục hồi của loài này là một dấu mốc quan trọng đối với công tác bảo tồn.

Dự án chuyển giao loài vượn màu trắng này được thực hiện theo kế hoạch và tài trợ của Trung tâm Cứu hộ loài linh trưởng (CIVIC PAWS VIET) là địa.

Until mid 1990's the Trang An area was home of one of the world's rarest primates, the Delacour's langur (*Rhathypithecus delacourii*), but poaching reduced the small population.

The Delacour's langur can only be found in Vietnam and nowhere else in the world. Delacour's langur from a captive breeding program at the Endangered Primate Rescue Center in Cuc Phuong National Park will be reintroduced into Trang An World Heritage Site - an exciting return of this primate to one of its original homes.

The project is generously sponsored by FOUR PAWS World Wildlife Conservation Center.

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**CHI CÒ VIỆT NAM**  
*Rhathypithecus poliocephalus*

**CHI CÒ VIỆT NAM**  
*Rhathypithecus auratus*

**CHI CÒ VIỆT NAM**  
*Vượn mồi bèo*  
*Trachypithecus monoceros*

**CHI CÒ VIỆT NAM**  
*Vượn đen tuyền*  
*Delacour's langur*  
*Rhathypithecus delacourii*

**Vượn chà và chà xam**  
*Gery-thanked doug*  
*Pygathrix cinerea*

**Vượn đen tuyền phôi Đổng**  
*Eastern black gibbon*  
*Nomascus nasutus*

**KẾ HOẠCH HÀNH ĐỘNG CHO LINH TRƯỞNG AN ACTION PLAN FOR PRIMATES**

Việt Nam là quốc gia có số lượng các loài linh trưởng cao nhất trong lục địa Đông Nam Á với 25 loài linh trưởng phân bố. Trang An là địa điểm liệt trong danh sách "25 loài Linh trưởng Nguy cấp nhất thế giới".

Chính phủ Việt Nam đã khẳng định trách nhiệm bảo tồn các loài linh trưởng thông qua Kế hoạch hành động bảo tồn khẩn cấp các loài linh trưởng ở Việt Nam đến năm 2025, tầm nhìn đến năm 2030 phê duyệt trong năm 2017.

Tất cả các loài linh trưởng ở Việt Nam đều được pháp luật bảo vệ. Các hành vi săn bắn, bẫy bả, buôn bán và nuôi giữ các loài linh trưởng đều bị nghiêm cấm.

25 primate species occur in Vietnam, the highest number in Southeast Asian countries on the continental mainland.

Five primate species occurring in Vietnam count to the "25 World's Most Endangered Primates".

The Government of Vietnam recognizes its responsibility for the survival of these primates and passed in 2017 the "Urgent Conservation Action Plan for Primates in Vietnam to 2025, Vision to 2030" to save the species from extinction.

All primates in Vietnam are protected by law. Hunting, trading and keeping is strictly prohibited.

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Fig.3. A poster exhibition inform visitors about the value of Trang An World Heritage Site and the conservation activities for the Delacour's langur.

## Vegetation survey

In order to ensure that sufficient food resources exist on the island release site for the Delacour's langur (a leaf-eating species of primates) vegetation surveys were carried out on-site in September 2017 and again in December 2018 (O'Donnell & Nguyen Thi Mai Huong 2017; Rabett et al. 2019). These surveys established that one of the most abundant families of plant on the island is Moraceae (predominantly *Ficus*) (Table 1). This alone accounts for more than 30 per cent of the around 70 preferred species of plant in the diet of wild Delacour's langurs (Nadler & Brockman 2014; Workman 2010). The remainder of the open limestone scrub on the island comprises shrubs and woody climbers in the plant families Annonaceae, Rutaceae, Leguminosae, Cornaceae, Vitaceae and Rubiaceae. Additional observations in the limestone vegetation of adjacent mainland areas included several other plant species that are recorded by Workman (2010) to be important food resources for Delacour's langurs in the Van Long Nature Reserve: *Broussonetia papyrifera* (Moraceae), *Alangium kurzii* (Cornaceae), *Lantana camara* (Verbenaceae) and *Mallotus philippensis* (Euphorbiaceae). The presence of these plants is further indication that suitable habitat elements utilized by this species of langur exist within the Trang An landscape. As such, the immediate and local surveys undertaken in the lead-up to the trial release give good reason to expect that there will be appropriate plant resources to support the initial group and encouraging evidence for potential future phases in the reintroduction program.

**Table 1.** Plant species and families obtained from field observations on the Trang An island release site in September 2017 and December 2018 (O'Donnell & Nguyen Thi Mai Huong, 2017).

Species	Family	%
<i>Desmos</i> aff. <i>chinensis</i>	Annonaceae	30
<i>Boehmeria</i> sp.	Urticaceae	20
<i>Ficus</i> spp.	Moraceae	15-20
<i>Alangium</i> aff. <i>chinensis</i>	Cornaceae	15
<i>Zanthoxylum</i> aff. <i>nitidum</i>	Rutuaceae	10
<i>Dasymaschalon rostratum</i>	Annonaceae	3-5
<i>Dracaena</i> aff. <i>cochinchinensis</i>	Asparagaceae	3-5
<i>Mallotus</i> spp.	Euphorbiaceae	3-5
<i>Bauhinia</i> sp.	Leguminosae	3-5

## Preparation for the transfer of the Delacour's langurs from the Endangered Primate Rescue Center to Trang An World Heritage Site

A group of three Delacour langurs (a male and two females) born in captivity was selected for the transfer:

Male	Date of birth: 13.05.2013
Female	Date of birth: 10.10.2015
Female	Date of birth: 24.02.2018

In April 2020, the animals were moved from a cage at the EPRC to the 5 ha semi-wild area at the Center to help them familiarize them with the natural substrate. Whilst here they were also trained daily by a whistle to return to a cage that was set within the area and take a small bite of sweet potato. At the end of June, during a detailed health check following the IUCN Guidelines (Baker 2002), and ahead of the transfer to Trang An planned for August 2020, it was determined that the older female was pregnant with a fetus about seven weeks along. In order to avoid stress for the animal it was decided to postpone the island transfer. However, during a further routine health check in July it was found that the female had unfortunately lost the fetus for no evident cause. It was therefore decided that an August transfer could be carried out as originally planned.

On the island itself an area was selected to set up a cage where the animals would stay briefly after transfer and to which they would be called back subsequently for management or treatment. This portable cage (3m x 4m x 2.5m) was designed, built and transported to the island in mid-August (Fig. 4, 5). Three guards under the employment of the Trang An Management Board received a week of training at the EPRC that prepared them to deal with feeding the animals during the short period of time they would remain in the cage, and how to call the animals back after they have been released.



**Fig.4.** Transport of the cage parts to the island in Trang An World Heritage Site. Photo: Tilo Nadler.



**Fig.5.** Erecting the cage on the island. Photo: Tilo Nadler.

### Transfer of the langurs and release

For the island transfer, which took place on 27<sup>th</sup> August, the animals were caught and transported in individual boxes to Trang An, about 30 km away from the EPRC. After boat transport from the property's Main Wharf and Visitor Centre the animals were moved to the release cage (Fig. 6, 7). They were then allowed to acclimatize to the new surroundings over a period of 14 days before being released to range freely over the island on 9<sup>th</sup> September. In the days that followed the langurs were observed exploring the island and searching for food (Fig. 8). Every day at 9 am the animals are called back to the cage with a whistle, following the routine established in the EPRC. While to date this has not always been successful, overall the procedure has worked well. Occasionally, the animals will also return to stay in the open cage for a period during the day. Copulation of the langurs has already been observed and it is hoped that a first langur will be born on the island within the trial period.





**Fig.6.** Transportation of the animals to the island in Trang An World Heritage Site. Photo: Tilo Nadler.



**Fig.7.** Delacour's langur group after the move to the cage on the island. Photo: Tilo Nadler.



**Fig.8.** A Delacour's langur ranging across the island in Trang An. Photo: Tilo Nadler.

## Monitoring of the langurs on the island

The langurs are closely monitored from a guard station on the mainland shore immediately adjacent to the island. The waters around the island are patrolled and it is currently the guards' responsibility to track the habits of the langur group, recorded as sightings in different squares of a spatial grid that takes in the whole island. This preliminary data will help establish preferred areas and food trees, as well as the group and the daily movements. The anticipated period for the initial release and associated monitoring is around 12 months. During which time a decision for further action will be made.

## Conclusion

The trial reintroduction of Delacour's langurs into Trang An marks a positive step in an arc of conservation research that began almost 20 years ago, when the lead author conducted surveys in this area to assess the species' local status. Following recommendations for the establishment of a new sub-population in Trang An (Nadler 2015b), efforts to realise this ambition have brought together a wide variety of stakeholders, including partnership with an academic research project that is reconstructing the impact of palaeoenvironmental changes during Trang An's prehistory. This kind of novel collaboration highlights the potential value of extending dialogue across the traditional boundaries between scientific disciplines to help meet the challenges that face wildlife conservation today

Trang An presents an ideal site for this trial release not only because habitat conditions are well-suited and reserve is protected by stringent legislation, but also because of the existing socio-economic and ecotourism-based context of the property. Trang An has the benefit of a large relationship-network with local communities (Bui Van Manh & Pham Sinh Khanh 2018). As such the philosophy and returns that a project like this embodies will likely be familiar to many local residents. The aim is that these existing conditions, taken in combination with suitability and security, will provide a sound basis for establishing a new population of Delacour's langur here over the coming years; and a socio-economic outcome that will hopefully enable the trial release reported herein to follow a similar growth trajectory to that already witnessed in the Van Long Nature Reserve (Nguyen Van Linh et al. 2019). In building ecotourism as a sustainable local economy in Ninh Binh this initiative will hopefully not only mark an important step towards securing the future of this endemic species but also help to strengthen the heritage value of Trang An and the communities that depend upon it.

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# Photo evidence for the occurrence of the black ‘*ebenus*’ morph of the Hatinhlangur (*Trachypithecus hatinhensis*) in the Phong Nha-Ke Bang National Park and comments on this morph

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**Key words:** Hatinh langur, *Trachypithecus hatinhensis*, black morph, *Trachypithecus ebenus*

## Summary

Camera trap photos taken in Phong Nha-Ke Bang National Park prove the presence of the black morph ‘*ebenus*’ of the Hatinhlangur. This black morph has a relatively wide distribution in Laos, from the southern part of the Phou Hin Boun NBCA to the Hin Nam No NBCA in the east and to the south in limestone massifs of the northern Savannakhet Province. For Vietnam, there are so far only few records of the occurrence of these morph. Intermediate forms of Hatinhlangurs between individuals with the characteristic feature of the white beard reaching over the ears to the neck and the completely black form of the ‘*ebenus*’ morph were observed in several areas in Laos. Despite the parapatric to partially sympatric occurrence, the forms seem to be locally stabilized without creating a total mixed population.

## Bằng chứng hình ảnh sự xuất hiện của hình thái ‘*ebenus*’ đen thuộc loài Voọc Hà Tĩnh (*Trachypithecus hatinhensis*) tại Vườn Quốc gia Phong Nha-Kẻ Bàng và nhận xét về hình thái này

### Tóm tắt

Những bức ảnh chụp bằng bẫy ảnh ở Vườn Quốc gia Phong Nha-Kẻ Bàng chứng minh sự xuất hiện của hình thái ‘*ebenus*’ đen thuộc loài Voọc Hà Tĩnh. Hình thái đen này có sự phân bố tương đối rộng ở Lào, từ phía Nam của Khu bảo tồn Đa dạng sinh học Quốc gia Phou Hin Boun đến Khu bảo tồn Đa dạng sinh học Quốc gia Hin Nam No ở phía Đông và phía Nam và các dãy núi đá vôi ở phía Bắc của tỉnh Savannakhet. Đối với Việt Nam, cho đến nay có rất ít dữ liệu về sự xuất hiện của hình thái này. Các hình thái thuộc Voọc Hà Tĩnh giữa các cá thể với đặc điểm đặc trưng là bộ râu trắng dài qua tai tới cổ và dạng đen hoàn toàn của hình thái ‘*ebenus*’ đã được quan sát ở một số khu vực ở Lào. Mặc dù có sự tương đồng đối với sự xuất hiện một phần giao cảm biến, các dạng này dường như được ổn định cục bộ mà không tạo ra một quần thể hỗn hợp.

### Introduction

Phong Nha-Ke Bang National Park is located about 500 km south of Hanoi and 50 km northwest of the city of Dong Hoi, Quang Binh Province. As one of the largest limestone massifs in Indochina with an area of 123,326 ha and its geological and biological importance, it was awarded UNESCO World Heritage Site status in 2003.

Within the framework of an UNESCO project, 70 camera traps were installed in 2018/2019 especially to record the occurrence of ten endangered mammal species. Cameras were used in an area about 15 km from the Laotian border.

Pictures taken with the camera traps show a group of Hatinhlangurs representing the black morph *ebenus* of this species (Fig. 1 ,2).



**Fig.1.** Camera-trapped group of Hatinhlangurs in Phong Nha-Ke bang National Park. All individuals belong to the black ebenus morph (recorded 9<sup>th</sup> April 2019).



**Fig.2.** The langur group consisted of 5-7 individuals, 1 adult male, 3-4 adult females and 2 subadults (recorded 9<sup>th</sup> April 2019).

### **On the occurrence and distribution of the *ebenus* morph of the Hatinhlangur and various intermediate forms**

The systematic position of the black langur was long debated after its description (Brandon-Jones 1995) and this form was considered both as a subspecies of the Hatinhlangur and as a valid species (Groves 2001; Nadler 2009; 2013). The occurrence of the completely black morph of the Hatinhlangur is documented for the Khammouane Province in Laos. In the northern part of the Phou Hin Boun National Biodiversity Conservation Area (NBCA), only the Lao langur (*Trachypithecus laotum*) is found, while in the southern part, the *ebenus* morph of the Hatinhlangur is present (Duckworth et al. 1999; 2010; Nadler 2009; Phiapalath 2010). A similar division in distribution exists between the Hin Nam No NBCA in Laos and the adjacent Phong Nha-Ke Bang National Park on the Vietnamese side. In Phong Nha-Ke Bang NP typical Hatinhlangurs with white beard are present. However, there is the observation of a group of black langurs in the northeastern part of the national park (near Tram Me, Thung Ba Dau 17°36'N / 106°17'E)(Nguyen Xuan Dang et al. 1998; Pham Nhat & Nguyen Xuan Dang 1999). This was the first record of the black morph for Vietnam. Another one for Vietnam was provided by Le Kha Quyet (2004) from the Nui Giang Man area, Quang Binh Province, north of Phong Nha-Ke Bang NP and a provisional record was reported on Phong Nha-Ke Bang NP (Dinh Hao Duong 2004).

In the Hin Nam No NBCA some animals with different extension of the white beard or white hair tips on the ear pinna were observed (Phiapalath pers. observ.) but black morphs are predominant

(Ruggieri & Timmins 1995; Timmins & Khounboline 1996; Walston & Vinton 1999; Meijboom & Ho Thi Ngoc Lanh 2002). The distribution of black morphs in Laos ranges from Khammouane Province to the south to isolated limestone blocks in the northern part of Savannakhet Province. Also in these areas there are some animals with indicated white beard or white hairs on the ear pinna (Duckworth et al. 2010; Nadler pers. observ. Phiapalath pers. obs.). In the Nakai-Nam Theun area white-bearded Hatinhlangurs are predominant, but on some individuals the white beard ends at the ears and is not extended to the neck (Duckworth et al. 2010) with photographs of camera traps (Fig. 3, 4).



**Fig.3.** Camera-trapped Hatinhlangur from Nakai-Nam Theun National Protected Area. The white beard strip ends at the ear and does not reach to the neck. (From Duckworth et al. 2010).



**Fig.4.** A Camera-trapped Hatinhlangur of the same group as Fig. 1. with the typical elongated beard up to the neck. (From Duckworth et al. 2010).

The camera-trap photos from Phong Nha-Ke Bang NP are the first photo evidence of the black morph for the national park. According to observations the group consists of 5-7 individuals, one adult male, 3 to 4 adult females and 2 subadult individuals.

In Hatinhlangurs, as in all these 'limestone-langurs', the subadult males leave their family group as they grow up to subadults, then usually form bachelor groups with subadult males from other groups and later try to take over an existing group, or separate females from an existing group to form a new group.

