

Establishing the home range, behavioural ecology and habitat use of the Bornean tarsier (*Tarsius bancanus borneanus*).



Alice Miles

B.Sc. Zoology

Dr. Benoît Goossens

Danau Girang Field Centre

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Abstract

Information regarding the Bornean tarsier is outdated by more than 20 years. During this time, much of the land in Sabah, Borneo where this study took place, has been converted for agriculture, mainly palm oil. The spectral tarsier (*Tarsius spectrum*) is the only species of tarsier to date to show seasonal variation in home range size. Changes in home range size indicate that species are able to adapt to their surroundings. We investigated whether the Bornean tarsier (*Tarsius bancanus borneanus*) home range size is influenced by seasonal changes, as well as updating our knowledge on aspects of their behavioural and social ecology. The study was conducted from February 2012 to the beginning of July 2012, following two adult female tarsiers of which one had an infant. The tarsiers inhabited different habitats; semi inundated and mixed riparian. GPS points and observations of the animals were taken while tracking during the night and locating their sleeping sites during the day. These points were used to establish the home ranges of the two females, 6.51 ha and 5.48 ha. The sizes were similar to the last home range study conducted on this species, however the method used may overestimate size and other models may give a better representation of what factors affect their home range. We found no significant difference between distance travelled and rainfall, suggesting home range is not affected by seasonality. However, we suggest a longer study period may produce more reliable results. We also observed a new behaviour, believed not to have been seen in wild tarsiers before and only documented in one other free ranging primate. A longer study and more behavioural observations are needed to ascertain how Bornean tarsiers are surviving in decreasing habitats.

Introduction

Understanding an animal's home range gives us an insight in to the relationship an animal has with its habitat. Home range is commonly referred to as 'the area traversed by the individual in its normal activities of food gathering, mating and caring for young' (Burt, 1943). Previous studies have shown that home ranges are influenced by a number of environmental, behavioural and climatic factors (Sylviane *et al.*, 2011). Studies on species of primates found body size (Milton & May, 1976; Lehman *et al.*, 2007), group size (Takasaki, 1981) and seasonality (Anderson, 1981; Sylviane *et al.*, 2011) all affected how animals responded to their environment, thus affecting the size

of home ranges. Home ranges studies have helped to see if animals are able to adapt to changes in their surroundings (Nugent, 1994) and whether the environment is meeting an animal's requirements (Perry & Garland, 2002). This information can be used to evaluate their habitat and help conservation planning (Li *et al.*, 2000), making home ranging an important aspect to understand.

Most animals are difficult to observe, mostly small mammals which are often nocturnal and arboreal (Wiens & Zitzmann, 2003). These difficulties contribute to the lack of information on Southeast Asian nocturnal primates (Duckworth, 1994; Gursky, 1998; Merker & Muhlenberg, 2000). Recent advances in technology however, has made estimating animals' home ranges a lot easier by, using the combination of very high frequency (VHF) radio telemetry, GPS locations and mapping programs (Kie *et al.*, 2010; Mitchell & Powell, 2008). Although there are limitations when using VHF technology, such as it being weather dependent, it can quickly help quantify an animal's use of space easily and reliably (Kie *et al.*, 2010). Often mammals are too small for GPS technology to be used, thus VHF is the only option to gain location data. This method has been used for many different species of small mammal, including the nocturnal primate, the tarsier.

Tarsiers are found throughout Southeast Asia and nine species make up the genus *Tarsius* (*T. bancanus*, *T. dentatus*, *T. lariang*, *T. pelengensis*, *T. pumilus*, *T. sangirensis*, *T. syrichta*, *T. tarsier*, *T. tumpara*) (Gursky, 2007; Shekelle *et al.*, 2008). They are small, nocturnal primates weighing between 67-153 g with a fur colour ranging from grey to pale yellow (Niemitz 1979; 1984) and both weight and pelage vary between different populations. Their head and body lengths range from 10 – 15 cm and they have a relatively long tail (20-25 cm long), which is usually twice the length of the body (Niemitz, 1984). The tuft of hair at the end of the tail also varies between species; it is either lacking in some species or very hairy in others (Musser & Dagosto, 1987; Gursky, 2007). They have huge eyes that lack a reflective tissue (*tapetum lucidum*) behind the retina, thus resulting in them having no eye shine (Schwartz, 2003). The focal species of this project is the Bornean tarsier (*T. bancanus borneanus*), one of four sub-species of the Western tarsier (*T. bancanus*) and is found in Sabah, Sarawak, Brunei and Kalimantan on the island of Borneo (Brandon-Jones *et al.*, 2004).

