Activity budget, home range, spatial movements and habitat preferences of male Philippine slow lorises (*Nycticebus menagensis*)

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Reflection

I cannot fault my overall experience at DGFC, the opportunity is a rare one and I will never regret spending a year of my life in Borneo. I was allowed to devise a project on my own, luckily a project was already set up and I opted in for one following tarsiers. Even though it was an established project, I was still allowed to be independent, deciding what I actually wanted to look at. Unfortunately, the tarsier project did not work out; my subjects kept dying, or went missing. It was getting late in the year and I hadn't really collected a proportionate amount of data therefore, I switched to slow lorises because the capture rate was successful. This is why my project only started in January. However, I had a complete years' worth of nocturnal primate training, so apart from a smaller data collection period than most, I do not feel that I lost out on any education.

During my time at DGFC, and under my project, I developed skills in radio telemetry, distance sampling and animal collaring. I was also able to grow as a person because the data collection conditions were tough, especially with the 6 hour nocturnal shifts. I really believe that they were beneficial for my development as it taught me that I can handle tough physical conditions in future.

I was also able to participate in other projects so I also developed skills in camera trapping, parasite analysis (using McMaster method) and botanical plots. My employee skills also developed; I can now more successfully work in a close environment and part of a team. I also gained communication skills through running field courses and giving presentations about my project regularly. I believe that is invaluable and I am extremely happy that I had to give presentations. My presentation skills have increased dramatically.

Living at DG was great, I was looked after, fed really well and living costs were low. The local staff were wonderful and they became like family members. In the interview Benoit Goossens said that DG is like a family and what he said is very true. Doing your PTY year with fellow Cardiff PTY students was also great. DG was also really good in the sense that you could make many work contacts, through the numerous field courses, even lecturers and Professors from Cardiff University. This is another invaluable thing provided by DGFC. My year at DG has helped me to be a better employee and has really focused my mind on what I want to do, and what I can expect from a career in scientific research.

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Abstract

Nycticebus menagensis is possibly the most understudied slow loris species. Not much is known about this species, yet, their natural habitat is dwindling and they are threatened by the pet trade. Home range use and population demographics were studied in order to assess whether the species is affected by changes in habitat. The population density of *N. menagensis* in the Lower Kinabatangan Wildlife Sanctuary, Malaysian Borneo, was 8.93 ind. km^{-2}. A single male slow loris was the study subject; his home range was estimated to be 0.09151 km^2, using LoCoH method. Female home range overlap and territoriality were the main factors affecting home range size. Behaviour significantly varied throughout the night (p-value<0.05) however, the time budgeted for travelling was constant throughout the night, (approximately 50%). Time period did not significantly affect distance travelled during night shifts. *N. menagensis* was found to be lunar neutral but closer inspection of height measurements recorded during tracking suggested that the individual was lunar philic, the count of 15-20m observations was greater when the moon was brighter (p-value<0.0001). Rainfall did not significantly influence distance travelled between sleeping sites. Sleeping sites were deemed an important component of home range use, and were affected by tree species (via comparisons with tree species used for foraging). The results, although based on a small sample size, expand the understanding of this particular species, whilst also providing information relevant to other nocturnal primates in terms of habitat management and further study. Rainforest can be managed to provide a more suitable habitat as there is better understanding of home range use and required tree species.

Introduction

The slow loris (*Nycticebus spp.*) is a nocturnal prosimian, different from other species as it is the only venomous primate (Bearder 1987). Brachial arm glands secrete a venom which the individual then mixes with saliva, and is suggested to be used for predator deterrence (Krane *et al.* 2003; Nekaris *et al.* 2013). Another predator evasion tactic is camouflage via immobility, they can remain still without fatigue; specific morphological characteristics such as *rete mirabile* and a large flexor muscle in the hind legs enable this (Ankel-Simons 2007). Cryptic slow climbing often follows immobility, giving the name 'slow'. As with many nocturnal mammals they have a reflective eye layer behind the retina, the *tapetum lucidum* (Nekaris and Bearder 2007), and are solitary (Bearder 1987). Communication is via scent marking (Starr *et al.* 2012; Gursky 2003) and vocalisations (Nekaris *et al.* 2013).

There are currently eight species of slow loris recognised, four of which are found in the rainforests of Borneo (*Nycticebus bancanus*, *N. borneanus*, *N. kayan* and *N. menagensis*). There have been studies on all slow loris species in South East Asia (Wiens and Zitzmann 2003b; Collins 2007; Starr and Nekaris 2013) and India (Radhakrishna *et al.* 2006), with the exception of the species found in Malaysian Borneo. This study will focus on the Philippine slow loris (*N. menagensis*) which is found in North and East Borneo, as well as in the Philippines (Munds *et al.* 2013). The genus was recently reclassified (Munds *et al.* 2013) with the suggestion of splitting *N. menagensis* further into sub-species due to variation found within the species (Nekaris and Munds 2010). This variation, however, is difficult to categorise as loris species are polymorphic and demonstrate cryptic characteristics (Munds *et al.* 2013).

N. menagensis has a body weight of 265-610g (Munds *et al.* 2013), the species does not demonstrate sexual dimorphism of morphological characteristics (Nekaris and Bearder 2007). *N. menagensis* can be distinguished from other species genetically, as well as morphologically from differences in pelage colouration, facial mask colouration and the absence of a second upper incisor (Nekaris *et al.* 2007; Munds *et al.* 2013). *N. menagensis* is classified as Vulnerable and was added to CITES Appendix I in 2008, which protects it from commercial and international trade (IUCN 2008). It is thought to be the least threatened of the loris species (Nekaris *et al.* 2007) and abundant (Meijaard *et al.* (2005) cited in Nekaris *et al.* (2007)) with an encounter rate of 0.12 ind. km^{-1} in Borneo (Nekaris and Nijman 2007).