It seems, however, that these subadult males do not travel greater distances when attempting a group acquisition, otherwise there would be a further mixing of the two forms and there would be more individuals with an intermediate feature. The existing forms in the features seem to be locally stable.

There are no geographical barriers that would prevent or restrict migration, but on the contrary,



the karst blocks of Phong Nha-Ke Bang NP and Hin Nam No NBCA form a geological and biological unit. It would be interesting to see how anthropogenic influences through habitat changes, such as forest conversion to agricultural land, road construction, construction of river dams, etc., would affect the shifting or mixing of forms.

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## Transmission of *Echinococcus ortleppi* at the Endangered Primate Rescue Center, Cuc Phuong National Park

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**Key words:** Primates, helminths, *Echinococcus*, food, dog

### Summary

According to the statistical report of the Endangered Primate Rescue Center, the prevalence of the cystic disease in four langur species (*Trachypithecus hatinhensis*, *T. delacouri*, *Pygathrix nemaeus*, *P. cinerea*) was on average 63.4% (N=41). Of which, five individuals were confirmed to be infected with *Echinococcus ortleppi*. To clarify the transmission route of infection in primates, we investigated the prevalence of intestinal helminths in leaves, the food for these primate species and in dog fecal samples collected in the surrounding areas of the center.

Only *Ancylostoma* spp. and *Isospora* spp. were detected in leaves samples, with the infection rate of 7.07% and 1.01% respectively. In addition, survey on 156 dog feces samples showed that the overall prevalence of gastrointestinal parasites was quite high (73.55%). However, *Echinococcus* eggs still remained undetected.

## Con đường truyền lây *Echinococcus ortleppi* ở Trung tâm Cứu hộ Linh Trưởng Nguy cấp (EPRC), Vườn Quốc gia Cúc Phương

### Tóm tắt

Tại Trung tâm Cứu hộ Linh trưởng Nguy cấp, đã ghi nhận 41 trường hợp nhiễm nang sán ở linh trưởng với tỷ lệ là 63.4%. Trong đó, năm cá được xác định là nhiễm *Echinococcus ortleppi*. Để xác định con đường truyền lây mầm bệnh cho linh trưởng, chúng tôi tiến hành xét nghiệm mẫu lá cây và mẫu phân chó thu thập xung quanh trung tâm. Đối với mẫu lá, phát hiện hai mầm bệnh là *Ancylostoma* spp. và *Isospora* spp. với tỷ lệ nhiễm lần lượt là 7.07% và 1.01%. Đồng thời khảo sát trên 156 mẫu phân chó thu thập xung quanh trung tâm thấy tỷ lệ nhiễm chung các loại ký sinh trùng khá cao, lên tới 73.55%. Tuy nhiên, nghiên cứu này vẫn chưa phát hiện được sự xuất hiện của trứng *Echinococcus*.

### Introduction

Cystic echinococcus (CE) is a zoonotic disease that is widely distributed in large parts of Europe and Asia (Ito & Budke 2017) that can develop asymptotically for years. The life cycle of *Echinococcus* involves dogs as the definitive host and some wild species such as dingo, wolf, jackal, red fox and hyenas (Dybicz et al. 2019). Cattle, sheep, goats and pigs are known to be susceptible as intermediate hosts to *Echinococcus ortleppi*.

The transmission of CE is typically accidental, as a result of ingestion of water, food and/or soil contaminated with pathogens from dog feces. When intermediate hosts (also primates or humans) eat these contaminated materials, metacestodes can live in several organs like the liver, kidneys or lungs where it develops into hydatid cysts. Cysts grow gradually in the body, which interfere with normal organ function and cause animals to suffer from intense pain. It can sometimes develop into a fatal cyst within the brain (Kvascevicus et al. 2016). To date, studies on cystic echinococcus are still very limited in Vietnam.

The Endangered Primate Rescue Center (EPRC) is located in northern Vietnam and houses more than 150 individuals of 15 primate taxa. The center provides sanctuary and rehabilitation to primates of the Genus *Nomascus*, *Nycticebus*, *Trachypithecus* and *Pygathrix* with their IUCN Red List status ranging from 'Vulnerable' to 'Critically Endangered'. Medical problems associated with these primates include enteritis, parasites and occasional trauma. However, the most significant disease today is hydatid cyst disease (Fig. 1). Hydatidosis due to *Echinococcus ortleppi* appears to be a common cause of death for the langur population in EPRC, which was first reported in 2009 (Plesker et al. 2009). The disease is not only posing a health risk to primates, but also affects humans as intermediate hosts, especially for those who live in endemic areas. In order to improve the effectiveness of disease prevention and treatment, the aim of this study was to investigate the prevalence of parasites in leaves and dog fecal samples in the surrounding areas of the center to find possible routes of transmission of the infection in primates with *E. ortleppi*.



**Fig.1.** Lungs of a red-shanked douc langur (*Pygathrix nemaeus*) with white cysts. Photo: Vo Duy Thanh.

## Material and Methods

### Animals

In the EPRC, primates live in enclosures mimicking their natural habitat. Data of deceased langurs were precisely recorded by experts/veterinarians.

### Post-mortem examinations

After death, carcasses of primate individuals were kept under -20°C. A comprehensive necropsy procedure was conducted shortly thereafter. Tissues and cysts of interest would be collected and fixed in 70% ethanol, and sent to the Primate Genetics Laboratory of the German Primate Centre for PCR testing.

### Sample collection

The study was conducted at the Endangered Primate Rescue Center (EPRC), Ninh Binh Province from July to November 2019. The leaves samples used in the experiment were collected from the surrounding area of the center where leaves were frequently collected as food for primates, including those located at the foothills and along the forest edge as well as on hills higher than 10 m. During the same period, following verbal consent from owners, dog fecal samples were collected freshly off the ground, put into a sterile zipper bag, and sent to the laboratory. Households were randomly chosen among seven villages surrounding the center (Nga, Sam, Bai Ca, Ao Luong, Met, Dong Tam, Ky Phu). The majority of investigated dog breeds were Indochinese Dingo. The total number of leaves

and fecal samples for this study are 99 and 156 samples, respectively.

### Parasite examination

Fecal samples were examined for intestinal helminths using flotation technique with saturated sugar solution (SG: 1.28)(Dryden et al. 2005) using microscope, under 400x magnification for helminth eggs and 100x magnification for tapeworm eggs. The same procedure was used to examine leaf samples after leaves were cut into small pieces by a pair of scissors.

### DNA extraction method

#### For egg sample

*Echinococcus* suspected egg samples during fecal examination were collected and fixed in 70% ethanol. DNA was extracted from egg samples using QIAamp DNA Stool Mini kit (Quiagen, Germany), according to manufacturer's instructions.

#### For cyst sample

DNA was isolated from ethanol fixed cyst material as described by Dinkel et al. (1998). About 0.5 g of the cyst wall was cut into small pieces and digested in the presence of 2 mg/ml proteinase K in 500 µl of 10 mM Tris-HCl (pH 7.5), 10 mM EDTA, 50 mM NaCl, 2% sodium dodecyl sulfate and 20 mM dithiothreitol. DNA was extracted with phenol chloroform isoamyl alcohol (25:24:1) and ethanol precipitation. After drying, the DNA was suspended in 200 µl TE-buffer (pH 7.6).

### PCR

#### For egg sample

Amplification of a fragment of the COX-1 mitochondrial gene was performed according to Correa et al. 2018. Briefly, an initial reaction at 95°C (5 min) followed by 35 cycles of 94°C (55 s), 54°C (55 s), 72°C (60 s), and final extension at 72°C (10 min). The primer set for the reaction was Eco1 (5'-TTT TTT GGG CAT CCT GAG GTT TAT-3') and Eco2 (5'-TAA AGA AAG AAC ATA ATG AA ATG- 3'). All positive PCR products were purified and subjected to sequencing using Gene JET PCR purification kit, Thermo and 1<sup>st</sup> Base – Malaysia and analysis using bioinformatics software (Sequencer v4.1.4, BLAST tool, Clustal X v2.1, MrBayes v3.2).

#### For cyst sample

Polymerase chain reaction A cestode specific PCR (cs PCR) was done as described by Dinkel et al. (1998; 2004) in 50 µl reaction mixture containing 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 2.5 mM of MgCl<sub>2</sub>, 200 µM of each dNTP, 20 pmol of each primer and 1.25 units of Ampli-Taq Polymerase (Applied Biosystems). Amplification was done for 40 cycles (denaturation for 30 s at 94°C, annealing for 1 min at 55°C and elongation for 30 s at 72°C). For identification of genotypes and species of *Echinococcus* a semi-nested PCR assay specific for *E. canadensis* G6/7 and *E. ortleppi* as described in Dinkel et al. (2004) was performed. For the first PCR (g5/6/7), the 50 µl reaction mixture consisted of 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 2 mM of MgCl<sub>2</sub>, 200 µM of each dNTP, 25 pmol of each primer, and 1.25 units of Ampli-Taq Polymerase (Applied Biosystems) for 40 cycles (denaturation for 30 s at 94°C, annealing for 1 min at 53°C and elongation for 40 s at 72°C). To discriminate between *E. ortleppi* and *E. canadensis* G6/7, the semi-nested PCRs for *E. ortleppi* (g5 PCR) and *E. canadensis* G6/7 (g6/7 PCR) were used in a second step, both in a 50µl reaction mixture containing 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 2 mM of MgCl<sub>2</sub>, 200 µM of each dNTP, 25 pmol of each primer, and 1.25 units of Ampli-Taq Polymerase (Applied Biosystems) for 40 cycles (denaturation for 30 s at 94°C, annealing for 1 min at 60°C and elongation for 30 s at 72°C). For all PCR's, target sequence for amplification is a part of the mitochondrial 12S rRNA gene. For subsequent gene sequencing, two additional PCR's were performed as described by Bowles et al. (1992) and Bowles & McManus (1993) with the target sequences of a part of the mitochondrial cox 1 and nad 1 genes. All amplification products were resolved on a 1.5% ethidium bromide stained agarose gel.

**Results**

During the period from 1994 to 2018, 41 deceased langurs of the species *Trachypithecus delacouri*, *T. hatinhensis*, *Pygathrix nemaeus*, *P. cinerea* were necropsied. The necropsy records have shown that the prevalence of the cystic disease in langurs of four species was on average 63.4% (Table 1). Of which, *P. cinerea* has the highest prevalence rate, at 87.5%. Five cysts from randomly selected individuals were subjected to PCR for molecular identification. All samples showed positive to *E. ortleppi*.

Ninety-nine leaves samples were collected within 20 km radius of the center, scattered from the ground to the hills. Eight out of 99 leaf samples were infested with *Isopora* spp. and *Ancylostoma* spp., at 1.01% and 7.07% respectively. However, *Echinococcus* eggs were not found. (Table 2).

**Table 1.** Post-mortem results of langur species at the EPRC, 1994-2018.

Species	Number of necropsied individuals	Number of langurs diagnosed with cysts	Prevalence of cysts (%)	Number of PCR positive for <i>E. ortleppi</i>
<i>Trachypithecus delacouri</i>	4	2	50	-
<i>Trachypithecus hatinhensis</i>	11	6	54.5	-
<i>Pygathrix nemaeus</i>	10	4	40	2
<i>Pygathrix cinerea</i>	16	14	87.5	3

**Table 2.** Parasitic prevalence in leaf samples collected as a food source for primates.

Location/ height	Number of samples	<i>Isospora</i> spp. positive	<i>Ancylostoma</i> spp. positive
2-20 km at 0-10 m	55	0	4
2-20 km at > 10 m	44	1	3
<b>Total</b>	<b>99</b>	<b>1</b>	<b>7</b>

The prevalence of intestinal helminths in 156 dog fecal samples is quite high, accounting for 73.55% (n=114). *Ancylostoma* spp. has the highest infection rate (68.39%), followed by *Toxocara* spp. (25.81%), *Trichuris* spp. (10.97%) and *Isospora* spp. (7.1%). The eggs of *Taenia* spp. are also found in six samples (3.87%) (Table 3). These species are all common intestinal parasites, which had been recorded previously in Vietnam.

**Table 3.** Gastrointestinal parasites identified in dog fecal samples at the area around the Endangered Primate Rescue Center.

Parasite species	No. of positive samples	Infection rate (%)
<i>Taenia</i> spp.	6	3,87
<i>Ancylostoma</i> spp.	106	68,39
<i>Toxocara</i> spp.	40	25,81
<i>Trichuris</i> spp.	17	10,97
<i>Isospora</i> spp.	11	7,1

## Discussion

*E. ortleppi*'s life cycle includes dogs as definitive hosts and cattle as intermediate hosts. These are all common and widely distributed animals, but the infection rate of *E. ortleppi* in the world is negligible. To the best of our knowledge, only ten human cases of *E. ortleppi* infection were recorded from some parts of the world (i.e. Argentina, Brazil, Mexico, South Africa, Netherlands, Poland, France, China, India, and Vietnam) (Grenouillet et al. 2014; Rojas et al. 2014; Dybicz 2019; Shi et al. 2019). It is suggested that the low incidence may be due to the fact that cattle are mainly slaughtered in locations away from residential areas, and dog access to these areas is limited, thereby inhibiting transmission to the local dog population (Nguyen Van De & Duyet Le Van 2017). However, cases of hydatid cysts have been recorded in the EPRC for many years, suggesting the existence of *Echinococcus* pathogens in the direct environment and finding out the cause of the disease is necessary.

The first case of *E. ortleppi* infection in Vietnam was reported in the langurs housed at EPRC (Plesker et al. 2009). Later, two human cases were also detected in Thanh Hoa Province, Vietnam (Nguyen Van De & Duyet Le Van 2017). These data suggest the existence of zoonotic cycles of *Echinococcus* pathogens in the environment among neighboring provinces. In the EPRC, primates are kept by pair or in groups in separated enclosures. Each enclosure was built to mimic their natural habitat, with a safety distance of at least 1.5 m away from visitors. Therefore, it is impossible for the animals at the center to come into contact with definitive hosts.

Eighteen out of 55 leaves samples from the foothills and forest edge were collected around the landfill and places which dogs and cats frequently showed up (villages Nga, Bai Ca, etc.) making them easy targets to get contaminated. Even for those collected on hills higher than 10 m, with less presence of dogs, 3 samples were still found to be positive with hookworms. During collecting leaves as food for primates, staff could not bring the leaves with them all the time and had to put on the ground, and this may be the reason why they could easily get contaminated with pathogens. Additionally, leaves are collected in the forests around the center where wild animals have access, which is a potential source of diseases. *Echinococcus* eggs can survive for a prolonged period of time (Federer et al. 2015; Veit et al. 1995). High prevalence of intestinal parasites in primates of the center was also reported (62.63%), in which *Strongyloides* spp. constituted the highest proportion (48.48%), followed by *Trichuris* spp. (31.31%), *Ancylostoma* spp. (8.08%) and *Capillaria* spp (5.05%) (Bui Khanh Linh et al. 2018). This was mostly the case that primates frequently ingested contaminated food sources, thus they were vulnerable to these parasitic diseases. However, it is very difficult to determine the source of infection as there is little correlation between the number of investigated samples and the daily primate food intake. On the other hand, 155 fecal samples of dogs were examined, in which the overall infection rate was quite high (73.55%). The figure for *Ancylostoma* spp. was the highest (68.39%), followed by *Toxocara* spp. and *Trichuris* spp. Similarly, previous studies on the prevalence of intestinal parasites in dogs in Hanoi and Ho Chi Minh City showed five common species, namely *Spirocercalupi*, *Toxocaracanis*, *Ancylostoma* spp., *Trichuris vulpis*, *Taenia* sp. (Quyen et al. 2015; Nguyen Phi Bang et al. 2016). In our study *Isopora* and *Taenia* eggs were also identified, at the rate of 7.1% and 3.87% respectively. The prevalence of parasite infection in fecal samples was higher than that of leaf samples. However, *Echinococcus* spp. still remained undetected, probably due to the small number of samples or because of its small size (30-43µm in diameter), which might have been missed during examination.

During our investigation, we observed that each household normally owned one to three dogs. In addition, dogs were not routinely dewormed or kept in cages, posing the high risk of spreading pathogens in the environment. In addition, they could become infected if they accidentally ingest intestinal organs with hydatid cysts from cattle. It is also observed from our study location that after being slaughtered at local slaughterhouses, unused cow parts are thrown away or consumed by the butcher's dogs, which might contribute to the circulation of pathogens in the dog population.