The Bornean tarsier moves through primary and secondary forest by vertically leaping and clinging through the undergrowth, reaching distances of up to 3 m in one jump

(Crompton *et al.*, 2010). They are usually found below the heights of 11 m, with a median height of 1 m (Niemitz, 1979). Tarsiers are faunivores, eating only prey they kill themselves, and are completely carnivorous. They are considered insectivores, but some species include reptiles and amphibians in their diet and some species have been observed preying on small mammals and sleeping birds (Niemitz, 1979; Crompton & Andau, 1987; Gursky, 2007). There is much variation between all of the species of tarsiers regarding social and mating systems, however it is reported that, unlike for example the spectral tarsier (*T. spectrum*) which sleeps in groups, the Bornean tarsier is solitary; foraging and sleeping alone (Crompton & Andau, 1987). Thus to communicate with other individuals they use scent markings and vocalizations. Similarly to other species of tarsier they give birth to a single offspring after a gestation period of 6 months (Izard *et al.*, 1985; Roberts, 1994). The infant is born with the ability to cling to small branches and reaches nutritional independence after 80 days (Roberts, 1994).

Most tarsier species have healthy populations (Merker & Mühlenberg, 2000; Shekelle & Salim, 2009) but this is unknown for the Bornean tarsier. It is classified as 'Vulnerable' on the International Union for Conservation of Nature (IUCN) Red List (2008) due to population reduction as a result of habitat loss, as well as the illegal pet trade. Furthermore, data regarding this species is insufficient. Many studies focus only on the behavioural aspects of tarsiers in Malaysian Borneo (Fogden, 1974; Niemitz, 1979, 1984; Crompton & Andau, 1987) and although they include home range size (Crompton & Andau, 1987), these studies are outdated by more than 20 years. Short population studies have been conducted in Borneo more recently and found that the Bornean tarsier is in low abundance: 0.07 tarsiers/km in Central Kalimantan, Indonesian Borneo (Blackham, 2005) and 0.06 tarsiers/km in Sabah, Malaysian Borneo (Munds, 2010). Although population data is important, Mühlenberg (1993) states that home range information may be of more use than density estimates, as abundance alone may not necessarily reflect the suitability of the habitat.

Research conducted on home ranges of other tarsier species show that they can also be affected by the season and the habitat itself (Gursky, 2000; Merker *et al.*, 2005 respectively). Gursky (2000) observed seasonal differences on spectral tarsiers in Sulawesi, Indonesia. Her findings showed that foraging and distance travelled increased during the dry season when insects were less abundant and decreased during

the wet season, as insects were more abundant. Merker and Mühlenberg (2005) also found that the quality of habitat also plays a role in tarsier home ranging.

South East Asia has one of the highest rates of deforestation in the world (Sodhi *et al.*, 2010). Between the 1950s and 1990s the Northern region of Borneo, Eastern Sabah was subjected to both commercial and illegal logging. Over the last 20 years this has led to the region being largely converted into palm oil plantations (McMorrow & Talip, 2001). This has consequently left the remaining forest areas largely fragmented and in some cases, isolated. It has already had negative impacts on many species of Borneo, including one of the flagship species; the Bornean orangutan (*Pongo pygmaeus*) (Goossens *et al.*, 2005; Goossens *et al.*, 2006). The Lower Kinabatangan Wildlife Sanctuary (LKWS) in Sabah, Borneo (Fig.1) is a classic example of the result of logging. Fragmented forest patches of various degradation, form a ‘corridor’ connecting coastal mangrove forests, to dry forests up the Kinabatangan River (Goossens *et al.*, 2005). The Bornean tarsier inhabits this area, but during these last two decades of land conversion, research on the Bornean tarsier has been lacking.

Field studies involving behavioural ecology and home range data are needed to ascertain how wild populations of the Bornean tarsier are surviving in decreasing habitats. The aim of this study is to update our knowledge on tarsier home ranging and basic behaviour, by radio-collaring and tracking animals in two different habitats. This is in order to (1) establish their home ranges and find out whether they are seasonally influenced, (2) record sleeping site preferences and (3) collect and analyse data on their general behaviour. Comparisons between tarsiers in different habitats will also be made. It is predicted that the home range size will increase during the dry season due to increased foraging for food, assuming that insect abundance decreases during this period. It is also predicted that the animals are solitary and their sleeping and foraging behaviours may vary between habitats.

