HIDING IN PLAIN SIGHT: INVESTIGATING THE EXISTENCE OF THE BENGAL SLOW LORIS (*NYCTICEBUS BENGALENSIS*) IN HUAI KHA KHAENG WILDLIFE SANCTUARY, WESTERN THAILAND

by

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A Thesis Submitted to the Faculty of
The University of North Carolina at Charlotte
in the partial fulfillment of the requirements
for the degree of Master of Arts in
Anthropology

Charlotte

2024

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ABSTRACT

MADEJA RHEDDICK. Hiding in Plain Sight: Investigating the existence of the Bengal slow loris (Nycticebus bengalensis) in Huai Kha Khaeng Wildlife Sanctuary, western Thailand
(Under the direction of DR. LYDIA LIGHT)

The main goal of this project was to investigate whether there are any Bengal slow lorises (*Nycticebus bengalensis*) in the vicinity of Khao Nang Rum Wildlife Research Station (KNR) in Huai Kha Khaeng Wildlife Sanctuary (HKK) in western Thailand. I conducted field work between June and November collecting data that include trees characteristics and camera height. This was done by using arboreal camera trapping methods. The Bengal slow loris is currently considered endangered. Because of this, conservation efforts have been implemented in various ways but tend to be limited. For this study, 34 total cameras were placed in the savanna habitat around KNR research station. This included 16 cameras on the ground and 18 in the canopy. Tree characteristics were taken for all canopy cameras to identify any correlations between selected trees further. I found that a majority of the cameras that captured images of lorises were higher and larger on average than cameras that did not. Loris cameras were also shown to have more natural bridge connectivity. This study is important because it sheds light on an endangered species that has limited conservation efforts in place. This could invite future programs around KNR for slow lorises, adding to conservation efforts as a whole.

ACKNOWLEDGMENTS

I would like to express my deepest appreciation to my professor and chair of my committee for her highly valued patience and feedback. I am grateful for my defense committee, who generously provided knowledge and their expert opinion on various topics. Additionally, I appreciate the overall support from the graduate school and Dr. Jon Marks, who financed my research. I am also thankful to the research assistants, Thai field guides, and wonderful Thai hosts during this project. Lastly, many thanks to my family for their endless love and motivation.

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LIST OF ABBREVIATIONS

HKK	Huai Kha Khaeng Wildlife Sanctuary
KNR	Khao Nang Rum Wildlife Research Station
DBH	Diameter at breast height
GIS	Geographic information system
NSS	Non-Study Species
SD	Standard deviation
SEM	Standard Error of Mean

Introduction

Strepsirrhini is a suborder of primates that contains an array of species, including galagos, pottos, and lorises. Among these, the loris stands out as a nocturnal primate primarily found in the lush forests of South and Southeast Asia. With its "solitary" arboreal lifestyle, the loris spends most of its time among the canopies. Most solitary mammals are nocturnal, and many times, they are both small and arboreal. Oftentimes, this makes them difficult to study (Weins and Zitzmann, 2003). Among the eight recognized slow loris species, two are classified as Critically Endangered. Although the remaining are not classified as the same, the others still face significant threats, highlighting the urgent need for conservation measures (Nayak, 2017). Despite concerted conservation endeavors, lorises confront an uncertain future marked by escalating risks to their survival.

This study aims to investigate the presence of Bengal slow lorises (*Nycticebus bengalensis*) within the vicinity of Khao Nang Rum Wildlife Research Station (KNR) inside Huai Kha Khaeng Wildlife Sanctuary (HKK) in western Thailand. Notably, about 25 years ago, evidence of *Nycticebus bengalensis* was identified within leopard scat in HKK, yet there were no further investigations on the matter (Simcharoen et al., 2018). Using arboreal camera traps, this study seeks to determine the current status of Bengal slow lorises near KNR. The success story of HKK in conserving other species, such as the tiger (*Panthera tigris*), emphasizes its potential to serve as a stronghold for conserving the Bengal slow loris. The outcome could serve as a first step in the development of a research site for the species, leading to more opportunities to gather valuable information. This study, therefore, holds promise in bolstering conservation efforts and safeguarding the future of this enigmatic primate within a highly protected sanctuary.

Loris taxonomy, appearance, and morphology

As of recently, there are three primary genera recognized within the loris family: the slender loris (*Loris*), the slow loris (*Nycticebus*), and the newly elevated pygmy loris (*Xanthonycticebus*) (Poindexter and Nekaris, 2017; Nekaris and Nijman, 2022). The term "*Loris*" finds its origins in the Dutch word "loerus," meaning "clown," while "*Nycticebus*" translates to "night ape" (Lydekker, 1893; Nayak and Singh, 2017). The genus name “*Xanthonycticebus*” refers to the species' orangish color and their nocturnal activity pattern: Xanto; Yellowish-orange, nykt-; night, kêbos; monkey (Gainsford, 2020; Nekaris and Nijman, 2022). At this moment, there are only two recognized species of *Xanthonycticebus*; *Xanthonycticebus pygmaeus*, which refers to the southern taxon, and the northern taxon, *Xanthonycticebus intermedius* (Blair et al., 2023). The slender loris includes six distinct types divided into two species, each with two to four recognized subspecies. These include the Mysore Slender loris (*Loris lydekkerianus lydekkerianus*), Malabar slender loris (*Loris lydekkerianus malabaricus*), Northern Ceylon gray slender loris (*Loris lydekkerianus nordicus*), Highland Ceylon slender loris (*Loris lydekkerianus grandis*), Western Ceylon slender loris (*Loris tardigradus tardigradus*), and Horton Plains Slender loris (*Loris tardigradus nycticeboides*) (Campbell et al., 2011). Currently, there are eight recognized species of slow lorises, including the Sunda or Greater slow loris (*Nycticebus coucang*), Javan slow loris (*Nycticebus javanicus*), Sumatran Slow Loris (*Nycticebus hilleri*), Philippine slow loris (*Nycticebus menagensis*), Kayan river slow loris (*Nycticebus kayan*), Bornean slow loris (*Nycticebus menagensis*), Bangka slow loris

(*Nycticebus bancanus*), and Bengal slow loris (*Nycticebus bengalensis*) (Poindexter and Nekaris, 2017).