Variation between population densities of a species shows that population-level changes can occur due to the altered spatial use of a home range (Gerber *et al.* 2015). Therefore, population densities can show whether a species will cope with landscape change elicited by deforestation. Low densities initiate further studies so that future environmental and population management aid the conservation of a particular species. Population densities of slender lorises, *Loris lydekkerianus*, in Sri Lanka show that each taxa responds differently to human disturbance but loris presence is negatively associated with primary forest (Nekaris and Jayewardene 2004). This suggests that there could be a benefit to living in disturbed forests. The ability of *N. menagensis* to adapt to disturbed forest is unknown, as is the possibility of increased life fitness in secondary forest.

Home range size, behaviour, activity budget and diet have not been studied for *N. menagensis*. A key way of understanding the ecology of a species is by studying home range use and factors that affect said usage. For instance, when differences between male and female ranges are identified, revelations about home range use and behaviour arise; female field vole, *Microtus agrestis*, home ranges are often determined by food abundance whereas the male home ranges are determined by female density (Nelson 1995). In diurnal and gregarious species of primates, home ranges are affected solely by food availability (Bitetti 2001) which is in contrast to that of solitary species, where male home ranges are influenced by female distributions, and females by food availability (Bearder 1987; Broomhall *et al.* 2003). In solitary mountain gorillas, (*Gorilla gorilla beringei*), the effect of social factors also supersedes the effect of ecological factors in males (Watts 1994). Gerber (2015) suggests that resource availability, sociality and habitat alteration collectively affect home range use in Milne-Edwards' Sifaka (*Propithecus edwardsi*). Home range sizes in species of slow loris other than *N. menagensis* are affected by habitat type but not sex; in *N. coucang*, home ranges in primary forest were smaller than that of secondary/degraded/disturbed forest (Wiens and Zitzmann 2003a; Wiens and Zitzmann 2003b). On the other hand, home ranges are affected by sex in other loris species, males have larger home ranges than females (Nekaris and Jayewardene 2004). It is unknown whether habitat type and sex cause variation in the home ranges of *N. menagensis*.

Studies of the effect of environmental variables on the ecology of *N. menagensis* are non-existent. For example, the influence of moon luminosity on *N. menagensis* is unstudied even though it is an important nocturnal variable for other nocturnal mammals such as *Dipodomys merriami*, *Phyllotis xanthopygus* and *Caluromys*

philander (Bowers 1990; Kramer and Birney 2001; Laferriere 1997) and the spectral tarsier, *Tarsius spectrum*, (Gursky 2003). Other loris species have shown a variation in their response, for example, *N. pygmaeus* was found to be lunar philic (increased activity with moonlight) (Starr *et al.* 2012), whereas *N. javanicus* was found to be lunar neutral (no effect from moonlight) (Nekaris *et al.* 2014) and *N. bengalensis* was found to be lunar phobic (decreased activity with moonlight) (Rogers and Nekaris 2011). Rainfall could also influence the ecology of *N. menagensis* as it is an important part of the ecology of a rainforest. Rainfall changes with season in Malaysian Borneo as there is a wet and dry season (Ancrenaz *et al.* 2004). In other species of primates, such as *Cebus apella nigritus*, seasonality has been shown to effect primate home range use (Bitetti 2001). In the Endangered Milne-Edwards' Sifaka, (*P. edwardsi*) individuals shifted their core range with season (Gerber *et al.* 2015). The effect of rainfall, thus seasonality, on home range use in *N. menagensis* is unstudied.

Sleeping sites are important to all primates as roughly half of their life is spent in one, this means that knowledge about the location of the site, physical characteristics of the site and behaviour in proximity to the site, help in understanding how a species uses its home range (Anderson 1984; Anderson 1998).The effect of tree species on sleeping site choice and the subsequent effect on home range use is unstudied in *N. menagensis* but in other species of primates, tree species is shown to influence sleeping site choice through variation in fruit production (Bitetti 2001). Studying the difference in tree species will show whether *N. menagensis* chooses a particular species of tree to sleep in so that when they wake, they are close to their required food resources.

Calculating the population density of N. menagensis was a main objective in this study. Discussion included how the calculated density differs from species of loris in other environments. Habitat type and sex was examined in this study in order to assess how they affect home range size, sleeping site choice or nightly spatial movements. The effect of moon luminosity on activity was also explored. This study aimed to investigate whether activity at night and distances between sleeping sites are affected by rainfall. Another aim was to look into the effect of tree species on sleeping site choice and night time activity. By studying these variables a more complete understanding of the ecology of N. menagensis can be achieved. The outcomes of this paper will enable better management of slow loris habitat and aid future conservation of this Vulnerable species.

Materials and Methods

Study Site

This study took place along the Kinabatangan River, the longest river (560 km) in the state of Sabah, Malaysian Borneo. Located in Lot 6 of the Lower Kinabatangan Wildlife Sanctuary (LKWS, 5°10′–5°50′N; 117°40′–118°30′E) is Danau Girang Field Centre (DGFC), a research centre. This area has a wet and humid climate and experiences average monthly temperatures of 21°C-34°C (Ancrenaz *et al.* 2004). The region is subject to a wet and dry season, the major monsoon is from November to March. Mean annual rainfall is approximately 3000mm (Ancrenaz *et al.* 2004). The vegetation surrounding DGFC is comprised of semi-inundated and riparian forest. The area surrounding DGFC is 123 ha (Munds *et al.* 2013) and the study took place there from January to July 2015.

Census

Distance sampling was used to estimate a population density. Six line transects were surveyed, each transect was surveyed in shifts; 6pm-9pm, 10pm-1am or 2am-5am. Each shift was walked four times so overall each transect was walked 12 times. Pre-made trails (Fig. 1) were used to minimise further damage to the forest and avoid the time needed to cut new transects. The trails used were the ones originally designed to be transects that cover all the types of habitat surrounding DGFC. The average transect length was 960 m which was walked at an average speed of 539 mh-1. Each survey was conducted by a minimum of three people. Two of the three people were kept constant to reduce observer bias.