Another hypothesis is that primates might be exposed to pathogens in the wild before being rescued to the Center. Thus, we are going to have a follow-up plan on primate individuals born and raised in the center to determine whether there is a case of infection in this group.



## Conclusion

*Echinococcus* eggs have not been found in our current study. However, considering high prevalence of intestinal helminths in leaf and dog fecal samples collected in the surrounding areas of the center, more research needs to be conducted on a larger scale (e.g. further testing of dog fecal samples, consideration of cases of hydatid cysts in local cattle slaughterhouses etc.) to confirm the circulation of pathogens in this region.

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## Feeding behaviour and diet of grey-shanked douc langurs (*Pygathrix cinerea*) in Kon Ka Kinh National Park, Vietnam

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**Key words:** Grey-shanked douc langur, *Pygathrix cinerea*, feeding behaviour, diet

### Summary

The data on feeding behaviour of grey-shanked douc langurs were collected from August 2007 to July 2008 in Kon Ka Kinh National Park, Gia Lai Province, Vietnam. In total, 880 feeding records, among 7,390 observations were made within 480 hours of direct observation of the study groups and 166 plant species of 40 plant families were identified as diet of the grey-shanked douc langurs. The feeding list comprises 115 species identified based on food remains and 51 species identified based on direct observation. Top 10 plant families comprise 59% of all species in the feeding list. Moraceae, Fagaceae and Myrtaceae are the top 3 tree families with the highest number of food plant species. Myrtaceae, Sapindaceae and Moraceae are the top 3 most eaten tree families. The top 10 most eaten families highly overlap with the top 10 most abundant families in the study site. *Pometia pinnata* was the most selected plant species in the diet with the selection ratio value 59.4 based on stem density and *Syzygium petelotii* was the most selected species with selection ratio value 129.2 based on the total basal area. The grey-shanked douc langurs fed 49.5% on young leaves, 21.9% on ripe fruits 19.1% on unripe fruits and only 9.3% on mature leaves. The proportion of food items eaten by the monkeys varied significantly over the months. The highest proportion of young leaves were eaten in February and the highest proportion of fruit in October. The monthly consumption of young leaves was significantly correlated to the abundance of the young leaves, but the monthly consumption of fruits was not significantly correlated to the abundance of fruits. The consumption of food items changed significantly between the wet and the dry season. The doucs ate mostly young leaves in the dry season (82%) when it was abundant and switched to fruits (~70%) in the wet season when young leaves became rare and fruits were abundant. Mature leaves were consumed more often in the wet season. Among the douc langur species, the grey-shanked doucs eat more leaves (58.8%) than black-shanked doucs ( $\bar{x}=47.2\%$ ) but less than red-shanked doucs ( $\bar{x}=72\%$ ). The grey-shanked doucs eat fruits and seeds more than red-shanked doucs ( $\bar{x}=18.4\%$ ) and the same proportion as black-shanked doucs ( $\bar{x}=40\%$ ). The doucs have a flexible dietary and feed on a high proportion of fruits and seeds. Among the odd-nosed monkey group (douc langurs, snub-nosed monkeys and proboscis monkeys) the diet composition and proportion of plant parts of the douc langurs is rather similar to that of the proboscis monkeys than to the snub-nosed monkeys. The douc langurs and proboscis monkeys feed mostly on leaves and fruits while snub-nosed monkeys consume a substantial high amount of lichen.

## Tập tính ăn và thức ăn của loài chà vá chân Xám (*Pygathrix cinerea*) ở Vườn Quốc gia Kon Ka Kinh, Việt Nam

### Tóm tắt

Số liệu về tập tính ăn của loài chà vá chân xám được thu thập từ tháng 8 năm 2007 đến tháng 7 năm 2008 tại Vườn Quốc gia Kon Ka Kinh, Tỉnh Gia Lai, Việt Nam. Tổng số có 880 dữ liệu tập tính ăn trong 7,390 quan sát từ 480 giờ theo dõi trực tiếp các bầy chà vá chân xám trong điều kiện tự nhiên. Nghiên cứu đã xác định được 166 loài thực vật thuộc 40 họ là thức ăn của loài chà vá chân xám. Danh sách bao gồm 115 loài được ghi nhận từ mẫu thức ăn còn thừa rơi vãi trên đất, và 51 loài quan sát trực tiếp. Có 10

họ thực vật chiếm đến 59% tổng số loài là thức ăn của chà và chân xám. Các họ Moraceae, Fagaceae, và Myrtaceae là 3 họ có số loài là thức ăn nhiều nhất. Trong khi đó, các họ thực vật Myrtaceae, Sapindaceae, và Moraceae là 3 họ có số cây được ăn nhiều nhất. Top 10 họ thực vật được ăn nhiều nhất có sự giao thoa rất lớn với top 10 họ thực vật phổ biến nhất trong khu vực nghiên cứu. Loài *Pometia pinnata* được chọn nhiều nhất trong số các loài thực vật là thức ăn với tỷ lệ chọn là 59,4 căn cứ trên mức độ phong phú của số cây. Loài *Syzygium petelotii* được chọn nhiều nhất với tỷ lệ chọn là 129,2 căn cứ trên tổng diện tích ngang của cây. Chà và chân xám ăn 49,5% lá non, 21,9% quả chín, 19,1% quả xanh, và chỉ có 9,3% là già. Thành phần thức ăn của chà và chân xám thay đổi khác biệt giữa các tháng. Lá non được ăn nhiều nhất vào tháng 1 và quả (chín và xanh) được ăn nhiều nhất vào tháng 10. Mức tiêu thụ lá non có mối quan hệ thống kê chặt với mức độ phong phú của lá non hàng tháng, tuy nhiên không có mối quan hệ rõ ràng giữa mức tiêu thụ quả và sự phong phú của quả theo tháng. Mức độ tiêu thụ các loại thức ăn khác nhau thay đổi một cách có ý nghĩa thống kê giữa mùa mưa và mùa khô. Chà và chân xám ăn chủ yếu là lá non vào mùa khô (82%) khi lá non phong phú, và đổi sang ăn quả (70%) vào mùa mưa khi lá non hiếm và quả trở nên phong phú. Đồng thời, lượng lá già cũng được ăn đáng kể trong mùa mưa. Trong số 3 loài chà và, chà và chân xám ăn nhiều lá (58,8%) hơn chà và chân đen ( $\bar{x}$  = 47%), nhưng ít hơn chà và chân nâu ( $\bar{x}$  = 72%). Chà và chân xám ăn nhiều quả và hạt hơn chà và chân nâu ( $\bar{x}$  = 18,4%) và tương đương với loài chà và chân đen ( $\bar{x}$  = 40%). Chà và chân xám có sự thay đổi linh hoạt thành phần các loại thức ăn, và ăn nhiều quả và hạt. So sánh trong nhóm khỉ mũi lạ (odd-nosed monkey) gồm có voọc chà vá, voọc mũi hếch, và khỉ proboscis cho thấy, thành phần loài thức ăn và loại thức ăn của voọc chà vá có nhiều điểm tương đồng với khỉ proboscis. Cả voọc chà vá và khỉ proboscis đều ăn chủ yếu lá và quả, trong khi đó voọc mũi hếch ăn một lượng đáng kể địa y.

## Introduction

As a colobine monkey, the grey-shanked douc langurs (*Pygathrix cinerea*) shares the common characteristic of their unique digesting system among primates. Digesting process of the colobine monkeys is quite similar to that of ruminants (Bauchop & Martucci 1968; Chivers 1994; Kay & Davies 1994). The stomach of colobine monkeys is characterised by enlarged and sacculated chambers containing an array of bacteria that ferment the ingested food to produce volatile fatty acids absorbed by the monkeys (Kay & Davies 1994). The digesting structure is an adaptation to response to the chemical problems of digesting leaves, as well as to neutralising the affects of digestion inhibitors and toxins (Chivers 1994; Caton 1998).

The typical diet of the Asian colobines consists of young leaves, unripe fruits and seeds, which are preferred over mature leaves. Ripe fruits are usually avoided (Yeager & Kool 2000). Since 1970's diet of the colobines have been studied comprehensively in Africa (Oates 1977; Struhsaker & Oates 1979; Dasilva 1994; Fashing 2001; Chapman & Chapman 2002) and Asia (Bennett 1983; Davies 1984; Kirkpatrick 1998; Yeager & Kool 2000; Matsuda et al. 2009). The colobines are determined as folivorous monkeys but in some studies their diet contains also large proportion of fruits and seeds. For example, *Presbytis rubicunda* eat over 80% seeds in some months (Davies 1991).

Since 1980's feeding behaviour and diets of the odd-nosed monkey group including *Rhinopithecus*, *Pygathrix* and *Nasalis* were studied in Southeast Asia and China (Yeager 1989; Boonratana 1993; Kirkpatrick 1998; Lippold 1998; Kirkpatrick et al. 2001; Li 2006; Guo et al. 2007; Grüter 2009; Matsuda et al. 2009). However, field research on *Pygathrix* genus is still limited due to the difficulty of access for researchers to habitat countries; Vietnam, Laos and Cambodia. However, early knowledge on feeding ecology on *Pygathrix* was acquired since the Vietnam War. Kavanagh (1972) and Gotchfield (1974) reported rare food-sharing behaviour among individuals of red-shanked douc langurs (*P. nemaeus*) in captivity and in the wild. Pham Nhat (1993) conducted a study of food components in stomachs of red-shanked douc langurs and provided a list of 50 food tree species. The main food items eaten by the red-shanked douc langurs were leaves, buds, fruits, seeds and flowers. However, the proportion of food items was not clear. Lippold (1998) proposed that food of red-shanked douc langurs contains mostly leaves and a little flowers and seeds. Hoang Minh Duc (2007) conducted a study on the ecology of black-shanked douc langurs (*P. nigripes*) in the national parks Nui Chua and Binh Chau Phuoc Buu, Vietnam and reported that the langurs eat at least 152 plant species of 37 plant families.

Up to date, information about feeding behaviour and ecology of the grey-shanked douc langur is still limited. This study should add more information on feeding behaviour and diet.

## Material and Methods

### Locality and study period

The data on feeding behaviour were collected from August 2007 to July 2008 in Kon Ka Kinh National Park, Gia Lai Province, Vietnam (Fig. 1)

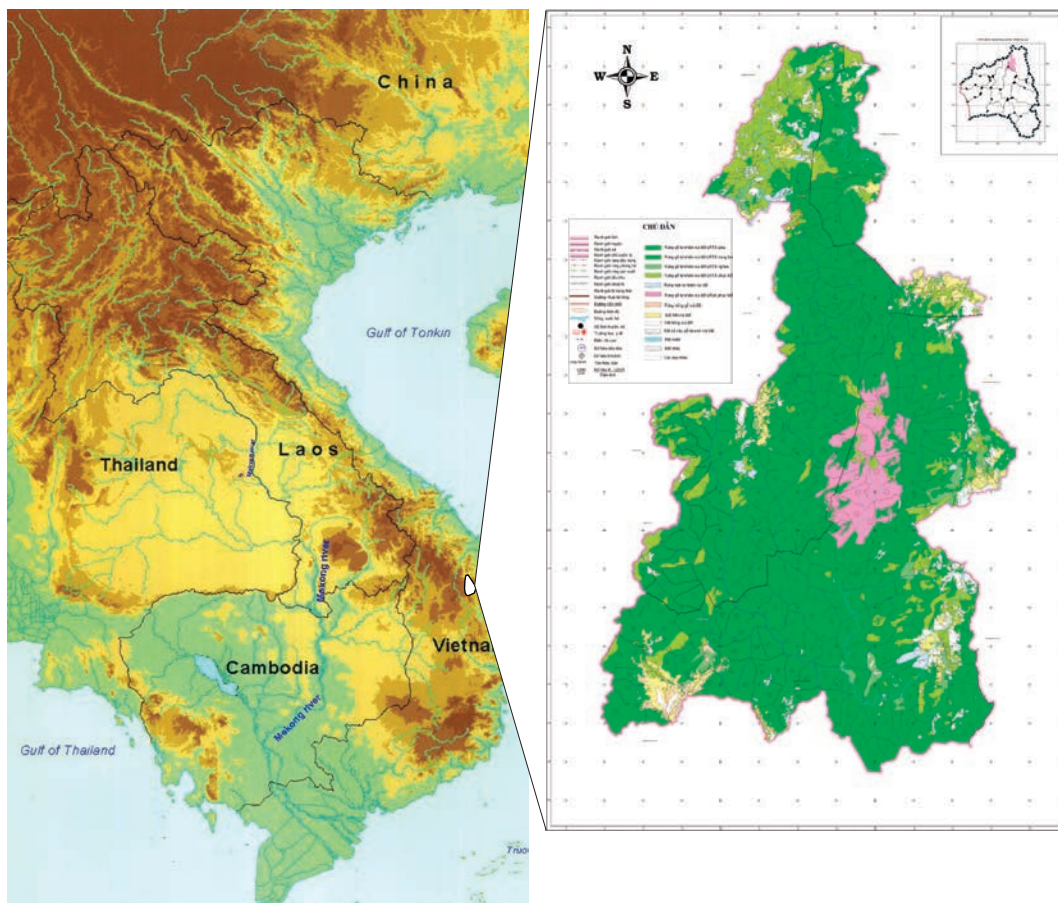


Fig.1. Kon Ka Kinh National Park in Vietnam.

### Activity recording

In total 880 feeding records among 7,390 observations were made within 480 hours of direct observation of the study groups. Data were collected using instantaneous scan-sampling method (Altmann 1974; Martin & Bateson 1993) with 5-minute intervals. The activity recorded for each individual was the first activity that lasted for more than 3 seconds once the individual was sighted. This requirement would reduce eye-catching behaviour such as playing behaviour, from being overrepresented in the data set (Bennett 1983; Fashing 2001). The cut-off was set at 5 individuals - adults, juveniles and infants - in each scan. Since the 5 individuals were the maximum number of individuals to scan effectively without counting the same individual twice during a scan (Fashing 2001). However, many occasions there were less than 5 individuals in one scan due to limited visibility.

Feeding was defined when a group member was inspecting food, bringing it to the mouth, chewing and swallowing it. When an individual was seen eating plant items (leaves, fruit seeds, flowers and others), the feeding score was recorded for that item. If the monkey was feeding at the time of a scan, the tree where the monkey fed on was tagged with a number and later a herbarium sample collected. The leaves were classified as young leaves, mature leaves, and fruits were classified as ripe and unripe.

### Collection of food items

Species of plants eaten by the langurs were collected using two methods:

1. Direct observation on each scan when the langurs feed, feeding trees were tagged with a number and herbarium specimens later on collected;
2. Collection of food remains on the ground after the monkey left the site.

The food remains that were less than two-days old were also collected. In this case, the samples were examined carefully to ensure that the remains belong to the langurs and not to another species. The obvious sign of the food remains from douc langurs was the shape of the bite mark on the leaves (Fig. 2). When collecting fruits the indentation from the teeth was carefully examined and compared with the indentation of the bite shapes on the leaves. Only young leaves and mature leaves were counted (leaf buds were included in the leaf category), seeds were lumped into the fruit category. The method used in this study followed suggestions made on recording data on food item remains for studies on primate diet by McGrew et al. (1988).



**Fig.2.** Signs used to determine the food remains (leaves and fruits) of grey-shanked douc langurs. Photo: Ha Thang Long.

### Data analysis

Kavanagh (1978) proposed that bias towards those scans during which many subjects were visible would be reduced by weighting each scan equally. Weighting data was done by dividing each observation by the total number of observations in a scan (Kool 1989). For example, if there are 5 observations in a scan, each observation will be scored as 1/5. In this study, un-weighted data were used to analyse the proportion of time spent in feeding. The reason was that the number of individuals in each scan was quite consistent and under 5 individuals.