This study will not only update our knowledge on these primates, but also determine whether these animals are naturally found in low abundance due to possible large home ranges, or whether they are seriously affected by anthropological threats; such as human encroachment and habitat destruction.

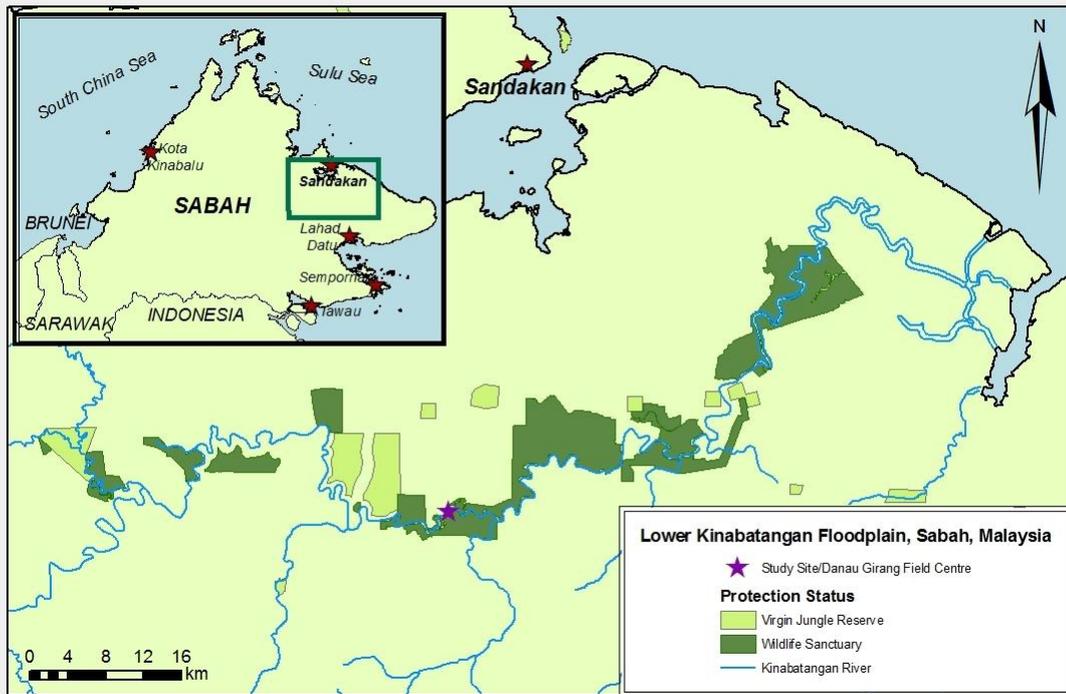


Fig. 1: Map showing the Lower Kinabatangan Wildlife Sanctuary (LKWS) along the Kinabatangan River. Inner map shows the location of the study region in Eastern Sabah, Malaysian Borneo. Map courtesy of Danica Stark.

Materials and methods

Study site

The study was conducted around Danau Girang Field Centre (DGFC) between February and the beginning of July 2012. DGFC is situated in Lot 6 of the Lower Kinabatangan Wildlife Sanctuary (LKWS) which stretches along the 560km long Kinabatangan River located in Northern Borneo, Sabah, Malaysia ($5^{\circ}10' - 5^{\circ}50'N$; $117^{\circ}40' - 118^{\circ}30'E$) (Fig. 1).

Tarsiers have been confirmed in the forest surrounding the centre (Munds, 2010), which is comprised of two habitat types; seasonally inundated and mixed riparian.

The climate is hot, wet and warm with humidity above 90 % with a mean annual precipitation between 2500-3500mm (Ancrenaz *et al.*, 2004). The wet season occurs between November and March (Scott, 1989).

Surveys

To locate and catch the tarsiers, surveys were conducted along the existing trails (Fig. 2) around DGFC to avoid causing further disturbance by cutting new trails. A marked distance of 1km was walked at a slow pace by at least two people for safety purposes

and a maximum of three people to keep noise at a minimum. The trails walked and times of the surveys alternated, starting between 8 pm and 2 am, when tarsiers are active. Surveys were cancelled when there was heavy rain due to the difficulties in spotting the animals and for safety purposes. To locate the tarsiers, we used white light to detect the ‘dull red glare’ of the tarsiers’ eyes (Munds, 2010; personal obs.). Once observed, the following data was recorded; a GPS point of their location, behaviour of animal upon detection, weather, height of animal and the tree the animal was in was flagged.