In order to detect the slow loris, a LED Lenser H7 head torch was used to stimulate the *tapetum lucidum*. When exposed to light this layer shines with a golden hue making detection easy, aiding in detection when the loris was high. When a loris was detected, the time, height and distance from transect was recorded. If possible, behaviour was also recorded.

In order to compare with a previous study (Munds *et al.* 2013), the density of N. menagensis was calculated using D=n/2wl, where n is the number of animals observed, l is the total trail length, w is the half width of the trail (attained by removing the furthest 10% of sightings from n).

Radio Collar

DGFC has a long term project studying the native nocturnal primates; *N. menagensis* and the Western tarsier, *Cephalopachus bancanus borneanus*. Previously only females or juveniles had been collared, therefore, in order to expand the study adult male lorises were targeted. During this study one male loris, weighing 710g, was captured (March 2015) and fitted with a Biotrack VHF collar (Holophil PD-2C). Following collaring, he was then located by tracking the radio wave emitted by the collar using a receiver (R100 Telonics) and antenna (RA-23K VHF Antenna Telonics). Beeps emitted from the receiver increases in volume with increasing proximity to the animal.

Tracking

To determine spatial movement and record the behaviour of the animal in its natural environment, tracking occurred in six hour shifts (6pm-12am and 12am-6am). Every 15 minutes a GPS point and a series of variables were recorded: behaviour, height (five metre ranges), weather, moon luminosity (estimated percentage categories: 0 = 0%, 1 = 0.1-24.9%, 2 = 25-49.9%, 3 = 50-74.9% and 4 = 75-100%) and the length of time in a particular tree (a tree was marked if the loris spent more than 15 minutes in the same tree). Two six hour shifts made a cycle and one cycle represented one night of behaviour and spatial movement.

Sleeping sites

A component of determining home range usage is to locate sleeping trees, which was done using the VHF receiver and antenna. Measures were taken to establish the level of gain/sensitivity on the receiver that signified closeness to the sleeping tree. The signal was then followed until this level of gain was reached. Further tuning and triangulation (the signal is tested at three points around a tree, the direction of all the signal tests should point to the tree) were used to choose a single tree. Binoculars were then used to get a visual, although a visual was not always possible. Sleeping trees were then tagged with a laminated number and neon biodegradable flagging tape. A GPS point was taken at the base of the tree. The existing number was recorded for reused trees. The GPS points were used to return to the trees with a specialist for species identification if they could not be identified in the field. The estimated moon luminosity for nights between sleeping sites was achieved using timeanddate.com with Kota Kinabalu as the reference.

Statistical analysis

For statistical analysis, R software (R Core Team 2015) was used. The home range map was made using ArcGIS (version 10). The home range was estimated using sleeping site GPS data only which was plotted in ArcGIS, this was analysed using the adaptive Local Convex Hull method. The adaptive value was 1117 as this was the distance in metres between the furthest GPS points. 95% and 50% isopleths were created to represent the entire home range and core home range respectively. A home range estimate for a female N. menagensis was available for comparison via unpublished data obtained by previous work at DGFC (Wilson 2014). The two estimates could not be statistically tested for comparison but they were discussed in the discussion.

A Chi-squared test was used to establish whether there was a difference between the observed behaviours of the early tracking shift and the late tracking shift.

A two sample t-test was used to compare the distance travelled during 1800-2400 with the distance travelled between 0000-0600. The untransformed data had a normal distribution and equal variances.

A multiple regression was used to examine the significance of rainfall and moon luminosity as influential factors on distance travelled between sleeping sites. Distance between sleeping sites was estimated using the GPS points in Garmin Basecamp (version 4.4.6). An average weekly distance, average weekly rainfall (mm) and average weekly moon luminosity (0 = 0%, 1 = 0.1-24.9%, 2 = 25-49.9%, 3 = 50-74.9% and 4 = 75-100%) were used for the regression. Each weekly average was calculated using the same weeks. The data used to calculate weekly rainfall was collected at DGFC.

Results

Census

The size of this study effort was 67.23 km. The half-width for *N. menagensis* was 15 m. For sighting distances from the transect, the range was 0-20m, for height of sightings, the range was 5–25 m. The study amassed 18 *N. menagensis* sightings, resulting in a density of 8.93 ind. km^{-2}.

