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Cover: Annamese silvered langur (*Trachypithecus margarita*). Photo: Tilo Nadler.

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Effectiveness of thermal infrared drone surveys in detecting the diurnal primate community in Cat Tien National Park, South Vietnam

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Key words: Thermal Infrared Imagery, drone survey, black-shanked douc langur, Annamese silvered langur, southern yellow-cheeked gibbon, long-tailed macaque, northern pig-tailed macaque, stump-tailed macaque.

Summary

Thermal infrared (TIR) imaging and drone technology have recently emerged as valuable tools in wildlife monitoring, offering advantages over traditional survey methods. We conducted manual and systematic TIR drone surveys from April 2022 to May 2023 in Cat Tien National Park, Dong Nai Province, southern Vietnam, to assess their effectiveness in detecting and counting six diurnal sympatric primate species at their sleeping sites. Our study revealed successful detections of black-shanked douc langurs (*Pygathrix nigripes*), Annamese silvered langurs (*Trachypithecus margarita*), southern yellow-cheeked gibbons *Nomascus gabriellae*), long-tailed macaques (*Macaca fascicularis*), and pig-tailed macaques (*Macaca leonina*). However, detection reliability varied among species, with arboreal langurs showing higher reliability compared to semi-terrestrial macaques or gibbons. Ecological and behavioral factors influenced species' detection effectiveness, with large-bodied, arboreal species being more reliably detected. For instance, black-shanked douc langurs exhibited distinct thermal signatures, facilitating their detection and count. In contrast, gibbons showed avoidance behavior during drone surveys, posing challenges for detection. We developed a scoring system based on these factors to assess thermal detection reliability, which could assist in evaluating detectability in multispecies studies and the reliability of TIR drone surveys. The low resolution of TIR drone imagery also limited species differentiation, particularly for species with similar morphology or behavior. We recommend combining TIR drone surveys with ground-truthing methods, camera trap surveys, and passive acoustic monitoring for comprehensive primate monitoring research. Our findings underscore the potential of TIR drone technology for detecting and monitoring large arboreal species like langurs, while highlighting the need for developing global scoring system to assess TIR detection reliability for different primate species. This study contributes to understanding sympatric primate behavior and ecology, aiding conservation efforts, and emphasizes the importance of innovative technologies in primate monitoring.

Hiệu quả của khảo sát bằng máy bay không người lái hồng ngoại nhiệt trong việc phát hiện quần thể linh trưởng ban ngày ở miền Nam Việt Nam

Tóm tắt

Công nghệ hình ảnh hồng ngoại tầm nhiệt (TIR) và công nghệ Drone đã trở thành các công cụ có giá trị trong việc giám sát động vật hoang dã, mang lại lợi ích cao so với các phương pháp khảo sát truyền thống. Chúng tôi đã tiến hành các cuộc khảo sát Drone TIR thủ công và có hệ thống từ tháng 4 năm 2022 đến tháng 5 năm 2023 tại Vườn Quốc gia Cát Tiên, tỉnh Đồng Nai, Nam Việt Nam, để đánh giá hiệu quả của thiết bị trong việc phát hiện và đếm kiểm sáu loài linh trưởng cùng phân bố tại các địa điểm ngủ của chúng. Kết quả nghiên cứu cho thấy đã ghi nhận thành công các loài như Chà vá chân đen, Voọc bạc An Nam, Vượn má vàng miền Nam, Khỉ đuôi dài, Khỉ mặt đỏ và Khỉ đuôi lợn. Tuy nhiên, độ tin cậy phát hiện khác nhau giữa các loài, đối với các loài voọc sống trên cây cho thấy độ tin

cây cao hơn so với các loài khỉ hoặc vượn ở tầng dưới của tán rừng. Các yếu tố sinh thái và hành vi đã ảnh hưởng đến hiệu quả phát hiện loài, đối với các loài sống trên cây mà có cơ thể lớn, sự phát hiện loài có độ tin cậy cao hơn. Ví dụ, voọc Chà vá chân đen thể hiện dấu hiệu nhiệt riêng biệt, tạo điều kiện thuận lợi cho việc phát hiện và đếm chúng. Ngược lại, vượn có ứng xử tránh né trong suốt quá trình khảo sát bằng thiết bị Drone TIR, gây ra những thách thức cho việc giám sát bằng thiết bị này. Một hệ thống điểm đã được thiết lập dựa trên các yếu tố này để đánh giá độ tin cậy của việc phát hiện loài bằng cảm biến nhiệt. Hệ thống này có thể hỗ trợ đánh giá khả năng phát hiện loài trong các nghiên cứu đa loài và độ tin cậy của các khảo sát bằng Drone TIR. Độ phân giải thấp của hình ảnh từ Drone TIR cũng hạn chế khả năng phân biệt các loài, đặc biệt là đối với các loài có hình dáng hoặc hành vi tương tự nhau. Chúng tôi khuyến nghị kết hợp phương pháp khảo sát bằng thiết bị Drone TIR với các phương pháp xác minh trên thực địa, khảo sát bằng bẫy ảnh và âm sinh học để có một hệ thống giám sát động vật linh trưởng toàn diện. Các kết quả của chúng tôi nhấn mạnh tiềm năng của công nghệ Drone TIR trong việc phát hiện và giám sát các loài linh trưởng lớn sống trên tầng cao của tán rừng như voọc, đồng thời nhấn mạnh sự cần thiết phát triển hệ thống điểm toàn cầu để đánh giá độ tin cậy của phương pháp phát hiện loài bằng TIR đối với các loài linh trưởng khác nhau. Nghiên cứu này đóng góp vào việc hiểu biết về hành vi và sinh thái của các loài linh trưởng cùng sinh sống với nhau, hỗ trợ các nỗ lực bảo tồn, và nhấn mạnh tầm quan trọng của các công nghệ đổi mới trong giám sát động vật linh trưởng.

Introduction

In recent years, the application of thermal infrared (TIR) imaging and drone technology has gained prominence in the field of wildlife monitoring (Wich & Koh 2018). TIR drones enable the detection of animals by capturing their thermal signatures, facilitating wildlife surveys and identification of species that may not be discernible to the naked eye or through conventional imagery (Wich et al. 2021). This innovative approach offers significant advantages over traditional survey methods. It enabled researchers to conduct aerial surveys with improved efficiency and accuracy, particularly in detecting various forest-dwelling primate families, such as Atelidea and Cebidae families in the Neotropics (Kays et al. 2019; Spaan et al. 2019; Whitworth et al. 2022), and Cercopithecidae, Hylobatidae and Hominidae families in Asia (Burke et al. 2019; He et al. 2023; Mirka et al. 2022; Rahman et al. 2022; Zhang et al. 2023). Specifically, in Southeast Asian countries, Vietnam is increasingly using TIR drones to monitor and count threatened Vietnamese primates such as the 'Critically Endangered' Delacour's langurs (*Trachypithecyus delacouri*, Trinh Dinh Hoang 2022), Tonkin snub-nosed monkeys (*Rhinopithecus avunculus*, Le Khac Quyet 2022), eastern black gibbons (*Nomascus nasutus*, Wearn et al. 2023), grey-shanked douc langurs (*Pygathrix cinerea*) and the 'Endangered' Hatinh langurs (*Trachypithecus hatinhensis*, Gazagne et al. 2023).

Cat Tien National Park in southern Vietnam encompasses a rich primate community that includes seven sympatric species: the 'Critically Endangered' black-shanked douc langur (Hoang Minh Duc et al. 2021), the 'Endangered' Annamese Silvered Langur (Hoang Minh Duc et al. 2022), the 'Endangered' southern yellow-cheeked gibbon (Rawson et al. 2020), the 'Endangered' long-tailed macaque (Hansen et al. 2022), the 'Vulnerable' northern pig-tailed macaque (Boonratana et al. 2022), the 'Vulnerable' stump-tailed macaque (*Macaca arctoides*) (Chetry et al. 2020), and the 'Endangered' pygmy loris (*Xanthonycticebus pygmaeus*) (Blair et al. 2021). The current study is part of a broader project aimed at studying the distribution and sleeping site selection of the diurnal primate community via systematic TIR drone nocturnal surveys in Cat Tien National Park. However, before proceeding, it is imperative to assess the effectiveness of TIR drones in detecting and counting the six diurnal primate species at their sleeping sites.

By combining data, collected through manual and systematic TIR drone surveys in the lowland dry-evergreen forests of the eastern sector of Nam Cat Tien (< 100 km^2), we aimed to assess the reliability of TIR drones in detecting black-shanked douc langurs, Annamese silvered langurs, southern yellow-cheeked gibbons, long-tailed macaques, pig-tailed macaques, and stump-tailed macaques. We hypothesize that inter-species variations in the effectiveness of TIR drone detectability at a short scale will be influenced by primate physiological factors (e.g. body and tail

length), ecological factors (e.g. group size and home range size), and behavior at their sleeping site (e.g. sleeping position in the canopy strata and species' behavioral response to the drone). For instance, we predicted that large-bodied and highly arboreal species, with smaller home range such as black-shanked douc langurs (Hoang Minh Duc et al. 2021), would be easier to detect and identify locally through TIR imagery than semi-terrestrial species with large home ranges and elusive behavior such as stump-tailed macaques (Chetry et al. 2020). Finally, we aimed to build a local scoring system to assess thermal detection reliability that could be adapted to other study sites with similar sympatric species to assess viability of TIR drone use.

Study site

Cat Tien National Park (738.78 km^2; 11°2' to 11°48'N; 107°10' to 107°34'E), located in southern Vietnam, comprises three sectors (Cat Tien National Park 2020): Nam Cat Tien in Dong Nai Province (383.02 km^2), Tay Cat Tien in Binh Phuoc Province (51.41 km^2) with both moderate terrain (elevation ranging from 200 to 300 m asl), and Cat Loc in Lam Dong Province (304.35 km^2) with high mountain topography (elevation ranging from 200 to 600 m asl) (Fig. 1). Our study focused on the lowland Eastern Nam Cat Tien forest complex, covering approximately 100 km^2 with elevations reaching a maximum of 150 m above asl (Fig. 2). The area experiences a tropical monsoon climate with two distinct dry (November to April) and rainy seasons (May to October). The average annual temperature is 26.7°C, average annual rainfall is 2,227 mm, and average humidity level is 82% (Cat Tien National Park 2020). Habitat types include primary and secondary evergreen forest, semi-evergreen forest, mixed forest (including bamboos and other plants), bamboo forest, grassland, wetlands and lakes (Fig. 3).

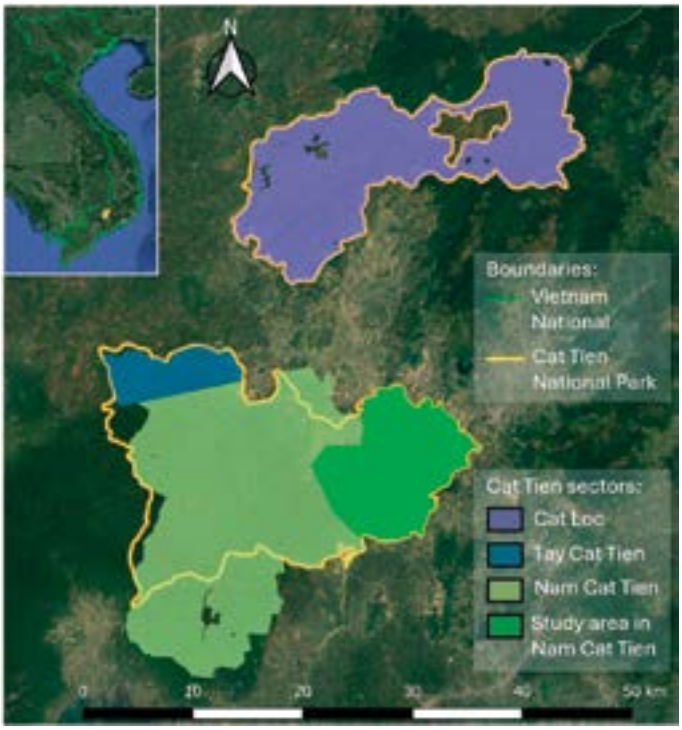

Fig.1. Satellite image of Cat Tien National Park and its three sectors located in southern Vietnam: Cat Loc, Tay Cat, and Nam Cat Tien. The study area is covering approximately 100 km^2 within the lowland dry-evergreen forests of Eastern Nam Cat Tien.

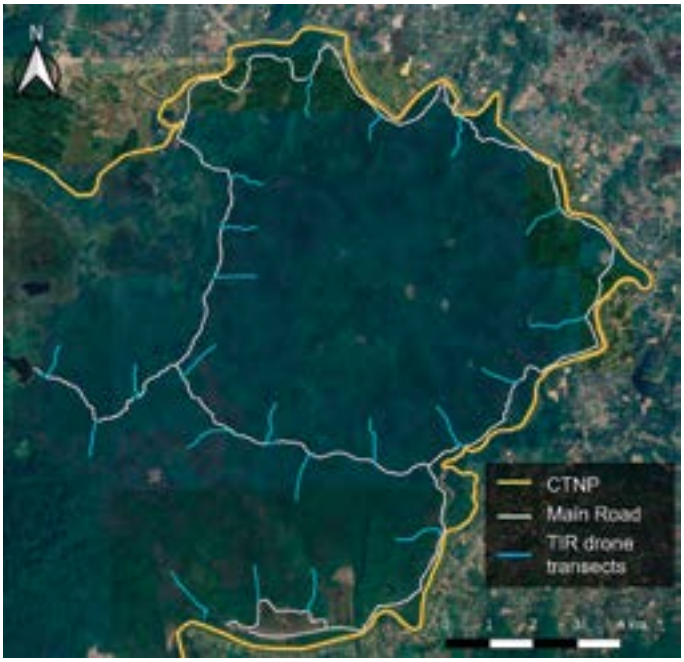

Fig.2. Zoomed-in satellite image of the study area in Cat Tien National Park. We conducted Thermal Infrared drone surveys along 22 <1-km aerial transects, spaced more than 1 km apart, and overlapping with ground transects adjacent to the main road.

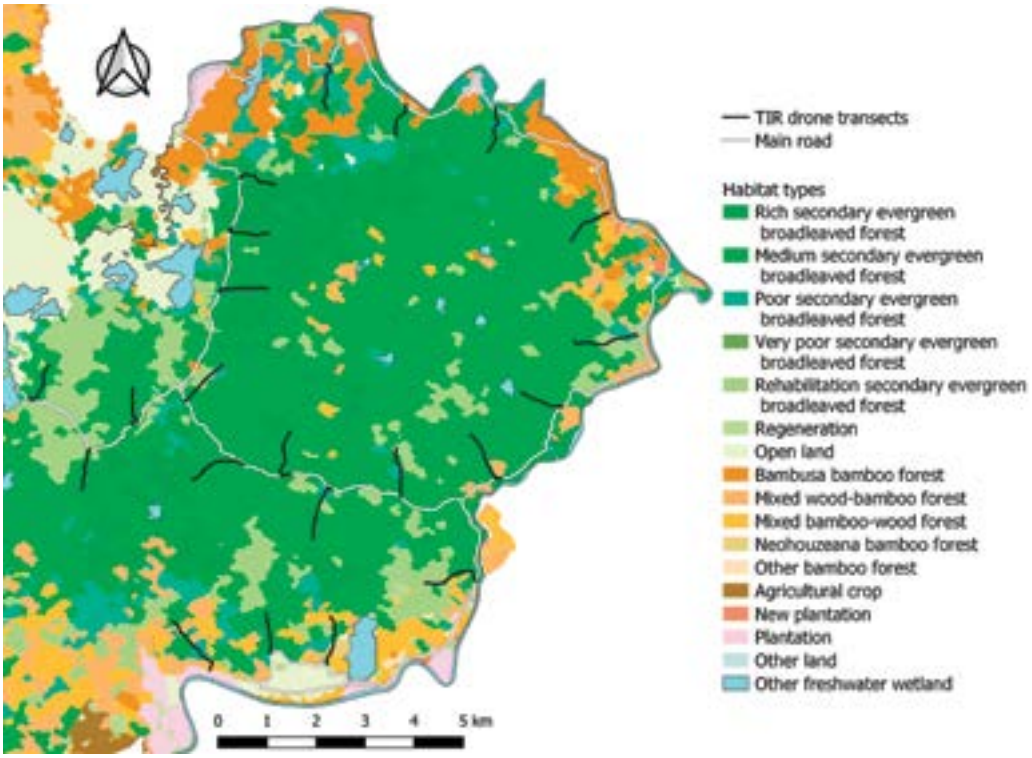

Fig.3. Habitat types within the study area which is predominantly characterized by secondary evergreen forests, including 'rich', 'medium', 'poor', 'very poor', and 'rehabilitation' secondary evergreen broadleave forests on soil mountains, as well as mixed bamboo forests, comprising both bamboo and evergreen trees.

Material and Methods

Material

For pilot surveys conducted in 2022, we used a DJI Mavic 2 Enterprise Advanced Drone (M2EA) equipped with a thermal camera. For systematic surveys in 2023, we employed a DJI Mavic 3 Thermal (M3T) drone. Both drones featured a 12-µm pixel pitch, uncooled VOx microbolometer sensor operating within a 8–14 µm spectral band, a 640x512-pixel resolution at 30 Hz framerate, and a 48 megapixel standard camera. The M2EA is equipped with a 35 mm lens providing a 84° field of view and a 16x digital zoom, while the M3T possesses a 61° diagonal field of view and a 56x hybrid zoom. We captured still images and videos of primate detections using the Ironbow color palette (Gazagne et al. 2023).

Primate species detection and identification with TIR drones

To test TIR drone detectability of the six diurnal primate species inhabiting Cat Tien National Park, we conducted pilot surveys from April 2022 to November 2022. For these exploratory surveys, we executed 34 TIR drone flights manually at 40 m to 80 m Above Ground Level (AGL), during nighttime (nocturnal surveys) and sunrise (diurnal surveys), over locations where the principal investigator (E.G.) had previously observed various primate species during daylight hours. Each TIR detection was validated through subsequent ground-truthing: (i) either primate groups were followed to or near sleeping sites before conducting targeted aerial surveys above this location, or (ii) unknown sleeping sites were identified through nocturnal TIR drone surveys, with species confirmation achieved after sunrise through direct observation. We recorded the detected species, counted detected individuals, evaluated the number of groups present, and collected ad *libitum* sleeping behavior (e.g. sleeping position height in the canopy, number of sleeping trees used etc.).