### Selection ratios

The selection for food species in the diets of the study group in terms of ratios was calculated by measuring dietary selectivity. A food species that was selected is eaten more frequently than expected based on its proportional representation in the forest. When the ratio is greater than one, the monkeys ate a given species to a greater extent than would be expected if they were feeding at random. So, they were being selective in what they ate (McKey et al. 1981; Kool 1993; Fashing 2001). Two formulas were used to calculate selection ratios, one based on the stem density of tree species



and the other based on the basal area (BA).

$$\text{Selection ratios 1} = \frac{\% \text{ of annual feeding time spent feeding on species (i)}}{\% \text{ of stem density contributed by species (i)}}$$

$$\text{Selection ratios 2} = \frac{\% \text{ of annual feeding time spent feeding on species (i)}}{\% \text{ of total basal area contributed by species (i)}}$$

### Productivity Index

Data were collected on relative abundance of young leaves (YL), flowers (FL) and fruits (FR), as they were recognised as main foods of the douc langurs in previous studies. The relative abundance of plant parts was estimated, using a visual-count method (Chapman et al. 1992). At first, one branch was sub-sampled by counting for new leaves, flowers and fruits on the branch then extrapolated for the whole crown of the tree. The relative abundance of plant parts at 4 levels was scored as follows: 1= in 0-25%; 2= in 26-50%; 3= in 51-75% 4= in 76-100% of the whole tree crown. In total, 327 trees with dbh  $\geq$  30 cm were monitored. The monthly Productivity Index of fruits, flowers and young leaves was calculated:

$$\text{Productivity Index (fruits, flowers, young leaves) (month}_i\text{)} = \frac{\sum_{k=1}^4 P[k]_i \cdot k}{\sum_{k=1}^4 P[k]_i}$$

k = score levels of young leaves, fruits and flowers from 1 to 4

P[k]<sub>i</sub> = total trees counted in month *i*, at different score level

Productivity Index with a value range between 1 and 2

## Results

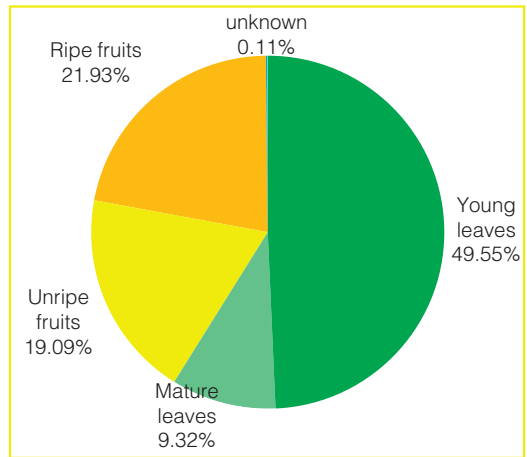
### Feeding pattern

The langurs started to eat immediately as soon as they moved out from the sleeping tree between 5:00 and 6:00 am. The langurs fed all the day, but there are two peaks of feeding time, one in the early morning at 6:00 am and another in the afternoon at 4:00 pm. The lowest feeding time was around 9:00 am. During this time the langurs spent the longest time for resting.

There is a difference in the time budget for feeding between wet and dry season. In the wet season (May to November) the langurs fed more extensively in the early morning and late afternoon and in the dry season (from December to April) they fed more frequently during different hours of the day. In the course of a year, the langurs spent the highest proportion of feeding time in January and lowest proportion in November. The nutrition value of plant parts the langurs eat and the availability of them during different time of the year might lead to such patterns.

### Food items annually

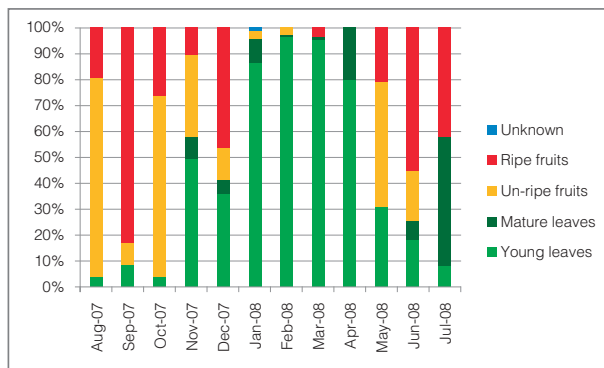
Four main food items eaten by the monkeys were: young leaves, mature leaves, unripe fruits and ripe fruits during the 12 months of study. Annually, the langurs fed mainly on young leaves which accounted for about 49.5% of food items. Ripe fruits and unripe fruits were also eaten in high proportions, 21.9% for ripe fruits and 19.1% for unripe fruits, respectively. Mature leaves were eaten but in low proportion with only 9.3% (Fig. 3).



**Fig.3.** Annual proportion of food items fed by the grey-shanked douc langurs.

### Food items monthly

The monthly proportion of food items varied significantly over the months ( $X^2=912.5$ ,  $df=33$ ,  $p<0.0001$ ). The langurs fed more on young leaves in the dry months from December to April with a peak in February, and fed on more fruits in the wet months from May to November with a peak in October (Fig. 4; Table 1). For example, in February 2008 the langurs fed the greatest proportion of young leaves (96.4%), while they fed far less on unripe fruits and mature leaves for 2.7% and 0.9% respectively. In October 2007, the langurs ate mainly fruits (96.2%) and only 3.8% young leaves.



**Fig.4.** Monthly proportion of food items fed by the grey-shanked douc langurs.

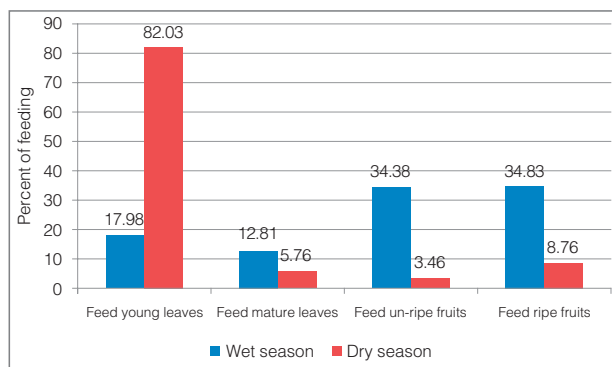
**Table 1.** Monthly proportion of food items fed by the grey-shanked douc langurs.

	Young leaves	Mature leaves	Unripe fruits	Ripe fruits	Unknown
Aug-07	3.8	0.0	76.9	19.2	0.0
Sep-07	8.3	0.0	8.3	83.3	0.0
Oct-07	3.8	0.0	69.8	26.4	0.0
Nov-07	48.9	8.5	31.9	10.6	0.0
Dec-07	35.6	5.5	12.3	46.6	0.0
Jan-08	86.2	9.2	3.4	0.0	1.1
Feb-08	96.4	0.9	2.7	0.0	0.0
Mar-08	95.5	0.9	0.0	3.6	0.0
Apr-08	80.0	20.0	0.0	0.0	0.0
May-08	30.9	0.0	48.1	21.0	0.0
Jun-08	18.2	7.3	19.1	55.5	0.0
Jul-08	7.8	50.0	0.0	42.2	0.0

The monthly changing in consumption of food items is related to the abundance of the food items. The correlation between Young Leaves Productivity Index and consumption of young leaves was positive significant ( $r_s = 0.77$ ,  $p = 0.003$ ). An example being that the langurs fed on the greatest proportion of young leaves in February 2008 when the Productivity Index of young leaves was highest (1.9). It means they ate young leaves when it was most abundant. Similarly, the monkeys fed the greatest proportion on fruits in October 2007 when the Productivity Index of fruits was highest (1.28). Although the correlation between Fruit Productivity Index and consumption of fruits was not significant ( $r_s = 0.52$ ,  $p = 0.07$ ).

### Seasonal changes in food items

The consumption of food items changed significantly between the wet and the dry season ( $X^2 = 371.4$ ,  $df = 3$ ,  $p < 0.0001$ ). In the dry season, the langurs fed mostly on young leaves (82%) and far less on mature leaves (5.7%), ripe fruits (8.7%) and unripe fruits (3.4%). In the wet season, the langurs fed mostly on fruits ~70%, their diet comprising of 34.8% ripe fruits and 34.4% unripe fruits. Young leaves were also eaten but in a low proportion of 17.9%. Mature leaves were eaten least among the food items with only 12.8% (Fig. 5).

**Fig.5.** Seasonal proportion of food items fed by the grey-shanked douc langurs.

In conclusion, although mature leaves are available year-round they were rarely eaten. Young leaves were more available in the dry season and the langurs fed extensively on these food items (Fig. 6). Fruits, including seeds were also eaten extensively in the wet season when they were more abundant (Fig. 7).

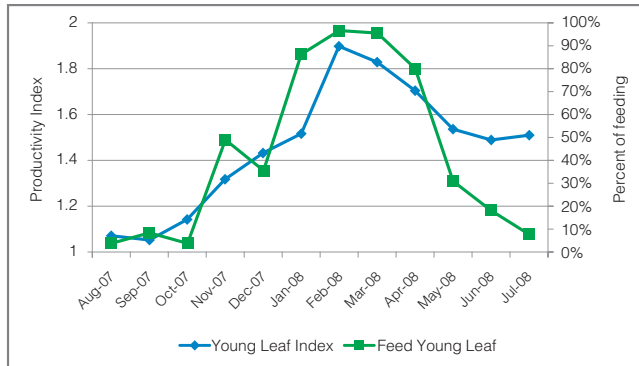


Fig.6. Correlation between 'Young Leaf Index' and monthly fed young leaves ( $r_s = 0.77$ ).

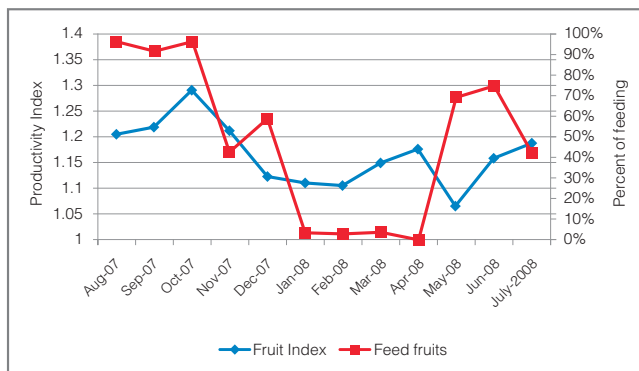


Fig.7. Correlation between 'Fruit Index' and monthly fed fruits ( $r_s = 0.52$ ).

### Plant species in the diet

In total, 166 plant species were identified as diets of the langurs (see Appendix: Table 2 and 3). The feeding list comprises 115 species identified on food remains and 51 species identified during direct observation. Among the 166 plant species, 89 species were found in the vegetation transect and 77 species not. This suggests that the langurs feed on quite a diverse amount of plant species since there were 344 plant species identified in the vegetation transects. The langurs ate leaves of 109 species (65%), fruits of 49 species (29%) and both the fruit and leaves of 23 species (13%).

The 166 plant species belong to 40 plant different families. The top 10 plant families comprise 59% of all species in the feeding list. There were 16 families that only had one species in the feeding list. There were three plant families that provided the most important food for the langurs: Moraceae, Fagaceae and Myrtaceae.

Moraceae and Fagaceae have the largest number of food plant species at 15. The langurs ate leaves of 11 Moraceae species and the fruit of 7 species. The two species *Ficus superba* and *Ficus annulata* were among the top 10 most eaten species having the langurs consume both the leaves and fruit. In the family Fagaceae, the langurs ate the leaves of 8 species and the fruit of 5 Fagaceae species. There were no species belonging to Fagaceae in the top 10 most eaten species.

Myrtaceae ranked third in the overall diversity of feeding species with 11 species. Three species *Syzygium cumini*, *Syzygium petelotii*, and *Syzygium oblatum* of this family were among the top 10

most eaten plant species. The langurs ate mainly leaves of *Syzygium cumini* and *Syzygium petelotii*, while they ate both leaves and fruits of *Syzygium oblatum*.

Based on 473 direct observations on feeding, a list of the top 10 species most eaten by the langurs was analysed. The top species are *Pometia pinnata*, *Camellia furfuraceae*, *Syzygium cumini*, *Quercus fructisepta*, *Syzygium petelotii*, *Syzygium oblatum*, *Xanthophyllum colubrinum*, *Ficus superba*, *Ficus annulata*, and *Syzygium polyanthum* (see Appendix: Table 4). The species *Pometia pinnata*, in the family Sapindaceae was the most eaten plant with the proportion of feeding 14.38%. Although the species only occurred at a density of 1.4 trees/ha. The langurs only fed on young leaves of this plant species. The species *Timonius jambosella*, family Rubiaceae was the least eaten plant with feeding proportion at only 0.21%.

Most food plants occur at a density of less than 10 trees/ha, except *Syzygium cumini* (14.3 trees/ha), *Nephelium melliferum* (14.3 trees/ha), *Garcinia oligantha* (14.8 trees/ha) and *Grewia bulot* (11.5 trees/ha).

### Selection ratios

A particular food may be “selected” to consume more often than would be expected from the species’ density if: (1) it is available for a long period of time, (2) it occurs at high density on an individual tree, or (3) the animal prefers it to other foods (Clutton-Brook 1975).

In this study, selection ratios for each feeding species were compared in terms of density and dominance (see Appendix: Table 5). This was calculated based on 473 observations (53% of total observations) of which the plant species eaten by the langurs could be identified. The selection ratio could not calculate the species identified from food remains because we did not know the exact time that the langurs spent on eating these species.

Using a selection ratio based on stem density, *Pometia pinnata* was the most selected plant species in the diet of the langurs with the selection ratio value 59.4. On average, there was only 1.4 trees/ha of *Pometia pinnata* in the study site. The least selected species was *Grewia bulot* with the selection ratio value 0.2. On average, there were 11.5 trees/ha of *Grewia bulot* in the study site but using a selection ratio based on basal area, *Syzygium petelotii* was the most selected species with selection ratio value of 129.2. *Grewia bulot* was the least selected species with the selection ratio value of 0.2.

There was no correlation between percent of time feeding on a species and stem density of the same species ( $r_s = -0.035$ ,  $p=0.86$ ). There was also no correlation between percent of time feeding on species and total basal area of the species ( $r_s = -0.075$ ,  $p=0.71$ ). This suggests that neither the density nor dominance of trees in the forest influences the choice of feeding tree. In fact, species such as *Garcinia oligantha*, *Nephelium melliferum*, and *Grewia bulot* were quite abundant in the study site but the langurs seldom fed on these species. Conversely, species such as *Pometia pinnata* and *Ficus superba* were very rare in terms of stem density, but the langurs fed on these species quite often. In the middle, *Syzygium cumini* was eaten quite often and was quite abundant at the site. The nutrition value of food items (young leaves, fruits, and seeds) that the tree species provide might be a more important factor to influence the choice of the tree species.

### Comparison of food species, tree families and its availability in the forest

A list of the top 10 most eaten plant families was calculated based on direct observations. The list of top 10 most diverse families in the feeding list was calculated based on direct observations and food remains. A comparison of the top 10 most eaten plant families and the top 10 most important families in two types of forests (Table 6):



**Table 6.** Comparison of the top 10 most density families in the feeding list and the top 10 families most important in the habitat of both forest types. FIV: Family Important Value.

No.	Family	No. of feeding species	Forest type 1	FIV	Forest type 2	FIV
1	<b>Fagaceae</b>	15	<b>Moraceae</b>	30.11	<b>Fagaceae</b>	38.31
2	<b>Moraceae</b>	15	<b>Myrtaceae</b>	25.93	<b>Euphorbiaceae</b>	34.00
3	<b>Myrtaceae</b>	11	<b>Lauraceae</b>	25.90	Sapindaceae	23.90
4	<b>Euphorbiaceae</b>	10	<b>Fagaceae</b>	24.23	<b>Lauraceae</b>	23.10
5	<b>Guttiferae</b>	10	<b>Euphorbiaceae</b>	23.99	<b>Guttiferae</b>	19.77
6	<b>Lauraceae</b>	9	Sapindaceae	21.78	<b>Myrtaceae</b>	19.71
7	<b>Meliaceae</b>	8	<b>Guttiferae</b>	20.01	<b>Moraceae</b>	15.34
8	Elaeocarpaceae	7	<b>Theaceae</b>	11.26	<b>Meliaceae</b>	12.68
9	<b>Sapotaceae</b>	7	<b>Sapotaceae</b>	11.03	Rubiaceae	10.39
10	<b>Theaceae</b>	7	<b>Rubiaceae</b>	9.65	Magnoliaceae	9.23

Type 1: Closed evergreen, lower montane moist sub-tropical forest.