Home Range

Using the LoCoH method of home range analysis, the home range of the male loris was calculated to be 0.09151 km^2 and the core range was 0.01960 km^2 (Figure. 1). The home range spanned riparian and semi-inundated rainforest.
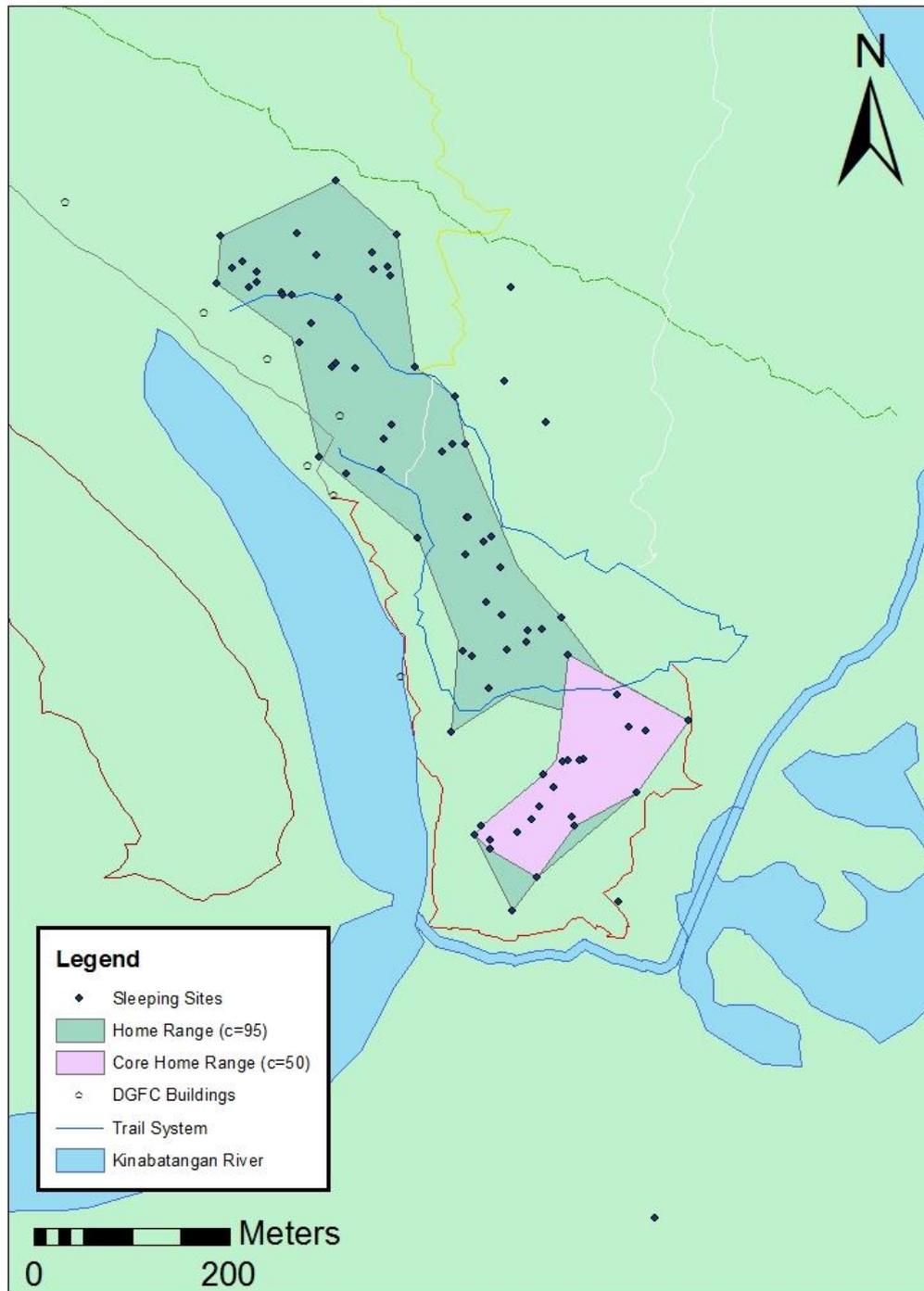

Figure 1: The entire (0.09151 km^2/9.151 ha) and core (0.01960km^2/1.960 ha) home range of a male slow loris (*Nycticebus menagensis*), estimated using the Local Convex Hull (LoCoH) method of home range estimation.

Behaviour

The slow loris was followed for 84 hours, during this time 341 behaviour events were recorded. In both time periods, 1800-2400 pm and 0000-0600 am, the common activity was movement, nearly 50% of the loris' time was allocated to moving (Figure 2). The time allocation for behaviours was significantly different between the shifts (X-squared = 16.0509, df = 6, p-value < 0.05). The loris was observed feeding on leaves, insects, vine exudate, tree exudate and flowers. There direct social encounters, one encounter resulted in copulation and social sleeping, and another resulted in a territorial fight with a male loris. The final encounter was with a loris suspected to be female however the interaction occurred high in a tree so the exact nature of the behaviour was unknown. Direct interaction behaviours included allogrooming (mutual with a female loris), following and vocalisation through clicking. Some behaviour observations suggested an indirect social interaction; the loris was following scent marks left by another loris.
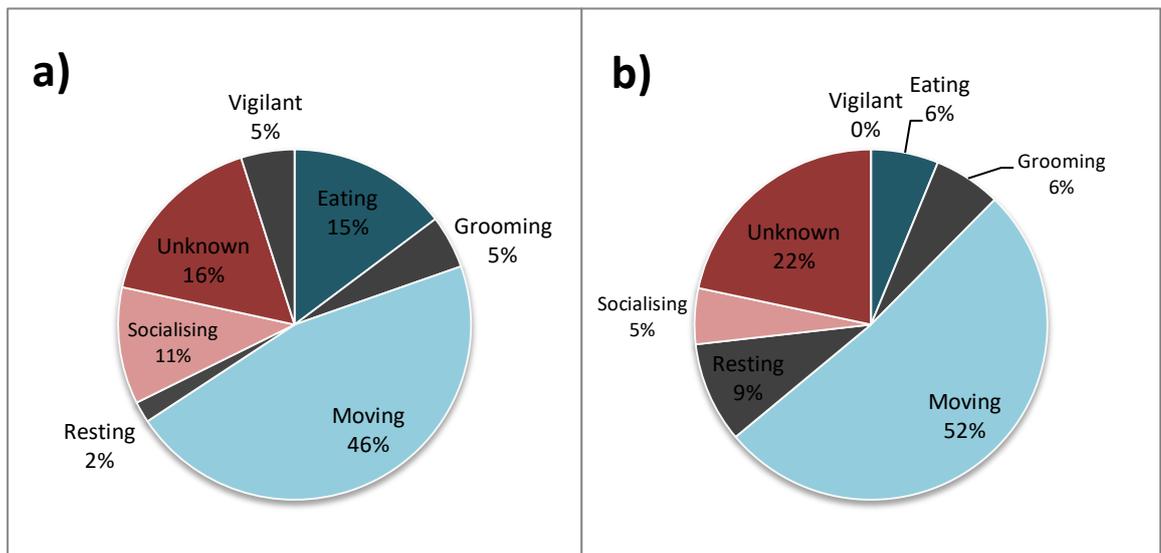

Figure 2: The percentage of time allocated to a particular behaviour during six hour tracking shifts following a male slow loris (*Nycticebus menagensis*) at night. The time allocation for the early shift, 1800-2400 pm, (a) was significantly different from the late shift, 0000-0600 am, (b) (X-squared= 20.7106, df= 7, p-value= 0.004223).