We conducted 132 nocturnal systematic TIR drone surveys along 22 transects (6 replicates per transect) from January to May 2023, using flight routes programmed with the DJI RC Pro Enterprise control unit (Fig. 1.). The drone maintained a flight speed of 3 m/s, oriented toward the flight route, and a flight altitude of 60 m (94 surveys) or 70 m AGL (38 surveys), depending on the canopy height (respectively <30 m or >30 m). The altitude was set to ensure a distance >30 m between the drone and the top canopy, providing sufficient resolution for animal visibility in the upper canopy while minimizing disturbance (Burke et al. 2018; Kays et al. 2019). The length of flight routes averaged 940 ± 155 m, ranging from 656 m to 1,269 m based on drone signal capacities. Each flight lasted on average 14'33''± SD 00'02'' minutes. Nocturnal flights were conducted when the temperature difference between primates and the surrounding canopy was greater, and allowed for more visible thermal detections: before sunrise at 5:08 AM ± SD 00:21 (n=99) or at dusk at 7:46 PM ± SD 00:34 (n=21). Similar to pilot surveys, nocturnal detections were verified through ground-truthing during diurnal ground surveys conducted the same day and along the same flight route as each aerial survey. Suspected species detected via TIR drone were confirmed if primate species were detected and identified in the same area a few hours later or earlier, corresponding to early morning or evening nocturnal surveys. However, unconfirmed TIR detections were classified as unknown species. We recorded the detected species, the count of individuals and groups. Finally, to assess drone disturbance, we documented whether detected individuals were inactive (i.e. no visible response), in movement (i.e. at least one individual exhibited movement but remained within the sleeping site), or exhibited flight response (i.e. rapid movement and departure from the sleeping sites).

Local Thermal Detection Reliability Score

We developed a local Thermal Detection Reliability Score to assess the likelihood of successful thermal detection for the diurnal primate species in Cat Tien National Park (Table 1). Due to the elusive nature and low abundance of *M. arctoides*, we were unable to collect sufficient behavioral data or confirm thermal detections during this study. As a result, this species was not included in the scoring system. This scoring system, ranging from 1 to 5 (i.e. low to high detectability), integrates ecological influences and behavior on detectability. We considered physiological characteristics such as body length and tail length, with larger species and longer-tailed species deemed easier to detect and

identify. Additionally, we incorporated ecological factors like average group size and home range size, with larger group size making detection easier, and species with smaller home range sizes being considered easier to detect locally (based on previous knowledge of the target species range). Finally, based on observations from ground-based surveys and TIR drone survey in this study, we integrated primate sleeping behavior and responses to the drone in our detectability scoring system: species sleeping in emergent trees and high canopy strata were considered easier to detect, while those exhibiting flight or movement behaviors during drone flights were more difficult to detect. The cumulative scores provide an assessment of thermal detection reliability for each species (Table 1).

Table 1. Annual Forest Appreciation Program participation.

Species	Body length (cm)[a]	Tail length (cm)[a]	Group size[b]	Home Range (km^2)[b]	Sleeping site selection and sleeping position[c]	Behavioural response to drone	Thermal signature[c]	Thermal detection reliability
Pygathrix nigripes	54-67	65-85	7	0.25	Sleep in emergent trees, One Male Units (OMU) use few sleeping trees, sometimes OMUs reunite into large bands.	No visible response or movement in sleeping tree.		Very high
Score	***5***	***5***	***2***	***5***	***5***	***4***		***26***
Trachy-pithecus margarita	42-58	60-80	18	1.34	Sleep in low to high strata in the canopy, use few sleeping trees.	No visible response.		High
Score	***3***	***4***	***3***	***3***	***3***	***5***		***21***
Macaca fascicu-laris	31-63	31-71	22	1.57	Sleep in low to medium strata in the canopy in subgroup, use low to high number of sleeping trees.	Movement in sleeping site.		Medium
Score	***1***	***3***	***4***	***2***	***2***	***3***		***15***
Macaca leonina	47-62	14-25	53	4.50	Sleep in low to medium strata in the canopy in subgroup, use low to high number of sleeping trees.	Movement in sleeping site.		Medium
Score	***4***	***2***	***5***	***1***	***2***	***3***		***15***
Nomas-cus ga-briellae	45-50	NA	4	0.52	Sleep in high stra-ta in the canopy in family group, use few sleeping	Avoidance and flight but stay in-or-return to sleeping site		Low
Score	***2***	***1***	***1***	***4***	***4***	***1***		***13***

Note. [a] Nadler & Brockman 2014; [b] Galan-Acedo et al. (2019); [c] This study. Due to the variability in TIR sensor readings and the strong influence of environmental conditions on thermal signatures, we did not incorporate thermal intensity measurements into our scoring system.

Results

Pilot survey

We detected black-shanked douc langurs in 16 surveys, pig-tailed macaques in 11 surveys, long-tailed macaques and yellow-cheeked gibbons in five surveys, silvered langurs in three surveys, and stump-tailed macaques in zero survey. On three occasions, TIR detections could not be identified to species level. We observed douc langurs sharing sleeping sites with pig-tailed macaques twice and with silvered langurs once.

In total, we observed 188 black-shanked douc langurs, distributed across 26 distinct groups. Each group averaged 7.2 individuals and utilized three sleeping trees on average, with group sizes ranging from 1 to 35 individuals. Douc langurs slept in emergent trees or on upper branches in the canopy strata. Pig-tailed macaques were more challenging to detect as they slept in the lower strata of the canopy or on lower branches of large emergent trees. We counted an average of 8.8 individuals per group, ranging from 4 to 18 macaques over more than five sleeping trees. Similarly, we observed long-tailed macaque sleeping in medium strata of the canopy and in bamboo patches, potentially reducing detection reliability. Detected group averaged 11 individuals (ranging from 8 to 15 individuals), spanning three to eight sleeping trees. While gibbons were initially easier to detect as they slept in emergent trees or high canopy strata, they exhibited the most movement in response to the drone flying over their sleeping trees. Each gibbon group averaged 4.2 individuals (ranging from 3 to 7 individuals) and used one to three sleeping trees. All detected groups exhibited movement or flight behaviours, but subsequent surveys over the same sleeping trees revealed individuals returning to their original location after the disturbance event. Finally, silvered langurs were repeatedly detected at the same location, with counts of 7, 22, and 19 individuals utilizing two to five sleeping trees.

Systematic surveys

In total, we detected 1,756 primate individuals via TIR imagery during systematic surveys, belonging to 283 groups (Table 2). This total count may include potential re-detection across survey replicates. Black-shanked douc langurs accounted for 65% of detections with 1,138 individuals, demonstrating the effectiveness of TIR drone surveys in detecting and counting this arboreal species (Fig 4 a). In comparison, we observed lower numbers of long-tailed macaques and pig-tailed macaques (Fig. 4 d, e) and fewer gibbons and silvered langurs (Fig. 4 b, c) (Table 2). Unfortunately, we could not confirm whether we detected stump-tailed macaques or not. We collected 162 individuals that we could not identify to species via TIR imagery and ground-truthing. However, although some detections could not be identified at the species level (classified as unknown), we could attribute a genus to some detections based on our ecological knowledge of those primate species. For instance, we identified *Macaca* due to the high number of individuals detected within a group spanning many sleeping trees in the same areas (Fig. 5, 6). During ground surveys, although we were unable to identify the species (i.e. long-tailed macaques, northern pig-tailed macaques, or stump-tailed macaques), we heard contact calls and observed movement within branches similar to travelling macaques, confirming the genus detected.

Table 2. Thermal infrared (TIR) detections of the diurnal primate community in Cat Tien National Park at their sleeping sites during nocturnal TIR drone surveys. We conducted 132 systematic surveys along 22 transects from January 2023 to May 2023. The table presents the total number of individuals and groups detected per species, as well as the percentage of detections where at least one individual exhibited movement or a flight response.

Species	Individuals	Groups	Movement (%)
Pygathrix nigripes	1138	283	21
Trachypithecus margarita	15	2	0
Nomascus gabriellae	22	8	67
Macaca leonina	258	35	33
Macaca fascicularis	138	20	31
Macaca arctoides	0	0	-
Unidentified	162	96	35

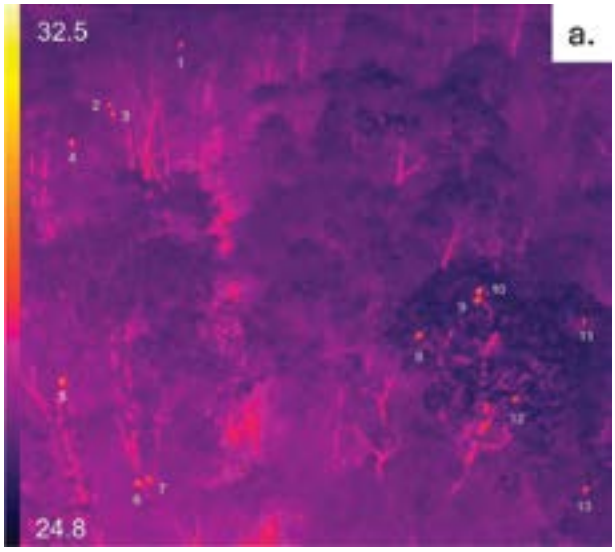

Fig.4a. Illustrations of Thermal Infrared (TIR) detections of five diurnal primate species at their sleeping sites obtained with a DJI Mavic 2 Enterprise Advanced (M2AE) and a Mavic 3 Thermal (M3T) drone during nocturnal surveys conducted in the lowland dry-evergreen forests of Eastern Nam Cat Tien National Park, from April 2022 to May 2023. a. Black-shanked douc langurs (*Pygathrix nigripes*),

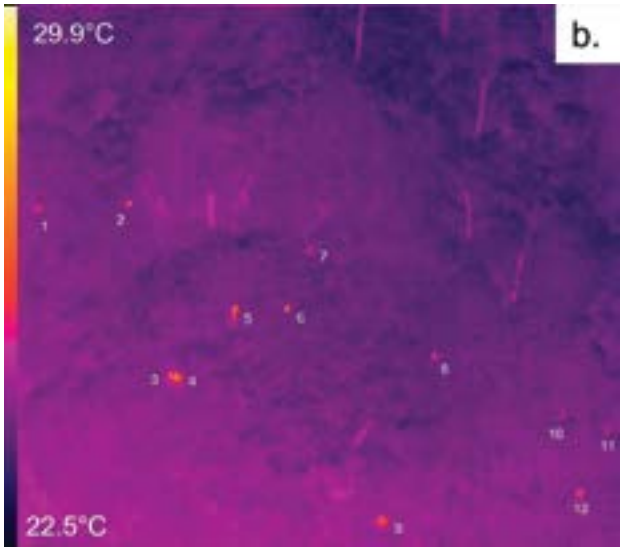

Fig.4b. Annamese silvered langur (*Trachypithecus margarita*).

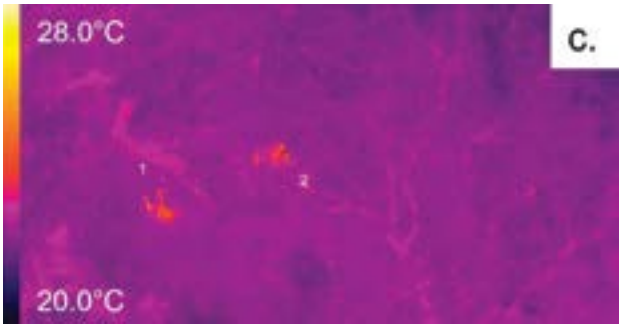

Fig.4c. Southern yellow-cheeked gibbon (*Nomascus gabriellae*).

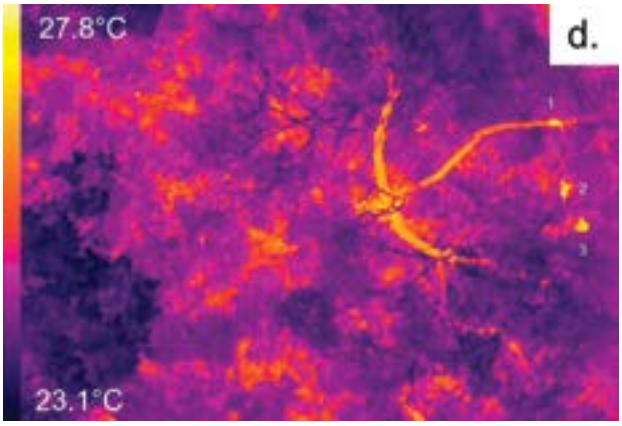

Fig.4d. Long-tailed macaque (*Macaca fascicularis*).

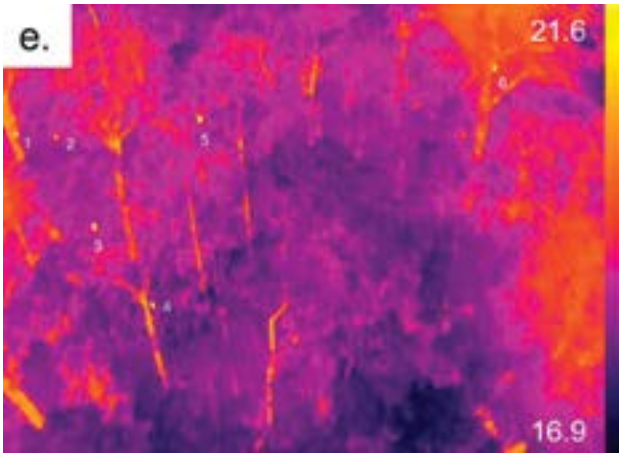

Fig.4e. Northern pig-tailed macaque (*Macaca leonina*). TIR primate detections correspond to the hotter thermal spots or body shapes (in yellow or orange color) highlighted with the white numbering. Note: all primate species in the given images were also visually verified from the ground.

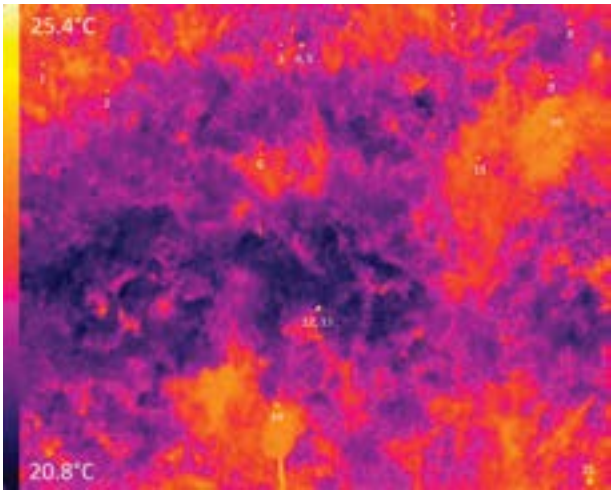

Fig.5. The detection of two unidentified groups of macaques within rehabilitation secondary evergreen forest mixed with bamboo patches using a DJI Mavic 3T. Individuals are highlighted with numbering but could not be identified via TIR imagery due to the low-resolution of the detections (drone flight about 50 m above the canopy) and the absence of visible response from the individuals (no movement or flight response). Image captured on April 19th 2023 (we detected a total of 35 macaques belonging to this group) at 05:07.

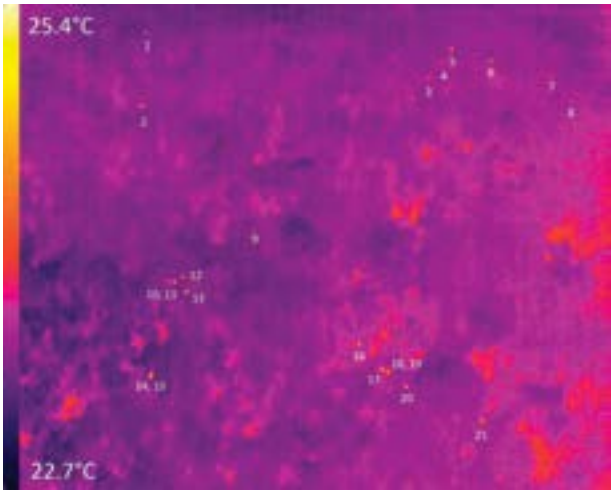

Fig.6. Image captured on May 9th 2023 at 05:09 am (we detected a total of 36 macaques belonging to this group) on the same transect segment.

Local Thermal Detection Reliability Score

Based on data collected through our pilot and systematic TIR drone surveys, we assigned higher scores for sleeping behavior to douc langurs, gibbons, and silvered langurs as they exhibited more arboreal sleeping position than macaque species (Table 2). Additionally, langurs showed no or little response to flying drones so we assigned them the highest score, compared to gibbons that exhibited disturbance response (Table 3). Our final thermal detection reliability score indicates that langurs, especially black-shanked douc langurs, are ideal candidates for monitoring with TIR drones compared to macaques or gibbons (Table 2). This finding is consistent with our field data, where we could be identifying this species solely based on TIR imagery due to their body size, characteristic body shape (e.g. tail-size, arms-size, sitting position), locomotion pattern, combined with their social behavior and organisation at sleeping sites, as well as their arboreal behavior.

Discussion

We conducted manual and systematic TIR drone surveys from April 2022 to May 2023 and

successfully detected populations of five of the six diurnal primate species present in the lowland dry-evergreen forests of eastern Nam Cat Tien: black-shanked douc langurs, Annamese silvered langurs, southern yellow-cheeked gibbons, long-tailed macaques, and northern pig-tailed macaques. However, within a multispecies study site, the reliability of TIR drone detection for monitoring and counting primates varied among species. It was higher for arboreal langurs compared to semi-terrestrial macaque species or gibbons, which were less tolerant to drone surveys.

Consistent with our hypothesis, ecological and behavioral factors influenced the effectiveness of the detection and counting of primate species at sleeping sites: large-bodied species with characteristic features such as a long tail, sleeping in emergent trees (or high strata in the canopy), and exhibiting minimal movement during drone flight, such as black shanked langurs, were more reliably detected and counted using TIR drone imagery (Table 1, 2). For instance, through pilot manual flights above black-shanked douc langur sleeping sites, we observed an average of 7.2 individuals per One Male Units (OMUs), with social structures ranging from single males to bands of 35 individuals. These results align with findings from ground-based surveys, where OMUs averaged 7.5 individuals, ranging up to groups comprising more than 40 individuals (Rawson 2009; O'Brien 2014). Although we detected a few Annamese silvered langur groups, TIR drone surveys appeared effective in monitoring this species (Table 1, 2). Since silvered langurs were detected at the same sleeping trees across several surveys, this may suggest re-detection of the same group or sub-group consistently using the same sleeping sites (Nijman 2022). The low detection rates may be attributed to the low abundance of this species within Cat Tien National Park, but ground-based census data are necessary for validation (Hoang Minh Duc et al. 2022). As predicted, semi-terrestrial macaques, which live in large groups spanning numerous sleeping trees and occupying lower strata in the canopy, were less reliably detected and counted with TIR drone surveys (Table 1). For example, we observed an average of 8.8 individuals per group of pig-tailed macaques sleeping over five trees, significantly fewer than the known groups sizes of the species, which can range from 30 to 153 individuals across several trees while sleeping (Gazagne et al. 2020).