Type 2: Mixed broad-leaf and needled-leaf, lower montane moist sub-tropical forest.

As a result, it revealed that 8 out of 10 most important families in the forest Type 1 overlap with the top 10 densest families in the feeding list. For the forest Type 2, 7 out of 10 most important plant families were overlapping with top 10 densest families in the feeding list (Table 7).

**Table 7.** Comparison of the top 10 most feeding families and the stem density of the top 10 most families in both forest types.

No.	Family	Feeding (%)	Forest type 1	Density (%)	Forest type 2	Density (%)
1	Myrtaceae	21.8	Myrtaceae	10.32	Euphorbiaceae	11.43
2	Sapindaceae	17.5	Sapindaceae	9.81	Lauraceae	9.67
3	Moraceae	14.8	Euphorbiaceae	8.54	Sapindaceae	9.01
4	Theaceae	9.1	Lauraceae	8.15	Guttiferae	8.79
5	Fagaceae	8.9	Moraceae	7.39	Fagaceae	7.03
6	Guttiferae	3.4	Guttiferae	7.13	Myrtaceae	6.81
7	Flacourtiaceae	3.2	Fagaceae	7.01	Moraceae	5.71
8	Tiliaceae	3.2	Rubiaceae	3.82	Rubiaceae	3.96
9	Alangiaceae	3.0	Theaceae	3.82	Meliaceae	3.74
10	Loranthaceae	3.0	Sapotaceae	3.57	Annonaceae	3.30

For example, the langurs ate 15 species of Moraceae. Moraceae was also among the most important in the forest Type 1 (ranked 1<sup>st</sup>, Table 6) and in the forest Type 2 (ranked 7<sup>th</sup>, Table 6). The langurs ate 15 species of Fagaceae and this family was also the most important family in the forest Type 2 and ranked as 4<sup>th</sup> in the forest Type 1 (Table 6). This means that the langurs exploited the plant species which belong to the most important families in the habitat. Noted that the ‘Family Important Value’ (FIV) indicates that the families are not only diverse, but also have a higher stem density and are the most dominant at the site. This is a sign that food resources in both types of forests are quite sufficient to support long term survival of the doucs. And the langurs have adapted very well to their habitat. The top 20 most consumed species were compared with top 20 species most abundant in two forest types (see Appendix: Table 8). There was an important overlap between feeding species and the most abundant species in each forest. For example, the species *Syzygium cumini*, which was eaten in high proportion by the langurs, (ranked 3<sup>rd</sup>, Table 8) was quite abundant in the forest Type 1 (ranked 3<sup>rd</sup>). The *Garcinia oligantha* was quite abundant in forest Type 2 (ranked 2<sup>nd</sup>, Table 8) and was also often consumed by the langurs (ranked 12<sup>th</sup>, Table 4). In particular, *Xerospermum*

*noronhianum*, the most abundant species in the both forest types, was eaten by the langurs, although, they fed a very little amount on this species. This suggests that the langurs exploited the abundant food resources in the site at the species level and the habitat could provide sufficient food to the grey-shanked douc langur population. This could be explained in that due to the abundance of food resources the doucs do not need to compete between the members of the group. In fact, the grey-shanked douc langurs can gather in a big troop of up to 100 individuals.

## Discussion

### Comparison of food items among the odd-nosed monkey group

The odd-nosed monkey group comprised of 10 species and 4 genera *Pygathrix*, *Rhinopithecus*, *Nasalis* and *Simias* is distributed only in Southeast Asia and Southwest China (Groves 2001). The study on feeding ecology of *Pygathrix* and *Rhinopithecus* was not focused on until China and Vietnam opened their countries to foreign scientists in the 1990's.

Within the genus *Pygathrix*, Pham Nhat (1993) reported that the diet of red-shanked douc langurs in Phong Nha-Ke Bang National Park comprised 63% of leaves and 37% of fruits. Lippold (1998) also reported that the red-shanked douc langurs in Son Tra, Danang feed mostly leaves (82%) and relatively low amount of fruits and seeds (14%). However, these studies were conducted only in a very short period. The diet of red-shanked douc langurs in captivity was studied on a semi-wild area at the Endangered Primate Rescue Center, Cuc Phuong National Park Otto (2005). Up to 62% leaves, 13% fruits and 25% flowers were recorded. Diet of the black shanked douc langur (*P. nigripes*) was reported in two long-term research studies, one in Cambodia (Rawson 2006) and one in Vietnam (Hoang Minh Duc 2009). Rawson reported for the black-shanked douc langurs an amount of 39.9%, leaves, 11.5% fruits and a remarkable proportion of seeds with 39.7%. Hoang Minh Duc listed for the black-shanked douc langurs in the Nui Chua and Binh Phuoc National Parks an amount of 54.6% leaves, 29.3% fruits and 14.5% flowers.

In the presented study, the grey-shanked douc langurs fed on 58.8% leaves and 40.1% fruits and seeds. In comparison to the other two douc langur species the grey-shanked douc langurs eat more leaves than the black-shanked douc langurs ( $\bar{x}$  = 47.2%) but less than red-shanked douc langurs ( $\bar{x}$  = 72%). And they ate fruits including seeds more than red-shanked douc langurs ( $\bar{x}$  = 18.4%) and the same proportion like the black-shanked douc langurs ( $\bar{x}$  = 40%).

It is to conclude, that all three douc langur species have a significant amount of fruit and seeds in their diet (range from 18.4% to 40.1%). But, the amount of leaves is still substantial when compared to other foodstuffs in their diets (from 39.9% to 87.8%)(see Appendix: Table 9). Chivers (1994) suggested that the genus *Pygathrix*, despite its low body weight, would appear to be in the more folivorous category. This data revealed that the diet of *Pygathrix* is more flexible. In a manner of speaking they have an intermediary position of folivorous and frugivorous, a flexible diet and consume a high proportion of fruits and seeds.

Within the genus *Rhinopithecus*, there are two different patterns of diet (Table 9). The snub-nosed monkeys including the Yunnan snub-nosed monkey (*R. bieti*), the golden snub-nosed monkey (*R. roxellana*), lichens appeared to be vital food type to these species, specially for the populations that live in conifer forest habitat (Kirkpatrick et al. 1998; Ding & Zhao 2004; Zuo-Fu Xiang et al. 2007). As an example, *R. bieti* fed heavily on lichens, up to 86% of the diet. In contrast, the Guizhou snub-nosed monkey (*R. breilichi*), the black snub-nosed monkey (*R. strykeri*) and the Tonkin snub-nosed monkey (*R. avunculus*) have remarkable diverse and flexible diet. Leaves and fruits were eaten in higher proportions ( $\bar{x}$  = 50%) and ( $\bar{x}$  = 29.4%), respectively (Bleisch et al. 1993; Yang et al. 2019; Boonratana & Le Xuan Canh 1998; Dong Thanh Hai 2008). Probably, richness of plant species in the tropical and sub-tropical habitat led to the diet of *R. breilichi*, *R. strykeri*, and *R. avunculus* more divers and flexible than the diet of *R. roxellana* and *R. bieti* in poor habitat.

The sole species in the genus *Nasalis*, the proboscis monkey (*N. larvatus*) consumed a high proportion of leaves ( $\bar{x}$  = 58.2%) and fruits ( $\bar{x}$  = 29.5%) while other plant parts were eaten in a low proportion (Table 9). Matsuda et al. (2009) described the fruit eating habit of proboscis monkeys in Menanggul River, Sabah, Malaysia as follow: the monkeys devoted 25.9% to feeding on fruits and

unripe fruits accounted for 90.4%. Seeds and fruit flesh accounted for 64.1% of unripe fruits, while only seeds were fed on ripe fruits.

In general, the diet component and proportion of plant parts in the diet of douc langurs is rather similar to that of *Nasalis* than *Rhinopithecus*. Douc langurs and proboscis monkeys feed mostly on leaves and fruits. These species live in tropical forests in Southeast Asia with high food plant diversity.

### Seasonal changes of food items

Van Schaik et al. (1993) suggested that there are six types of responses that primates might exhibit during a food scarcity period: (1) occasional famine and mass mortality, (2) dietary switching, (3) seasonal breeding, (4) seasonal movement, (5) altitudinal migration, and (6) hibernation. Many primates adapt to a dietary switching strategy when they face seasonal food scarcity.

The grey-shanked doucs in this study changed their diet component significantly following the seasonal availability of food items which they mainly feed on. In the dry season, the doucs fed mostly on young leaves (82%) and they ate a very low proportion of mature leaves (5.1%) and fruits (12.1%). In the wet season, the langurs fed extensively on fruits (~70%), mature leaves (12.8%), but a small proportion on young leaves (17.9%). In fact, when the young leaves became scarce, they switched their habits and fed on fruits, seeds and mature leaves which were more available during the wet season.

Evidence from other taxa of primates was also available. Stone (2007) reported that squirrel monkeys living in the Amazon forest remarkably change their diet components in different seasons. The squirrel monkeys feed mostly on insects ( $\bar{x} > 50\%$ ) and small amount of fruits, seeds and flowers. In the dry season, the monkeys consume high number of insects (79%) as their abundance is quite high. However, when insect abundance decreases in the wet season, they shift to feed more on fruits, seeds and flowers.

### Diet and food availability

Diet and dietary breadth are important factors influencing the ability of primates to survive (Wong et al. 2006) while quality and quantity of food available especially during the period of food scarcity are important factors that determine primate population carrying capacity of the habitat (Gautier-Hion et al. 2002). The diet of the grey-shanked douc langurs in Kon Ka Kinh National Park show that the monkeys have a remarkable wide range of food plants at both the species and family level. How this wide range of plants match with the food plant availability in the habitat is an interesting question. So, the list of the monkey's diet and the list of the most dominant family in the habitat were compared. It revealed that almost all of the food plants that the langurs fed on were quite abundant in the habitat. For example, the top 3 most eaten families Myrtaceae, Sapindaceae, and Moraceae were found significantly abundant in both types of forests where the langurs live. Myrtaceae ranked 1<sup>st</sup> in the forest Type 1 and 6<sup>th</sup> in the forest Type 2. Sapindaceae ranked 2<sup>nd</sup> in the forest Type 1 and 3<sup>rd</sup> in the forest Type 2. Moraceae ranked 5<sup>th</sup> in forest Type 2 and 7<sup>th</sup> in the forest Type 2. So, in terms of quantity, the habitat of the grey-shanked douc langurs in the Kon Ka Kinh National Park is highly capable to support the species.

The quality of habitat is another important factor to assess the carrying capacity of habitat (Davies 1994). This was not measured in this research project. Further study on nutritional value of food items from young leaves to mature leaves, as well as fruits and seeds at this study site are necessary.

### Important of research food remains

Among the 166 species identified as food plants of the grey-shanked doucs, 115 species were identified base on food remains. In the field, limited visual condition often prevented the ability to number all feeding trees of the langurs, so the study of foodstuffs remains in order to provide essential information of diet composition. This method was found useful in another field research as well. For example, the study of diet composition of *Rhinopithecus bieti* based on food remains and feces samples resulted in a list of 59 plant species, 42 genera and 28 families (Ding & Zhao 2004). Data on the diet of chimpanzees in forest of Kahuzi is comprised of 114 species from 57 plant families and was also analysed based on food remains and feces samples (Basabose 2002).

The diet of the grey-shanked douc langurs in the Kon Ka Kinh National Park contains mostly of young leaves and quite a significant amount of fruits. Seasonal changes affect the food items that the doucs eat on a monthly basis. There were 166 species of plants eaten by the grey-shanked douc langurs and the habitat of the species is highly capable in supporting the species.

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## Appendix

Table 2. List of food trees species eaten by the grey-shanked douc langurs. Fruits are combined ripe and unripe fruits.

No.	Species	Family	Food remains	Observation	Leave	Fruit	Unclassified
1	<i>Acer flabellatum</i>	Aceraceae	x		x		
2	<i>Saurauia roxburghii</i>	Actinidiaceae	x				x
3	<i>Alangium salvifolium</i>	Alangiaceae		x	x	x	
4	<i>Buchanania lucida</i>	Anacardiaceae	x		x		
5	<i>Pegia sarmentosa</i>	Anacardiaceae	x			x	
6	<i>Polyalthia jenkinsii</i>	Annonaceae	x		x		
7	<i>Schefflera bodinieri</i>	Araliaceae	x		x		
8	<i>Schefflera crassibracteata</i>	Araliaceae	x		x		
9	<i>Schefflera leroyiana</i>	Araliaceae	x		x		
10	<i>Schefflera pes-avis</i>	Araliaceae	x			x	
11	<i>Schefflera poilaneana</i>	Araliaceae	x		x		
12	<i>Schefflera trungii</i>	Araliaceae		x	x	x	
13	<i>Betula alnoides</i>	Betulaceae	x		x		
14	<i>Acrodes dungii</i>	Burseraceae	x		x		
15	<i>Canarium bengalense</i>	Burseraceae		x		x	
16	<i>Canarium littorale</i>	Burseraceae	x		x	x	
17	<i>Cassia javanica</i>	Caesalpinioideae		x	x	x	
18	<i>Capparis eurycibe</i>	Capparaceae	x		x		
19	<i>Capparis grandis</i>	Capparaceae	x			x	
20	<i>Capparis rigida</i>	Capparaceae	x			x	
21	<i>Rourea minor</i>	Capparaceae	x			x	
22	<i>Mastica arborea</i>	Cornaceae	x			x	
23	<i>Dipterocarpus obtusifolius</i>	Dipterocarpaceae	x				x
24	<i>Dipterocarpus turbinatus</i>	Dipterocarpaceae	x				x
25	<i>Diospyros bangoiensis</i>	Ebenaceae	x		x	x	
26	<i>Diospyros crumenata</i>	Ebenaceae	x				x
27	<i>Elaeocarpus darlacensis</i>	Elaeocarpaceae	x		x		
28	<i>Elaeocarpus grandiflora</i>	Elaeocarpaceae		x	x		
29	<i>Elaeocarpus grumosus</i>	Elaeocarpaceae	x		x	x	
30	<i>Elaeocarpus harmandii</i>	Elaeocarpaceae	x		x		
31	<i>Elaeocarpus hygrophilous</i>	Elaeocarpaceae		x	x		

32	<i>Elaeocarpus kontumensis</i>	Elaeocarpaceae	x		x		
33	<i>Elaeocarpus petelotii</i>	Elaeocarpaceae	x		x		
34	<i>Actephila excelsa</i>	Euphorbiaceae	x		x		
35	<i>Actephila anthelmintica</i>	Euphorbiaceae	x		x		
36	<i>Bischofia javanica</i>	Euphorbiaceae	x		x		
37	<i>Drypetes assamica</i>	Euphorbiaceae	x				x
38	<i>Endospermum chinense</i>	Euphorbiaceae	x		x		
39	<i>Oligoceras eberhardtii</i>	Euphorbiaceae	x				x
40	<i>Ostodes paniculata</i>	Euphorbiaceae	x		x		
41	<i>Phyllanthus lingulatus</i>	Euphorbiaceae	x				x
42	<i>Sapium discolor</i>	Euphorbiaceae	x		x		
43	<i>Trigonostemon annamensis</i>	Euphorbiaceae		x	x	x	
44	<i>Castanopsis recurira</i>	Fagaceae	x		x		
45	<i>Castanopsis wilsonii</i>	Fagaceae	x				x
46	<i>Lithocarpus chevalier</i>	Fagaceae	x		x		
47	<i>Lithocarpus gymnocarpus</i>	Fagaceae		x		x	
48	<i>Lithocarpus kontumensis</i>	Fagaceae	x		x	x	
49	<i>Lithocarpus megastachyus</i>	Fagaceae	x		x		
50	<i>Lithocarpus microbalanus</i>	Fagaceae	x		x		
51	<i>Lithocarpus pariei</i>	Fagaceae	x		x	x	
52	<i>Lithocarpus rhabdistachyus</i>	Fagaceae	x				x
53	<i>Lithocarpus toumorangensis</i>	Fagaceae	x		x		
54	<i>Quercus edithae</i>	Fagaceae	x				x
55	<i>Quercus fructisepta</i>	Fagaceae		x		x	
56	<i>Quercus macrocalyx</i>	Fagaceae	x				x
57	<i>Quercus setulosa</i>	Fagaceae		x		x	
58	<i>Quercus thorelii</i>	Fagaceae	x		x		
59	<i>Casearia annamensis</i>	Flacourtiaceae	x		x		
60	<i>Casearia membranacea</i>	Flacourtiaceae	x		x		
61	<i>Homalium ceylanicaum</i>	Flacourtiaceae		x	x		
62	<i>Hydnocarpus annamensis</i>	Flacourtiaceae		x		x	
63	<i>Hydnocarpus kurzii</i>	Flacourtiaceae		x	x		
64	<i>Garcinia lanessanii</i>	Guttiferae	x			x	
65	<i>Calophyllum dongnaiensis</i>	Guttiferae	x			x	
66	<i>Calophyllum rugosum</i>	Guttiferae	x			x	
67	<i>Calophyllum tetrapterum</i>	Guttiferae	x		x		
68	<i>Garcinia tinctoria</i>	Guttiferae	x			x	
69	<i>Garcinia oblongifolia</i>	Guttiferae	x		x		
70	<i>Garcinia oligantha</i>	Guttiferae		x	x	x	
71	<i>Garcinia schefferi</i>	Guttiferae	x		x		