Spatial Movements

The average distance covered by the slow loris in one night was 640.8571 m (±168.73 m), in the early shift: 340.7143 m (±115.6888 m) and in late shift: 300.1429 m (±109.155 m). The mean distances travelled per time period were not significantly different from each other (t = 0.6749, df = 12, p-value > 0.05).

Sleeping sites

There were 80 trees recorded as sleeping sites for the male loris, some trees were reused so the total sleeping site count was 117. Of the reused trees, some were reused more than once, maximum reuse was four. Reuse never occurred on consecutive days. The range of sleeping height was 5–20 m. The average distance between sleeping sites (n=117) was 257.2931 m (±150.6732 m). The range was 17 m-646 m. On one occasion the loris travelled 356 m away from the southernmost sleeping site. This individual had to cross a small tributary, only spent one night and never returned to the area.

Environmental Variables

When distance between sleeping sites was predicted in the multiple regression, rainfall (t value = 6.995, p-value>0.05) and moon luminosity (t value = -1.254, p-value>0.05) were shown to be insignificant factors. The overall model fit was adjusted R^2 = -0.01764.

The most common height when the moon was 0 was: 10-15 m, 1 was: 0-5 m, 2 were: 10-15 m, 3 was: 0-5 m and 15-20 m and 4 was: 10-15 m (Table 1). The variation in height when the moon was 0 was significantly different from the variation when the moon was 1 (p-value<0.0001), 2 (p-value<0.001), 3 (p-value<0.0001) and 4 (p-value<0.001). When the moon was 1, the height variation was significantly different from 2 (p-value<0.0001), 3 (p-value<0.0001) and 4 (p-value<0.0001). When the moon was 2, the variation was significantly different from 3 (p-value<0.0001) but not from 4 (p-value>0.05). When the moon was 3, the variation was significantly different from that of 4 (p-value<0.05).

Table 1: A count of height recordings during six hour tracking shifts of a slow loris (Nycticebus menagensis) in Malaysian Borneo. Height was recorded every 15 minutes if there was a visual of the animal. Each moon category represents a range of moon luminosity (0 = 0%, 1 = 0.1-24.9%, 2 = 25-49.9%, 3 = 50-74.9% and 4 = 75-100%)

Moon Category	Height Range (m)				
	0-5	5-10	10-15	15-20	20-25
0	0	0	11	2	0
1	19	2	5	4	1
2	6	4	13	6	3
3	22	11	16	22	1
4	10	8	13	10	9

Tree Species

Eleven sleeping tree species were identified and species identification was successful for 48 of the total 80 trees. *Pterospermum diversifolium* was the most common tree species (used 24 times), followed by *Mallotus muticus* (used 13 times), then *Colona serratifolia* (used 12 times). Eight other species were also used but in fewer instances than the three species aforementioned (Figure 3). Tree species did not significantly affect sleeping site choice (p-value>0.05).