Additionally, macaque species tend to sleep in lower canopy strata, or under thick canopy vegetation, making them challenging to detect via TIR imagery. However, reliable identification to the species level was sometimes unattainable with TIR drones for macaques; we could still identify the *Macaca* genus based on their sleeping behavior, such as high number of individuals detected within a group spanning many sleeping trees in the same areas (Fig. 5, 6). Unfortunately, we could not confirm whether some unidentified TIR drone detections belonged to stump-tailed macaques due to their low abundance and elusive nature during ground surveys. However, this does not imply that this species cannot be surveyed with TIR drone surveys, but possibly their low abundances in the area. In fact, it may be more feasible in study sites with fewer sympatric macaque species or with prior knowledge on group ranges. Overall, in Cat Tien National Park, we recommend conducting camera trap surveys to monitor the macaque community (Masseloux et al. 2022; 2023) in combination with TIR drones to capture behaviors that are difficult to observe via traditional ground-based surveys, such as spatial organization at sleeping sites (Gazagne et al. 2020). Although other studies have detected gibbon species with diurnal TIR drones (*Hylobathes moloch*, *Nomascus hainanus* and *N. nasutus* in Rahman et al. 2022; Zhang et al. 2023; Wearn et al. 2023), we encountered challenges in monitoring southern yellow-cheeked gibbons in Cat Tien. Similar to our previous study in semi-wild enclosures in the Endangered Primate Rescue Center (EPRC) in northern Vietnam (Gazagne et al. 2023), Southern yellow-cheeked gibbons exhibited avoidance behavior during drone surveys, even with drone flying more than 30 m above the canopy. Our findings suggest aerial surveys might induce disturbance to *N. gabriellae* (Table 1, 2). Additionally, unless gibbons were in motion during the survey (identifiable locomotion behavior), inactive thermal spots of gibbons were impossible to identify based solely on TIR imagery. While TIR drone survey effectiveness on gibbons may be species- and site-specific, we recommend favoring passive acoustic monitoring surveys to monitor southern yellow-cheeked gibbons in Cát Tiên (Vu Tien Thinh & Tran Manh Long 2019). Lastly, although we did not include the nocturnal pygmy loris in our study, applying our scoring system to the species (Table 1) would likely yield the lowest thermal detection reliability score due to their small body length, low density, solitary

behavior, habitat preferences such as vine entanglements and bamboo thickets, and tendency to sleep at low heights (Blair et al. 2021; Kenyon et al. 2014). To assess the effectiveness of TIR drones on lorises, tests should be conducted directly above the known locations of radio-collared individuals (Kenyon et al. 2014).

As we conducted replicates on the same transects, it is likely that we re-detected the same groups. Therefore, our individual and group counts do not aim to provide population abundance or distribution. However, our study demonstrates that TIR drone surveys can effectively detect and count large arboreal species such as langurs and could be utilized for long-term monitoring. Therefore, we encourage conservation managers to integrate TIR drone surveys with RGB drone surveys and/or traditional ground-based surveys to determine the distribution and population size of *Pygathrix* species, *Rhinopithecus* species, *Trachypithecus* species or other Cercopithecoidea with similar arboreal behavior and identifiable morphotypes such as proboscis monkey (*Nasalis larvatus*), with minimal disturbance (Burke et al. 2019; Gazagne et al. 2023; Le Khac Quyet 2022; Trinh Dinh Hoang 2022). These technologies could be used not only to assess species behavior and habitat selection but also to monitor long-term population trends, as well as the integration and survival of released individuals as part of population reintroduction and recovery activities.

The choice of nocturnal, pre-programmed TIR drone surveys in this study was driven by the benefits of consistency and the enhanced thermal contrast provided by lower ambient temperatures at night. This approach allowed us to systematically survey the area and detect primates at their sleeping sites. However, this method has trade-offs, such as reduced flexibility compared to manual diurnal surveys, which offer real-time adjustments and the potential for visual confirmation through RGB cameras, reducing the risk of misidentification. Diurnal surveys can be particularly effective for detecting active primates during early morning or late afternoon periods. Understanding these trade-offs allows future studies to adapt their approaches based on the specific requirements of their study area and target species (Table 3).

Table 3. Comparison of nocturnal versus diurnal Thermal Infrared (TIR) imaging and systematic (pre-programmed) versus manual drone surveys, summarizing key factors in TIR drone surveys for diurnal primate detection.

FACTOR	NOCTURNAL TIR	DIURNAL TIR	SYSTEMATIC FLIGHT	MANUAL FLIGHT
THERMAL CONTRAST	**High:** Greater temperature difference improves detection.	**Low:** Reduced contrast in daytime temperatures.	**High:** Consistent imaging across surveys.	**Low:** Varies with operator decisions and conditions.
SPECIES IDENTIFICATION	**Low:** No RGB images lead to potential misidentification.	**High:** Daylight allows RGB images facilitating identification.	**Low:** Fixed paths limit adjustments for optimal identification.	**High:** Manual adjustments improve identification accuracy.
DISTURBANCE TO PRIMATES	**Low:** Less disturbance while diurnal primates are sleeping.	**High:** Active primates may exhibit avoidance behaviors.	**Moderate:** Fixed paths may cause disturbance but less noise overall.	**Moderate:** Can adjust for minimal disturbance but generates more noise.
DETECTION RELIABILITY	**High:** Easier to detect stationary primates and prevent overcounting.	**Low:** Active primates may be harder to detect or lead to inaccurate/ duplicate counts.	**Low:** Fixed paths may miss individuals or behavioral cues.	**High:** Real-time adjustments improve detection of moving primates.

COUNT ACCURACY	**Moderate:** May undercount individuals hidden.	**Low:** Active primates increase risk of missed or double counts.	**High:** Consistent paths reduce observer bias in counting.	**Moderate:** Variability in counting, but can detect dispersed individuals.
URVEY FLEXIBILITY	**High:** Can survey entirety of night time hours.	**Low:** Small window where TIR surveys can be conducted.	**Low:** Fixed routes with no real-time adjustments.	**High:** Adjustments of flight paths based on real-time observations and conditions.
SURVEY EFFICIENCY	**High:** Stationary primates may increase efficiency.	**Low:** Primate activity may reduce efficiency.	**High:**: Automated path covers larger areas in less time.	**Low:** Requires active control, reducing coverage per unit time.
SURVEY CONSISTENCY & AUTOMATION	**High:** Usually more stable nighttime conditions.	**Moderate:** Variable daylight conditions and primate activity reduce consistency.	**High:** Consistent coverage and data collection with fixed parameters.	**Low:** Operator variability and manual adjustments introduce inconsistencies across surveys
OPERATOR SKILL REQUIREMENT	**Moderate:** Requires night flight expertise but less active control.	**Moderate:** More skill needed for navigation with active primates but increased visibility.	**Low:** Minimal operator input needed as flights are automated.	**High:** Requires skilled operators for real-time adjustments.

Lastly, we encountered challenges during aerial surveys that should be considered for further studies. While our study area had lowland terrain with minimal risk of tree collisions during nocturnal surveys, we recommend conducting diurnal drone flights beforehand to identify any potential obstacles, such as elevated terrain or structures, especially when conducting systematic flights. Additionally, the low resolution of TIR drone imagery limited our ability to differentiate species with similar morphology or behavior, especially when flying high above the canopy (Burke et al. 2018; Kays et al. 2019). We recommend adjusting drone flight height based on habitat type. Although maintaining a constant flight height was convenient, it compromised image resolution in habitats with lower canopy heights, such as the rehabilitation secondary evergreen forest mixed with bamboo patches (Fig. 3). Consistent with previous studies, we suggest flying at approximately 30 m above the canopy to achieve sufficient resolution for detecting animals in the upper canopy (Burke et al. 2018; Kays et al. 2019; Rahman et al. 2022; Spaan et al. 2019). However, species-specific disturbance studies are needed to assess tolerance to drone surveys, particularly for species that are vulnerable to raptors as predators and may exhibit increased fear of flying animals and objects (Fam & Nijman 2011; Schad & Fischer 2022). Additionally, in multispecies studies where misidentification is a risk, a combination of TIR and RGB image drone surveys or ground-truthing surveys is recommended (Rahman et al. 2021). Thermal intensity analysis could potentially enable clearer species-specific insights, especially when considering fur thickness and color, which can significantly affect body surface temperature. As TIR imaging technology advances, incorporating thermal intensity into the scoring system could enhance detection reliability across species. Finally, we were unable to survey interior forest areas not adjacent to roads due to the limited reception range of drones in dense forests, as signal loss frequently occurred beyond 1 km. Therefore, we recommend focusing

monitoring efforts on species with smaller ranges or ranges that include roads or open areas, considering logistical constraints like drone takeoff, landing, and reception range.

Conclusions

We found that TIR drone surveys can be effectively used to monitor large arboreal primate species, such as black-shanked douc langurs. In study areas with multiple species, if species-level identification is not possible, combining sleeping behavior with ecological knowledge can help identify species at the genus level (e.g. *Macaca, Pygathrix, Rhinopithecus, Trachypithecus, Nomascus, Hylobates*, etc.). This preliminary knowledge can serve as a starting point for identifying areas of interest for further ground-based studies. Alternatively, combining diurnal TIR and image drone surveys can identify species without ground-truthing. We also recommend developing a universal scoring system to assess TIR detection reliability for different primate species. Finally, our research contributes to the understanding of sympatric primate behavior and ecology, thereby making a substantial contribution to conservation efforts, and highlights the potential of innovative technologies in primate monitoring.

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Rediscovery of a remnant population of the 'Critically Endangered' Delacour's langur (*Trachypithecus delacouri*) in the Yen Mo limestone complex, Ninh Binh Province, Vietnam

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Key words: Delacour's langur, *Trachypithecus delacouri*, survey, drone, Yen Mo limestone complex.

Summary

A remnant population of Delacour's langurs (*Trachypithecus delacouri*) was rediscovered in the Yen Mo limestone complex. This significantly expanded our knowledge of the distribution and conservation status of the species. Through a combination of interview surveys, ground surveys, and drone surveys, 37 individuals across four groups were documented, primarily confined within the Yen Mo District forest. This discovery marks the third-largest population of the species. In addition, the survey also provided comprehensive insights into other wildlife, revealing diverse species, including rhesus macaques (*Macaca mulatta*) and Assamese macaques (*Macaca assamensis*), Indochinese serows (*Capricornis* [*milneedwardsii*] *maritimus*) and keeled box turtles (*Cuora mouhotii*). The Indochinese serow is listed as 'Vulnerable' and the keeled box turtle as 'Endangered'.

However, persistent threats such as hunting activities, although no direct evidence on langurs, along with other anthropogenic activities such as agriculture and limestone quarrying, underscore the urgent need for conservation action. The current fragmented management of the area poses significant challenges, necessitating a unified management approach that transcends administrative boundaries. Establishing a management board, strengthening enforcement measures, and upgrading the protection status of the area are crucial steps toward safeguarding the Delacour's langur in the area. This species, in turn, has the full potential to serve as a flagship species for the entire limestone complex, drawing attention to its conservation needs and highlighting the importance of preserving its broader ecosystem.

Tái phát hiện quần thể sót lại của loài được xếp hạng 'Cực kỳ nguy cấp' - Voọc mông trắng (*Trachypithecus delacouri*) tại quần thể núi đá vôi Yên Mô, tỉnh Ninh Bình, Việt Nam

Tóm tắt

Nghiên cứu này báo cáo việc phát hiện lại một quần thể còn sót lại của loài voọc mông trắng (*Trachypithecus delacouri*) tại Khu phức hợp núi đá vôi Yên Mô, nâng cao đáng kể kiến thức về sự phân bố và hiện trạng bảo tồn của loài. Thông qua kết hợp khảo sát phỏng vấn, khảo sát mặt đất và khảo sát bằng máy bay không người lái, 37 cá thể thuộc bốn đàn đã được ghi nhận, chủ yếu được giới hạn trong Khu rừng phòng hộ Yên Mô. Khám phá này đánh dấu quần thể lớn thứ ba của loài. Ngoài ra, cuộc khảo sát cũng cung cấp những hiểu biết toàn diện về các loài động vật hoang dã khác, phát hiện về đa dạng các loài bao gồm khỉ vàng (*Macaca mulatta*) và khỉ mốc (*Macaca assamensis*), Sơn dương Đông Dương (*Capricornis* [*milneedwardsii*] *maritimus*) và rùa sa nhân (*Cuora mouhotii*). Sơn dương Đông Dương được liệt kê là 'Dễ bị tổn thương' và rùa sa nhân là 'Nguy cấp'.

Tuy nhiên, các mối đe dọa vẫn còn diễn ra như hoạt động săn bắt, mặc dù không có bằng chứng

trực tiếp đe dọa tới voọc mông trắng nhưng cùng với các hoạt động tiêu cực khác do con người gây ra như canh tác nông nghiệp và khai thác đá vôi. Do vậy, cấp thiết có các hoạt động bảo vệ rừng và bảo tồn sinh cảnh nơi đây được nghiêm ngặt hơn. Việc quản lý và bảo vệ khu vực hiện nay đặt ra những thách thức đáng kể, đòi hỏi một cách tiếp cận quản lý thống nhất vượt qua ranh giới hành chính. Thành lập ban quản lý, tăng cường các biện pháp thực thi và nâng cấp tình trạng bảo vệ khu vực là những bước quan trọng để bảo vệ voọc mông trắng. Đối với loài linh trưởng này hoàn toàn có đầy đủ tiềm năng để đóng vai trò là một loài xếp hàng đầu cho toàn bộ quần thể núi đá vôi nơi đây, thu hút sự chú ý đến nhu cầu bảo tồn và làm nổi bật tầm quan trọng của việc bảo tồn hệ sinh thái rộng lớn hơn của loài.

Introduction

Vietnam hosts a rich diversity of 25 primate species (Prime Minister of Government 2017; Blair et al. 2023). However, an alarming 80% of these species are teetering on the brink of extinction, as highlighted by the IUCN Red List of Threatened Species (Nadler 2010). Among the most imperiled is the Delacour's langur (Nadler et al. 2020a). This folivorous primate, renowned for its striking dichromatic black and white fur, thrives in limestone habitats, where its adaptation is especially remarkable (Nadler et al. 2003; Zhijin Liu et al. 2019; Tengcheng Que et al. 2021). Endemic to Vietnam, the Delacour's langur is confined to a small area in the north-central region, intensifying its vulnerability to habitat loss and fragmentation (Nadler et al. 2003; 2004; 2015). Classified as 'Critically Endangered' by the IUCN Red List of Threatened Species, this species frequently appears on the list of 'The World's 25 Most Endangered Primates', underscoring the urgent need for conservation efforts (Schwitzer et al. 2017). Despite dedicated conservation efforts, the species continues to encounter persistent threats. Historically, these threats have been attributed to poaching, while recent challenges arise from rapid habitat destruction and consequent fragmentation, notably driven by expanding land use and large-scale limestone quarrying. These pressing issues underscore the urgent need to intensify surveying efforts to assess the status of remaining populations and take informed conservation actions.

Recent drone surveys have confirmed the largest population of the species within the limestone complex of Van Long Nature Reserve and the adjacent unprotected Dong Tam area. The survey identified 179 individuals in 28 groups across the surveyed plots, with modeling estimating a total of around 300 individuals in 44 groups for the entire area (Trinh Dinh Hoang et al. 2024). Similarly, using the same drone survey method, the second-largest subpopulation was confirmed within the unprotected Kim Bang limestone complex of Ha Nam Province, comprising 104 individuals in 16 groups across all survey plots, with a modeling estimation of 175 individuals in 25 groups (Trinh Dinh Hoang 2022). Additionally, an extra, smaller population exists in Trang An, consisting now of 7 individuals, as a result of a reintroduction project aimed at creating an additional safeguarded population (Nadler et al. 2020). Although the likelihood of most scattered subpopulations across the region being eradicated due to the lack of sightings over several years is high (Nadler 2004; 2010; Nadler & Brockman 2014).

One area where a small population of Delacour's langurs could possibly still be found was in the Yen Mo limestone complex (Fig. 1).

The first information on the occurrence of Delacour's langurs in this limestone mountain was obtained during a survey in 1996. A complete group of 6 individuals was hunted in 1994. The remaining population was estimated at only 5-6 individuals (Nadler 1996; Baker 1999). Further surveys in 2000 (Nadler & Luong Van Hao 2000) and 2002 (Le Thien Duc & Le Huu Oanh 2002) reported a population of 9-10 individuals in the area. In a 2009 survey, 2 groups with a total of 9-10 individuals were found (Luong Van Hao & Nadler 2009). Recent interviews with authorities and locals have reported sightings of Delacour's langur, suggesting that a remnant population may still exist.