The loris family, regardless of species, typically exhibits certain common physical traits. They are characterized by a compact body structure with thick, soft fur. Their arms and legs are of similar lengths, while their tails are either short or completely absent (Poindexter and Nekaris, 2017). For the *Nycticebus* genus, the head and snout are notably rounded, distinguishing them from the *Loris* genus, who possess a narrower snout (Figure 1). The *Nycticebus* genus can weigh up to 2,200 grams (4lb), with the Bengal slow loris being the largest among them. They often bear light-colored fur along their arms, emphasized by a dark dorsal stripe. The fur coloration within the genus varies from yellowish-gray, dark-brown, grayish-white, to reddish-brown hues. Possessing large forward-facing eyes, slow lorises have evolved to enhance their visual sensitivity, which is crucial for navigating within the canopy and foraging for fruits, nectar, and flowers. This adaptation enables them to perceive depth effectively, a trait known as stereoscopic vision (Nekaris and Bearder, 2011). Arboreal climbers by nature, Members of the loris family adeptly maneuver through the tree canopies using a precise "hand over hand" motion, leveraging specialized blood vessels in their limbs to optimize oxygen flow to muscles. Their left-hand bias in climbing has been noted among all strepsirrhines (Poindexter et al., 2018). Equipped with a tooth comb, slow lorises use this specialized dental feature for grooming and occasionally feeding. The tooth comb, characterized by elongated, forward-facing incisors, is a hallmark trait among strepsirrhines.

Slow loris behavior and ecology

The species that make up the genus *Nycticebus*, spend most of their lives within the canopies of a variety of forest types, including dry evergreen, plantation, dry dipterocarp, rain forest, moist deciduous, deciduous, and scrub forest (Oliver et al., 2019; Kumara, 2006). These habitats are often rich in biodiversity and provide suitable habitats for many different potential predators. However, besides humans, slow lorises only have a few documented predators, including snakes, hawks, eagles, orangutans, viverrids, civets, and sun bears (Nayak and Singh, 2017). When the slow loris (*Nycticebus spp.*) feels threatened, it automatically stops moving and sits motionlessly. As a defense mechanism when motionlessness is not sufficient, slow lorises (*Nycticebus spp.*) mix saliva with secretions from glands within their arm, making a toxic chemical that is thought to repel other species. “This toxic bite is a rare trait among mammals and unique to lorisidae primates. It may also be used for defense against other slow lorises and parasites" (Nayak and Singh, 2017:200). Case studies have also shown that bites by the *Nycticebus* species have varied consequences on humans, from mild to severe, even showing life-threatening effects on some (Gardiner et al., 2018). Female slow lorises (*Nycticebus spp.*) have even been shown grooming their young with the toxin, and this is believed to provide them with additional defense to warn off predators (Nayak and Singh, 2017).

The lorisform’s diet consists primarily of tree gum with the addition of fruits, arthropods, birds, eggs, nectar, and vegetation (Wiens and Frank, 2006; Nayak and Singh, 2017). “Both genera show extreme adaptations to these dietary lifestyles in terms of life history, digestive tract, dentition, and their use of grasping” (Poindexter and Nekaris, 2017:2). A study done in the Khao Ang Rue Nai Wildlife Sanctuary in eastern Thailand found that the Bengal slow loris rarely fed on plant gum and rather relied on floral nectar, fruit, and animal matter (Pliosungnoen et al., 2010). Since Bengal slow lorises have a particular diet, they must have adaptations that allow them to access and digest certain foods (Poindexter and Nekaris, 2017). The *Nycticebus* species have a long, narrow tongue, which allows them to get into crevices that their fingers cannot reach. They also have a relatively large cecum, allowing them to digest complex carbohydrates. Sometimes, the insects they eat may be poisonous, however, their short duodenum helps them to get rid of anything toxic they may have consumed. While slow lorises weigh only about three to four pounds, they consume large amounts of food at a time due to their slow metabolic rate. Thus, while it takes longer for their body to burn calories, they are able to have energy that lasts longer. Since they are nocturnal, they search for food at night, which gives them an advantage because there is less competition present.

While lorisforms are typically thought of as solitary, recent studies have shown that social relationships between slow lorises (*Nycticebus spp.*) can be much more complicated (Poindexter. et al., 2018). A typical night for the *Nycticebus* species is spent 93.3% solitary. Oftentimes, they forage alone; however, they may also be seen together, showing that they are solitary foragers while also belonging to a spatial group (individuals that share parts of their home ranges) (Weins and Zitzmann, 2003). Individual interactions or forms of communication may be more beneficial to the species rather than living in large groups. They sleep during the day, either alone, with their dependent offspring, or with one other adult. Male slow lorises are very aggressive, especially towards one another when it comes to their territory (Nayak and Singh, 2017). One of the main ways the *Nycticebus* species communicate with one another is through urine markings since vocal communication can be limited as they are often not close enough to one another to be able to hear a vocalization. The scent from the urine can be picked up from other slow lorises. When slow lorises are close enough to communicate effectively through vocalizations, their vocalizations can be categorized as friendly vocalizations (squeak), call vocalization (quaink), disturbed vocalizations (growl and high-pitched chatter from adults, clicks, and squeaks from infants), and estrus vocalizations (whistle) (Daschbach et al., 1981).

Social diversity exists even in solitary animals. Various species have been found to have higher rates of direct inter-individual encounters than previously expected (Weins and Zitzmann, 2003). This shows how complex solitary animals really are. In Malaysia, the radio-location of sleeping slow lorises during the day and radio-tracking of active slow loris during the night were used to map the movements of 13 Greater slow lorises (Weins and Zitzmann, 2003). The findings suggested that there was a great deal of overlap between the home ranges of slow lorises. Out of the 13 slow lorises, 11 were thought to be members of the same spatial group (Weins and Zitzmann, 2003). Some slow lorises could be identified as belonging to multiple spatial groups. It was found that all spatial groups recorded included an adult male, an adult female, and one to three younger individuals, with home ranges often overlapping.