There was significant difference between the number of species used for sleeping sites and for activity at night (p-value<0.0001). *Planchonia valida* was the most common tree species used at night whilst there were only two *P. valida* sleeping trees; all the species noted for activity were also used as sleeping trees (Figure 4).
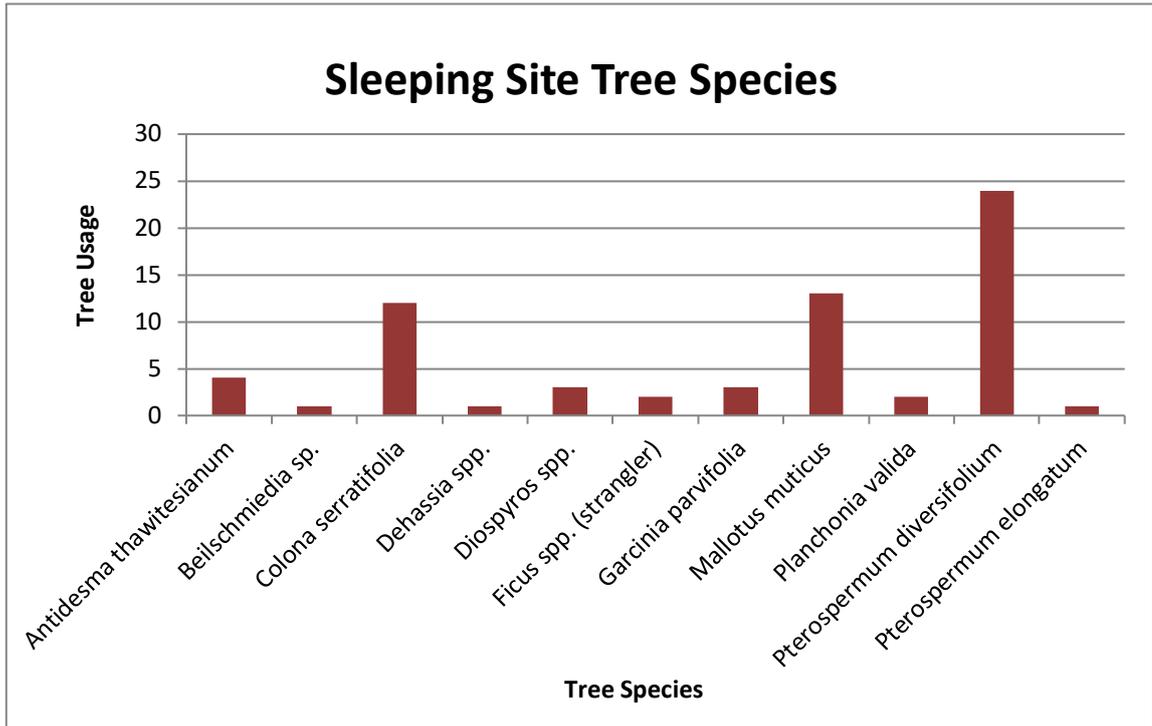
Figure 4: The variation of tree species used by a male slow loris (*Nycticebus menagensis*) in Malaysian Borneo for sleeping sites and how many times each species was used for a sleeping site.
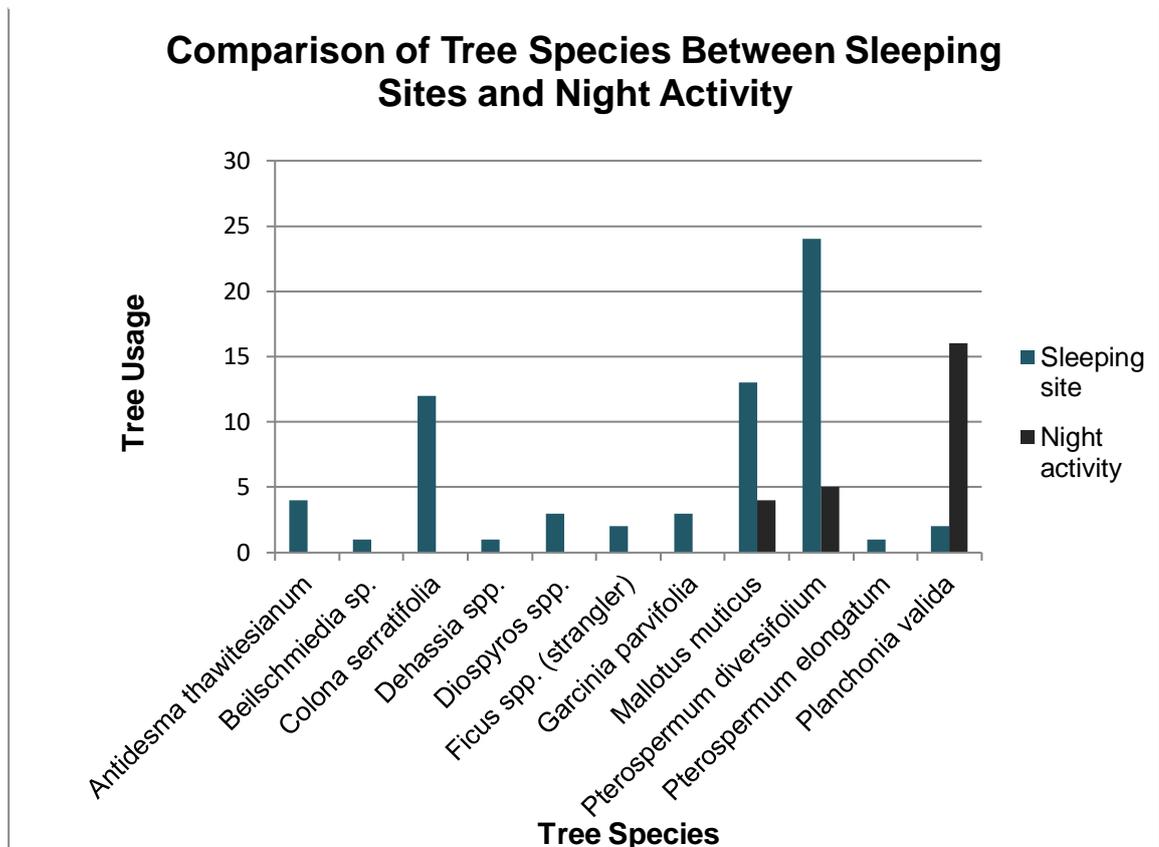

Figure 3: Comparison between the number of times a particular tree species was used by a male slow loris (*Nycticebus menagensis*) in a Malaysian Bornean rainforest. The comparison is between sleeping site trees and trees that were used for longer than 15 minutes at night. The variation in sleeping site tree species was significantly different from trees used during the night (p-value<0.0001).

Discussion

The density for *N. menagensis* was calculated to be 8.93 ind. km^{-2}, this does not compare well to encounter rate estimates of other slow lorises (*N. coucang*: 0.66-0.74 ind. km^{-1}; *N. bengalensis*: 0.10–0.13 ind. km^{-1}; *N. pygmaeus*: 0.05–0.08 ind. km^{-1} (Nekaris *et al.* 2007)) nor to the estimate for *N. menagensis*: 0.12 ind. km^{-1} (Nekaris and Nijman 2007) as the study did not express the results as densities. However, if the results from the current study were expressed in the same way, the value would be 0.26 ind. km^{1}. The encounter rate for *N. menagensis* was devised by combining the rates from a disturbed (Sebangau, Indonesia), 0.2 ind. km^{-1}, and primary (Danum, Malaysia), 0.02 ind. km^{-1}, rainforest (Nekaris and Nijman 2007). The published encounter rate for *N. menagensis* in DGFC is 0.12 ind. km^{-1} (Munds *et al.* 2013), although the encounter rate from this study is greater, it still supports the idea that encounter rates for *N. menagensis* are greater in secondary forest. Rainforest tree diversity around the world is shifting in response to forest fragmentation and other anthropogenic factors (Wright 2005). Secondary/disturbed forest is different to primary forest, trees are generally shorter and there are fewer species. Increased liana growth is common in secondary forests (Schnitzer and Bongers 2011), lorises use lianas and other vines to move therefore *N. menagensis* populations may be greater in secondary forest due to the habitat being more suitable. This proposed explanation suggests that loris species could positively adapt their home range use to altered landscapes. On the other hand it may suggest that lorises are just easier to detect in secondary rainforest due to poorer quality forest. This explanation would be supported by Nekaris and Jayewardene's (2004) finding that detection of lorises in primary forest is low.