The Yen Mo limestone complex, intersected by provincial borders between Ninh Binh and Thanh Hoa Provinces, spans from Northwest to Southeast, encompassing Yen Mo and Tam Diep

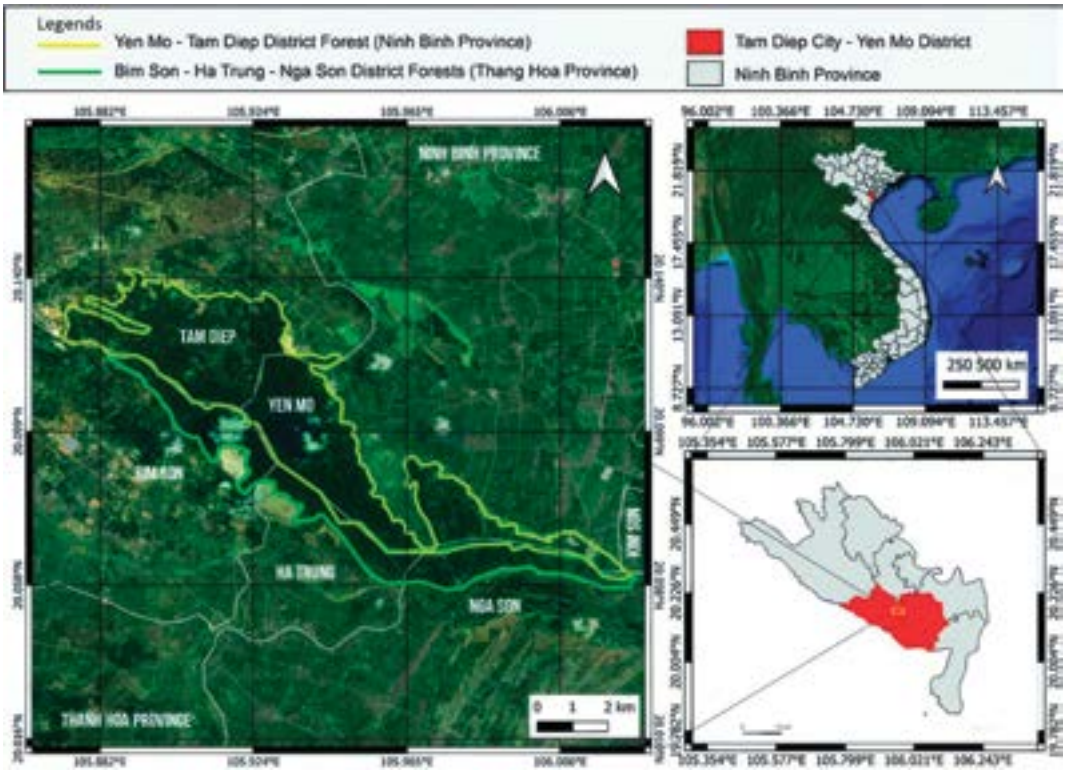

Fig.1. Location of the Yen Mo limestone complex in northern Vietnam, encompassing Ninh Binh and Thanh Hoa Provinces. The yellow outline represents the Yen Mo – Tam Diep District forests, while the green outline represents the Bim Son, Ha Trung, and Nga Son District forests in Thanh Hoa Province.

Districts in Ninh Binh Province and extending to Bim Son, Ha Trung and Nga Son Districts in Thanh Hoa Province. Each section falls under the jurisdiction of the People's Committee of its respective province, while the daily management of natural resources is supervised by the district authorities. The forest's protection status across the different districts is mostly designated as protection forests, currently under a relatively low level of protection. The landscape of the Yen Mo limestone complex is characterized by razor-sharp limestone karst formations and steep mountainous terrains with covered with evergree limestone forst alternating with significant portions of large bare rock surfaces (Fig. 2).

Fig.2. Typical landscape in the Yen Mo Limestone Complex. Photo: Tilo Nadler.

To navigate the challenging terrain of steep limestone cliffs, we employed a combination of interview, ground, and drone surveys between October 2023 and March 2024, each offering unique

strengths. However, due to logistical and administrative complexities, the study was limited to the Ninh Binh portion of the complex, still covering approximately 75% of the entire limestone complex. By integrating different survey methodologies, the study aimed to comprehensively assess the current status of the Delacour's langur population in the Yen Mo limestone complex and establish a baseline dataset for long-term population monitoring. Ultimately, this approach aims to facilitate targeted and informed conservation interventions for both the population of Delacour's langur in the Yen Mo limestone complex and the species as a whole.

Methods

Interview Survey

Interviews were opportunistically conducted with local authorities, residents who frequently access the forest, and experienced hunters. The primary objective of these interviews was to gather data on potential hotspots of Delacour's langur, as well as other wildlife, existing threats, terrain details, and accessibility. With the support of locals, waypoints were established on a map where the langurs have been previously observed in the limestone complex, facilitating the creation of a map depicting their potential distribution. To supplement this, historical records on Delacour's langur were collected (Nadler 1996; Baker 1999; Nadler & Luong Van Hao 2000; Le Thien Duc & Le Huu Oanh 2002; Luong Van Hao & Nadler 2009)

Ground Survey

Survey transect lines were established as the survey team explored various areas, aiming to cover as much of the limestone complex as possible, assisted by 1-2 local guides (Fig. 3). The ground survey lasted for 14 days, spanning two months between November and December 2024, and encompassed a total distance of 119 km. Tools such as a Nikon P900 camera, Vixen binoculars, and various tracking applications like GPS-map 62 (Garmin), Locus maps, Cybertracker, and Gaia GPS were used to document observations on paths, topography, wildlife, and threats. Data from this survey method also aided in identifying take-off areas for the subsequent drone survey.

Fig.3. Ground survey in the Tam Diep and Yen Mo District forests within the Ninh Binh Province section of the Yen Mo limestone complex. The track lines indicate the routes taken by survey teams to monitor and record data on the presence and distribution of wildlife, particularly Delacour's Langur.

Drone survey

Following the ground survey, the drone study spanned three months from January to March 2024 and involved surveying the area using the DJI Mavic 3T drone, equipped with a high-resolution optical camera (48 MP) and a thermal camera (640 x 512 PX). The survey design comprised 33 plots with its epicenter each spaced 1000 m apart in a grid-like structure, with radii ranging from 100-300 m depending on the valley structure (Fig. 4). Ultimately, 27 plots could be surveyed due to no-flight zone restrictions imposed by authorities. Each plot was surveyed a minimum of four times over 2-3 consecutive days, with two sessions in the morning and two in the afternoon. Flights lasted one full battery charge, approximately 45 min, during which langurs were actively searched. When flying around the edges of the plots, and a group was observed outside the plots, the geolocation was also allocated. Thermal imaging was utilized to detect heat signatures emitted by live animals within the forest canopy. Detected heat signatures were recorded, and the drone flew vertically above the object to obtain precise GPS coordinates. Subsequently, focusing on areas with detected heat signatures, the drone captured detailed images using the optical camera with zoom capabilities to visually confirm and identify the animals.

Fig.4. Drone survey plots established in the Tam Diep and Yen Mo District forests within the Ninh Binh Province section of the Yen Mo limestone complex.

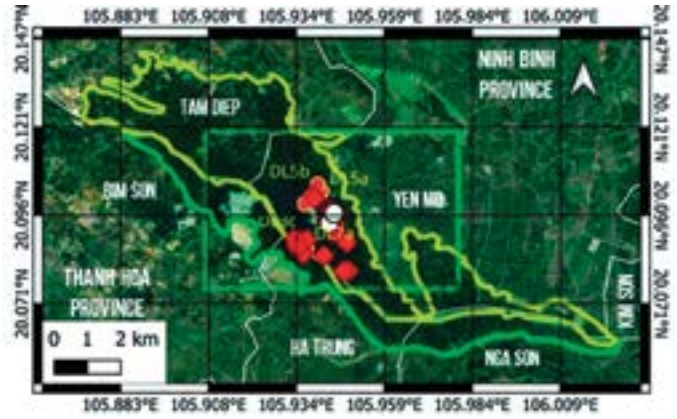

Fig.5. Overview combining all record points from all survey methods.

Results

Delacour's langur

The ground and drone surveys conducted along established transects provided comprehensive insight into the distribution and population of langurs within the limestone complex (Fig. 5 to 8, Table 1). Ground surveys confirmed the

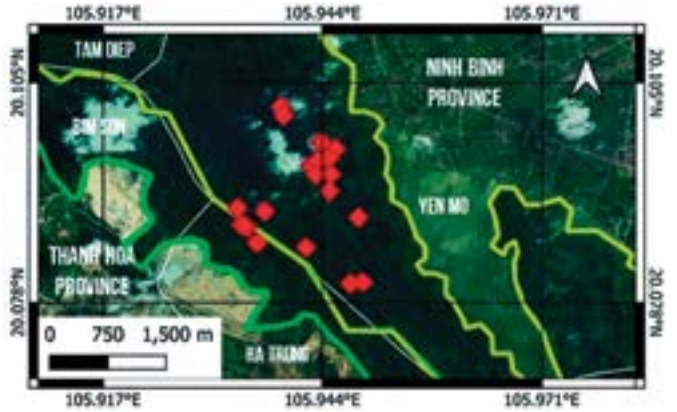

Fig.6. The occurance of Delacour's langurs identified through interviews.

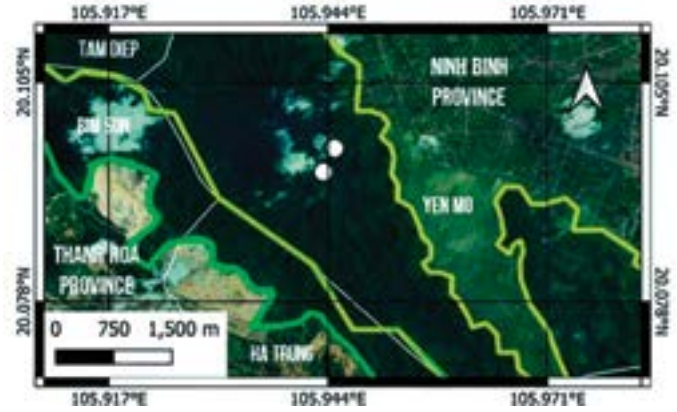

Fig.7. Locations of Delacour's langurs confirmed by ground surveys (2 groups, total 7 individual).

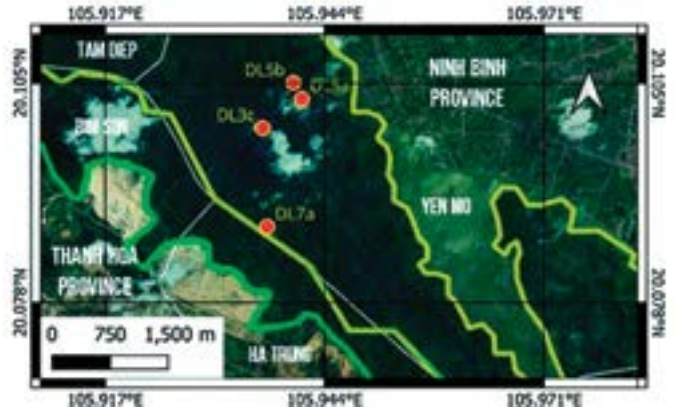

Fig.8. Specific sites of confirmed presence of Delacour's langurs from drone surveys (4 groups, total 37 individuals).

langurs' presence primarily in the central part of the Yen Mo District forest, aligning with hotspot locations identified through interview surveys. Conversely, langurs were notably absent from certain areas, such as the southeastern portion of Tam Diep District forest and the northwestern portion of Yen Mo District forest. The ground survey only counted two groups comprising a total of 7 individuals as factors like foggy weather and topographic obstructions hindered visibility, potentially impacting the count accuracy.

Table 1. Occurrence of Delacour's langur based on drone survey in Tam Diep and Yen Mo District forests within the Ninh Binh Province section of the Yen Mo limestone complex.

Date	Ref Survey plot	Ref Group	Group Size	Coordinates		Observation Survey plot	Maximum individuals
				Y	X		
01/02/2024	5	DL5a	11	20,102982	105,940822	inside	11
02/02/2024	5	DL5a	5	20,104975	105,939766	outside	
19/02/2024	1	DL5a	8	20,107483	105,938792	outside	
13/03/2024	5	DL5a	4	20,096059	105,940136	outside	
02/02/2024	5	DL5b	7	20,098675	105,942567	inside	7
02/02/2024	6	DL5b	4	20,097088	105,943084	outside	
13/03/2024	5	DL5b	1	20,096059	105,940136	outside	
12/03/2024	3	DL3c	2	20,099583	105,936543	outside	5
13/03/2024	3	Dl3c	5	20,099375	105,935977	outside	
27/02/2024	7	DL7a	5	20,086935	105,93771	outside	14
27/02/2024	7	DL7a	14	20,087171	105,93652	outside	
	Total groups	4				Total individuals	37

In contrast, drone surveys provided enhanced efficiency and resolution in locating langur groups. These aerial observations confirmed that the population is mainly confined to the central part of the limestone complex. Four groups totaling 37 individuals were identified. The dynamic nature of langur behavior, including subgroup formations during foraging, required careful follow-up to clearly delineate distinct groups. Additionally, langurs were mostly observed outside established survey plots, necessitating the inclusion of all sightings for a comprehensive assessment. Consequently, due to the species' rarity and the limitations of strict plot surveys, extrapolation models for the entire limestone complex were not applied to ensure an accurate representation of the langur population size.

For comparative purposes, the current distribution was compared with historical interview and ground survey records conducted before 2010 (Fig. 9). While the historical numbers could not be ascertained, the comparison revealed a similar distribution of langurs in the Yen Mo District forest, with a few observations in the adjacent southern strip of the limestone complex within Thanh Hoa Province. The present study was hampered in studying this area; however, given its relatively small size and the ongoing intensive limestone quarrying in that section, we do not expect to find a significant number of individuals.

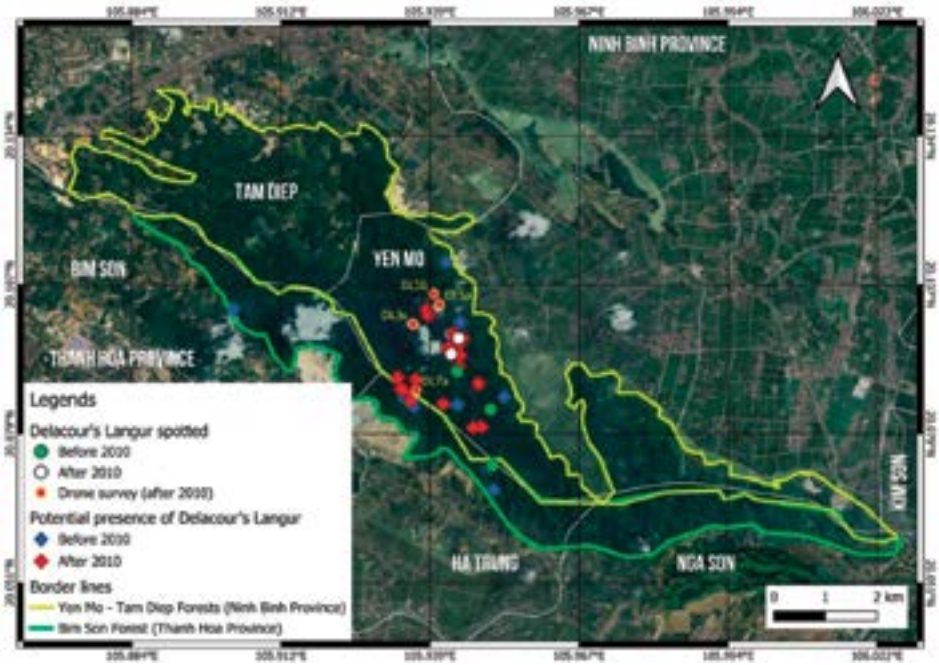

Fig.9. Distribution of Delacour's langur before and after 2010. Records of potential occurrences are based on interviews with locals in the field.

Other wildlife

While the primary aim of the present study was to assess the status of Delacour's langur in the Yen Mo limestone complex, the study also gathered information on other wildlife species in the area through ground transects and drone plots. Locals reported the presence of notable wildlife such as Indochinese serow (*Capricornis* [*milneedwardsii*] *maritimus*), Assamese macaques (*Macaca assamensis*), and Rhesus macaques (*Macaca mulatta*) (Figs. 10, 11; Table 2). The ground and drone surveys confirmed the occurrence of all these species, but also the keeled box turtle (*Cuora mouhotii*), Pallas's squirrel (*Callosciurus erythraeus*), and the oriental pied hornbill (*Anthracoceros albirostris*). Notably, given its relative rarity in the area, the presence of Indochinese serow, listed as 'Vulnerable' by the IUCN and included in Appendix I of CITES, was detailed. The drone survey counted only five

individuals during the entire drone survey, consisting of an adult-juvenile pair located in Tam Diep District forest and three other individuals scattered throughout the Yen Mo District forest.

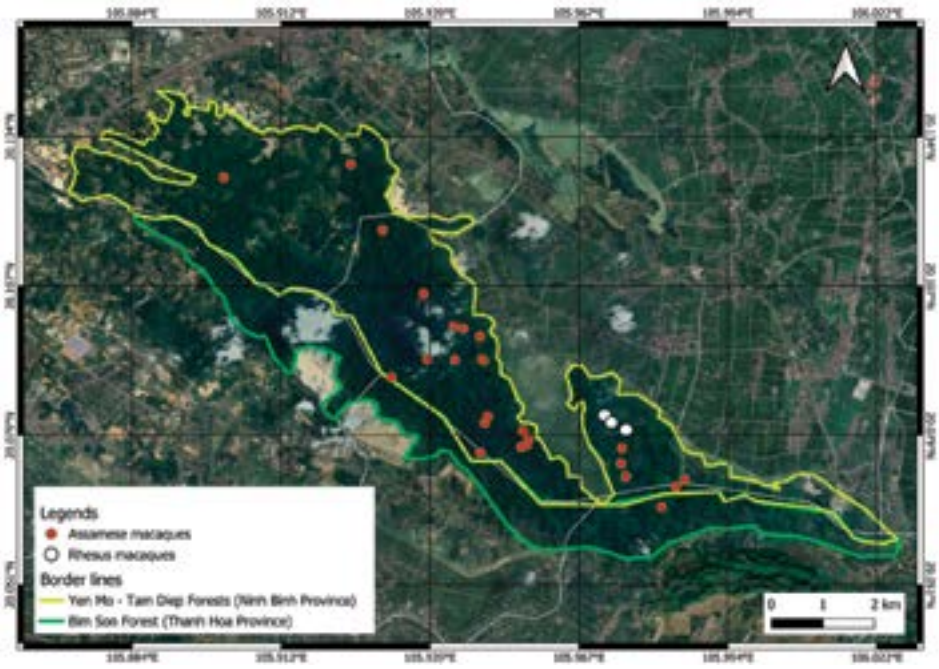

Fig.10. Distribution of Assamese and rhesus macaques, as a result of the ground survey. For the Assamese macaque, a total of 210 individuals were distributed among 15 different groups, while for the rhesus macaque, there was one large group consisting of 47 individuals.