Slow loris (*Nycticebus spp.*) spatial groups are typically composed of an adult pair and their offspring, leading researchers to characterize the mating system as monogamous (having one mate at a time) (Wiens and Zitzmann, 2003). However, some articles have described slow lorises as being polygynandrous (having multiple mates at one time) (Yamanashi et al., 2021). There is no specific mating season for slow lorises, and infants are born at all times of the year. While the adults look for food, the infants are usually left on branches or are carried by either a parent or current group member if available. Slow lorises have a six-month gestation period and give birth to small litters of highly dependent offspring, resulting in a slow reproductive rate and little potential for population growth (Nayak and Singh, 2017). The young disperse anywhere between 16-27 months of age, and females are able to start reproducing between 18 and 24 months of age. Males reach sexual maturity at around 17 months of age.

The home ranges of female slow lorises were found to be smaller than that of the males, with males having an estimated home range of 25 ha and females having an estimated 0.4ha (Weins and Zitzmann, 2003). One male's home range typically covered the same area as several female home ranges, similar to spacing patterns in orangutans (Delgado and van Schaik, 2000). Home range areas differed greatly between individuals. The smallest home range of the slow loris was 1.6% of the largest home range (Weins and Zitzmann, 2003). It was found that habitat resources, such as food abundance, indeed have an effect on the home range size; however, home range size was not affected by age. There was indeed an overlap between the home ranges occupied by the different individuals.

A study looking at behavior and habitat use by the Bengal slow loris in Cambodia showed activity patterns that took place during the wet season. The study determined that a large portion of their overall time was spent resting (41%) and moving (36%); the remainder was spent alert (7%), sleeping (7%), feeding (6%), and grooming (4%) (Rogers and Nekaris, 2011). All of the interactions occurred between individuals with overlapping home ranges. Slow lorises participated in allogrooming, which is a type of caregiving using the hands, mouth, or other body parts to aid in the removal of ectoparasites from a social partner (Russell, 2017). Therefore, it is beneficial to have other slow lorises within the same home range. Allogrooming occurs either shortly before or after sunset between slow lorises that have overlapping home ranges (Weins and Zitzmann, 2003). Individuals share food resources with other members of their spatial group; however, this is not done simultaneously. They take turns sharing the same resources.

During the day, slow lorises spend their time sleeping off the ground in the canopy of the trees. Slow lorises can be seen using a number of different sleeping sites, such as tangles, holes, branches/forks, and bamboo (Svensson et al., 2018). When sleeping on said branches, the height can range from 1.8m to 35m (Weins and Zitzmann, 2003). They do this for their protection, as this helps them avoid detection by predators. Some slow lorises sleep alone, while others have been observed sleeping with up to two others. When sleeping in a trio, there is always an infant present, and when sleeping in a duo, one slow loris is always a female. However, while slow lorises sometimes sleep with others, they more commonly sleep alone.

Slow lorises move rather slowly during their active periods. Their behavior of solitariness, nocturnality, and arboreality allows them to avoid predators (Weins and Zitzmann, 2003). The slow loris does not use an alarm call or a warning call. This is because a call could potentially attract a predator. This puts the slow loris at risk, and since they are slow-moving primates, they cannot take any chances.

Loris Conservation

The genus *Nycticebus* is found in South and Southeast Asia, thriving in both primary and secondary rainforests. Their range extends from Northeast India to the southern Philippines, China, and all of Southeast Asia (Nayak and Singh, 2017). The Bengal slow loris has the largest geographical range of the slow loris family, extending from southeastern Asia to southern China to northeast India. Currently, four of the eight listed species of slow loris on the IUCN Red List are Endangered, and two are Critically Endangered. Two of the biggest threats to slow loris survival include rapid deforestation and the exotic wildlife trade (Nekaris et al., 2008). Loss of habitat forces them into unfamiliar areas and leaves them prone to predation. It is also easier to spot the slow loris when there is less vegetation to help them hide in.

Since the slow loris uses natural canopy bridges, loss of habitat can interfere with movement from tree to tree. If trees are too far apart and do not have a connection point to one another, they will not be able to move through the canopy naturally. They are unable to leap between branches and over roads. Their movements are very precise, and their "hand over hand" motion, as described above, does not allow for leaping movement seen in other primates. Slow lorises have been seen coming to the ground when they are unable to move throughout the canopy. This puts them at further risk for predation. They have also been witnessed climbing on power lines, which is also not suitable for the species and presents a risk of electrocution. This restricted movement prevents them from dispersing between different forest fragments to hide from humans and other predators.

Lorises are often captured and put into the exotic pet trade or killed and used for various motives (Nayak and Singh, 2017). Because they are used for food, traditional medicines, photo props, and as pets, this makes them a desirable target for those trying to make money within the illegal wildlife trade (Thach et al., 2018). While conservation efforts have been put in place to help many of the slow loris species, most are still considered Endangered or Critically Endangered, like the Endangered Bengal slow loris, which continues to experience a steady decline in population size. "Despite their CITES Appendix I status and local legal protection, slow lorises are still threatened by both local and international trade due to problems with enforcement" (Nayak and Singh, 2017: 202). In many countries, there are laws to protect the Bengal slow loris. For example, in Thailand, the Bengal slow loris is Protected by the Wildlife Protection Act of 1992. This law prohibits hunting as well as possessing and trading of the species (Nekaris and Starr, 2015). Every nation that has slow lorises occurring there naturally has implemented conservation efforts to aid in their overall protection; however, it is often executed poorly.