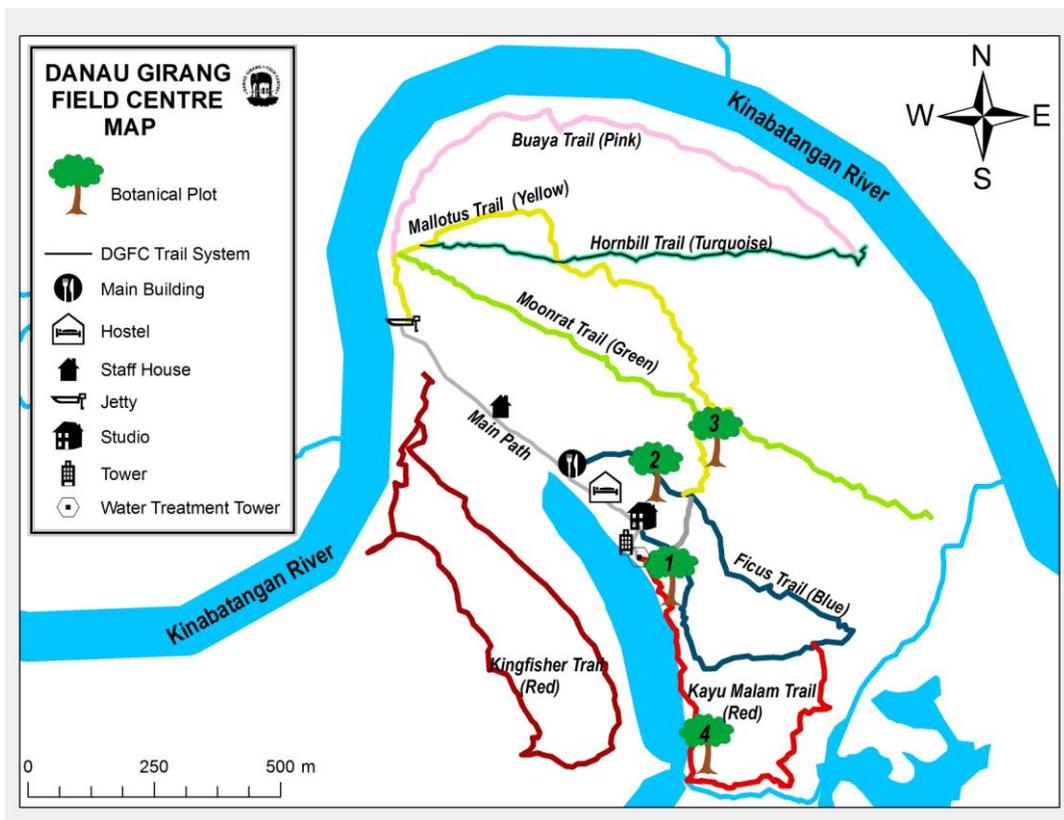


Fig. 2. Map of the trail system around Danau Girang Field Centre.

Collaring

If a tarsier was found at a height within reach, they were caught by hand with a heavy duty glove to avoid bites. The Ethical guidelines for the ‘trapping and handling of animals’ was followed.

The tarsiers were transported in a light material mammal bag back to the centre’s lab. Here they were fitted with a small radio collar, provided by ‘Biotrack Ltd’ which weighed less than 8 % of the animals’ body weight. A selection of morphological measurements were noted (Table. 1), as well notching the ear. This was for

identification purposes if the collar came off and also for a tissue sample. Faecal samples were also taken and both samples were kept apart in ethanol. Red light was used throughout this process to avoid further stress to the animal. Afterwards, the tarsier was returned back to the tree it was found on and left for a few days to allow them to settle.

Head length (mm)
Head breadth (mm)
Ear height (mm)
Neck circumference (mm)
Hand span (mm)
Arm length (mm)
Hind limb length (mm)
Foot span (mm)
Testes width if applicable (mm)
Body length (mm)
Tail length (mm)
Tail tuft length (mm)

Table 1: Morphological measurements taken of each tarsier.