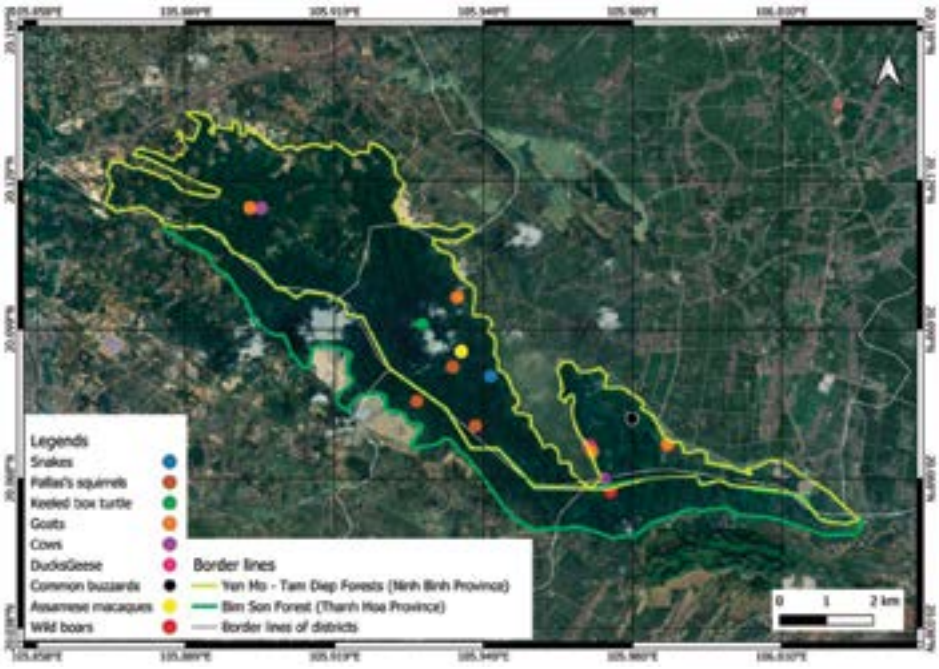

Fig.11. Records of animals during the ground survey.

Table 2. Animal records during ground and drone surveys.

No.	Common name	Scientific name	CITES	IUCN Red list	Ground survey			Drone Survey		
					Observed	Groups	Individuals	Observed	Groups	Individuals
1	**Delacour's langur**	*Trachypithecus delacouri*	Appendix II	CR	YES	2	7	YES	4	37
2	**Assamese macaque**	*Macaca assamensis*	-	NT	YES	1	15	YES	15	200
3	**Rhesus macaque**	*Macaca mulatta*	-	LC	NO	-	-	YES	1	47
4	**Indochinese serow**	*Capricornis* [*milneedwardsii*] *maritimus*	Appendix I	VU	NO	-	-	YES	-	5
5	**Pallas's squirrel**	*Callosciurus erythraeus*	-		YES	-	not assessed	YES	-	not assessed
6	**Common buzzard**	*Buteo buteo*	Appendix II	LC	YES	-	1	YES	-	not assessed
7	**Oriental pied hornbill**	*Anthracoceros albirostris*	Appendix II	LC	NO	-	-	YES	-	not assessed
8	**Keeled box turtle**	*Cuora mouhotii*	-	EN	YES	-	2	NO	-	not observed
9	**Duck/ Goose**	domestic	-	-	YES	-	± 40	YES	not assessed	not assessed
10	**Goat**	domestic	-	-	YES	-	± 40	YES	-	± 50
11	**Cow**	domestic	-	-	YES	-	± 23	YES	-	unknown
12	**Pig**	domestic	-	-	YES	not assessed	not assessed	YES	-	± 60

Noteworthy to further detail is the primate fauna in the area, particularly the macaques. The drone survey revealed several macaque groups with relatively large numbers of individuals scattered across the limestone complex. Among these, the Assamese macaque predominates, estimated to comprise approximately 200 individuals distributed among 15 different groups, while the Rhesus macaque was identified with only one group, of 47 individuals. Although the Assamese macaque was among the species identified with the largest population and the highest number of groups, the majority of them were concentrated in the Yen Mo District forest. Meanwhile, rhesus macaques were sighted in one localized area in Yen Mo District forest in relative proximity to upland agricultural areas.

Threats

Local resident's report that over a decade ago, wildlife sightings, especially mammal species, were more frequent, but have since become rare, indicating a decline in populations. Interviews and ground surveys revealed persistent hunting activities, with evidence of various traps (footholds, snares, live traps, and mist nets) indicating widespread hunting practices targeting wildlife, including small mammals and birds (Fig. 12). Furthermore, residual agricultural products and litter accumulation were observed across the area, suggesting continuous agricultural activities. Agricultural cultivation, primarily for commercial trade and livestock husbandry, was observed in arable valleys, involving crops like Cassava, Achira, and Maize, leading to forest degradation. The presence of domestic animals, including ducks, geese, cows, pigs, and goats, was detected, particularly at forest edges and valleys, indicating land use for livestock (Fig. 11). Notably, the drone survey showed over 50 roaming goats, which are known to directly compete with Delacour's langur for food resources and space. Of particular concern is also the ongoing limestone quarrying, which, if left uncontrolled, poses one of the most significant threats in the long run whereby an estimated 400 ha of the 4,473 ha of the Yen Mo limestone complex has already been completely excavated, with no signs of halting.

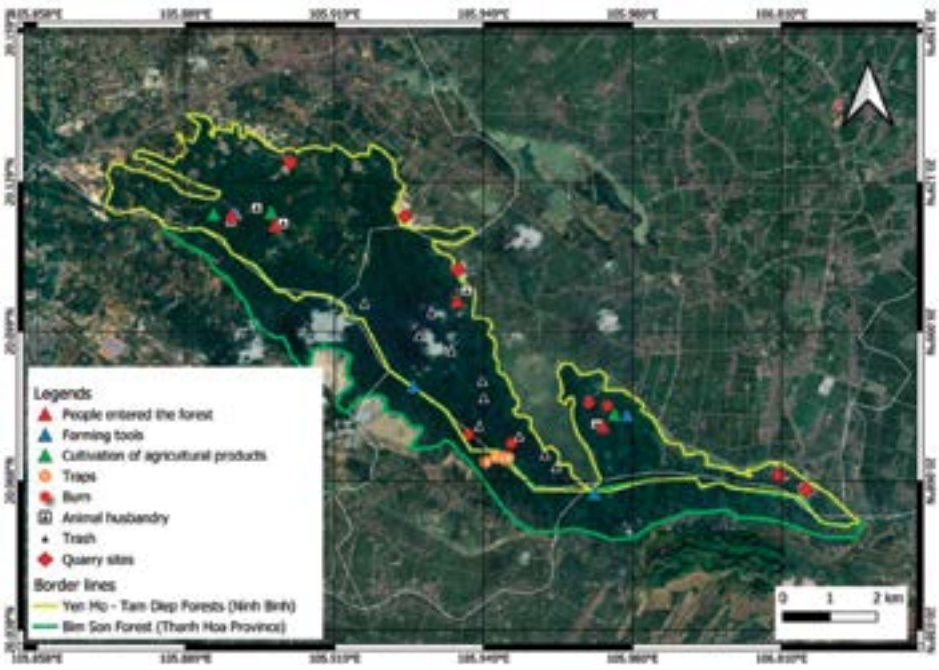

Fig.12. Identified threats during the ground survey.

Discussion

Delacour's langur, confined to a restricted area in northern Vietnam, has witnessed a significant shrinking in its distribution over the past few decades, with most subpopulations likely extinct (Nadler 2004; 2015). Given the species' critically endangered status, the search for remaining subpopulations is imperative. Our surveys led to the rediscovery of 37 individuals across four groups, marking it as the third-largest known population after the ones in and Van Long Nature Reserve and Kim Bang Forest (Fauna & Flora International 2024; Trinh Dinh Hoang et al. 2024), highlighting the importance of the population for conservation of the critically endangered Delacour's langur

The data gathered though combined interview, ground and drone surveys enabled us to map the distribution of the langur, revealing its primary occurrence within Yen Mo District forest in the central portion of the Yen Mo limestone complex. Based on the drone survey, the species' core distribution

was about 100 ha, but considering its potential home range, it would occupy approximately 400 ha of the 4,473 ha limestone complex. Comparison of this information with historical records indicates a similar distribution pattern consistent with present records, with langurs concentrated in the central part of the Yen Mo limestone complex and absent from its southeastern and northwestern sections. Historical surveys also noted langur presence in a narrow strip south of Yen Mo District forest, in Thanh Hoa Province, specifically in Bim Son and Ha Trung Districts. Due to administrative and logistical limitations during the present study, this area could not be re-surveyed. Future surveys should aim to assess the presence of remaining langurs in that section. However, given the relatively small size of this area and the intensive quarrying in that section, no significant increase in the known number of total langurs for the entire limestone complex is anticipated.

The concentration of the Delacour's langur in a constrained area rather than being scattered across the entire limestone complex raises questions about the factors influencing their distribution. Langurs are sensitive to environmental factors such as topography, climate and vegetation (Blair et al. 2021). For instance, no langurs were observed in the extended rocky surface with low vegetation coverage near Yen Thai communes in the southeastern part of the limestone complex. Furthermore, distribution might be influenced by the co-occurrence of other animal species. The survey revealed significant populations of 200 Assamese macaques and 47 Rhesus macaques distributed across the limestone complex, indicating potential competition between macaques and langurs (Nadler et al. 2019; Nguyen Dac Manh et al. 2020). A negative correlation between Delacour's langurs and Assamese macaques was found (Trinh Dinh Hoang pers. comm.). While natural factors may influence distribution and require further research, it is more likely that prolonged anthropogenic impacts, such as habitat destruction and hunting, have significantly influenced their distribution and population size over the recent decades.

While no direct evidence was found of current hunting activities targeting Delacour's langur, ground surveys revealed hunting activities, including the discovery of several traps. Hunting pressure is expected to significantly impact the local fauna, as reflected in the scarcity of species like the Indochinese serow, with only five individuals detected across the study area. Additionally, activities such as waste disposal, agriculture, and burning were observed, along with the presence of a significant number of goats, known for damaging vegetation and competing for resources with langurs (Wojciechowski & Nguyen Hong Chung 2013). Of particular concern are quarrying activities, which already affected nearly 8% of the Yen Mo limestone complex, especially in its southern border in Thanh Hoa Province. The quarrying activities has led to the complete flattening of limestone formations in these areas, vanishing the flora and fauna that depend on them. If left unchecked, the swift and seemingly relentless expansion observed in the neighboring Kim Bang limestone complex, where we estimate based on satellite images that 31% (±2102 ha) of the 4713 ha block has already been excavated, is likely to result in comparable adverse effects in the Yen Mo limestone complex.

Mitigating the anthropogenic threats is crucial to prevent the extirpation of the Delacour's langurs in the Yen Mo limestone complex. Without immediate conservation efforts, the species faces a high risk of localized extinction, as evidenced by the dramatic reduction of the species historical range over the past 15 years. Surveys before 2010 identified 16 subpopulations (Nadler 2004; Nadler et al. 2015), but the lack of recent sightings in 12 subpopulations (75%) suggests that these groups have likely become extinct in less than two decades. The discovery in the present study of a still viable, though precarious, population presents the last opportunity for timely conservation. These remaining groups have potential for recovery, making these efforts critical for preserving both the local population and the species as a whole. The feasibility of such actions is demonstrated by the population in Van Long Nature Reserve, which quadrupled due to similar efforts since the 1990s (Nguyen Van Linh et al. 2019). Preserving genetic diversity and safeguarding remaining subpopulations will improve adaptability, disease resistance, and overall survival, reducing the risk of the species' extinction (Ebenau et al. 2011; Nadler 2015).

The rediscovery of the Delacour's langur population in Yen Mo District forest presents a critical opportunity for targeted conservation efforts. Their restricted distribution within the central part of

the limestone complex exacerbates their vulnerability to localized threats, yet also provides an opportunity to implement intensified patrolling units in this specific portion of the limestone complex. However, given that the langurs do not adhere to artificial borders, a comprehensive conservation strategy encompassing the entire limestone complex is essential. This necessitates the establishment of a management board for this limestone complex comprising governmental representatives from the relevant districts and provinces, alongside stakeholders such as NGOs, citizen representatives, and industries such as quarry managers. In the longer term, upgrading the forest status to a higher protection level using the Delacour's langur as a flagship species is crucial for safeguarding the area's biodiversity. This effort also involves on-the-ground law enforcement, offering ecotourism as an alternative income source for the community, and fostering environmental awareness about the area's significance and the urgent need to preserve it.

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The development of pelage coloration in Delacour's langurs (*Trachypithecus delacouri*)

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Key words: Delacour's langur, *Trachypithecus delacouri*, change of coat color.

Summary

The Delacour's langur is a 'Critically Endangered' and endemic Vietnamese primate species that only occurs in a very limited area of northern Vietnam. Until the early 1990s there was no photo of a living Delacour's langur. The fur colouration of the young animals and their development were unknown. In 1993, the Frankfurt Zoological Society started a primate project in Vietnam focusing on the protection, status and distribution of Delacour's langurs. As part of the project, the Endangered Primate Rescue Center (EPRC) was founded in Cuc Phuong National Park and a captive breeding programme was started with confiscated animals. Over a period of 28 years, 37 young animals were born at the EPRC.

This enables a statement to be made about the development of fur coloration in young animals. The information can be helpful for the age determination of young animals in the wild, which in turn can contribute to conclusions about the social behaviour of the species.

Delacour's langurs are born with a uniform yellow coat. The bare skin parts face and ears, hands and feet are yellowish white. After about a week, a brownish tinge appears on the lower back and the tail becomes darker brown and forms a distinct tassel. Over the third and fourth month the back continues to darken and in the fourth month already has a dark brown to black coloring. From about the fifth month onwards, the hips and thighs, the area that later forms the typical trousers, become increasingly lighter in colour until it is almost completely white in the tenth month. The back, arms and legs become deep black.

After the tenth month, the young have almost the same coloring as the adults; except for the head with yellowish remnants usually remain visible. The trousers become increasingly white; the rest of the body is black. At about one year of age, the young animals resemble the adults in coloring. There is no visible difference in the development of pelage coloration between males and females. However, there are significant individual differences in the progression of coloration.

Sự phát triển của màu lông của voọc mông trắng (*Trachypithecus delacouri*)

Tóm tắt

Voọc mông trắng là một loài linh trưởng đặc hữu của Việt Nam 'Cực kỳ Nguy cấp' và chỉ xuất hiện ở một khu vực rất hạn chế ở miền Bắc Việt Nam. Cho đến đầu những năm 1990, không có bức ảnh nào về loài voọc mông trắng còn sống. Màu lông của động vật non và sự phát triển của chúng vẫn chưa được biết đến. Năm 1993, Hội Động vật học Frankfurt (FZS) bắt đầu một dự án Bảo tồn linh trưởng tại Việt Nam tập trung vào việc bảo vệ, hiện trạng và phân bố voọc mông trắng. Là một phần của dự án, Trung tâm Cứu hộ Linh trưởng Nguy cấp (EPRC) được thành lập tại Vườn Quốc gia Cúc Phương và một chương trình nhân giống nuôi nhốt đã được bắt đầu với động vật bị tịch thu. Trong khoảng thời gian 28 năm, 37 con non đã được sinh trưởng tại EPRC.

Điều này cho phép đưa ra những công bố về sự phát triển của màu lông ở động vật con non. Thông tin có thể hữu ích cho việc xác định độ tuổi của động vật con non trong tự nhiên, từ đó có thể

góp phần đưa ra những đánh giá về hành vi xã hội của loài.

Voọc mông trắng được sinh ra với bộ lông màu vàng đồng nhất. Các bộ phận da trên mặt và tai, bàn tay và bàn chân có màu trắng vàng. Sau khoảng một tuần, một màu nâu xuất hiện ở lưng dưới và đuôi trở nên màu nâu sẫm hơn và tạo thành một tua rua riêng biệt. Trong tháng thứ ba và thứ tư, lưng tiếp tục sẫm màu và trong tháng thứ tư đã có màu nâu sẫm đến đen. Từ khoảng tháng thứ năm trở đi, hông và đùi, khu vực phía sau này tạo thành như chiếc quần tây điển hình, ngày càng nhạt hơn cho đến khi nó gần như hoàn toàn trắng vào tháng thứ mười. Lưng, cánh tay và chân trở nên đen đậm.

Sau tháng thứ mười, con non có màu sắc gần như giống với con trưởng thành; ngoại trừ phần đầu với chút pha màu vàng thường vẫn còn nhìn thấy. Phần hông đến đùi như chiếc quần ngày càng trở nên trắng rõ; phần còn lại của cơ thể có màu đen. Vào khoảng một tuổi, những con non giống với con trưởng thành về màu sắc. Không có sự khác biệt rõ ràng trong sự phát triển của màu lông giữa con đực và con cái. Tuy nhiên, có sự khác biệt đáng kể của mỗi cá thể trong sự tiến triển tông màu sắc.

Introduction

The Delacour's langur is a rare endemic Vietnamese primate species that only occurs in a very limited area of northern Vietnam. Until the early 1990s there was no photograph of a living Delacour's langur. The fur colouration of the young animals and their development was unknown. With a primate project of the Frankfurt Zoological Society, which started in 1993, the species came into focus and an intensive search for remaining populations began. At the same time, the Endangered Primate Rescue Center was founded in Cuc Phuong National Park. A captive breeding programme was started with confiscated animals and over the course of 28 years, 37 animals were born at the center. This also made it possible to record the development of the fur coloration of the young animals. This forms the basis for a rough age determination of young animals in the wild. Knowing the age of the young allows conclusions to be drawn about the social behaviour of the animals, such as mating periods, birth frequency and group takeovers of males over the course of the year.

For young animals confiscated from the illegal pet trade, determining the age of the animals can be helpful in determining nutrition and feeding.

Material

The course of pelage coloration of 10 juveniles was recorded in a protocol and with photographic evidence. The recording covered different periods of time - from six months to 18 months. During the first two to three months of life, photos and notes were taken weekly, thereafter approximately monthly.

The development of pelage colouration

All juveniles of the seven so-called 'limestone langurs': Delacour's langur, white-headed langur (*T. leucocephalus*), Cat Ba langur (*T. poliocepahlus*), Francois' langur (*T. francoisi*), Laos langur (*T. laotum*) and Hatinh langur (*T. hatinhensis*), including the all-black colour morph *ebenus*, are born with a yellow coat with brownish to orange tints. The differentiation in coat coloration of newborn animals between these species is very slight, but with experience the animals can still usually be assigned to one species.

New born animals and first month

Delacour's langurs are born with a uniform yellow coat. The bare skin parts, face and ears, hands and feet are yellowish-white. The tail has a brownish tinge from the end, which fades into the yellow approximately to the center of the tail (Fig. 1, 2).

After about a week a brownish tinge appears on the lower back, which gradually darkens by the end of the first month. The brownish coloring of the tail also gradually darkens and by the end of the first month a tail tassel forms. The hair above the wrists and ankles becomes brownish in color.