72	<i>Garcinia vilersiana</i>	Guttiferae	x			x	
73	<i>Mesua ferruginea</i>	Guttiferae	x		x		
74	<i>Beilschmiedia yannanensis</i>	Lauraceae	x		x		
75	<i>Cinnamomum bonii</i>	Lauraceae		x			x
76	<i>Cinnamomum glaucescens</i>	Lauraceae	x		x		
77	<i>Cryptocarya metcalfiana</i>	Lauraceae		x		x	
78	<i>Dehaasia caesia</i>	Lauraceae	x		x	x	
79	<i>Lindera annamensis</i>	Lauraceae	x		x		
80	<i>Litsea baviensis</i>	Lauraceae	x		x		
81	<i>Litsea variabilis</i>	Lauraceae		x	x		
82	<i>Phoebe attenuata</i>	Lauraceae		x	x		
83	<i>Strychnos umbellata</i>	Loganiaceae		x		x	
84	<i>Macrosolen dianthus</i>	Loranthaceae		x	x		
85	<i>Michelia constricta</i>	Magnoliaceae	x		x		
86	<i>Michelia mediocris</i>	Magnoliaceae	x				x
87	<i>Michelia subulifera</i>	Magnoliaceae	x		x		
88	<i>Paramechelia baillonii</i>	Magnoliaceae		x		x	
89	<i>Memecylon chevalieri</i>	Melastomataceae		x	x		
90	<i>Aglaia annamensis</i>	Meliaceae	x				x
91	<i>Aglaia lawii</i>	Meliaceae	x		x		
92	<i>Aglaia verrucosa</i>	Meliaceae		x	x		
93	<i>Dysoxylum juglans</i>	Meliaceae	x		x		
94	<i>Dysoxylum excelsum</i>	Meliaceae	x				x
95	<i>Walsura elata</i>	Meliaceae		x		x	
96	<i>Walsura robusta</i>	Meliaceae	x		x		x
97	<i>Walsura vilosa</i>	Meliaceae	x		x		
98	<i>Artocarpus gomezianus</i>	Moraceae	x		x		
99	<i>Artocarpus lakoocha</i>	Moraceae		x	x	x	
100	<i>Artocarpus melinoxyla</i>	Moraceae	x		x		
101	<i>Artocarpus rigida</i>	Moraceae	x				x
102	<i>Artocarpus styracifolia</i>	Moraceae	x		x		
103	<i>Brosimum galactodendron</i>	Moraceae	x		x	x	
104	<i>Ficus amplissima</i>	Moraceae		x			x
105	<i>Ficus annulata</i>	Moraceae		x	x	x	
106	<i>Ficus callophylla</i>	Moraceae	x		x		x
107	<i>Ficus callosa</i>	Moraceae		x	x		
108	<i>Ficus hederacea</i>	Moraceae		x		x	
109	<i>Ficus superba</i>	Moraceae		x	x	x	
110	<i>Ficus talbotii</i>	Moraceae	x		x		
111	<i>Ficus tinctoria</i>	Moraceae		x	x	x	

112	<i>Ficus vasulosa</i>	Moraceae		x		x	
113	<i>Knema globularia</i>	Myristicaceae	x		x	x	
114	<i>Acmena acuminatissimum</i>	Myrtaceae	x				x
115	<i>Harpullia cupanioides</i>	Myrtaceae	x		x		
116	<i>Syzygium aromaticum</i>	Myrtaceae	x		x		
117	<i>Syzygium circumcissa</i>	Myrtaceae	x				x
118	<i>Syzygium cumini</i>	Myrtaceae		x	x		
119	<i>Syzygium oblatum</i>	Myrtaceae		x	x	x	
120	<i>Syzygium pachysarcum</i>	Myrtaceae		x	x		
121	<i>Syzygium petelotii</i>	Myrtaceae		x	x		
122	<i>Syzygium polyanthum</i>	Myrtaceae		x		x	
123	<i>Syzygium tinctorium</i>	Myrtaceae	x				x
124	<i>Syzygium tramnion</i>	Myrtaceae		x	x		
125	<i>Bulbophyllum guttulatum</i>	Orchidaceae	x				x
126	<i>Dendrobium chlorostylum</i>	Orchidaceae	x		x		
127	<i>Podocarpus neriifolius</i>	Podocarpaceae		x	x		
128	<i>Sorbus granulosa</i>	Rosaceae	x		x		
129	<i>Adina thanhoaensis</i>	Rubiaceae	x				x
130	<i>Canthium dicocum</i>	Rubiaceae	x		x		
131	<i>Psychotria sarmentosa</i>	Rubiaceae	x		x		
132	<i>Tarenna collinsae</i>	Rubiaceae	x				x
133	<i>Timonius jambosella</i>	Rubiaceae		x	x		
134	<i>Dimocarpus longan</i>	Sapindaceae	x				x
135	<i>Litchi sinensis</i>	Sapindaceae		x	x	x	
136	<i>Nephelium lappaceum</i>	Sapindaceae	x				x
137	<i>Nephelium melliferum</i>	Sapindaceae		x		x	
138	<i>Pometia pinnata</i>	Sapindaceae		x	x	x	
139	<i>Xerospermum noronhianum</i>	Sapindaceae	x				x
140	<i>Madhuca elliptica</i>	Sapotaceae	x		x		
141	<i>Madhuca subquiconcialis</i>	Sapotaceae		x	x		
142	<i>Palaquium annamensis</i>	Sapotaceae	x		x		
143	<i>Palaquium elliptica</i>	Sapotaceae	x				x
144	<i>Palaquium obovatum</i>	Sapotaceae	x				x
145	<i>Sarcosperma affinis</i>	Sapotaceae	x		x		
146	<i>Sarcosperma laurinum</i>	Sapotaceae	x		x		
147	<i>Ailanthus altissima</i>	Simaroubaceae	x		x		
148	<i>Ailanthus integrifolia</i>	Simaroubaceae		x			x
149	<i>Rehderodendron kweichowense</i>	Styraceae	x				
150	<i>Pyrenaria jonquieriana</i>	Theaceae		x	x		
151	<i>Camellia assimilis</i>	Theaceae	x				

152	<i>Camellia furfuraceae</i>	Theaceae		x	x	x	
153	<i>Camellia tsai</i>	Theaceae		x	x		
154	<i>Eurya trichocarpa</i>	Theaceae	x		x		
155	<i>Gordonia bidoupensis</i>	Theaceae	x		x		
156	<i>Ternstroemia kwangtungensis</i>	Theaceae		x	x		
157	<i>Colona nubla</i>	Tiliaceae		x	x		
158	<i>Grewia bulot</i>	Tiliaceae		x		x	
159	<i>Grewia calophylla</i>	Tiliaceae	x		x	x	
160	<i>Vitex leptobotrys</i>	Verbenaceae		x	x		
161	<i>Cissus rosea</i>	Vitaceae	x				x
162	<i>Parthenoissus landuk</i>	Vitaceae	x		x		
163	<i>Tetrastigma godefroyanum</i>	Vitaceae	x		x		
164	<i>Tetrastigma heterophyllum</i>	Vitaceae	x		x		
165	<i>Tetrastigma petelotii</i>	Vitaceae	x		x	x	
166	<i>Xanthophyllum colubrinum</i>	Xanthophyllaceae		x	x		
		<b>Total</b>	115	51	109	49	31

**Table 3.** List of plant families eaten by the grey-shanked douc langurs with percentage of feeding leaves and fruits, based on direct observation and food remains.

No.	Family	No. of species	%	No. of species langurs ate leaf	%	No. of species langurs ate fruit	%
1	Moraceae	15	9.0	11	10.1	7	14.3
2	Fagaceae	15	9.0	8	7.3	5	10.2
3	Myrtaceae	11	6.6	7	6.4	2	4.1
4	Guttiferae	10	6.0	5	4.6	6	12.2
5	Euphorbiaceae	10	6.0	7	6.4	1	2.0
6	Lauraceae	9	5.4	7	6.4	2	4.1
7	Meliaceae	8	4.8	5	4.6	2	4.1
8	Elaeocarpaceae	7	4.2	7	6.4	1	2.0
9	Theaceae	7	4.2	6	5.5	1	2.0
10	Sapotaceae	7	4.2	5	4.6	0	0.0
11	Sapindaceae	6	3.6	2	1.8	3	6.1
12	Araliaceae	6	3.6	5	4.6	2	4.1
13	Flacourtiaceae	5	3.0	4	3.7	1	2.0
14	Vitaceae	5	3.0	4	3.7	1	2.0
15	Rubiaceae	5	3.0	3	2.8	0	0.0
16	Capparaceae	4	2.4	1	0.9	3	6.1
17	Magnoliaceae	4	2.4	2	1.8	1	2.0
18	Burseraceae	3	1.8	2	1.8	2	4.1



Table 3. continuation

19	Tiliaceae	3	1.8	2	1.8	2	4.1
20	Anacardiaceae	2	1.2	1	0.9	1	2.0
21	Ebenaceae	2	1.2	1	0.9	1	2.0
22	Orchidaceae	2	1.2	1	0.9	0	0.0
23	Simaroubaceae	2	1.2	1	0.9	0	0.0
24	Dipterocarpaceae	2	1.2	0	0.0	0	0.0
25	Alangiaceae	1	0.6	1	0.9	1	2.0
26	Caesalpinioideae	1	0.6	1	0.9	1	2.0
27	Myristicaceae	1	0.6	1	0.9	1	2.0
28	Cornaceae	1	0.6	0	0.0	1	2.0
29	Loganiaceae	1	0.6	0	0.0	1	2.0
30	Aceraceae	1	0.6	1	0.9	0	0.0
31	Annonaceae	1	0.6	1	0.9	0	0.0
32	Betulaceae	1	0.6	1	0.9	0	0.0
33	Loranthaceae	1	0.6	1	0.9	0	0.0
34	Melastomataceae	1	0.6	1	0.9	0	0.0
35	Podocarpaceae	1	0.6	1	0.9	0	0.0
36	Rosaceae	1	0.6	1	0.9	0	0.0
37	Verbenaceae	1	0.6	1	0.9	0	0.0
38	Xanthophyllaceae	1	0.6	1	0.9	0	0.0
39	Actinidiaceae	1	0.6	0	0.0	0	0.0
40	Styraceae	1	0.6	0	0.0	0	0.0
	<b>Total</b>	166		109		49	

Table 4. Annual percentage of time spent feeding on specific food items based on direct observations (n=473).

No.	Species	Family	Young leaves %	Mature leaves %	Unripe fruit %	Ripe fruit %	Total %
1	<i>Pometia pinnata</i>	Sapindaceae	14.38				<b>14.38</b>
2	<i>Camellia furfuraceae</i>	Theaceae	0.85		0.42	6.34	<b>7.61</b>
3	<i>Syzygium cumini</i>	Myrtaceae	7.61				<b>7.61</b>
4	<i>Quercus fructisepta</i>	Fagaceae			6.77		<b>6.77</b>
5	<i>Syzygium petelotii</i>	Myrtaceae	1.69		2.54		<b>4.23</b>
6	<i>Syzygium oblatum</i>	Myrtaceae				3.81	<b>3.81</b>
7	<i>Xanthophyllum colubrinum</i>	Xanthophyllaceae			3.81		<b>3.81</b>
8	<i>Ficus superba</i>	Moraceae		0.63	2.75		<b>3.38</b>
9	<i>Ficus annulata</i>	Moraceae	2.54		0.21	0.42	<b>3.17</b>
10	<i>Syzygium polyanthum</i>	Myrtaceae				3.17	<b>3.17</b>

Table 4. continuation

11	<i>Macrosolen dianthus</i>	Loranthaceae	1.48		1.27		2.75
12	<i>Garcinia oligantha</i>	Guttiferae	1.06		1.27	0.42	2.75
13	<i>Artocarpus lakoocha</i>	Moraceae	1.69		0.85		2.54
14	<i>Colona nubla</i>	Tiliaceae	2.54				2.54
15	<i>Ficus vasulosa</i>	Moraceae				2.33	2.33
16	<i>Schefflera trungii</i>	Araliaceae	0.21			2.11	2.33
17	<i>Alangium salvifolium</i>	Alangiaceae	1.27		0.42		1.69
18	<i>Hydnocarpus kurzii</i>	Flacourtiaceae	1.69				1.69
19	<i>Ficus amplissima</i>	Moraceae	0.42		1.06		1.48
20	<i>Phoebe attenuata</i>	Lauraceae			0.21	1.27	1.48
21	<i>Quercus setulosa</i>	Fagaceae			1.48		1.48
22	<i>Homalium ceylanicaum</i>	Flacourtiaceae	0.42	0.85			1.27
23	<i>Canarium bengalense</i>	Burseraceae				1.27	1.27
24	<i>Elaeocarpus grandiflora</i>	Elaeocarpaceae	1.27				1.27
25	<i>Nephelium melliferum</i>	Sapindaceae				1.27	1.27
26	<i>Strychnos umbellata</i>	Loganiaceae	1.27				1.27
27	<i>Syzygium tramnion</i>	Myrtaceae	0.85		0.21	0.21	1.27
28	<i>Alangium ridlay</i>	Alangiaceae				1.06	1.06
29	<i>Madhuca subquiconcialis</i>	Sapotaceae	1.06				1.06
30	sp3	sp3	1.06				1.06
31	<i>Camellia tsai</i>	Theaceae		0.85			0.85
32	<i>Ficus hederacea</i>	Moraceae				0.85	0.85
33	<i>Podocarpus neriifolius</i>	Podocarpaceae	0.63			0.21	0.85
34	<i>Pyrenaria jonqueriana</i>	Thaceae	0.85				0.85
35	<i>Vitex leptobotrys</i>	Verbenaceae	0.42			0.21	0.63
36	<i>Litchi sinensis</i>	Sapindaceae	0.63				0.63
37	<i>Garcinia cf. tinctoria</i>	Guttiferae				0.42	0.42
38	<i>Grewia bulot</i>	Tiliaceae	0.42				0.42
39	<i>Litsea variabilis</i>	Lauraceae	0.42				0.42
40	sp1	sp1			0.42		0.42
41	<i>Walsura elata</i>	Meliaceae	0.42				0.42
42	<i>Cryptocarya metcalifiana</i>	Lauraceae				0.21	0.21
43	<i>Elaeocarpus japonicus</i>	Elaeocarpaceae			0.21		0.21
44	<i>Paramechelia baillonii</i>	Magnoliaceae				0.21	0.21
45	sp2	sp2	0.21				0.21
46	sp4	sp4	0.21				0.21
47	<i>Syzygium pachysarcum</i>	Myrtaceae		0.21			0.21
48	<i>Timonius jambosella</i>	Rubiaceae		0.21			0.21

**Table 5.** Selection ratios (SR) for all plant species in the annual diet of the grey-shanked douc langurs.

SDSR: Selection ratio based on stem density; BASR: Selection ratio based on basal area; N/A: the species did not appear along the tree enumeration transects.