Sleeping sites

During the day, tarsiers were located using the VHF receiver (Telonics) to establish their sleeping trees. The tree they were on was approached slowly and quietly to avoid disturbing the animal. The tree was numbered by using biodegradable coloured tape and a GPS point was taken. Trees which were within close proximity to one another, or were within the same tree fall, were considered a 'site'. Grouping the trees in to sites would allow a better representation of trees to be selected for habitat analysis and not to be grouped in one area. The height the animal was sleeping was also recorded, as well as any other information e.g. whether it was sleeping with another individual.

Habitat analysis

Ten trees were randomly selected from those identified as sleeping sites for each tarsier. Ten trees which the tarsiers were never observed sleeping on were also selected; these trees were named 'neutral' trees. Neutral trees were selected by creating minimum convex polygons in ArcGIS, which excluded the areas containing the sleeping trees, as well as a 10 m radius around each. Ten GPS points were then generated and the tree nearest to that point was chosen as a neutral tree. This was

done for each tarsier. Following the methodology of Munds (2010), a 5 m radius around the ten sleeping and ten neutral trees was set up. The species of the sleeping tree was identified and the diameter at breast height (DBH) and height of all the trees (taller than an estimated 1 m) in the plot was recorded. In each plot, a picture of the canopy was taken which could be analysed using Image J software to work out the canopy density.

Tracking

The tarsiers were also tracked during the night which was divided in to three hour periods over four successive nights (6 pm–9 pm, 9 pm–12 am, 12 am–3 am and 3 am–6 am), so as to cover one full night. This was considered a ‘cycle’ and was repeated with a day off in between, allowing the animal a night off from any human disturbance. Occasionally, tracking had to be cancelled due to rain or lightning for safety purposes. If this were to happen, the tracking would be pushed back a night. The tarsiers were followed from a minimum distance of 5 m; close enough to observe the animal, but avoiding causing it any interruptions or affecting natural behaviour. This was not possible at all times, as when searching for the tarsiers in dense vegetation they were hard to spot. Red light or head torches covered with a red filter were used during observations to aid observing natural behaviour and to prevent damaging the tarsiers’ eyes.

Every 15 minutes the height, behaviour (see Table 2) and location of the animal were recorded. The height was estimated to the nearest 0.5 of a metre using markers on our bodies to aid, and a Garmin GPS was used to record the animals’ position.

Behaviour	Definition
Resting	Animal is not moving with head upright and ears still. Eyes may be closed.
Foraging	Head is directed downward searching for prey. Ears moving, actively listening for prey.
Eating	Actively eating prey.
Grooming	Cleaning body and tail with tongue or hands.
Other	Involves scent marking, vocalising or any behaviour which cannot be classed as those above.

Table 2: Behaviours recognised during tracking observations and their definitions.

Statistical analysis

Home range and seasonal influences

GPS points collected during tracking and sleeping site identification, were used to generate minimum convex polygons (MCPs) in ArcGIS to estimate the home range size of the tarsiers. The data was abnormal and transformations proved unsuccessful, thus Spearman's rank correlation analysis was used to test for a correlation between the distances travelled during tracking sessions and rainfall.

Sleeping site preference

Firstly, 10 sleeping trees were selected from each tarsier and compared. The Anderson Darling test was used to test for normality for sleeping heights ($P = <0.005$), DBH ($P = <0.005$) and tree height ($P = 0.553$). The non-parametric test Wilcoxon's Rank sum test was used to test for variation in the sleeping heights and DBH, whereas a student t test was used to test for variation in tree height, after a log transformation.

Next, the ten sleeping plots and ten neutral plots of each tarsier subjected to habitat analysis were compared. The vegetation data was tested for normality using the Anderson Darling test and found to abnormal ($P = <0.005$), thus non parametric tests were used. The Kruskal Wallis analysis of variance was used to test for variance between the sleeping and neutral plots of tarsiers. Wilcoxon's Rank sum test was used to test between two groups.

A Generalised Linear Model (GLM) was used to incorporate both habitat and climatic factors to see whether one factor influenced sleeping site selection more than others. Although it was found that some factors did have a significant effect on sleeping site selection e.g. moon phase vs distance from river, the data was abnormal and transformations proved unsuccessful (See Appendix I).

All tests were run in Minitab with a 95% confidence level.