Conservationists are starting to use the slow loris as a symbol of the illegal wildlife trade (Nekaris, 2014). This is to aid in making conservation efforts for the slow loris a more popular movement and to educate people on the issue. These primates were once unknown to the public. This species became popular once cultural beliefs that hailed from Asian regions became more well-known globally. The internet has furthermore exploited the issue. Videos of slow lorises being illegally caught and placed into the pet trade have millions of views (Nekaris, 2014). Conservation efforts have been implemented; however, they have been limited in scope due to the lack of support from the community. Slow lorises also provide a large financial gain to those willing to capture and sell them illegally. Although the countries in which slow lorises reside contain some type of protection for them, it is not always implemented at the level it needs to be in order for regulations to be effective.

Project Goal and Significances

This project's main goal is to use arboreal camera trapping methods to determine if the Bengal slow loris is still present within the vicinity of Khao Nang Rum Wildlife Research Station in Huai Kha Khaeng Wildlife Sanctuary in western Thailand. Nocturnal walks to look for lorises using traditional methods are not safe for researchers given the presence of dangerous wildlife active at night (Indochinese tiger *Panthera tigris corbetti* and Asian elephant *Elephas maximus*). I hypothesized that camera trap locations that successfully record images of Bengal slow lorises will differ in their ecological characteristics, predicting that camera height will differ between camera traps with Bengal slow loris images and those without. I also predicted that images with Bengal slow lorises would be captured from camera traps placed in areas with greater natural bridge access and connectivity more often than camera traps recording images of isolated trees and the ground.

Finding the Bengal slow loris near Khao Nang Rum would create an opportunity for researchers to develop promising new conservation initiatives, increasing Thailand's strong reputation for wildlife research and management. The Huai Kha Khaeng Wildlife Sanctuary is a prized possession of Thailand. One goal of the country is to increase the population of Endangered species while providing them with a viable and natural habitat to thrive in. HKK is known for its tiger research and surveys and overall success with their efforts. Finding the species within Huai Kha Khaeng would give reason to establish a promising conservation program at this site, which is well protected through both legal and cultural means. Because of the success of the current tiger program, the loris program would likely be set up for success also.

Methods

Study Site

The Huai Kha Khaeng Wildlife Sanctuary is a 278,000-hectare reserve located in western Thailand (Bunyavejchewin et al. 2004). The sanctuary is believed to consist of several different forest types, including seasonal dry evergreen forests, mixed deciduous forests, and deciduous dipterocarp forests (Figure 2). They are all distributed in a mosaic across the landscape of the sanctuary. The wet season can last from May to October, with peaks of rainfall appearing during the months of May through June and September through October (Light, 2016). The study site at the Khao Nang Rum Wildlife Research Station sits at an altitude of 400-600m in the northern region of HKK. The mean canopy height of this area is 14.5m, with a maximum of 30m (Walker and Rabinowitz, 1992). The area surrounding the research station has been characterized into two separate habitat types. The evergreen habitat is mostly evergreen forest with patches of mixed deciduous forest within it (Walker and Rabinowitz 1992). The trees in this habitat can reach a height of 45m with a mean of 23m-25m. The savannah habitat can be characterized as having a discontinuous tree canopy with a high-light grass layer understory (Ratnam et al. 2011). The savannah habitat consists of primarily mixed deciduous and dry dipterocarp forests, with small patches of evergreen forest, with an average canopy high of 17m (Light, 2016).

Data Collection

I conducted this research from early July through late November 2023. During the initial week, I was introduced to several local Thai Research station staff and familiarized myself with the KNR site, assessing diverse forest conditions with the assistance of two research assistants and a field guide. I also used this time to determine suitable trees (based on size, type, and accessibility) for camera trap placement. Dr. Stephanie Poindexter from the University at Buffalo provided invaluable input for optimal camera trap placement, considering factors such as sleeping sites, travel paths, and feeding spots. Over the subsequent weeks (2 to 5), I placed approximately 18 non-flash Topiacam 4K native wifi trail cameras at varying heights within selected tree canopies. The wifi feature on these cameras facilitated image downloads without the need for climbing back into the canopy to retrieve the SD card. Additionally, I positioned 17 ground cameras in corresponding areas near the canopy, with cameras placed no higher than 2 meters off the ground to capture potential ground movement between trees. These cameras were equipped with No-glow Infrared Night Vision, 0.2 seconds Trigger speed, and a 65ft Triggering Distance. A Master lock Keyed python adjustable cable lock ensured humane attachment of each camera to the desired spot. To place the cameras at the selected height, I used standard tree climbing equipment and guidance from Griëtte van der Heide (PhD candidate, University of Colorado – Boulder) while also ensuring compliance with the safety standards outlined by Anderson and colleagues (2015). Assistance from a local Thai field assistant and a US field assistant (an MA graduate from the University at Buffalo concurrently studying phenology at the site) facilitated camera placement in the savannah habitat. After I finished placing all cameras, I collected GPS location points with a handheld GPS device (Garmin GPSMAP 64s). The evergreen habitat was excluded from the study due to its challenging accessibility and potential competition from flying squirrels (*Petaurista petaurista*). I checked camera traps for maintenance and data collection frequently throughout the remaining weeks. At the end of November, I retrieved all cameras using the same methods employed during placement.

I recorded all canopy tree characteristics at the end of November to further distinguish between each chosen tree. I recorded camera height (meters), diameter at breast height (DBH), tree genus and (whenever possible) species, natural bridge connectivity, and ground cover. Camera height was taken with a Nikon Forestry Pro II Laser Rangefinder/ Hypsometer before I removed the cameras. I estimated natural bridge connectivity based on a categorical four-point scale that was previously used for canopy cover estimations at this site. Natural bridge connections were observed and categorized by the percentage of how much the tree was covered in connections (1 = 0–25% connection, 2 = 26–50% connection, 3 = 51–75% connection, 4 = 76–100% connection) (Light et al. 2021). I estimated ground cover in a similar way (mostly open understory = 0-25%, somewhat open understory = 26-50%, dense understory = 51-75%, mostly dense understory = 76-100%).