No.	Species	Feeding time (%)	Density (tree/ha)	Density (%)	SDSR	Basal area (%)	BASR
1	<i>Pometia pinnata</i>	14.4	1.4	0.24	59.4	0.72	19.9
2	<i>Camellia furfuraceae</i>	7.6	N/A	N/A	N/A	N/A	N/A
3	<i>Syzygium cumini</i>	7.6	14.3	2.42	3.1	1.57	4.8
4	<i>Quercus fructisepta</i>	6.8	.	.	.	.	.
5	<i>Syzygium petelotii</i>	4.2	1.4	0.24	17.5	0.03	129.2
6	<i>Syzygium oblatum</i>	3.8	3.3	0.56	6.7	0.30	12.6
7	<i>Xanthophyllum colubrinum</i>	3.8	.	.	.	.	.
8	<i>Ficus superba</i>	3.4	0.5	0.08	41.9	0.21	16.3
9	<i>Ficus annulata</i>	3.2	.	.	.	.	.
10	<i>Syzygium polyanthum</i>	3.2	.	.	.	.	.
11	<i>Macrosolen dianthus</i>	2.7	.	.	.	.	.
12	<i>Artocarpus lakoocha</i>	2.5	1.9	0.32	7.9	0.18	14.3
13	<i>Colona nubla</i>	2.5	.	.	.	.	.
14	<i>Ficus vasulosa</i>	2.3	.	.	.	.	.
15	<i>Schefflera trungii</i>	2.3	.	.	.	.	.
16	<i>Garcinia oligantha</i>	2.7	14.8	2.50	1.1	1.47	1.9
17	<i>Alangium salvifolium</i>	1.7	0.9	0.16	10.5	0.64	2.7
18	<i>Hydnocarpus kurzii</i>	1.7	8.6	1.45	1.2	0.31	5.5
19	<i>Ficus amplissima</i>	1.5	1.4	0.24	6.1	0.70	2.1
20	<i>Phoebe attenuata</i>	1.5	4.3	0.73	2.0	0.55	2.7
21	<i>Quercus setulosa</i>	1.5	0.5	0.08	18.4	0.03	44.4
22	<i>Canarium bengalense</i>	1.3	.	.	.	.	.
23	<i>Elaeocarpus grandiflora</i>	1.3	0.5	0.08	15.7	0.26	4.8
24	<i>Homalium ceylanicaum</i>	1.3	.	.	.	.	.
25	<i>Nephelium melliferum</i>	1.3	14.3	2.42	0.5	1.47	0.9
26	<i>Strychnos umbellata</i>	1.3	0.9	0.16	7.9	0.10	12.4
27	<i>Syzygium tramnion</i>	1.3	2.4	0.40	3.1	0.38	3.3
28	<i>Alangium ridlay</i>	1.1	.	.	.	.	.
29	<i>Madhuca subquiconcialis</i>	1.1	0.9	0.16	6.6	0.08	13.3
30	<i>Camellia tsai</i>	0.8	0.5	0.08	10.5	0.08	10.7
31	<i>Ficus hederacea</i>	0.8	.	.	.	.	.
32	<i>Podocarpus neriifolius</i>	0.8	3.3	0.56	1.5	1.27	0.7
33	<i>Pyrenaria jonqueriana</i>	0.8	.	.	.	.	.
34	<i>Litchi sinensis</i>	0.6	1.9	0.32	2.0	0.59	1.1
35	<i>Vitex leptobotrys</i>	0.6	.	.	.	.	.

36	<i>Garcinia tinctoria</i>	0.4	0.9	0.16	2.6	0.18	2.3
37	<i>Grewia bulot</i>	0.4	11.5	1.94	0.2	2.05	0.2
38	<i>Litsea variabilis</i>	0.4	.	.	.	.	.
39	<i>Walsura elata</i>	0.4	2.4	0.40	1.0	0.15	2.8
40	<i>Cryptocarya metcalifiana</i>	0.2	.	.	.	.	.
41	<i>Elaeocarpus japonicus</i>	0.2	5.7	0.97	0.2	0.83	0.3
42	<i>Paramechelia baillonii</i>	0.2	.	.	.	.	.
43	<i>Syzygium pachysarcom</i>	0.2	3.3	0.56	0.4	0.55	0.4
44	<i>Timonius jambosella</i>	0.2	2.4	0.40	0.5	0.06	3.3

**Table 8.** Comparison of the top 20 most feeding species and top 20 most abundant species in both types of forest.  
DR: Relative Density; DA: Absolute Density.

Top 20 most feeding species		Forest type 1				Forest type 2			
Species	feeding time (%)	Species	No. trees	DR	DA	Species	No. trees	DR	DA
<i>Pometia pinnata</i>	14.38	<i>Xerospermum noronhianum</i>	31	3.95	24	<i>Xerospermum noronhianum</i>	25	5.49	31
<i>Camellia furfuraceae</i>	7.61	<i>Nephelium melliferum</i>	24	3.06	18	<b><i>Garcinia oligantha</i></b>	18	3.96	23
<b><i>Syzygium cumini</i></b>	7.61	<b><i>Syzygium cumini</i></b>	24	3.06	18	<i>Sapium discolor</i>	11	2.42	14
<i>Quercus fructisepta</i>	6.77	<i>Grewia bulot</i>	18	2.29	14	<i>Lithocarpus kontumensis</i>	10	2.20	13
<i>Syzygium petelotii</i>	4.23	<i>Dacryodes cf. dungii</i>	17	2.17	13	<i>Diospyros latisejala</i>	9	1.98	11
<i>Syzygium oblatum</i>	3.81	<i>Taxotrophis macrophylla</i>	17	2.17	13	<i>Litsea rubescens</i>	9	1.98	11
<i>Xanthophyllum colubrinum</i>	3.81	<i>Sapium aponicas</i>	16	2.04	12	<i>Aporosa ficifolia</i>	8	1.76	10
<i>Ficus superba</i>	3.38	<b><i>Garcinia oligantha</i></b>	13	1.66	10	<i>Glochidion obliquum</i>	8	1.76	10
<i>Ficus annulata</i>	3.17	<i>Litsea rubescens</i>	12	1.53	9	<i>Xylopia nitida</i>	8	1.76	10
<i>Syzygium polyanthum</i>	3.17	<b><i>Hydnocarpus kurzii</i></b>	11	1.40	8	<i>Buchanania lucida</i>	7	1.54	9
<i>Macrosolen dianthus</i>	2.75	<i>Ostodes paniculata</i>	10	1.27	8	<i>Cinnamomum durifolium</i>	7	1.54	9
<b><i>Garcinia oligantha</i></b>	2.75	<i>Canthium dicoccum</i>	9	1.15	7	<b><i>Hydnocarpus kurzii</i></b>	7	1.54	9
<i>Artocarpus lakoocha</i>	2.54	<i>Pterospermum lancaefolium</i>	9	1.15	7	<i>Adina thanhoaensis</i>	6	1.32	8
<i>Colona nubla</i>	2.54	<i>Beilschmiedia balansae</i>	8	1.02	6	<i>Calophyllum dongnaiensis</i>	6	1.32	8

Table 8. continuation

<i>Ficus vasulosa</i>	2.33	<i>Elaeocarpus aponicas</i>	8	1.02	6	<i>Grewia bulot</i>	6	1.32	8
<i>Schefflera trungii</i>	2.33	<i>Lithocarpus leiocarpa</i>	8	1.02	6	<i>Memecylon acuminatum</i>	6	1.32	8
<i>Alangium salvifolium</i>	1.69	<i>Lithocarpus microbalanus</i>	8	1.02	6	<i>Nephelium melliferum</i>	6	1.32	8
<b><i>Hydnocarpus kurzii</i></b>	1.69	<i>Walsura robusta</i>	8	1.02	6	<b><i>Syzygium cumini</i></b>	6	1.32	8
<i>Ficus amplissima</i>	1.48	<i>Cleistocalyx circumcissa</i>	7	0.89	5	<i>Artocarpus cf. styracifolius</i>	5	1.10	6
<i>Phoebe attenuata</i>	1.48	<i>Croton tiglium</i>	7	0.45	5	<i>Artocarpus gomezianus</i>	5	1.10	6

Table 9. Comparison of the diet in the odd-nosed monkey group.

Species	Site	Habitat	TL	YL	ML	Fr	Se	FI	B/B	L/F	O/U	Reference
<b><i>Pygathrix</i></b>												
<i>cinerea</i>	Kon Ka Kinh NP	Sub-tropical moist forest	58.9	49.5	9.3	41.0	-	-	-	-	0.1	This study
<i>nigripes</i>	Nui Chua NP	Tropical dry forest	54.6	-	-	19.8	9.6	14.6	-	-	1.5	Hoang Minh Duc 2007
<i>nigripes</i>	Seima Biodiversity Conservation Area (SBCA)	evergreen forest	39.9	-	-	11.4	39.7	8.8	-	-	0.2	Rawson 2009
<i>nemaeus</i>	Son Tra NR	Tropical lowland forest	82.0	-	-	14.0	-	4.0	-	-	-	Lippold 1998
<i>nemaeus</i>	Phong Nha	Tropical lowland forest	63.0	-	-	37.0	-	-	-	-	-	Pham Nhat 1993
<i>nemaeus</i>	Cuc Phuong	Semi-wild habitat	62.0	-	-	13.0	-	25.0	-	-	-	Otto 2005
<i>nemaeus</i>	Son Tra NR	Tropical lowland forest	87.8	68.6	31.4	10.2	-	1.6	0.4	-	-	Ulibarri 2013
<i>nemaeus</i>	Son Tra NR	Tropical lowland forest	65.5	-	-	17.8	2.0	5.3	-	-	9.4	Clayton 2018
<b><i>Rhino-pithecus</i></b>												



Table 9. continuation

<i>avunculus</i>	Tac Ke/Nam Trang	Tropical broadleaf forest	38.0	-	-	62.0	-	-	-	-	-	Boonratana & Le Xuan Canh 1998
<i>avunculus</i>	Khau Ca	Limestone broadleaf forest	53.1	46.2	6.9	25.0	7.2	12.2	-	-	2.4	Dong Thanh Hai 2008
<i>roxellana</i>	Qinling Mount	Deciduous broadleaf forest	24.0			29.4			15.3	29.0	1.0	Guo et al. 2007
<i>bieti</i>	Wuyapiya	Conifer forest	>6	-	-	-	-	-	-	86.0	8.0	Kirkpatrick et al. 1998
<i>bieti</i>	Tacheng, Yunan	Conifer forest/ broadleaf	31.0	-	-	-	-	-	-	60.0	-	Ding & Zhao 2004
<i>bieti</i>	Xiaochangdu, Tibet	Conifer forest	12.0	-	-	0.6	-	1.1	-	82.0	-	Zuo-Fu Xiang et al. 2007
<i>brelichi</i>	Fanjingshan	Temperate broadleaf forest	71.0	-	-	15.0	-	7.0	-	0.2	6.0	Bleisch et al. 1993
<i>strykeri</i>	Gaoligong Mountains	Sub-tropical evergreen broad-leaved vegetation	37.9	21.9	16.0	15.7	-	15.2	17.5	2.5	-	Yang et al. 2019
<i>strykeri</i>	Samumsam	Mangrove/ heath forest	41.0	-	-	41.0	15.0	3.0	-	-	-	Bennet & Sebastian 1988
<b><i>Nasalis</i></b>												
<i>larvatus</i>	Kinabatangan-Sukai	Peat swamp forest	74.0	73.0	<1	11.0	-	8.0	-	-	8.0	Boonratana 1993
<i>larvatus</i>	Tanjung Puting	Peat swamp forest	52.0	42.0	10.0	40.0	-	3.0	-	-	5.0	Yeager 1989
<i>larvatus</i>	Menanggul River	Riverbanks forest	66.0	66.0	-	26.0	-	-	-	-	-	Matsuda et al. 2009

TL: total leaves; YL: young leaves; ML: mature leaves; Fr: Fruit; Se: Seed; Fl: Flower; B/B: Bud and bark; L/F: Lichen and Fungi; O/U: Unidentified



## SHORT COMMUNICATIONS

### Unusual aggressive behaviour of Hatinh langurs (*Trachypithecus hatinhensis*)

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**Key words:** behaviour, Hatinh langur, *Trachypithecus hatinhensis*

A 3 to 4 ha forest area on karst in Huong Hoa District, Quang Tri Province, Vietnam was protected by the villagers for ritual reasons. It is surrounded by fields and has no direct contact with more distant karst forest areas. According to the villagers, a group of Hatinhlangurs (*Trachypithecus hatinhensis*) settled there 8 years ago, apparently over a long distance through fields.

The group, consisting of one male and 2 to 3 females, lives mainly in an area of about 1 ha in the forest, near a concrete road leading to a village.

Since July 2020 the male has been behaving extremely aggressively. Since then, the group has been staying mostly near the road and as soon as pedestrians or moped riders pass the spot, the male often jumps from a lurking position on a tree near the road onto the passing or driving person and tries to bite (Fig. 1, 2). In several cases there have been bite wounds, some of which had to be treated by sewing the wounds.



Fig.1. A Hatinhlangur male lurks on a tree along the road for passers-by. Photo: Hoang Tao.



**Fig.2.** A ranger from the forest protection department is piloting a motorcycle passed the aggressive Hatinhlangur. Photo: Hoang Tao.

Volunteers from the villages along the road were available to try to drive the aggressive animal into the woods at this section of the road, which is 500 to 600 m long (Fig. 3). The command of the border troops stationed near the border to Laos was requested to secure the road section with dogs. Banners were erected to warn the people (Fig. 4).

Human-primate conflicts are relatively low in Vietnam and especially concern crop-raiding by macaques. Aggressive behavior of macaques is also known from several tourist sites, due to the misconduct of tourists to feed the macaques. Langurs are usually shy because of the high hunting pressure and as leaf-eating primates they are not attracted by feeding, with a subsequent aggressiveness.

The cause of the behavior of the Hatinhlangur is unclear, but could possibly have been triggered by an aggressive behavior of humans towards a Hatinhlangur female. The catch of a young, or even the killing of a female and the associated removal of a young may be a trigger. In the Hatinhlangur groups at the Endangered Primate Rescue Center, which are kept as captive breeding population for reintroduction projects, the males often show a very aggressive behavior when a female is harassed with young.

It is hoped that this problem can be solved without harm to the people and the langurs.





**Fig.3.** Border guards, rangers and villagers protect passers-by from the Hatinhlangur's aggressiveness. Photo: Hoang Tao.



**Fig.4.** Banners warn passers-by on the road section of the Hatinhlangur's aggressiveness. Photo: Hoang Tao.





## SHORT COMMUNICATIONS

### 7<sup>th</sup> ASIAN PRIMATE SYMPOSIUM 2020, Guwahati, India and a preview of the 8<sup>th</sup> ASIAN PRIMATE SYMPOSIUM 2021, Vietnam

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**Key words:** Asian Primate Symposium 2020 / 2021

The 7<sup>th</sup> Asian Primate Symposium was hosted from the 8<sup>th</sup> to the 10<sup>th</sup> of February 2020 by the Gauhati University in the State of Assam in northeastern India. The symposium was organized in collaboration between Aaranyak, a leading wildlife NGO based in Guwahati, the Zoology Department of the Gauhati University, and the Primate Research Centre (Fig. 1, 2).



**Fig.1.** The 7<sup>th</sup> Asian Primate Symposium was hosted from the 8<sup>th</sup> to the 10<sup>th</sup> of February 2020 by the Gauhati University in the State of Assam in northeastern India. Photo: Tilo Nadler



**Fig.2.** The Secretary General of the APS 2020 and Vice President of the NGO Aaranyak Dr. Dilip Chetry (right) handed over a keepsake to Dr. Mewa Singh, Chair of the International APS Committee 2020. Photo: Tilo Nadler.

The 7<sup>th</sup> Asian Primate Symposium 2020 held under the overarching theme: “*Conserving Primate Diversity in the Anthropocene: Challenges and Strategies*”. It was also announced as the 1<sup>st</sup> International Conference on ‘Human-Primate Interface’. While both events were formally announced, there were no recognizable content-separation (e.g. into thematic complexes or separated side programs) so a reason for the double announcement remains vague.