Results

Surveys and collarings

The surveys mounted to a total survey effort of 7.47 km. Only two adult female tarsiers were spotted throughout the surveys, approximately 690 m apart, but both were caught by hand and fitted with a radio collar. Female 1 was 119 g, captured in a

riparian forest habitat and Female 2 weighed 150 g and was pregnant at the time. She inhabited a more semi inundated forest. Table 3 shows a summary of some of the morphological measurements and capture data taken for both of the tarsiers.

Animal	Weight (g)	Height captured (m)	Date	Time
Female 1	119	1.0	02/02/2012	22:50
Recapture -	125	1.5	15/05/2012	18:00
Female 2	150 (pregnant)	1.5	08/03/2012	01:10
Recapture -	120	2.0	16/07/2012	19:00

Table 3: Capture, recapture (height, date, time) and morphological data (weight) of the two tarsiers caught at DGFC.

Sleeping sites

Female 1's sleeping site was found on 69 occasions and Female 2's on 97. Both were always found clinging to vertical trunks or branches of trees and were often positioned partially behind leaves. For both tarsiers, the sleeping trees were often clustered in small groups throughout their range and Female 1 had the majority of her sleeping sites along the river bank. (Fig.3). Female 2 (Mdn: 3.5 m) slept significantly higher during the day than Female 1, (Mdn: 2 m) $W = 2143.0, P = <0.001$.

Female 1 was found on 28 different trees, made up of 5 species, which were grouped into 14 different 'sites'. Female 2 was found on 19 different trees (16 sites), made up of 4 species, 2 species the same as Female 1. Both tarsiers returned to the majority of their sleeping sites more than three times (Female 1 maximum time on one tree: 16 (Fig. 4), Female 2: 41 (Fig. 5)).



Fig. 3. Google Earth map of sleeping site locations of Female 1 (red) and Female 2 (green).

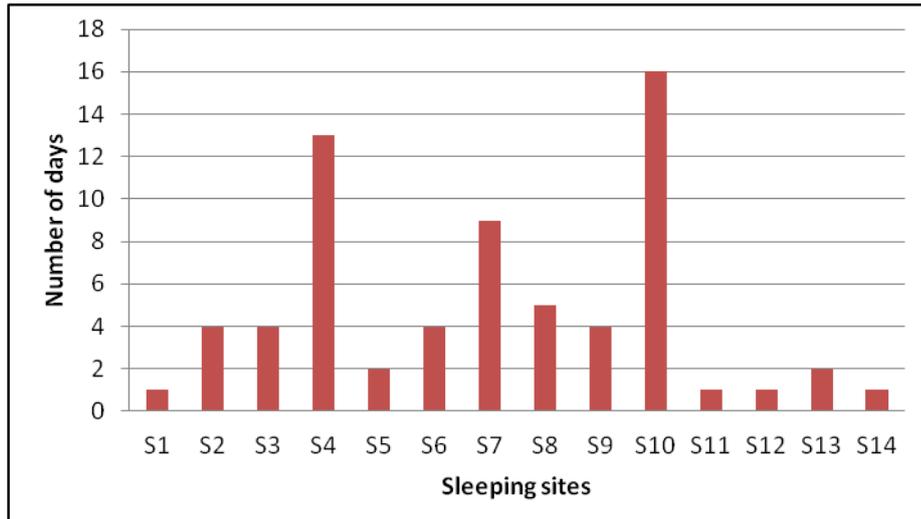


Fig. 4. Number of days Female 1 was observed on each sleeping site.

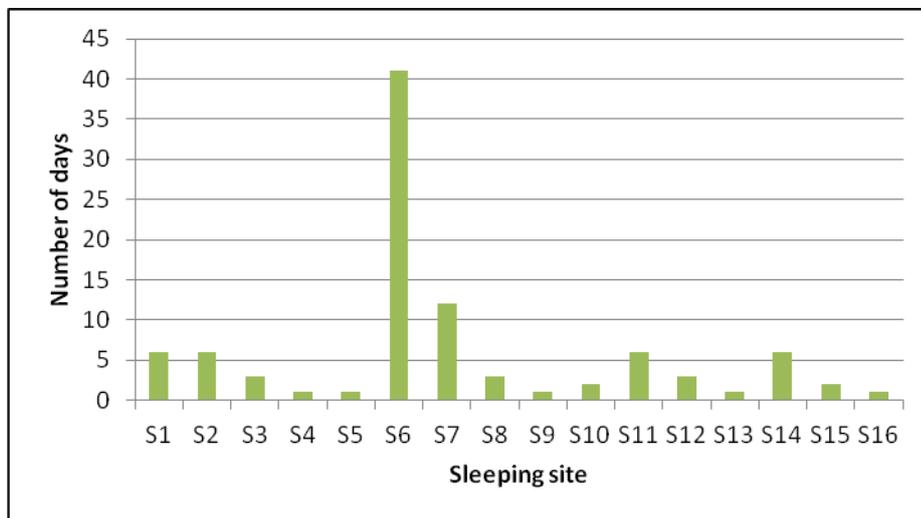


Fig. 5. Number of days Female 2 was observed on each sleeping site.