Upon returning to the USA, I downloaded images from each SD card onto a 1TB flash drive for image categorization. I removed any images without animal subjects and archived them. I also cataloged images containing Bengal slow lorises. Over a span of four weeks, I analyzed 17,185 images, categorizing them into respective folders labeled Blank images, Non-Study Species (NSS), and Bengal slow lorises for subsequent data analysis.

Data Analyses

I uploaded the location data of each camera trap placement to Basemap GPS management software and then imported this data into the ArcMap geographic information system (GIS) mapping program. The camera trap placement waypoints were categorized into three groups: those on the ground, those in the canopy without confirmed loris images, and those in the canopy with confirmed loris images. These points were overlaid onto a four-class vegetation layer created by Griëtte van der Heide to identify the specific forest types where the cameras were situated. I created an overall camera characteristics excel file that contained camera placement coordinates and all tree characteristics of the cameras placed in the canopy (Table 2). The tree characteristic sheet includes camera height (meters), DBH, basal area (calculated from DBH), tree species, natural bridge cover, and ground cover. I later input this into JMP Pro Version 16 for statistical analyses. I compared tree characteristics using pooled T-tests (basal area, camera height, and elevation) or Fisher's exact tests (natural bridge connectedness and ground cover) between trees with confirmed loris images and those without loris images. I used Pearson coefficient correlations to assess the linear relationships between all sets of variables. All statistical tests are two-tailed with a significance level at $p \leq 0.05$.

Results

There were 34 points in total for camera placement within the savanna habitat, including 16 on the ground, 10 in the canopy without loris images (hereafter “non-loris cameras”), and 8 in the canopy with confirmed loris images (hereafter “loris cameras”) (Figure 3). The 17,185 images were categorized within each respective folder, with 15,646 Blank images, 1,523 NSS images (selected NSS images in Appendices 1-18), and 16 Bengal slow loris images (Figures 4-19). The 16 ground cameras captured 633 images of NSS but zero loris images. The 10 canopy cameras without loris images captured 254 NSS images. The 8 canopy cameras with loris images captured 669 NSS images and 16 loris images. The NSS folder consisted of all Non-Study Species, which were further identified at the species level (Table 1).

For all arboreal camera trees, mean basal area was 0.30 m^2 (±0.38 m^2 SD). Mean elevation was 503.82 m (±68.30 m SD). Mean camera height was 12.29 m (±4.43 m SD). For all camera trees, 16% of the trees had 26-50% connectivity, 44% had 51-75% connectivity, and 38% had 76-100% connectivity. Median natural bridge connectivity was 51-75% connected (±17% SEM). For ground cover, 27% fell between 26-50% with somewhat open understory, 33% between 51-75% with dense understory, and 38% between 76-100% with mostly dense understory. Median ground cover was 51-75% dense understory (±19% SEM) (Table 2). For camera trees without loris images, mean basal area was 0.16 m^2 (±0.15 m^2 SD). Mean elevation was 505.07 m (±13.35 m SD). Mean camera height was 10.98 m (±4.79 m SD). For non-loris trees, 20% of the trees had 26-50% connectivity, 60% had 51-75% connectivity, and 20% had 76-100% connectivity. Median natural bridge connectivity was 51-75% connected (±21% SEM). For ground cover, 20% fell between 26-50% with somewhat open understory, 40% between 51-

75% with dense understory, and 40% between 76-100% with mostly dense understory. Median ground cover was 51-75% dense understory (±24% SEM). For trees with confirmed loris images, mean basal area was 0.47 m^2 (±0.52 m^2 SD). Mean elevation was 502.26 m (±105.33 m SD). Mean camera height was 13.93 m (±3.54 m SD). For loris-confirmed trees, 12% of the trees had 26-50% connectivity, 25% had 51-75% connectivity, and 62% had 76-100% connectivity. For ground cover, 37% fell between 26-50% with somewhat open understory, 25% between 51-75% with dense understory, and 37% between 76-100% with mostly dense understory. Median natural bridge connectivity was 76-100% connected (±26% SEM). Median ground cover was 51-75% dense understory (±32% SEM).

Loris image trees had a larger basal area than non-loris trees, and the difference approached significance ($t(16) = 1.81$, $p = 0.0892$). No other variables showed a statistically significant difference between loris camera trees and non-loris camera trees ($p > 0.05$). For all camera trees, I found that elevation was significantly negatively correlated to basal area ($r(7) = -0.72$, $p = 0.0006$). Elevation was positively correlated to ground cover, and this was approaching significance ($r(7) = 0.43$, $p = 0.0718$). Basal area was also positively correlated to natural bridge connectivity and this was approaching significance ($r(7) = 0.43$, $p = 0.0746$). For all trees that did not have confirmed loris sightings, I found that elevation was significantly positively correlated to basal area ($r(7) = 0.72$, $p = 0.0189$). For all trees that did have confirmed loris sightings, I found that elevation was significantly negatively correlated to basal area ($r(7) = -0.87$, $p = 0.0048$). For loris camera trees, camera height was negatively correlated to ground cover, and this relationship approached significance ($r(7) = -0.65$, $p = 0.0791$). Loris camera tree basal area had a notable negative relationship to ground cover, but it did not approach significance ($p > 0.05$).

Discussion

The main goal of this project was to find out if any Bengal slow lorises were in the vicinity of KNR. I found 16 loris images from the canopy cameras. In the process of this project, I have confirmed that Bengal slow lorises occupy the forests around KNR, confirming their continued existence in HKK. I also found that there was a positive correlation between basal area and natural bridge connectivity.