Fig.1, 2. Delacour's langurs are born with a yellow coat. The bare skin parts, face and ears hands and feet are yellowish white. All Photos: Tilo Nadler.

Second to fourth month

After about six weeks the back has dark brown patches on both sides of the spine. The tail is dark brown almost to the root and has a distinct tassel. The mop of hair in the center of the head begins to turn dark. The skin of the face takes on a grey tinge (Fig. 3, 4).

Fig.3, 4. After about a month, dark hairs appear on the back and the tail becomes darker brown from the end and forms a clear tassel. Bare skin of the face, ears, hands and feet turns grey.

Over the third and fourth month the back continues to darken and in the fourth month already has a dark brown to black tinge, as do the arms and legs, with the thighs acquiring a light grey tinge. The tail is now completely dark brown to black in color. The tassel of the tail is still clearly developed. The skin of the face, ears, hands and feet is dark grey. The mop of hair on the centre of the head is turning black (Fig. 5, 6).

Fig.5, 6. At the age of about four months, the juvenile is almost completely black, only the head remains yellow with an already black crest. The later white whiskers appear light grey and the later white trousers are faintly visible with a grey sheen. The facial skin becomes increasingly darker.

Fifth to tenth month

From about the fifth month onwards, the hips and thighs, the area that later forms the typical trousers, become increasingly lighter in color until it is almost completely white in the tenth month. The back, arms and legs become deep black. The head remains yellowish in color, with the black slowly spreading further from the mop of hair. In the tenth month, the facial skin is a very dark grey (Fig. 7, 8).

Ten months to one year

After the tenth month the young animals have almost the same coloring as the adults, except for the head, the trousers become increasingly white, the rest of the body is black. The head, which is still yellow, gradually turns black, starting from the mop of hair as well as from the hair above the forehead. The hair starting from the root of the tail becomes longer so that the tassel slowly disappears and the tail is about the same thickness from the root to the end (Fig. 9, 10).

Fig.7, 8. From about the fifth month onwards, the white trousers become more visible and contrast with the increasingly black upper body. From the root, the tail slowly turns black and the length of the hair increases. The tail slowly loses its tassel.

Fig.9, 10. At around 10 months, the young have almost the colouring of the adults, except for the still yellow head. The trousers are light grey, not yet white. The tail is black snd gradually takes on the carrot shape of the adults.

One year and older

At about one year of age, the young are similar in color to the adults. The trousers are not yet pure white, but still have a grey shimmer. A black stripe runs above the spine from the back to the base of the tail. This can remain visible until about four years of age, when it disappears into the white of the trousers.

The head is predominantly black, but yellowish remnants usually remain visible. The skin of the face and ears are black. The tail is still the same thickness, but the carrot shape of the adult is slowly developing.

After the complete change of color into the adult feature, only a clear difference in body size to the adults remains. Even sexually mature animals that are four to five years old still have a smaller body size than older animals that are around seven or eight years old (Fig. 11, 12).

Fig.11, 12. At the age of one year, the head also gradually darkens, but a slight yellow colouring can persist until the second year of life. A black line from the root of the tail to the back sometimes only disappears in the fourth year of life. (The back of the head and the crest only appear white in the picture due to the reflection of the sun, but are actually black).

Discussion

As with the Cat Ba langurs (Nadler 2020), there is no visible difference in the development of pelage coloration between males and females. However, there are significant individual differences in the progression of coloration. Individual differentiation increases over the period of development and can account for about one month in the development of pelage coloration at the age of one year. There can be a particularly large individual difference in the development of head coloration. Some animals may retain a yellowish coloration of parts of the head for well over a year, while other individuals may already have a completely black head at one year of age.

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A case of anaphylactic shock from a pygmy loris (*Xanthonycticebus pygmaeus*) bite in South Vietnam: an opportunity for factual knowledge to drive positive change in human and pygmy loris interactions

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Key words: Pygmy loris, *Xanthonycticebus pygmaeus*, South Vietnam, Illegal trade, venomous bite, anaphylactic shock, human and slow lorises co-existence.

Summary

Pygmy lorises (*Xanthonycticebus pygmaeus*) have adapted to the anthropogenic landscape in South Vietnam; bamboo scrub, cashew plantation or fruit garden are now often considered home for pygmy loris. This has resulted in greater opportunistic illegal hunting, or simply capture for safe transfer back to protected forest, with local belief that the pygmy loris are lost and must be returned into a protected zone. The Dao Tien Endangered Primate Species Centre located in South Vietnam has received 197 rescued pygmy loris from the Forestry Protection Department spanning a 16 year period, with 152 returned back to protected forest. Of these, 58 were fitted with VHF tags for post-release monitoring. On 26th August 2016 during a routine fitting of VHF tag at 17.30, under red light, an adult female, estimated in captivity <11 months, managed to swivel while being held in thick gloves and bite the person fitting the tag. Within 5 minutes the person bitten started to experience paraesthesia (tingling of the lips) followed by circumoral and limb angioedema (sudden swelling). After 70 minutes difficulty in swallowing was experienced. No treatment was administered until reaching the hospital at 10pm, by which time anaphylactic peak had passed, with swallowing and normal movement of limbs restored. Circumoral angioedema still remained for 24 hours. Six variables were confirmed to increase the likelihood of anaphylactic shock: (a) close proximity to conspecifics increasing preparedness to fight; (b) handler's pre-sensitisation from pygmy loris nips (through gloves) over a seven year period; (c) high stress levels; (d) mixing of saliva & brachial gland fluid; (e) locked jaw allowing a prolonged period for venom delivery; (f) peak of the pygmy loris aggressive mating season.

We hope this potentially 'diagnostic' event of an extreme and life threatening reaction to a pygmy lorises bite, could act as a catalyst for stories, memories and experiences of 'slow loris and human interaction', and so increasing factual knowledge of their venomous strong bite, throughout the community, from Government official to farmer. Ontologies (systems of organised knowledge) developed from the increased awareness could drive behaviour change towards a positive co-existence between humans and slow lorises, supporting welfare for both in this now shared home.

Một trường hợp sốc phản vệ do bị cắn bởi một cá thể cu li nhỏ/nhỡ (*Xanthonycticebus pygmaeus*) ở miền Nam Việt Nam: Cơ hội cho kiến thức thực tế để thúc đẩy sự thay đổi tích cực trong tương tác giữa con người và cu li nhỏ/nhỡ

Tóm tắt

Con cu li nhỏ (*Xanthonycticebus pygmaeus*) đã thích nghi với sinh cảnh gần con người ở miền Nam Việt Nam; như cây bụi rậm tre vầu luồng, đồn điền hạt điều hoặc vườn cây ăn quả hiện nay thường được coi là nơi sinh sống của loài cu li nhỏ. Điều này đã dẫn đến việc săn bắt bất hợp pháp

tăng cao hơn, hoặc đơn giản là bắt giữ để chuyển về rừng được bảo vệ an toàn, với niềm tin của người dân địa phương rằng cu li nhỏ đã bị mất và phải được trả lại khu vực được bảo vệ. Trung tâm Linh trưởng Nguy cấp Đào Tiên nằm ở miền Nam Việt Nam đã tiếp nhận 197 cá thể cu li **nhỏ/nhỡ** được cứu hộ từ lực lượng kiểm lâm trong khoảng thời gian 16 năm qua, với 152 cá thể đã được tái hòa nhập trở về rừng được bảo vệ. Trong số này, 58 cá thể được đeo thiết bị thẻ VHF để theo dõi sau khi thả. Vào ngày 26 tháng 8 năm 2016, trong một lần lấp thẻ VHF định kỳ lúc 17:30, dưới ánh đèn đỏ cho một cá thể cái trưởng thành, ước tính nó đã được chăm sóc trong điều kiện nuôi nhốt khoảng <11 tháng, cá thể này đã xoay người rất mạnh rồi cắn chuyên gia đang thực hiện đeo thẻ mặc dù có đeo găng tay dày. Trong vòng 5 phút, người bị cắn bắt đầu bị dị cảm (ngứa ran môi), sau đó là phù mạch chi (sưng đột ngột). Sau 70 phút, việc khó nuốt đã xảy ra. Không có phương pháp điều trị nào được thực hiện cho đến khi bệnh nhân được đưa đến bệnh viện lúc 10 giờ đêm, lúc đó đỉnh điểm phản vệ đã qua, với việc nuốt và chuyển động bình thường của các chi được phục hồi. Phù mạch tuần hoàn vẫn tồn tại trong 24 giờ. Sáu biến số đã được xác nhận làm tăng khả năng sốc phản vệ: (a) ở gần đồng loại làm tăng khả năng sẵn sàng chiến đấu; (b) người xử lý bị mẫn cảm trước khi bị cu li nhỏ cắn (qua găng tay) trong khoảng thời gian bảy năm; (c) mức độ bị căng thẳng cao; (d) nước bọt và dịch tuyến cánh tay bị pha trộn; (e) hàm bị khóa chặt cho phép kéo dài thời gian bị nhiễm nọc độc; (f) đỉnh điểm của mùa giao phối tạo sự hung hăn của cu li nhỏ. Chúng tôi hy vọng việc 'chẩn đoán' khả năng này về phản ứng cực đoan và đe dọa tính mạng đối với vết cắn của loài cui nhỏ. Điều này có thể hoạt động như một chất xúc tác cho những câu chuyện, ký ức và trải nghiệm về 'cu li nhỏ và những tương tác của con người', do đó giúp tăng kiến thức thực tế về vết cắn mạnh có nọc độc của chúng, đối với cộng đồng dân cư, từ quan chức chính phủ, lực lượng chức năng cho đến người nông dân. "Ontology" là bản thể học hay là hệ thống kiến thức có tổ chức được phát triển từ nhận thức ngày càng tăng có thể thúc đẩy sự thay đổi hành vi hướng tới sự chung sống tích cực giữa con người và loài cu li nhỏ, hỗ trợ phúc lợi cho cả hai trong ngôi nhà thiên nhiên chung này.

Introduction

Slow and pygmy lorises (*Nycticebus* spp. and *Xanthonycticebus* spp.) (hereon referred to collectively as slow lorises) are nocturnal and cryptic primates from South and Southeast Asia with at least ten recognized species (Blair et al. 2023; Munds et al. 2013), all of which are listed as threatened by the IUCN Red List of Threatened Species.

Vulnerable: Bornean slow loris *Nycticebus borneanus* (Nekaris KAI & Miard P 2020); Kayan slow loris *Nycticebus kayan* (Nekaris KAI & Miard P 2020); Philippine slow loris *Nycticebus menagensis* (Nekaris KAI, Miard P & Streicher U 2020).

Endangered: Sumatran slow loris Nycticebus hilleri (Nekaris KAI & Poindexter S 2020); Pygmy slow loris *Nycticebus pygmaeus* (Blair M, Nadler T, Ni O, Samun E, Streicher U & Nekaris KAI 2021); Greater slow loris *Nycticebus coucang* (Nekaris KAI, Poindexter S & Streicher U 2020); Bengal slow loris *Nycticebus bengalensis* (Nekaris KAI, Al-Razi H, Blair M, Das N, Ni Q, Samun E, Streicher U, Xue-long J & Yongcheng L 2020).

Critically Endangered: Javan slow loris *Nycticebus javanicus* (Nekaris KAI, Shekelle M, Wirdateti, Rode-Margono EJ & Nijman V 2020); Bangka slow loris *Nycticebus bancanus* (Nekaris KAI & Marsh C 2020).

Slow lorises have many special morphological traits that help them adapt to an ever-changing landscape driven by human activity (Alterman 1995; Streicher et al. 2013; Starr & Nekaris 2013; Das et al. 2014; Rode-Margono & Nekaris 2014; Ruf et al. 2015; Cabana et al. 2017; Nekaris et al. 2017; Poindexter et al. 2017; Geerah et al. 2019; Somura & Manone 2024;). In some localities human activities such as agroforestry and strong protective taboos benefit the slow lorises survival (Nekaris 2014; Nijman & Nekaris 2014; Karimloo et al. 2023; Oliver et al. 2019;). However, many activities are not positive; such as electricity cables increasingly producing slow lorises fatalities (Kumar et al. 2024; Quarles et al. 2023) and increasingly traditional taboos eroded or simply forgotten (Nijman & Nekaris 2014; Thach et al. 2018) resulting in widespread hunting.

Dao Tien Endangered Primate Species Centre, located in the lowlands of South Vietnam, is more frequently receiving pygmy loris after they enter houses; found by local people behind refrigerators or coming in at night and disturbing caged birds (Kenyon pers. comm). This fragmented landscape provides easier access for hunters, whether it be commercial large scale (Moore & Nekaris 2014; Karimloo et al. 2023) or smaller opportunistic hunting, as found in South Vietnam (Thach et al. 2018; Kenyon et al. 2023). Slow lorises are hunted for the pet trade, photo souvenirs, meat, traditional medicine and even black magic (Kumar et al. 2014; Moore & Nekaris 2014; Nekaris & Starr 2015; Osterberg & Nekaris 2015; Thach et al. 2018; Gnanaolivu et al. 2022; Quarles et al. 2023).

Lorises that come into the illegal trade through poaching in Vietnam are used locally and regionally in different ways, as meat, as pets, or for the production of traditional medicine. Bengal slow lorises (only naturally found in the North) are favoured for the pet trade, and the smaller pygmy loris for traditional medicine (Thach et al. 2018). With confiscations in South Vietnam dominated by pygmy loris (Kenyon et al. 2023), this may part explain the lack of a teeth pulling culture to reduce risk of the venomous bite, compared to areas dominated with the larger slow loris and demand focussed on the tactile pet trade.

The strengthening of law enforcement in Southeast Asia, effective Government and NGO campaigns has amplified the growth in numbers confiscated and transferred to *in-situ* rescue centres (Moore & Nekaris 2014; Fuller et al. 2018; Khudamrongsawat et al. 2018; Kenyon et al. 2023). For law enforcement authorities, rescue centre staff and local people who are all involved in managing the increased frequency of contact with slow lorises, a clear understanding of their venomous bite (Alterman 1995) and management is essential, to minimise risk and maintain welfare for both human and slow lorises.

Case Report

The Dao Tien Endangered Primate Species Centre located in Cat Tien National Park receives confiscated endangered primates from the illegal wildlife trade in South Vietnam, founded under Decision No. 2312/QDBNN-PTNT (09/07/2008) and continued with Decision No. 1220/QD-BNN-HTQT (03/23/2021) from Ministry Agriculture Rural Development. The centre opened in 2007 and on Christmas Day 2008 received the first pygmy loris, after being held in Forestry Protection Department custody for one week. Pygmy loris confiscations have since been increasing with illegal online sales, law enforcement and changes in buffer zone land use (Kenyon pers.comm.). The rescue centre regularly handles slow lorises, improving captive care protocols with activities including: catching individuals for weighing, creating social units for increased welfare and fitting VHF tags to enable post-release monitoring (Kenyon et al. 2014; Kenyon et al. 2023). All handling is done wearing gloves, except the person fitting the VHF tag, as the fine precision required cannot easily be done with thick gloves.

On 26th August 2016 at 5:30pm during a routine fitting of VHF tag under red light to a pygmy loris, the loris bit the person fitting the tag. The loris was an adult *post-partum* female, estimated in captivity <11 months after illegal hunting from Phu Yen Province (South central coast of Vietnam), after sale via an online trader. Unlike most pygmy lorises during VHF tag fitting, she did not remain calm under red light but managed to swivel in the gloved handler's hands. Obvious saliva was dripping from her mouth and she managed to lift her arms up to make contact with her brachial gland. She bit the tip of the digit finger on the left hand of the person fitting the tag, with her jaws locked for 5 minutes, before they could be safely unlocked and removed. At first the person bitten (hereon referred to as H) continued collaring, but after 5 minutes felt tingling in the lips (parathesia) and a little light headed. At this time collaring was completed by another member of the team and H went to lie down. H felt stable, but at 6:40pm started to feel difficulty in swallowing, so the decision was made to travel for medical support in Ho Chi Minh City. At this time, H's limbs and face were swollen but their airways open and heart and pulse rate stable (Fig. 1). At 7:20pm a car was available for the journey. On arrival to hospital at 10:00pm H was starting to feel much improved, walking with no difficulty and swallowing normally. H was treated intravenously with Solu-medrol (anti-inflammatory

glucocorticoid), Zantac (to stop acid reflux) and Dimedrol (antihistamine, sedative, antiemetic and antispasmodic, used to treat allergic diseases and is an adjunct to Adrenalin and other drugs in anti-anaphylaxis) in addition to antibiotic ointment at the wound site. Circumoral and limb angioedema remained for 24 hours. H continued to work at centre, but showed increased sensitivity, in particular to bamboo hairs and mealworm faeces for 24 months post bite, with periorbital angioedema (sudden swelling around the eyes) for up to 48 hours every time the triggers came in close contact to the face.

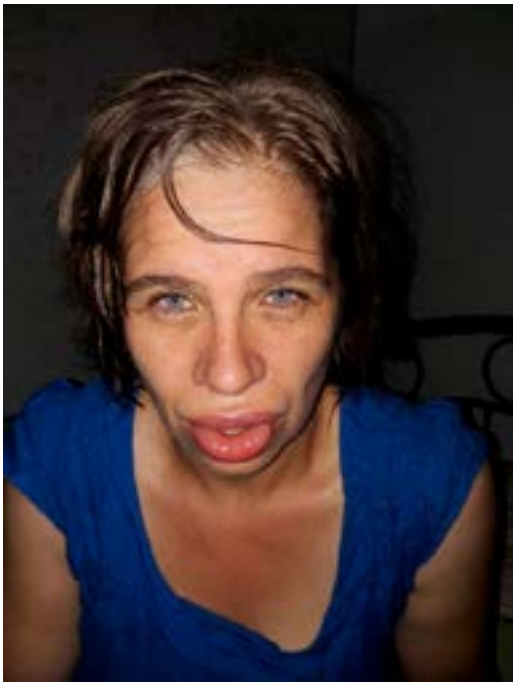

Fig.1. Anaphylactic reaction 70 minutes after a bite from a pygmy loris (*Xanthonycticebus pygmaeus*). All photos: Marina Kenyon.