The symposium was divided into 6 sub-themes:

1. Primate Biogeography, Ecology & Behaviour, Cognition, Climate Change and Conservation
2. Urban Primate Ecology and Human-Primates Interaction
3. Primate Health, Hygiene, Zoo Management and Conservation Breeding
4. Primate Phylogeny, Genetics and Forensic
5. Primate Trades and trans-boundary issues, Advocacy and Policy Management
6. Primate in Literature, Folklore, Outreach and Training

A total of 6 plenary lectures, 109 presentations, 70 lectures, and 39 posters were submitted. More specifically:

- The morning and afternoon sessions started with one of the 6 plenary lectures.
- The 109 presentations were assigned to each of the six sub-themes in the following way: 1 (55), 2 (22), 3 (8), 4 (5), 5 (16) and 6 (3).
- The 70 lectures and 6 plenary presentations were submitted from the following 18 countries: Bangladesh (4); Belgium (2); China (9); Germany (1); Hong Kong (2); India (35); Japan (1); Malaysia (4); Myanmar (1); Philippines (3); Nepal (1); Singapore (1); South Korea (1); Sri Lanka (4); Thailand (4); United Kingdom (1); US (1); Vietnam (2).
- The 39 poster presentations originated from the following 11 countries: Bangladesh (5); Czech Republic (1); India (23); Japan (1); Malaysia (1); Myanmar (1); Nepal (3); Philippines (1); Poland (1); Thailand (1); Vietnam (1),

The symposium was very well organized and the presented work truly inspiring. At the entrance

of the plenary hall the poster walls were placed, as well as a photo exhibition about the primates of the eastern Himalayan region. In this exhibition, a number of excellent and impressive photos were shown. The breaks were, as at every conference, used extensively for personal contacts, and were additionally inspirational thanks to the excellent culinary offer at the lunch buffets.

Unfortunately, there were some gaps in the lecture program due to the cancellations of participants. Indeed, due to travel restrictions since the very beginning of the COVID-era, it was unfortunately not possible for several announced participants (especially from China and Europe) to arrive. As a result, they could not present their work at the conference.

The conference fee for an early bird registration was with 100 USD very moderate, accommodation exclusive. The decentralized location and the relatively long distance of the hotel accommodations from the university campus were a little unfavorable. This required additional organizational effort and longer bus trips.

The symposium was preceded by a 3-day training course (February 5<sup>th</sup> to 7<sup>th</sup>) for students. The costs for the participation of 9 research students were sponsored by ICIMOD (International Centre for Integrated Mountain Development).

Several organized field trips were offered as a supplementary program to the symposium. However, the organizing committee - and here we would like to especially thank Dr. Dilip Chetry, the Secretary General of the Symposium who was generous enough to realize special requests. As such, I was privileged to visit the Kokajana Wildlife Sanctuary with a small group and had an incredible opportunity to see the golden langurs (*Trachypithecus geei*) (Fig. 3), as well as the Manas National Park with equally good sightings of capped langurs (*Trachypithecus pileatus*) and the Hollongapar Gibbon Sanctuary with an excellent opportunity to see western hoolock gibbons (*Hoolock hoolock*) and also capped langurs (Fig. 4, 5, 6). But the most fascinating experience was the visit of the Kaziranga National Park with its incredible fauna and unique population of rhinos, elephants, water buffalos, deer and an overwhelming birdlife (Fig. 7, 8). Another highlight was the visit of the breeding station for pygmy hog (*Porcula salvania*) in Guwahati, which gives hope that this species can be preserved (Fig. 9, 10).



**Fig.3.** Golden langur (*Trachypithecus geei*) in the Kokajana Wildlife Sanctuary. Photo: Tilo Nadler.





**Fig.4.** Entrance to the Hollongapar Gibbon Sanctuary. Photo: Tilo Nadler.



**Fig.5.** Western hoolock gibbon male (*Hoolock hoolock*) in the Hollongapar Gibbon Sanctuary. Photo: Tilo Nadler.





**Fig.6.** Western hoolock gibbon female (*Hoolock hoolock*) in the Hoolongapar Gibboin Sanctuary. Photo: Tilo Nadler.



**Fig.7.** Wild water buffaloes (*Bubalus arnee*) in Kaziranga National Park. Photo: Tilo Nadler.



**Fig.8.** Indian rhinoceros female with calf (*Rhinoceros unicornis*) in Kaziranga National Park. Photo: Tilo Nadler.



**Fig.9.** Part of the breeding centre for the 'Endangered' pygmy hog (*Porcula salvania*) in Guwahati. Photo: Tilo Nadler.





**Fig.10.** Pygmy hogs (*Porcula salvania*) at the breeding centre in Guwahati. Photo: Tilo Nadler.

Overall, the 7<sup>th</sup> Asian Primate Symposium was a successful and informative event. The vast majority of presentations by Indian primatologists gave a detailed insight into the state of primate research in the country and provided an overview of the status of the species, conservation activities and their needs, with a focus on the primate species of northern India.

Many thanks to all institutions, organizers, volunteers and helpers for hosting this symposium.

In a concluding forum discussion about the location of the next symposium, Malaysia and Vietnam prepared an offer to host the 8<sup>th</sup> Symposium. However, Malaysia is planning to host the 29<sup>th</sup> Congress of the International Primatological Society, which might lead to organizational overlaps. The possibility of organizing the 8<sup>th</sup> Asian Primate Symposium in Vietnam was presented by Tilo Nadler and supported by the participants. After organizing three international primate conferences “Conservation of Primates in Indochina”, to which the Endangered Primate Rescue Center in Vietnam has been the host every 5 years (1998, 2013, 2018), it was decided at the 6<sup>th</sup> Asian Primate Symposium in Dali, China, to merge these conferences with the Asian Primate Symposium.

With an optimistic and positive view into the future, unaffected by measures due to the ongoing Corona pandemic, the 8<sup>th</sup> Asian Primate Symposium is scheduled for November 2021 in Vietnam. The Vietnam National University of Forestry in Xuan Mai, near Hanoi, has agreed to host this symposium.

Vietnam offers a primatological highlight among the countries of Southeast Asia. With 25 primate species, Vietnam is also home for the highest number of primates of all countries on the Southeast Asian continent and is the only country in the region to host three endemic species.

We profoundly hope that the next symposium will not be affected by the pandemic. A detailed announcement is planned for spring 2021.



## SHORT COMMUNICATIONS

### Van Long Nature Reserve – the first area in Vietnam on the IUCN Green List of Protected and Conservation Areas



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**Key words:** Van Long Nature Reserve, IUCN Green List, Delacour's langur, *Trachypithecus delacouri*

The IUCN Green List of Protected and Conserved Areas is the first global standard of best practice for area-based conservation. It is a programme of certification for protected and conserved areas – national parks, natural World Heritage sites, community conserved areas, nature reserves and so on – that are effectively managed and fairly governed.

A protected or conservation area that reaches the IUCN Green List Standard is certified and recognised as achieving ongoing results for people and nature in a fair and effective way. Any site can join, and work its way towards achieving verified success, and then maintain the Standard or further improve.

Any protected and conserved area that gains 'Green List' status demonstrates:

- Respect: for the local community through fair and meaningful engagement of rights-holders and stakeholders
- Design: planning that identifies the needs to secure the important values of the area
- Effective management: monitoring of the status of these important values
- Successful conservation results: for nature and for people
- Clear contribution: to climate change responses, health and well-being and other challenges

The IUCN Green List was piloted in eight countries from 2012 to 2014. Following the completion of the pilot programme, the IUCN Green List Standard has been revised and an IUCN Green List User Manual and associated information management systems are now in place. Currently, 49 protected areas in 15 countries have been included in the IUCN Green List (Fig. 1), and another 44 protected areas are candidates for inclusion after fulfilling the established criteria.

The focus of the 'Vietnam Primate Conservation Program' of the Frankfurt Zoological Society was the protection and conservation of the Delacour's langur, one of Vietnam's endemic and critically endangered primates. The largest and only viable population in the Van Long Area was granted the status of Nature Reserve in 2001. With the establishment of a 'Community Protection Unit' consisting of 30 guards, who were recruited from the surrounding communities of the protected area, the work of the Management Board of the protected area could be actively supported. With the involvement of the communities in the protection and development of the area into a tourist highlight, poaching and habitat destruction in the area came to a halt. This is reflected in a remarkable development of the Delacour's langur population. Over a period of 20 years the population quadrupled from originally about 50 animals to currently about 200 animals. This positive development of the population of one of the world's rarest primates, the involvement of the local population in the protection and conservation activities and the development into a tourism highlight that also benefits the local population was recognized after the conditions were met with the inclusion of the area in 2020 in the IUCN Green List.





## SHORT COMMUNICATIONS

### *Trachypithecus popa* – a new primate species from central Myanmar

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**Key words:** Popalangur, *Trachypithecus popa*, new primate species, Myanmar

A new primate species named Popalangur (*Trachypithecus popa*) has been discovered in Myanmar after years of extensive study, including analysis of a 100-year old specimen kept in the Natural History Museum, London.

The Popalangur is described based on extensive genetic and morphological studies and field surveys undertaken by the German Primate Center (DPZ) – Leibniz Institute for Primate Research in Göttingen and the conservation NGO Fauna & Flora International (FFI) (Fig. 1).



**Fig.1.** Adult female and juvenile Popalangur (*Trachypithecus popa*) in the crater of Mount Popa, Myanmar. Photo: ThaugWin.

The Popalangur only occurs in central Myanmar and is named after the sacred Mount Popa, which holds the largest population of the species with about 100 individuals (Fig. 2). Mount Popa is an extinct volcano, which features an important nature reserve, as well as a sacred pilgrimage site, home to Myanmar's most venerated spirits, known as 'Nats'. Altogether there are only 200 to 250 individuals of the new species, which live in four isolated populations. Throughout its range the langur is threatened by habitat loss and hunting, and the new species can be considered as "Critically Endangered" by the IUCN Red List of Threatened Species. Just described, the Popalangur is already facing extinction.

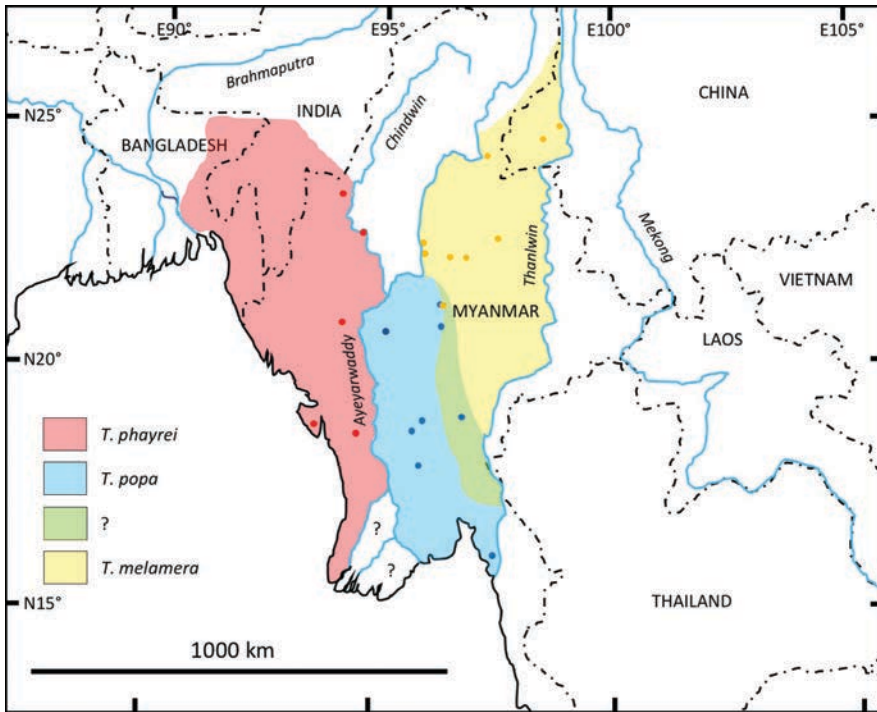


Fig.2. Distribution of the new discovered Popalanger (*Trachypithecus popa*) and closely related species.

Researchers of the DPZ and FFI in collaboration with partners from other non-government organizations, universities and natural history museums, investigated the evolutionary history and species diversity of langurs in Myanmar. Their study resulted in the description of this new langur species.

The Popalanger differs from known species in fur coloration, tail length and skull measurements. Genetic studies revealed that the new langur species separated from known species around one million years ago. The DNA for genetic analyses was obtained from fecal samples collected by FFI staff in the wild, as well as from tissue samples of historical specimens from the natural history museums in London, Leiden, New York and Singapore.

The studies about the new discovered species provides also a new insight to the phylogenetic relationship and divergence time among mitochondrial lineages of the genus *Trachypithecus*, which also occurs with six species in Vietnam.

#### ORIGINAL PUBLICATION

### **Mitogenomic phylogeny of the Asian colobine genus *Trachypithecus* with special focus on *Trachypithecus phayrei* (Blyth, 1847) and description of a new species.**

Christian Roos, Kristofer M. Helgen, Roberto Portela Miguez, Naw May Lay Thant, Ngwe Lwin, Aung Ko Lin, Aung Lin, Khin Mar Yi, Paing Soe, Zin Mar Hein, Margaret Nyein Nyein Myint, Tanvir Ahmed, Dilip Chetry, Melina Urh, E. Grace Veatch, Neil Duncan, Pepijn Kamminga, Marcus A. H. Chua, Lu Yao, Christian Matuschek, Dirk Meyer, Zhijin Liu, Ming Li, Tilo Nadler, Pengfei Fan, Le Khac Quyet, Michael Hofreiter, Dietmar Zinner, Frank Momberg (2020): Zoological Research, <http://www.zoores.ac.cn/en/article/doi/10.24272/j.issn.2095-8137.2020.254>

# INSTRUCTIONS FOR CONTRIBUTORS

The *Vietnamese Journal of Primatology* is a peer reviewed journal. It welcomes manuscripts from all areas related to the conservation and research of non-human primate taxa which occur in Vietnam and the neighboring countries of Cambodia, China and Laos. The journal publishes both original research papers and short communications.

**Submission:** Submit English manuscripts electronically (as unformatted Microsoft Word file attachments) to Tilo Nadler or Christian Roos:

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Vietnam  
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German Primate Centre,  
Göttingen,  
Germany  
e-mail <croos@dpz.eu>

**Manuscript Preparation:** Manuscripts should be divided into the major divisions given below in the order indicated.

## **Title Page**

The first page of the manuscript should include the title of the paper.

Affiliated institutions of the authors must be given under the headline with the e-mail address of the corresponding author.

## **Summary**

Each paper must include a summary of no more than 300 words, which clearly summarizes the contents of the paper. The Summary will be presented in English and Vietnamese.

## **Key Words**

A list of 3-8 key words in English should be included for indexing purposes.

## **Text**

Research articles must be organized into the following sections: Introduction, Materials and Methods, Results, Discussion, Conclusions, Acknowledgements and References. Acknowledgements may include funding sources such as agency and grant numbers, and the names of those who contributed.

## **Tables and illustrations**

Tables and illustrations should be sent as separate files (either in JPG or TIFF format). Tables require a heading and figures require a legend. All tables and illustrations must be cited in the text. For the reproduction of illustrations, only high quality drawings and photos will be accepted. Color illustrations are welcome. Photographer or artist name must accompany all illustrations. Submit each figure as a separate file.

## **References**

In the text, references should be cited consecutively with the authors' surnames and year of publication in brackets. Vietnamese and Chinese authors should be given with the full name (e.g.: Dao Van Tien). 'Personal observations' (pers. obs.) or 'personal communications' (pers. comm.) cited in the text should not be listed in the references. The reference list should be arranged alphabetically by first author's surname. Chinese and Vietnamese names should complete cited. Please punctuate and format references exactly as in the following examples:

### *Papers published in periodicals*

**Dao Van Tien** (1989): On the trends of the evolutionary radiation on the Tonkin Leaf monkey (*Presbytis francoisi*) (Primates: Cercopithecidae). *J. of Human Evolution* 4, 501-507.

**Fooden J** (1996): Zoogeography of Vietnamese Primates. *Int. J. Primatol.* 17, 845-899.

### *Books and Monographs*

**Groves CP** (2001): *Primate Taxonomy*. Smithsonian Institution Press, Washington DC.

### *Edited books and book chapters*

**Groves CP** 2004: Taxonomy and Biogeography of Primates in Vietnam and Neighbouring Regions. In: Nadler T, Streicher U. & Ha Thang Long (eds.): *Conservation of Primates in Vietnam*; pp. 15-22. Frankfurt Zoological Society, Hanoi.

### *Dissertations*

**Otto C** (2005): Food intake, nutrient intake, and food selection in captive and semi-free Douc langurs. PhD thesis, University Cologne, Germany.

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