Because the Bengal slow loris is a nocturnal primate with specific habitat requirements that are critical for its survival, they chose a higher percentage of dense vegetation in preference to a lower percentage. This would not only provide them with a food source but also protection from potential predators. I hypothesized camera trap locations that successfully record images of Bengal slow lorises would differ in their ecological characteristics. This was true for some tree characteristics more than others. When comparing loris trees to non-loris trees, I saw that the loris trees were bigger than the non-loris trees on average. This matches previous literature suggesting that slow lorises indeed prefer larger trees (Pliosungnoen et al., 2010). However, they may not be picking these trees specifically for their larger basal area. It could be that slow lorises are more attracted to higher percentages of natural bridge connectivity. My results confirm that trees with a larger basal area have more natural bridge connectivity, although this difference was not significant. When comparing the loris tree and non-loris tree, I found no significant correlation between basal area and natural bridge connectivity. This does not challenge the explanation above but could also suggest that because there is more connection, there could be more options for travel. The bigger a tree, the more canopy cover it has. This could lead to more branches, tree forks, and vegetation for the overall tree. When placing cameras in one specific spot, other areas could be overlooked in larger trees. This gives the loris an opportunity to completely avoid the camera's view.

I also saw that cameras with confirmed loris were placed higher than the non-confirmed cameras. It has been observed that some slow loris are accustomed to moving farther upward in trees to escape predation (Poindexter and Nekaris, 2017). However, it is also possible that I unintentionally placed cameras higher in trees with less understory growth. I have a lower percentage of loris cameras in the very dense category compared to non-loris cameras and a higher percentage of loris cameras in the less dense category than non-loris cameras. This shows that the understory was, on average, more overgrown for the non-loris cameras. It is possible that the cameras were easier to place when there was little understory in the way. With a better view, we were more inclined to find higher locations for climbing. This also likely correlates back to the positive correlation between basal area and natural bridge connectivity. With the increase of branches, tree forks, and vegetation, it makes it difficult for sunlight to reach the forest floor, resulting in a more open understory.

The current study can be interpreted as the first step to establishing a concrete conservation program at HKK for slow lorises. Future researchers should keep in mind some important factors when choosing trees to capture images of lorises. A tree with a large basal area and a high percentage of natural bridge connectivity is ideal. If the same method of placing the camera in the trees is used, then choosing a tree with minimal understory will help with the process of placing equipment in the desired place on the trees. I believe it would be worth it to expand the search to more of the surrounding savannah habitat, possibly gaining an idea of their overall home range for the area. I recommend that ground cameras be skipped altogether, and only canopy cameras should be used if lorises are the main goal.

Understanding wildlife and its ability to survive in an environment that is impacted by humans is important from a conservation perspective (Nekaris et al., 2017). To successfully incorporate conservation into an area, it is crucial to understand the local knowledge and beliefs about the species of interest. It is very important to obtain information from locals because they may know the most about a given species. This is significant when providing explanations of the importance of conservation to people when the subject is essential in their daily lives (Thach et al., 2018). Using this information could potentially raise awareness among the general public about slow lorises and their presence in the illegal wildlife trade (Nekaris, 2014). When asking the local researchers about slow lorises in the area, they would mention that they have at least seen them once in the area before. They seemed to be not as impressed to see them as much as I previously thought. These researchers are used to gathering data on big diurnal animals like the Asian elephant and tiger, so mentioning a nocturnal animal that was previously difficult to research in the past would understandably not be as big of a concern. Although the excitement for less charismatic species is almost non-existent, maintaining international research and conservation efforts is still important to the mission of preserving the slow loris species.

Conclusion

A total of 16 images were collected during the project. This confirmed the hypothesis that the Bengal slow loris still occupies the area around KNR. The sanctuary's overall conservation work is a continuous success with other species. With new evidence of the slow loris in KNR, expanding conservation efforts in the sanctuary to include loris could be a setup for success. The main takeaway for future researchers to think about is the selection of trees you choose. When looking for lorises, trees with large basal areas, more natural bridge connectivity, and high placement matter. Tree characteristic trends were present within the data set, showing that the loris trees had some correlations with different variables. It showed that higher cameras on larger trees with less understory and more natural bridge connectivity had a higher percentage of loris images. In this project, I demonstrated that camera traps can be a useful option for observing subjects that are difficult to observe directly. Camera traps are individually placed and have to be done so by setting up a rope climbing system for each tree. So, although camera traps can be very useful for difficult subjects, it can also become a very time-consuming process. This project highlights the challenges of studying the Bengal slow loris, prompting various approaches to comprehend its behavior, ecology, and habitat preferences.

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Tables

Table 1: All listed Species found on the cameras with the number of images for each

Species List:	# of images
Bengal slow loris *(Nycticebus bengalensis)*	16
White-handed Gibbon *(Hylobates lar)*	60
Indochinese grey langur *(Trachypithecus crepusculus)*	373
Northern pig-tailed macaque *(Macaca leonina)*	134
Black giant squirrel *(Ratufa bicolor)*	102
Grey-bellied squirrel *(Callosciurus caniceps)*	117
Himalayan striped squirrel *(Tamiops mcclellandii)*	14
Pallas's squirrel *(Callosciurus erythraeus)*	145
Shrew-faced Squirrel *(Rhinosciurus laticaudatus)*	20
Hairy-footed flying squirrel *(Belomys pearsonii)*	174
Red spiny rat *(Maxomys surifer)*	194
Small Indian civet *(Viverricula indica)*	10
Small-toothed palm civet *(Arctogalidia trivirgata)*	8
Yellow-throated marten *(Martes flavigula)*	10
Wild boar *(Sus scrofa)*	9
Gaur *(Bos gaurus)*	3
Barking deer *(Muntiacus muntjak)*	26
Sambar Deer *(Rusa unicolor)*	41