Discussion

Slow lorises use venom for conspecific interactions, negatively or positively. Smearing strong smelling venom to their head, neck and on 'parked' infants possibly warns conspecifics, deters predators with olfactory cues or protects with olfactory crypsis (Nekaris & Jaffe 2007; Grow & Nekaris 2015; Rode-Margono et al. 2015; Fuller et al. 2016). Intraspecific competition is considered the chief driver for venom production (Nekaris et al. 2020). Competition can be between males over access to females in the mating season. Pygmy loris mating season in South Vietnam is during the wet season (August / September) (Fitch-Snyder & Jurke 2003; Kenyon et al. 2023), a time when males increase testicle size and aggressiveness (Kenyon pers. comm.). At this time females in the wild also fight each other over competition for territories to defend gum sources, to fight off competing males and to reject mates. Increased aggression by both pygmy loris males and females (particularly adolescents), has been observed at the Dao Tien Endangered Primate Species Centre during the mating season. Pygmy loris released in the mating season by the centre have fought with wild conspecifics, returning with venom scars (Fig. 2), mirrored by rescued pygmy loris (male and female) who often have with healed wounds on the head or eyes at point of rescue (Fig. 3) (Kenyon et al. 2023). In this case the bite occurred during the peak of the mating season, a time when venom production is considered at its greatest.

Fig.2. Rehabilitated and released male pygmy loris after fighting with wild con-specifics in the mating season.

Fig.3. Rescued female pygmy loris with wild fighting injuries.

Additionally the female pygmy loris had been part of an illegal trade confiscation from Ho Chi Minh City, originally hunted from Phu Yen Province in central-south Vietnam. Slow lorises display high levels of stress in the illegal trade and in rescue centres (Moore et al. 2015; Khudamrongsawat et al. 2018; Chatpongcharoen et al. 2021) and naturally, stressed individuals present a greater envenomation risk (Gardiner et al. 2018). The female was part of a consignment of 8 pygmy loris, of which 5 were pregnant. The females infants did not survive (Kenyon et al. 2023), due to organ failure, proposed from over licking with venom, as the stressed female attempted olfactory crypsis or defence. At this time Dao Tien Endangered Primate Species Centre had a high number of rescued pygmy loris, creating an abnormally high number of conspecifics in close proximity, compared to wild densities (Starr & Nekaris 2020). It has been suggested that slow lorises either produce more venom when in proximity to conspecifics to enable intraspecific competitive success, or they meter their venom when a threat is posed to inclusive fitness (Gardiner et al. 2018). Thus the high proximity of other pygmy loris may have increased the venom strength or volume. Furthermore the venom was successfully activated and delivered. Many cases of slow loris bites do not result in a reaction (Fuller et al. 2013); this inconsistency often leading to the reluctance to accept the true potential risk. In slow lorises the venom delivery system (VDS) consists of two-steps; the brachial gland exudate (BGE) combined with saliva to activate (Alterman 1995; Nekaris et al. 2020). The brachial gland exudate is generated by a modified sebaceous gland in the flexor region of the upper arm. When threatened a

slow loris raise its arms above its head in a defensive "venom pose", allowing the BGE to be easily licked from the hairless gland, and mixed with saliva in the mouth to activate. The venom is then delivered by a bite compressing the needle-like toothcomb (incisor and canine), ideally a prolonged bite with locked jaws (Ligabue-Braun et al. 2012), enabling good envenomation. Both the two step activation and prolonged bite occurred in this case.

Accounts of human envenomation are documented ex-situ, with professional captive centres and illegal pet owners (Fuller et al. 2013; Fung & Wong 2016; Inoue et al. 2021) and *in-situ* with professional rescue centres, farmers or researchers (Wilde 1972; Madani & Nekaris 2014; Parveen 2019; Utap & Bin Mohd 2019; Kumar et al. 2022; Muldani et al. 2024). Bites to humans can result in a neurotoxin response (toxins that target the nervous system) resulting in anaphylactic shock (swelling of the face and airways), in extreme cases requiring medical attention. They can also result in only cytotoxic symptoms (toxins that target cells) including lethargy, headaches, festering wounds, paraesthesia and infections. However, production of BGE can be inconsistent - with slow lorises in highly stressful situations producing no BGE. This inconsistency has led to suggestions that slow lorises, like other venomous taxa (snakes) have the ability to meter the BGE (Alternam 1995), carrying out 'dry bites' (Pucca et al. 2020) possibly reserving energetically expensive venom until truly needed, or even modulate the venom type (Schendel et al. 2019) depending on the response required.

Reactions are normally instantaneous, and in some cases can have longer complications; healing time ranging from 1 day to >8 months with increased sensitivity to other allergens (i.e. bamboo fibre) (Wilde 1972; Madani and Nekaris 2014; Fung & Wong 2016; Utap & Bin Mohd 2019). One person who had presented anaphylaxis after a slow loris bite could only continue to work with them if they used an antihistamine (Gardiner et al. 2018). In this case, for 24 months post reaction H was sensitive to bamboo hairs and mealworm faeces, triggering periorbital angioedema. Due to the similarity BGE has to Fel-d-1 (Hagey et al. 2007), it was proposed that those with cat allergies were more likely to exhibit these more severe symptoms: this case does not support this, in fact only one reported case does (Fung & Wong 2016). Another suggestion is severe symptoms caused by sensitization; working with, touching and receiving small nips over time. In this case H had received several nips through gloves over a seven year period. Further investigation is needed to understand the possible immunotoxin effect of slow lorises venom (Fitzpatrick et al. 2023).

Conclusions

So far only three species of slow lorises have been tested for venom (*N. bengalensis*, *N. coucang* and *X. pygmaeus*) but observations suggest that the other species are equally venomous (Rode-Margono & Nekaris 2014). Nevertheless, the disparity and inconsistency in response to slow lorises bites, has led to doubt of how serious the bites can be, with claims as in this case, that the person having the reaction was simply weak. Throughout slow lorises geographical range, knowledge of their venomous and powerful bite varies; with the strongest knowledge generally found in hunter and trader communities (Nijman & Nekaris 2014; Thach et al. 2018; Kumar et al. 2024). Indonesia traders display factual knowledge, by pulling teeth to limit envenomation, and keeping a bucket of water ready when handling lorises to force the lorises to release grip should they begin to bite (Moore & Nekaris 2015). Specifically in Vietnam, slow loris hunters know to use a loop made from rattan, to prevent being bitten (Thach et al. 2018).

Within farming communities, who rarely spend time in their fields after dusk, limited knowledge of the venom is present (Nijman & Nekaris 2014); only 16% of cashew farmers near Dao Tien Endangered Primate Species Centre considered pygmy loris dangerous (unpublished data). This is of concern as this community, sharing their home with wild slow lorises are increasingly coming into conflict with them. Other communities where knowledge of envenomation risk needs to be strong; include Government authorities, confiscating and receiving slow loris, captive care staff, veterinarians, researchers and rangers releasing slow lorises back to the wild. The Dao Tien Endangered Primate Species Centre receives pygmy loris primarily from the Environmental Police and Provincial Forestry Protection Departments in South Vietnam. They can arrive in rat traps, bags or bird cages, rarely

removed from the container confiscated in, and if moved the arrested hunter or trader are asked to handle them. The centre has received pygmy loris in a plastic bottle (Fig. 4), which advocates some factual knowledge of the venomous bite risk, but not the protocol with consideration of good welfare.

Fig.4. Confiscated pygmy loris from the illegal wildlife trade, transferred to the Dao Tien Endangered Primate Species Centre in a plastic bottle.

This necessary factual knowledge of venomous slow lorises, driving behaviour change for safe welfare of humans and slow lorises is vital. We hope this story of a life threatening bite from an endangered pygmy loris, could be used as a diagnostic event for new ontologies, new stories generating the necessary factual knowledge needed in all communities to support a positive and safe human and slow lorises co-existence. Firstly for human families, now often found living alongside slow lorises in their fruit garden, a good factual knowledge of the slow lorises behaviour, knowledge of their venom and to not try and handle them, instead live commensally. Secondly if they must be moved, knowledge of safe handling practices to promote good welfare understood by the farmer, law enforcement officer, rescue centre staff and the ranger who will return them back to safe forest.

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Conserving Tonkin snub-nosed monkeys (*Rhinopithecus avunculus*) in Ha Giang Province, Vietnam

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Key words: Tonkin snub-nosed monkey, *Rhinopithecus avunculus*, protection activities.

Summary

The Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) is listed as 'Critically Endangered'. Of around 10 populations discovered and confirmed by surveys in the 1990s, only one population has survived in the Khau Ca area, Ha Giang Province. A further very small population was discovered in 2008 in the Quang Ba forest, Ha Giang Province. In addition to habitat loss, fragmentation and degradation, the main causes of this dramatic development is poaching, especially for the production of traditional medicine.

Fauna & Flora has collaborated with local authorities to implement and support activities aimed at protecting and conserving the species. During the program's early stages, Community Conservation Teams were formed to work closely with local authorities to address forestry law violations and ensure forest protection.

Data collected through monthly reports are updated and analysed collaboratively by the Fauna & Flora team and the local forestry department. Fauna & Flora has consistently supported community-based patrol teams as the foundation of conservation efforts for the species, resulting in measurable threat reductions, as evidenced by recent SMART records.

Over time, also efforts evolved to include raising awareness among local communities living near the forests where the species resides.

Bảo tồn Voọc mũi hếch Bắc Bộ (*Rhinopithecus avunculus*) ở tỉnh Hà Giang, Việt Nam

Tóm tắt

Voọc mũi hếch Bắc Bộ (*Rhinopithecus avunculus*) được liệt kê là loài 'Cực kỳ Nguy cấp'. Trong số khoảng 10 quần thể được phát hiện và xác nhận bởi các cuộc khảo sát vào những năm 1990, nay chỉ có một quần thể sống sót. Một quần thể khác đã được phát hiện vào năm 2008. Ngoài việc mất môi trường sống, phân mảnh và suy thoái, nguyên nhân chính của sự suy giảm đáng kể này là nạn săn bắt trộm, đặc biệt là để sản xuất "Cao khỉ" y học cổ truyền.

Tổ chức Fauna & Flora (F&F) đã hợp tác với chính quyền địa phương để thực hiện và hỗ trợ các hoạt động nhằm bảo vệ và bảo tồn loài. Trong giai đoạn đầu của chương trình, các Đội Bảo tồn Cộng đồng đã được thành lập để hợp tác chặt chẽ với chính quyền địa phương để giải quyết các vi phạm lâm luật và đảm bảo công tác bảo vệ rừng.

Dữ liệu được thu thập thông qua các báo cáo hàng tháng được cập nhật và phân tích hợp tác bởi Đội Bảo tồn Cộng đồng F&F và lực lượng kiểm lâm nghiệp địa phương. Tổ chức Fauna & Flora đã liên tục hỗ trợ các đội tuần tra dựa vào cộng đồng như là nền tảng của các nỗ lực bảo tồn loài, dẫn đến việc giảm mối đe dọa có thể đo lường được, bằng chứng là các hồ sơ SMART gần đây.

Theo thời gian, các nỗ lực cũng phát triển bao gồm nâng cao nhận thức của các cộng đồng địa phương sống gần các khu rừng nơi loài này cư trú.

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Introduction

The Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) is endemic to Vietnam and listed as 'Critically Endangered' on the IUCN Red List of Threatened Species (Le Khac Quyet et al. 2020) and also in the Vietnam Red Data Book (Ministry of Science and Technology & Vietnamese Academy of Science and Technology 2007). Since the IUCN Primate Specialist Group's biennial listing of the World's TOP 25 Most Endangered Primates in 2000 (Mittermeier 2000), the Tonkin snub-nosed monkey has been continuously listed. Over the past several decades, the species has experienced a significant decline in both population size and geographical range, with extinctions of key populations. These declines are primarily attributed to habitat loss and fragmentation, degradation of habitat quality, and hunting for meat and traditional medicine.

The Tonkin snub-nosed monkey was known from only few museum specimens until a WWF/FFI team conducted the first survey with the special emphasis on the species (Ratajszczak et al.1992). Since that time a series of surveys have been carried out which have improved our knowledge of the species and its distribution. About 10 areas with the occurrence of the species were found in the early 1990s. In 5 other areas, the species was already considered extinct at this time (Nadler et al. 2003). Currently, the species is known to survive in only two locations, both situated in Ha Giang Province, northern Vietnam. A population was found in 2002 in the Du Gia Nature Reserve (Le Khac Quyet 2002), and another population 2008 in the Tung Vai forest of the Quang Ba District (Le Khac Quyet & Covert 2010).

Protection activities of Fauna & Flora

Since then, Fauna & Flora has collaborated with local authorities to implement and support activities aimed at protecting and conserving the species. Initially, these efforts focused on forest protection and preventing behaviors that threaten both the forest and wildlife.

Over time, these efforts evolved to include raising awareness among local communities living near the forests where the species resides. Education programs emphasize the importance of nature protection and conservation. Fauna & Flora has also facilitated the establishment of protected areas for the Tonkin snub-nosed monkey and its habitat, enabling stricter enforcement of conservation regulations.

During the program's early stages, Community Conservation Teams (CCTs) were formed to work closely with local authorities to address forestry law violations and ensure forest protection (Fig. 1). Members receive comprehensive training on essential knowledge and skills, including first aid and the use of equipment for patrol activities. They are also provided with uniforms and necessary facilities for extended stays in the forest to conduct effective protection patrols.

Fig.1. The Community Conservation Team for the Tonkin-snub-nosed monkeys in the Khau Ca Habitat and Species Conservation Area.

As protection efforts became more effective and local awareness of Tonkin snub-nosed monkey conservation grew, the focus of activities has shifted. CCTs in Ha Giang are now also primarily responsible for conducting monitoring activities for the species. Equipped with the necessary tools and skills, team members collect valuable data on the snub-nosed populations and habitat conditions.

By 2024, CCTs members are well-trained and confident in applying Standard Operating Procedures and a systematic forest patrol framework for habitat patrolling and monitoring activities. They also use the SMART tool to collect and update data for analysis. This range of conservation interventions is now supported by technological applications and community engagement, and is a cornerstone of long-term efforts to prevent the species' extinction.

Data collected through monthly reports are updated and analysed collaboratively by the Fauna & Flora team and the local forestry department. Fauna & Flora has consistently supported community-based patrol teams as the foundation of conservation efforts for the species, resulting in measurable threat reductions, as evidenced by recent SMART records.

Monitoring data collected in recent years, analyzed through SMART, has provided critical insights for ongoing Tonkin snub-nosed monkey conservation efforts including locations where observations most frequently occur.

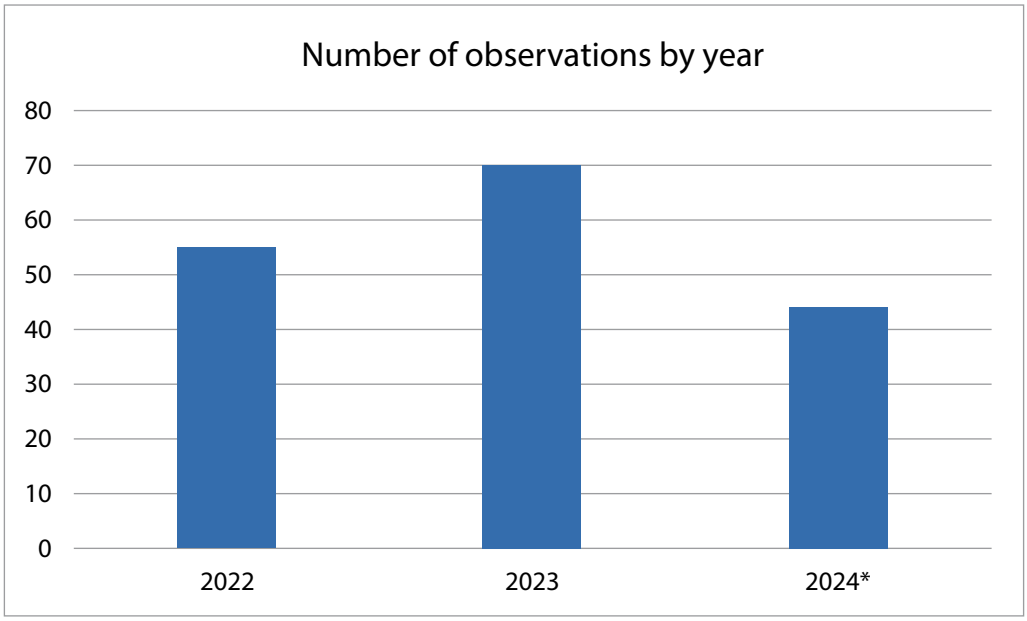
Survey methods

Survey methods conducted periodically include:

- **Installing camera trap systems** in grid cells for a certain period to record: the total number of camera traps installed for each survey is 45, and 40 audio devices to collect information, sound, and images.
- **Using drone with thermal imaging camera** to detect and track troops.
- **Manual survey** on the ground for direct observation.

Such surveys often yield varying results due to the challenges of searching for an illusive endangered primate in thick limestone forest (Table 1).

Table 1. Census results of Tonkin snub-nosed monkeys. A census was conducted every one to two years to monitor the population.



The long-term monitoring of the Tonkin snub-nosed monkey in Ha Giang Province is a multifaceted effort that combines government intervention, technological applications, and community engagement. By integrating these approaches, the program aims for the survival and recovery of this critically endangered species. Continued support and collaboration among all stakeholders are essential to ensure the Tonkin snub-nosed monkey does not vanish from the forests of Vietnam.

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A collaborative workshop to develop guidelines for management of the 'Endangered' proboscis monkey (*Nasalis larvatus*) and the 'Critically Endangered' red-shanked douc langur (*Pygathrix nemaeus*) under human care

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Key words: Red-shanked douc, *Pygathrix nemaeus*, Proboscis monkey, *Nasalis larvatus*, Husbandry management, Nutrition, Veterinary care.

Summary

On 23rd and 24th July 2024, 28 experts from eight organisations which house proboscis monkeys (*Nasalis larvatus*) and/or red-shanked douc langurs (*Pygathrix nemaeus*) participated in a workshop held at Mandai Wildlife Reserve in Singapore to collectively address challenges in the care of these colobine species. Through presentations, break-out group discussions and Q&A format, the two-day workshop covered the areas of current institutional practices and challenges in husbandry management, nutrition, and veterinary care. A document synthesising the recommended guidelines for the management of proboscis monkeys and red-shanked douc langurs under human care is being written up and will be available by 2025.