There are limitations to distance sampling as it has many assumptions, including: all individuals are detected; there is an adequate sample size; transects are randomly chosen; trails and transects are not reused (Buckland et al. 2001). The current study violated some of these assumptions but this probably did not affect the results as the assumption mentioned first was unlikely to have been violated. This is because the transects covered multiple habitats and the researchers were trained enough to spot every individual loris on, or close to, the transect. The speed that the transects were walked was within the optimal range proposed by Nekaris *et al.* (2014) so individuals would not have been missed.

Home range estimates for all species of *Nycticebus* are incomplete, *N. menagensis* has no published home range estimate and even published estimates for other species show intra-species variation only dependent on habitat type (Wiens and Zitzmann 2003b). In this study, the home range of the male was estimated to be 0.09151 km^2, this is larger than the unpublished estimation for a female in the same area (Wilson 2014), which was 0.04880 km^2. This does not support the findings from Wiens and Zitzmann (2003b) who suggested that for *N. coucang*, male home ranges are not significantly larger than female home ranges. There is however, a significant difference in home range size due to sex for slender lorises (Nekaris and Jayewardene 2004), the results from the current study are in support of this, regardless of the fact that the study species are different, generalisations are justified as slender lorises are also nocturnal and solitary. Therefore, sex could be a determinant of home range use for *N. menagensis*.

The reason for the difference in home range size between males and females of *N. menagensis* could be because of the species' life strategy. *N. menagensis* is a solitary species, therefore, territory must play a more important part than it does in gregarious species; chances for mating are rarer in solitary species because time spent with conspecifics is low (highlighted by the results in the current study), so, to ensure successful mating, a male must be in close proximity to a female and must maintain this proximity. This could be done by defending territory which encompasses multiple female ranges. The male in this study was believed to participate in territorial defence when he fought with another male, also note that this occurred near the female encounter location.

Overlap with multiple females is likely to be the cause of a larger home range in this species, especially considering that the individual in this study was observed interacting with two different females. These were observed at opposite ends of the male's home range. The areas where the females were observed were where the male spent most of his time, one social interaction occurred in his core range. He must also span enough land to obtain sufficient food resources so as to avoid competition with prospective mates. Food is a driver of home range variation (Nelson 1995) and therefore, it is, along with female defence, a plausible factor influencing home range use in *N. menagensis*.

Behaviour was significantly different between the two night shifts indicating that spatial use of the home range could change temporally. Separately, resting and vigilance showed variation in percentage activity budget allocation between the

shifts. Collectively, resting and vigilance garnered 7% and 9% of the activity budget during the early and late shift respectively, this is different from the percentage of rest and vigilance calculated for the activity budget in Mysore slender lorises, Loris tardigradus lydekkerianus, for this species Nekaris (2001) gives a value of 45%. This is substantially higher than the value given for this study as the 12 hours where the animals are asleep is included in the budget. Should this be done in the current study, the value would be approximately 66%, which is still substantially greater than 45%.

Studying behaviour also shows how the animal uses its home range in terms of feeding, and also allows prediction of future use by understanding feeding requirements (Bitetti 2001). The loris in this study spent 15% of its time eating in the early shift compared to 6% in the late shift, this was a significant difference. Eating occurred soon after awakening, the probable reason for this is that the loris was low on energy after fasting for 12 hours. Eating early in the night frees the latter hours for other activities.

The animal dedicated roughly half of its activity budget to movement, this is consistent with other species of loris, *Loris tardigradus lydekkerianus*, (Nekaris 2001). There was no significant difference between the average distances travelled during the shifts; this reflects the similar movement percentage. However, the slow loris moved slightly more in the late tracking shift than in the early shift, this could be due to the act of pursuing a sleeping site. Sleeping site choice is an important determinant of home range use in other primate species, such as baboons (Altmann 1974; Hamilton 1982; Anderson 1984; Bitetti 2001) which the current study supports.

Change in moon luminosity is a factor affecting spatial use patterns but, in the case of *N. menagensis*, the results seem to suggest lunar neutrality. Activity, or distance between sleeping sites, was not significantly greater or lower on nights with a full moon. This was also the conclusion achieved by Wilson (2014). How moonlight affects *N. menagensis* is akin to *N. javaniscus* (Nekaris et al. 2014). This is in contrast to *N. pygmaeus* (lunar philic) (Starr *et al*. 2012) and *N. bengalensis* (lunar phobic) (Rogers and Nekaris 2011). This is surprising, *N. menagensis* is one of the more insectivorous slow lorises (Ravosa 1998) which suggest that they could be more like tarsiers; tarsiers have to rely heavily on their site to catch prey (MacKinnon and MacKinnon 1980; Jablonski and Crompton 1994) so they are lunar philic as the increased light aids hunting (Gursky 2003). Perhaps *N. menagensis* has an increased predation risk in the study area and therefore, the trade-off between

increased food intake and likeliness of predation is not worth it. However, this would be more realistic if the species was lunar phobic (Rogers and Nekaris 2011). The *tapetum lucidum* could disprove this explanation as it helps the lorises see efficiently in low light conditions (Ollivier *et al.* 2004) therefore, extra moonlight is not as necessary for increased food intake as it is for tarsiers. Slow lorises also have a varied diet, eating plant exudates as well (Wiens 2002; Wiens and Zitzmann 2003a; Wiens and Zitzmann 2003b), this means that if insect populations are low, the animals will not struggle to feed. Applying this to the current study, it can be said that *N. menagensis* individuals may eat more plant material when the moon is darker, and then eat more insects when the moon is bright, moving the same amount for each activity. This would make it seem like there is no change in activity due to moon luminosity when in actual fact there could be; only it would be in terms of behaviour differences rather than distance travelled.