Table 2: All listed tree characteristics for each camera

Number of Cameras	Elevation	Loris Confirmed	Camera Height (meters)	DBH	Basal area (m^2)	Tree Species	Natural bridge cover #	Ground cover
1	504.6	YES	12.0	70.8	0.39	Shorea siamensis	4	2
2	487.9	YES	14.5	107.7	0.91	Garcinia sp.	4	3
3	486.8	YES	8.9	63.9	0.32	Pterocarpus macrocarpus	4	4
4	528.6	YES	16.8	60.4	0.29	Shorea siamensis	3	2
5	532.7	YES	10.3	23.0	0.04	Ficus sp.	3	4
6	507.8	YES	18.2	57.3	0.26	Pterocarpus macrocarpus	2	3
7	678.3	YES	12.7	17.6	0.02	Ficus sp.	4	4
8	291.1	YES	18.1	141.9	1.58	Lagerstroemia sp.	4	2
9	513.5	NO	9.3	69.0	0.37	Shorea siamensis	3	2
10	517.7	NO	7.8	65.0	0.33	Shorea siamensis	3	4
11	490.2	NO	6.4	36.9	0.11	Dillenia sp.	4	2
12	504.4	NO	3.5	23.8	0.04	Sawong sp.	2	3
13	490.4	NO	9.6	14.9	0.02	unknown 1	2	3
14	513.2	NO	10.4	67.4	0.36	Lagerstroemia sp.	3	4
15	526.4	NO	16.1	58.9	0.27	Miliusa sp.	4	4
16	500.1	NO	12.5	10.5	0.01	Ficus sp.	3	4
17	485.6	NO	14.7	30.6	0.07	unknown 2	3	3
18	508.8	NO	19.5	27.6	0.06	Shorea siamensis	3	3