The mean height of Female 1's sleeping trees was 4.11 m and 4.82 m for Female 2, there is no significant difference between the two results ($t(18) = 1.15, P = 0.265$).

There is a significant difference between the DBH of sleeping trees of Female 1 (Median (Mdn) 3.41 cm) and Female 2 (Mdn 4.44 cm) ($W = 133.0, P = 0.04$) and also between the heights at which the two tarsiers slept (Female 1: Mdn 2 m, Female 2: 3.5 m), $W = 2143, P < 0.001$. Female 2's sleeping trees have a significantly larger DBH than the sleeping trees of Female 1's and Female 2 also slept significantly higher.

Female 1 was found to sleep alone during all diurnal observations. Female 2 however, gave birth ten days after collaring and cradled the infant during daylight hours. As the infant aged, we observed it starting to sleep separately and away from its mother (see

Table 4 for summary). A wild tarsier was also observed sleeping in a tree about 2 m away from Female 2 on one occasion.

Age of infant (days)	Sleeping observations
16	First time observed not being cradled by mother, but from here on seen both cradled and sleeping apart.
57	First time observed sleeping on a different tree to the mother, 3.5 m away.
86	First time infant was not visually observed with mother or in a nearby tree, but vocalizations could be heard from the suspected infant. The next day the infant was sleeping on the same tree as the mother.

Table 4: Sleeping observation highlights of Female 2 and her infant.

Habitat analysis

Tree height

Comparison of the four study areas showed that the tree heights between Female 1's plots (Sleeping: Mdn 3.22 m, Neutral: Mdn 3.18 m) and Female 2's plots (Sleeping: Mdn 3.08 m, Neutral: Mdn 3.55 m) differed significantly, $H(3) = 9.75, P=0.02$. Table 5 shows the results of further analyses, showing that Female 2's neutral plots had significantly taller trees than her sleeping plots.

Test	Significant/No significant difference
Female 1 sleeping vs Female 1 neutral	No significant difference ($W = 75758.5, P = 0.779$)
Female 2 sleeping vs Female 2 neutral	Significant difference ($W = 103217.5, P = 0.002$)
Female 1 sleeping vs Female 2 sleeping	No significant difference ($W = 99649.0, P = 0.492$)
Female 1 neutral vs Female 2 neutral	No significant difference ($W = 47591.5, P = 0.171$)

Table 5: Tests conducted on whether tree height significantly differed between the 4 different plots of the two tarsiers.

DBH and tree number

The four plots significantly differed by DBH (Female 1 sleeping: Mdn 2.17 cm, Female 1 neutral: 2.31 cm, Female 2 sleeping: 2.20 cm and Female 2 neutral: 1.97cm), $H(3) = 14.27, P=0.003$) and tree number (Female 1 sleeping: Mean 46.6,

Female 1 neutral: Mean 19.9, Female 2 sleeping: Mean 34.3, Female 2 neutral: Mean 30).

Test	Significant/No significant difference
Female 1 sleeping vs Female 1 neutral	DBH: Significant difference ($W = 219595.5$, $P = <0.001$) Tree number: Significant difference ($t(18) = 5.32$, $P = <0.001$)
Female 2 sleeping vs Female 2 neutral	DBH: No significant difference ($W = 228647.0$, $P = 0.117$) Tree number: No significant difference ($t(18) = 0.92$, $P = 0.185$)
Female 1 sleeping vs Female 2 sleeping	DBH: No significant difference ($W = 288232.5$, $P = 0.176$) Tree number: Significant difference ($W = 132.0$, $P = 0.044$)
Female 1 neutral vs Female 2 neutral	DBH: Significant difference ($W = 96231.0$, $p = 0.001$) Tree number: Significant difference ($t(18) = -2.15$, $p = 0.023$)

Table 6: Comparisons made between the plots of the two tarsiers and the plots themselves and whether they differed significantly

Further analyses shown in Table 6 illustrate that Female 1 had significantly more trees in her sleeping plots than her neutral plots, with significantly smaller DBHs. Female 1's sleeping plots also had significantly more trees than Female 2's sleeping plots, but there was no significant difference between their DBHs. The neutral plots of both tarsiers significantly differed in both DBH and tree number; Female 1 had less trees with significantly larger DBH.