The method of collecting spatial movement data does have a flaw, GPS points do not take into account the distance the animal covers in a tree when changing height. Conclusions drawn based on distance between sleeping sites as a measure of activity, should be tentative. Slow lorises do not move on a flat plane and although height was measured, the exact distance incurred via movement in the same tree was not recorded. Change in moon luminosity could affect how the animal uses a tree. When the moon is bright, the individual may spend less time at the top of trees to avoid predation or may spend more time as the area will be lighter and the chance of catching prey increases. If height is dependent on moon luminosity, the conclusion that the species, or at the very least *N. menagensis* individuals in secondary forest, are lunar philic or phobic can be drawn. The results from the current study instead suggest that the species may be lunar philic, which fits with notion of being more insectivorous and thus relying more on eyesight. The male slow loris was observed significantly higher when the moon was 3 (50-74.9%) and 4 (75-100%) than when the moon was 1 (0.1-24.9%). Two-dimensional distance doesn't change with moonlight whereas tree use does change. The difference in conclusions based on moonlight in this study show how different methodologies can alter results, even within the same study, therefore, comparisons made between nocturnal primate moonlight studies should be taken lightly as several different methods are used to obtain the results (Nekaris *et al.* 2014).

In a place where the average annual rainfall is 3000 mm and periodically subjected to a monsoon season (Ancrenaz et al. 2004), changes in home range use due to rainfall would not surprise. However, the current study showed no effect of rainfall on *N.*

menagensis spatial use patterns. Realistically there is likely to be an effect but the study on this individual male began as the wet season was coming to an end. Therefore, all the data was from the dry season, it could be said that if the study occurred over both seasons, an effect may have been observed. In this case, the lack of effect shows that there is no weekly effect of rainfall. Instead, it is probable that rainfall affects home range use of the slow lorises on a seasonal level. Other species of primates are affected by seasonal variation (Li *et al*. 2000; Gerber *et al*. 2015) so this conclusion is not outrageous.

Pterospermum diversifolium (family Sterculiaceae) was selected most commonly for sleeping sites. *Mallotus muticus* (family Euphorbiaceae) and *Colona serratifolia* (family Malvaceae) were also common. These species are common along the Kinabatangan (Boonratana 2003; Matsuda 2008) which could explain the greater selection. However, the trees are tall and have a dense canopy; *P. diversifolium* has broad leaves, *M. muticus* has substantial liana growth in the canopy and *C. serratifolia* has small leaves in great abundance (personal observations), these factors make the trees suitable as sleeping sites because the loris will be protected from predation (Wiens 2002) whilst also having sufficient material to hold on to. Results showed that tree species did not affect sleeping site choice for the male loris. However, this is unlikely because tree species is been shown to affect sleeping site choice in other primates (Bitetti 2001; Fan and Jiang 2008). The explanation for non-significance here is possibly due to the method, analysis only included sleeping site species, and it did not include neutral species. If sleeping tree species were compared to randomly chosen, non-sleeping site trees, a difference in species composition is likely. This would then state that tree species affects sleeping site selection.

There was a statistical significance between the tree species used for sleeping sites and for activity, supporting the idea that tree species affects home range use (Bitetti 2001). The male loris was observed most frequently in *Planchonia valida*. *P. valida* is a tall tree, growing to 50 m in some places, has an open canopy, plentiful frit and exudes gum (Soepadmo *et al*. 2002). As lorises have been noted to eat gum, it is not surprising that *P. valida* is the most visited tree. Only two sleeping site trees were identified as *P. valida* therefore, *N. menagensis* probably chooses sleeping sites based on the physical characteristics of the sleeping site, rather than for its ability to provide fruit soon after awakening. Future research into sleeping site distribution around *P. valida* trees would examine whether the species chooses sleeping sites based on the combined effect of physical characteristics and proximity to resources.

Conclusion

Slow lorises are interesting to the field of primatology as they are the only venomous primate but they are understudied, and *N. menagensis* is possibly the most understudied of all the slow loris species. This study aimed to improve the knowledge of this species, in terms of behaviour, activity budget, sleeping site selection, home range use and the ability to adapt to a changing environment. Habitat type, sex, moonlight, tree species and food availability all affect the home range use of male N. menagensis. The current study is limited by a small sample size but the study was successful in expanding the understanding of N. menagensis. A greater study effort in the future will greatly improve management of habitats that are key to loris survival.

Acknowledgements

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Reflection

I cannot fault my overall experience at DGFC, the opportunity is a rare one and I will never regret spending a year of my life in Borneo. I was allowed to devise a project on my own, luckily a project was already set up and I opted in for one following tarsiers. Even though it was an established project, I was still allowed to be independent, deciding what I actually wanted to look at. Unfortunately, the tarsier project did not work out; my subjects kept dying, or went missing. It was getting late in the year and I hadn't really collected a proportionate amount of data therefore, I switched to slow lorises because the capture rate was successful. This is why my project only started in January. However, I had a complete years' worth of nocturnal primate training, so apart from a smaller data collection period than most, I do not feel that I lost out on any education.

During my time at DGFC, and under my project, I developed skills in radio telemetry, distance sampling and animal collaring. I was also able to grow as a person because the data collection conditions were tough, especially with the 6 hour nocturnal shifts. I really believe that they were beneficial for my development as it taught me that I can handle tough conditions in future.

I was also able to participate in other projects so I also developed skills in camera trapping, parasite analysis (using McMaster method) and botanical plots. My employee skills also developed; I can now more successfully work in a close environment and part of a team. I also gained communication skills through running field courses and giving presentations about my project regularly. I believe that is invaluable and I am extremely happy that I had to give presentations. My presentation skills have increased dramatically.

Living at DG was great, I was looked after, fed really well and living costs were low. The local staff were wonderful and they became like family members. In the interview Benoit Goossens said that DG is like a family and what he said is very true. Doing your PTY year with fellow Cardiff PTY students was also great. DG was also really good in the sense that you could make many work contacts, through the numerous field courses, even lecturers and Professors from Cardiff University. This is another invaluable thing provided by DGFC. My year at DG has helped me to be a better employee and has really focused my mind on what I want to do, and what I can expect from a career in scientific research.