Figures

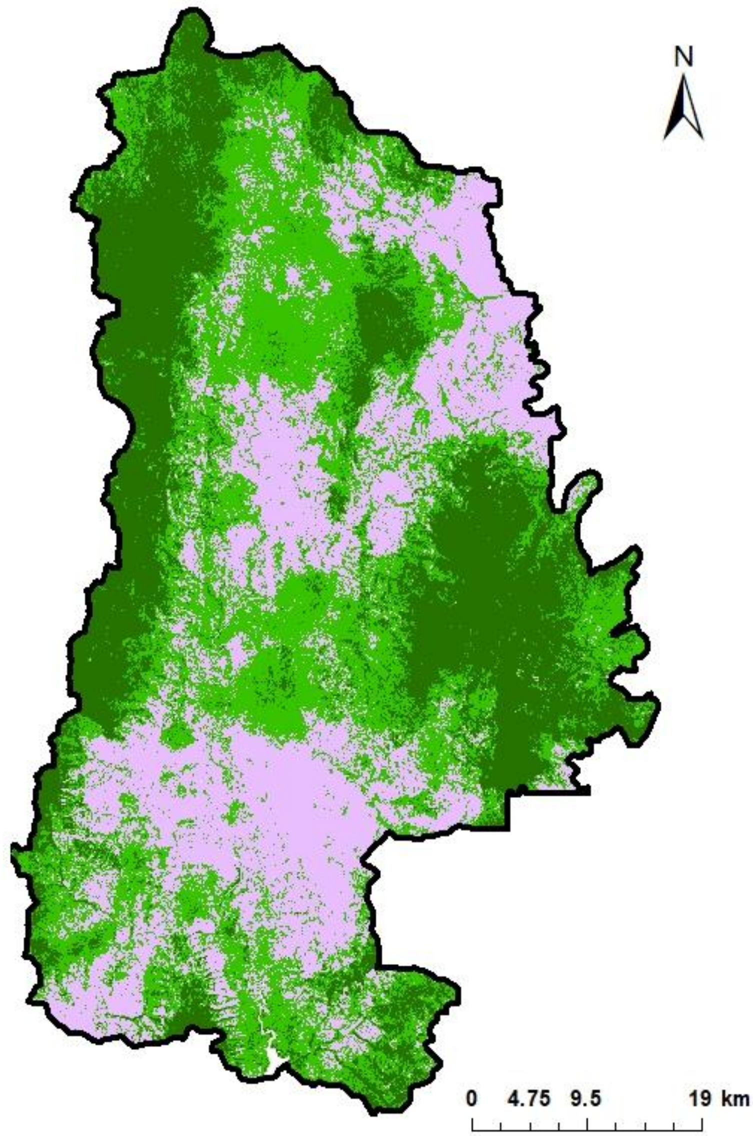


Figure 1: The map of HKK with a 3-category vegetation layer

A

B

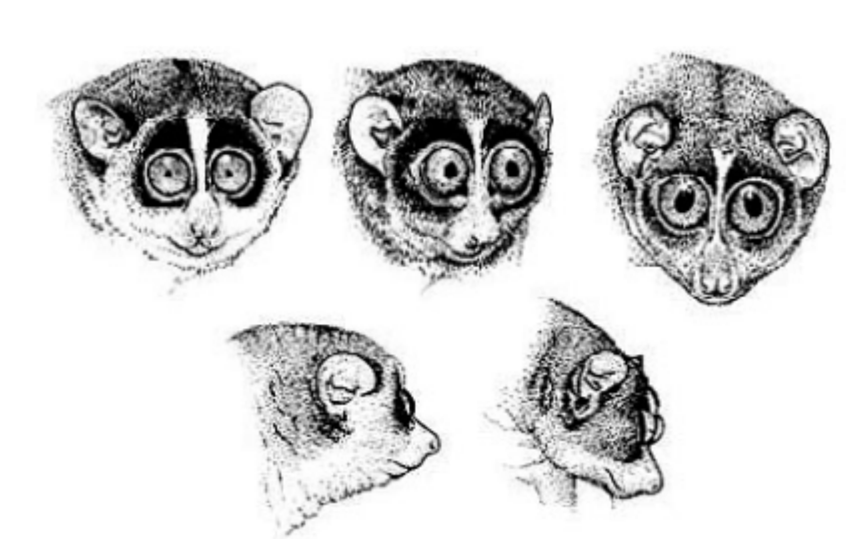
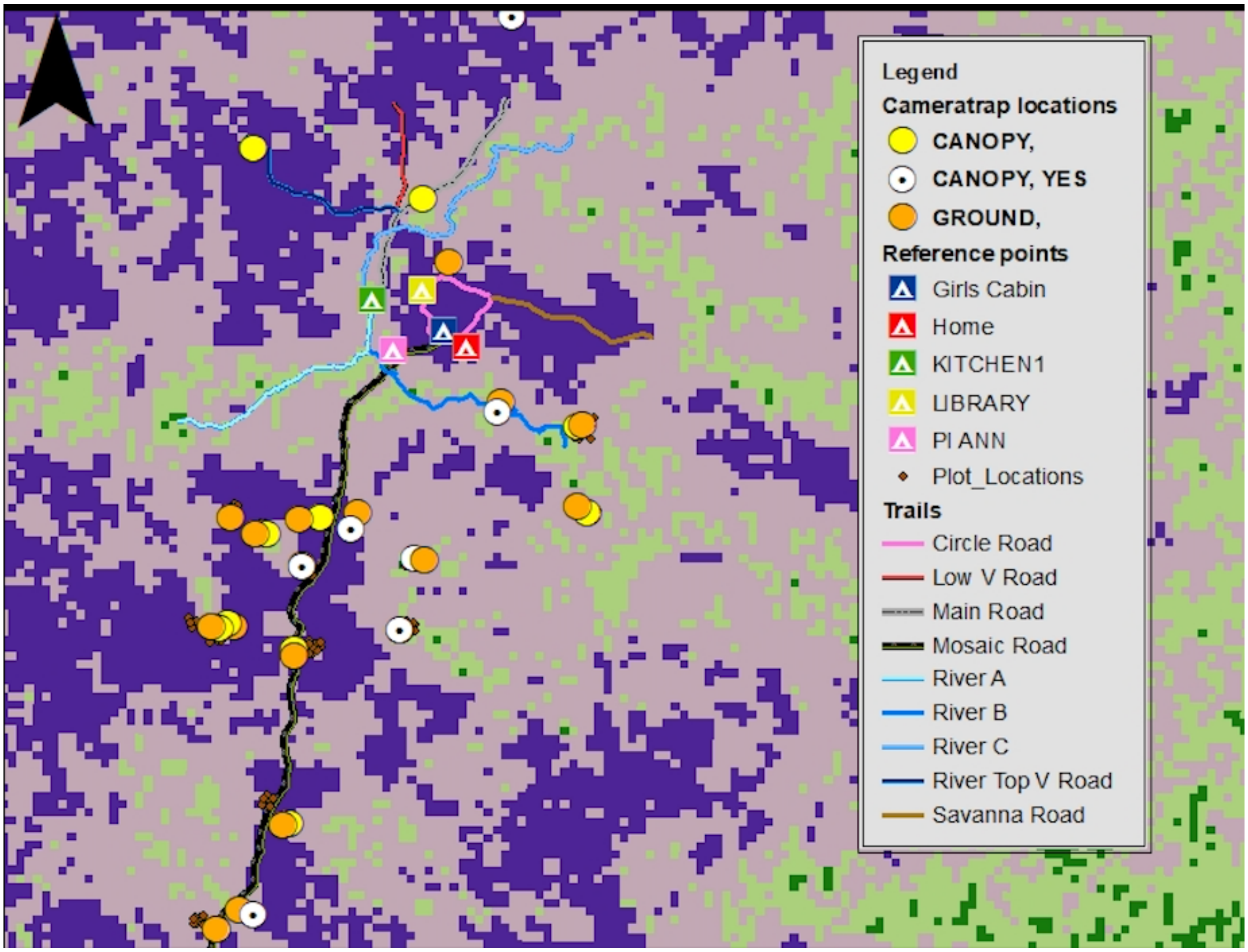


Figure 2: (A). The facial features of the genus *Nycticebus* and (B). the genus *Loris*



. **Figure 3:** Map of camera placement within KNR.

Figure 4. Camera GH04 with Loris in the bottom left corner

Figure 5. Camera GH08 with shining eye Loris

Figure 6. Camera GH08 with hidden in the background, Loris is on the back horizontal branch

Figure 7. Camera LL006 Loris in front of bamboo

Figure 8. Camera CamPark-T86 with moving shining eye Loris picture one

Figure 9. Camera CamPark-T86 with moving shining eye Loris picture two

Figure 10. Camera LL006 with moving Loris in front of bamboo

Figure 11. Camera plot 1 with white Loris

Figure 12. Camera LL0019 with hidden face Loris

Figure 13. Camera plot 1 loris with a small appearance in the button left

Figure 14. Camera LL0027 with vertical climbing Loris

Figure 15. Camera plot 1 with butt facing Loris

Figure 16. Camera PAPBEL 0004 with full body closeup Loris picture (1)

Figure 17. Camera PAPBEL 0004 with full body closeup Loris picture (2)

Figure 18. Camera PAPBEL 0004 with full body closeup Loris picture (3)

Figure 19. Camera PAPBEL 0004 with full body closeup Loris picture (4)

Appendices

Appendix A: Barking deer (Muntiacus muntjak)

Appendix B: Small Indian civet *(Viverricula indica)*

Appendix C: Shrew-faced Squirrel *(Rhinosciurus laticaudatus)*

Appendix D: Red spiny rat *(Maxomys surifer)*

Appendix E: Small-toothed palm civet *(Arctogalidia trivirgata)*

Appendix F: Yellow-throated marten *(Martes flavigula)*

Appendix G: Tickell's brown hornbill (*Anorrhinus tickelli*)

Appendix H: Grey-bellied squirrel *(Callosciurus caniceps)*

Appendix I: White-handed Gibbon *(Hylobates lar)*

Appendix J: Black giant squirrel *(Ratufa bicolor)*

Appendix K: Northern pig-tailed macaque *(Macaca leonina)*

Appendix L: Indochinese grey langur *(Trachypithecus crepusculus)*

Appendix M: Pallas's squirrel *(Callosciurus erythraeus)*

Appendix N: Gaur *(Bos gaurus)*

Appendix O: Wild boar *(Sus scrofa)*

Appendix P: Sambar Deer *(Rusa unicolor)*

Appendix Q: Himalayan striped squirrel *(Tamiops mcclellandii)*

Appendix R: Hairy-footed flying squirrel *(Belomys pearsonii)*