Cuộc hội thảo hợp tác để xây dựng các hướng dẫn quản lý loài khỉ vòi 'Nguy cấp' (*Nasalis larvatus*) và loài voọc chà vá chân đỏ 'Cực kỳ Nguy cấp' (*Pygathrix nemaeus*) dưới sự chăm sóc của con người

Tóm tắt

Vào ngày 23 và 24 tháng 7 năm 2024, 28 chuyên gia từ tám tổ chức chăn nuôi khỉ vòi (*Nasalis larvatus*) và/hoặc voọc chà vá chân đỏ (*Pygathrix nemaeus*) đã tham gia một hội thảo được tổ chức tại Khu bảo tồn động vật hoang dã Mandai ở Singapore để cùng nhau giải quyết những thách thức trong việc chăm sóc các loài khỉ ăn lá (colobine) này. Thông qua các bài thuyết trình, chia sẻ, thảo luận nhóm và định dạng hỏi đáp, hội thảo kéo dài hai ngày bao gồm các lĩnh vực thực tiễn hiện tại và những thách thức trong quản lý chăn nuôi, dinh dưỡng và chăm sóc thú y. Một tài liệu tổng hợp các hướng dẫn được khuyến nghị để quản lý khỉ vòi và voọc chà vá chân đỏ dưới sự chăm sóc của con người đang được viết và sẽ công bố vào năm 2025.

Introduction

The 'Critically Endangered' red-shanked douc langur (*Pygathrix nemaeus*) (Fig. 1) is an Asian colobine primate found in Vietnam, Cambodia and Lao People's Democratic Republic (Lao PDR) (Coudrat et al. 2020). Another colobine primate of interest is the 'Endangered' proboscis monkey (*Nasalis*

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larvatus) (Fig. 2) which is endemic to Borneo, inhabiting the three nations of Malaysia, Indonesia, and Brunei (Boonratana et al. 2021).

Fig.1. Red-shanked douc langur, male (*Pygathrix nemaeus*). Photo: Tilo Nadler

Fig.2. Proboscis monkey, male (*Nasalis larvatus*). Photo: Tilo Nadler.

There is a reasonable history of over three decades of caring for these two species in zoos and rescue centres both within their range countries as well as outside. Despite that, many unknowns still exist about the care for these two species. Many institutions caring for colobines historically have found it difficult to maintain healthy individuals in captivity. Animals tend to have shorter lifespans compared to free-ranging individuals. Both of these species have a reputation of being notoriously difficult to maintain and breed in captivity, with only a handful of organisations demonstrating successful long-term husbandry. The major problems related to *ex-situ* management include lack of knowledge pertaining to some variables required for their care and insufficient communication between organisations that have common challenges in caring for these species.

The overall objective of this workshop was to provide a common platform for sharing amongst various stakeholders who have worked with these primates. The discussions over the two days were broadly grouped into three overarching areas of interest (i) Housing & Husbandry; (ii) Nutrition and (iii) Healthcare.

Methods

Mandai Wildlife Group as the host institution identified all the possible organisations that hold either the red-shanked douc langurs or proboscis monkeys or both. They reached out to all organisations to check on their interest to participate in a workshop specifically to discuss husbandry and challenges with care for these two species. They requested the organisations to also suggest / recommend others who they felt might be interested in this workshop (Fig. 3).

Fig.3. Participants in the Colobine workshop.

Once a list of interested organisations and workshop participants was identified, each of them were requested to complete surveys to gather information on their current practices for care of these species specifically from a housing, enrichment, nutrition and veterinary perspective. This information formed the basis of the introductory session of the workshop. The workshop across the two days included a series of facilitated discussions on focussed topics identified as areas for improvement and collaboration.

Results and Discussion

Participants individually shared their organisational practices and protocols in each of these topics. There was sufficient time to identify common practices across multiple organisations, as well as identifying different protocols followed by some and trying to understand why they differed. All participants were very forthcoming in giving detailed information on their current knowledge about these species. Learnings from what has and has not worked were shared freely. After this cross-sharing, time was allocated to highlight specific challenges faced for each discussion topic.

The end of the workshop on Day Two allocated time for participants to breakout and work in three small groups to identify the specific topics that need to be included in the framework for the guidelines that will also serve as a valuable reference with recommendations for the common challenges identified for each topic.

Participants spent time developing a framework outline for a guideline that will be written up by all present in the workshop and can also include contributions from experts who were unable to attend. Table 1 lists all the specific areas that were identified. This guidelines document is anticipated to be an extremely useful reference for existing organisations working with these species as well as for organisations that are looking to start caring for them in the future.

Table 1. List of topics pertaining to care of red shanked douc and proboscis monkey that will be included in the guidelines document.

Natural History
- Morphometrics
- Biology
- Distribution and habitat
- Conservation status
- Feeding – Field Site Studies (if any)
- Reproduction
- Social system
- Longevity

Housing and Exhibition
- Exhibit / Enclosure design
- Design features
- Minimum requirements for housing
- Holding area / cage design / recovery room
- Construction materials
- Enclosure furniture and substrates
- Orientation and location of enclosure
- Weather protection
- Temperature and humidity
- Suitable plant species

General Husbandry
- Hygiene and cleaning
- Record keeping
- Methods of identification
- Interspecific compatibility
- Social grouping considerations
- Operant conditioning
- Enrichment

Captive Breeding
- Hand rearing
- Population management and breeding control
- Pregnancy management

Feeding
- Feeding regime
- Produce
- Browse
- Concentrate Feeds
- Others
- Nutrient Recommendations
- Nutritional concerns
- Diet Composition
- Changes and transition of diets
- Specialised diets
- Plants/Food to be avoided
- Method of feeding: eliciting natural foraging behaviour
- Feeding enrichments
- Storage of browse
- Food hygiene

Veterinary and Health Requirements
- Routine observation
- Clinical examination
- Routine treatment and prophylaxis
- Quarantine requirements
- Post-mortem examination
- Common disorders
- Natural and alternative remedies
- Anastesia
- Intensive care
- Formulatory
- Animal restraint

Handling and Transport
- Timing of capture and handling
- Transportation

Participants agreed that given both species are arboreal, folivores typically inhabiting forests in the tropics, specifications for their ex-situ care will be very similar. Both species being foregut-fermenting colobine primates also have many common problems that are experienced with their captive care. Hence, it was agreed unanimously by all participants that discussions from this workshop can be presented in a combined manner in one *ex-situ* care guidelines document. This document will also be mindful of the reality in range countries of these two species and ensure that the recommendations be practical and implementable by majority.

Development of the recommended guidelines for care of red-shanked douc langurs and proboscis monkeys is currently in progress and will be ready by 2025.

The 9th ASIAN PRIMATE SYMPOSIUM "*Living in Harmony with Primates*" Medan, North Sumatra, Indonesia - 23rd to 27th November 2024

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Key words: Asian Primate Symposium, Conservation, Collaboration.

Summary

The 9th Asian Primate Symposium (APS), held in Medan, North Sumatra – Indonesia from 23rd to 27th November 2024, brought together a diverse array of primatologists, conservationists, researchers, and practitioners to explore the theme "Living in Harmony with Primates." As one of Asia's most significant platforms for primate research and conservation dialogue, APS provided an opportunity to reflect on the intertwined futures of primates and humans in the region and facilitate the exchange of knowledge, information, and field experience.

The symposium, attended by 295 participants from 20 countries, 54% of whom were from Indonesia, featured six keynote speeches, 170 parallel oral presentations, and 33 posters addressing key challenges such as primate behavior and ecology, human-primate coexistence, technology, education, and the role of community engagement in primate conservation. Participants shared research findings, conservation strategies, and best practices, fostering cross-disciplinary collaboration and promoting harmonious relationships between humans and primates.

Moreover, the 9th Asian Primate Symposium showcased the power of collaboration, demonstrating that such a significant event could only be realized through the shared vision and collective efforts of diverse organizations. After a decade since the last APS was held in Indonesia, this year's symposium became a reality from the joint efforts of Indonesian organizations, including the Orangutan Information Centre (OIC), Yayasan Ekosistem Lestari (YEL), The Indonesian Orangutan Conservation Forum (FORINA), and Yayasan Konservasi Ekosistem Alam Nusantara (KIARA), with vital support from Universitas Sumatera Utara (USU). This united effort not only strengthened partnerships but also reaffirmed the importance of collaboration in advancing primate conservation across Asia.

HỘI NGHỊ CHUYÊN ĐỀ VỀ LINH TRƯỞNG CHÂU Á LẦN THỨ 9 "*Sống hòa hợp với các loài linh trưởng*" Medan, Bắc Sumatra, Indonesia - 23- 27 tháng 11 năm 2024

Tóm tắt

Hội nghị chuyên đề về linh trưởng châu Á lần thứ 9 (APS), được tổ chức tại Medan, Bắc Sumatra - Indonesia từ ngày 23 đến ngày 27 tháng 11 năm 2024, quy tụ nhiều nhà linh trưởng học, nhà bảo tồn, nhà nghiên cứu và học viên để khám phá chủ đề "Sống hòa hợp với các loài linh trưởng". Là một trong những nền tảng quan trọng nhất châu Á để nghiên cứu linh trưởng và đối thoại bảo tồn, APS đã tạo cơ hội để suy ngẫm về tương lai đan xen của linh trưởng và con người trong khu vực và tạo điều kiện trao đổi kiến thức, thông tin và kinh nghiệm thực địa.

Hội nghị chuyên đề với sự tham dự của 295 đại biểu tham gia từ 20 quốc gia, 54% trong số đó đến

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từ Indonesia, có sáu bài phát biểu quan trọng, 170 bài thuyết trình song song và 33 áp phích giải quyết những thách thức chính như hành vi và sinh thái của linh trưởng, cùng tồn tại giữa con người và linh trưởng, công nghệ, giáo dục và vai trò của sự tham gia của cộng đồng trong bảo tồn linh trưởng. Các đại biểu tham gia đã chia sẻ kết quả nghiên cứu, chiến lược bảo tồn và thực tiễn tốt nhất, thúc đẩy hợp tác liên ngành và thúc đẩy mối quan hệ hài hòa giữa con người và linh trưởng.

Hơn nữa, Hội nghị chuyên đề về Linh trưởng Châu Á lần thứ 9 đã thể hiện sức mạnh của sự hợp tác, chứng minh rằng một sự kiện quan trọng như vậy chỉ có thể được hiện thực hóa thông qua tầm nhìn chung và nỗ lực tập thể của các tổ chức đa dạng. Sau một thập kỷ kể từ APS trước đây đã được tổ chức tại Indonesia, hội nghị chuyên đề năm nay đã trở thành hiện thực nhờ những nỗ lực chung của các tổ chức Indonesia, bao gồm Trung tâm Thông tin Đười ươi (OIC), Yayasan Ekosistem Lestari (YEL), Diễn đàn Bảo tồn Đười ươi Indonesia (FORINA) và Yayasan Konservasi Ekosistem Alam Nusantara (KIARA), với sự hỗ trợ quan trọng từ Đại học Sumatera Utara (USU). Nỗ lực thống nhất này không chỉ tăng cường quan hệ đối tác mà còn tái khẳng định tầm quan trọng của sự hợp tác trong việc thúc đẩy bảo tồn linh trưởng trên khắp châu Á.

Highlights from the 9th ASIAN PRIMATE SYMPOSIUM

Non-human primates represent approximately 20% of global primate diversity, with Asia hosting a significant portion of this richness: five families, 19 genera, 119 species, and 183 taxa of non-human primates in the region. Cross-border collaboration and interdisciplinary approaches have become increasingly essential in addressing the complex challenges of primate conservation. Networking platforms like the Asian Primate Symposium (APS) are critical in fostering dialogue, collaboration, and action among stakeholders, enhancing outcomes for primates and their habitats in the Asia Region.

Indonesia is proud to host the 9th Asian Primate Symposium in Universitas Sumatera Utara, Medan, North Sumatra, from 23rd to 27th November 2024, following its selection during the 8th APS organized by the NGO Three Monkeys Wildlife Conservancy in Vietnam. The 8th APS identified Indonesia as the ideal host to continue fostering regional conservation dialogue. After a decade since Indonesia last hosted the event in 2014, the 9th APS marks a significant return, emphasizing the nation's critical role in primate conservation, which provides a unique setting to showcase its 64 recognized primate species, including newly described taxa such as the Tapanuli orangutan (*Pongo tapanuliensis*) and Sulawesi tarsier (*Tarsius supriatnai*). The 9th APS offers a platform for primatologists and conservationists to exchange knowledge, strengthen partnerships, and explore pathways for the sustainable conservation of Asia's primates. To reach a global audience further, we developed a website with detailed information regarding the symposium (aps2024.orangutancentre.org) and a social media account on Instagram (@aps.id2024).

Bring the theme "Living in Harmony with Primates," which we expected to be a call to action to protect primates and their habitats while fostering a shared understanding of the ecological, cultural, and intrinsic value of these species. This symposium brought together 295 participants from 20 countries, 54% of whom were from Indonesia, six keynote speeches, 170 parallel presentations, and 33 poster presentations to exchange knowledge and strengthen the network of primate researchers and conservationists working in Asia (Fig. 1).

Fig.1. Attendees at the 9th Asian Primate Symposium, held in Medan, North Sumatra, Indonesia, from November 23rd to 27th, 2024.

The five-day symposium began with a registration and welcoming ceremony on the first day (11/23/2024), followed by three days of a rich scientific agenda featuring keynote speeches, parallel oral presentations, and poster presentations. The presentations covered various topics, including primate behavior and ecology, population dynamics, ethnography, community empowerment, *ex-situ* conservation, education, and sustainable approaches, reflecting the symposium's commitment to multidisciplinary perspectives on primate conservation. The event concluded with an excursion to the Orangutan Haven and the Sumatra Rescue Alliance on the final day, providing participants with experience of on-the-ground conservation efforts (Fig. 2, 3).

Fig.2. A large number of the symposium participants visited the Orangutan Haven. Photo: Tilo Nadler.

Fig.3. Orangutan Haven was conceived as a sanctuary for organutans that could not be releases into the wild. Over the years, the project has evolved, aiming to become a role model for conservation, animal welfare, sustainable practices and a source of knowledge and education for further generations. Photo: Tilo Nadler.

The symposium's opening ceremony was initiated by the chief of the 9th APS Organising Committee, Mr. Panut Hadisiswoyo from Orangutan Information Centre (Fig. 4), vice-rector of Universitas Sumatera Utara, Dr. Poppy Anjelisa Zaitun Hasibuan, and Head of Natural Resources Conservation Agency (BKSDA) North Sumatra, Mrs. Novita Kusuma Wardani, who emphasized strengthen our shared commitment to conserving primates and fostering harmony between humans and wildlife.

Fig.4. The opening speech by the chief of the 9th APS organizing committee - Mr. Panut Hadisiswoyo from Orangutan Information Centre/OIC. Photo: Rahayu Octaviani.

Six speakers, including representatives of the Indonesian government and renowned global primatologists, presented a diverse array of keynote speeches during the symposium. Prof. Jatna Supriatna from the University of Indonesia presented the first speech highlighting a comprehensive review of the challenges faced by Indonesia's primates due to habitat loss and offering integrated and sustainable approaches to conserve Indonesia's rich primate biodiversity. This was followed by Dr. Aldrianto Priadjati from FORINA, who emphasized the critical role of collaboration in conserving not only Indonesia's orangutans and their habitats but also beyond. He stressed that strategic partnerships and shared goals are essential to overcoming challenges and achieving long-term conservation success. The following day, Mr. Nunu Anugrah, Director of Biodiversity Conservation of Species and Genetics – at the Ministry of Forestry Indonesia, emphasized the critical importance of biodiversity conservation as a foundation for human well-being and sustainable development. He also highlighted the importance of integrating conservation with development, fostering global collaboration, and leveraging innovative financial mechanisms to ensure biodiversity thrives. The keynote speech was continued by Dr. Andie Ang from Mandai Nature - Singapore, who focused on the Asian Langurs (*Presbytis*) Conservation Action Plan 2024–2034, a comprehensive strategy to safeguard these threatened primates. The plan provides a roadmap for addressing the critical challenges faced by Asian langurs, aiming to secure their survival over the next decade through science-based, community-driven conservation initiatives. On the last day, Dr. Susan M. Cheyne from the IUCN SSC Primate Specialist Group Section on Small Apes presented critical insights into the conservation of gibbons, emphasizing their ecological and cultural importance, the threats they face, and actionable solutions. She urged stakeholders to prioritize gibbon conservation as part of broader efforts to safeguard biodiversity. Lastly, Dr. Mewa Singh from the University of Mysore – India, shared valuable lessons from five decades of engagement in primate conservation, emphasizing the importance of interdisciplinary approaches, community involvement, and policy integration.

We recognize the critical role of early-career and young primatologists from primate-range habitat countries to expand their experience and develop networking through such event as APS, thus financial support through travel grants that fully covered expenses, including transportation, registration, meals, and accommodation was supported by IUCN SSC Primate Specialist Group – Section on Small Apes (five grantees from Bangladesh, India and Indonesia), and also Forum Konservasi Orangutan Indonesia/FORINA (one grantee from Indonesia). We hope this opportunity served as a foundation for their professional development and paved the way for their future contributions to primate conservation and research.

In addition, the 9th Asian Primate Symposium is a testament to the transformative power of collaboration and showcasing the collective strength of organizations united by a shared vision for primate conservation. This event was the result of tireless efforts and partnerships among Indonesian NGOs, including the Orangutan Information Centre (OIC), Yayasan Ekosistem Lestari (YEL), Indonesia Orangutan Conservation Forum (FORINA), and Yayasan Konservasi Ekosistem Alam Nusantara (KIARA) that highlighted the power of collective action. Moreover, the joint effort went beyond the symposium, catalyzing strengthening connections between organizations, researchers, and local stakeholders. It underscored the critical role of inclusivity and shared responsibility in addressing conservation challenges on a regional scale.

Moving forward, we are confident that the legacy of collaboration and dedication forged during these events will continue to thrive, fostering even greater unity among the primate conservation community. Upholding the tradition of passing the organizational baton to a new region, the honor of hosting the 10th Asian Primate Symposium (APS) now transitions to University Sabah Malaysia, which will serve as the next gathering's host (Fig. 5). This seamless succession ensures the continued success of the symposium, providing an enduring platform for knowledge exchange, strengthened partnerships, and collective action in primate conservation across Asia and beyond.

Fig.5. Tracing the history of the Asian Primate Symposium: A timeline of milestones from Bangkok in 2002 to the upcoming 2026 event in Sabah, Malaysia.

Acknowledgments

We sincerely thank everyone who contributed to the success of the 9th Asian Primate Symposium. This event was made possible through the collective efforts of dedicated individuals and organizations. Special thanks to all the speakers and presenters for their insightful contributions and for sharing invaluable perspectives. We deeply appreciate our volunteers, whose dedication and hard work ensured the event's smooth execution.

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.

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Papers published in periodicals

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

Books and Monographs

Groves CP (2001): Primate Taxonomy. Smthsonian 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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