Canopy density

There was no significant difference between Female 1's sleeping and neutral plot when comparing canopy density ($t(18) = 1.01$, $P = 0.328$) and no significant difference between the canopy density of Female 1's sleeping and Female 2's sleeping plots ($t(18) = -0.32$, $P = 0.755$). Female 2's sleeping plot had a significantly higher canopy cover than her neutral plot ($W = 132.5$, $P = 0.002$).

Tracking

Female 1 was tracked for a total of 77 hours and Female 2, 121 hours.

Primarily both tarsiers were observed to forage alone; however, both females were seen with other tarsiers. Female 1 was seen with a male tarsier on one occasion during

the night. They vocalised to each other before travelling and foraging together for 63 minutes when they moved in separate directions. Female 2 was also observed with a male tarsier on two separate occasions. On the first occasion, the male seemed to chase Female 2 until she made some loud vocalizations and the male moved away. On the second occasion, Female 2 joined the male high in a tree for no more than 10 minutes before vocalising and leaving. Suspected males were also observed in both of the Female’s ranges on a number of occasions.

Female 2 was observed to ‘park’ her offspring on small trees and saplings while she foraged close by, moving it every now and again by carrying it in her mouth. As the infant aged, we began to see it become more independent (see Table 7 for summary).

Age (days)	Observations during tracking
37	The last time the mother was observed carrying the infant
49	First time the infant is seen following the mother independently. Mother begins to return to the infant less often.
53	Last time the infant is seen suckling
63	First time the infant is seen catching prey for itself.

Table 7: Highlights of the observations between Female 2 and her infant.

Behaviour

Figures 6 and 7 show the behaviours observed of each tarsier throughout the night. Female 1 (Fig. 6) was most active at the beginning of the night between 18:00 and 21:00 which dropped in the middle of the night. She spent the majority of her time during the 21:00 to 06:00 observations resting and foraging.

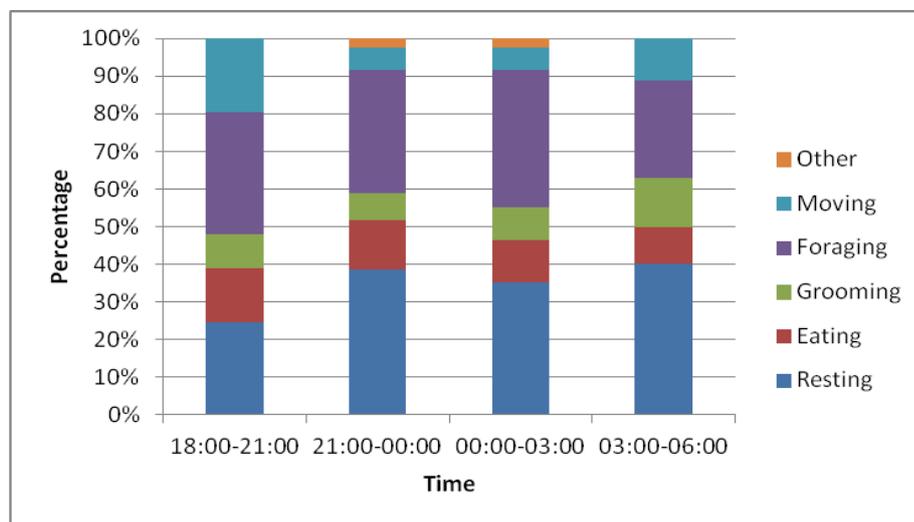


Fig. 6: Female 1 mean percentages of behaviour observed during each 3 hour segment.

Female 2 (Fig. 7) was more active at the beginning and end of the night. She was observed to rest for the majority of time (65 %) during the 21:00 to 00:00 segment. She foraged and groomed consistently throughout the night, but was observed eating the least between 21:00 and 00:00. Both tarsiers were observed eating, amphibians, reptiles and insects.

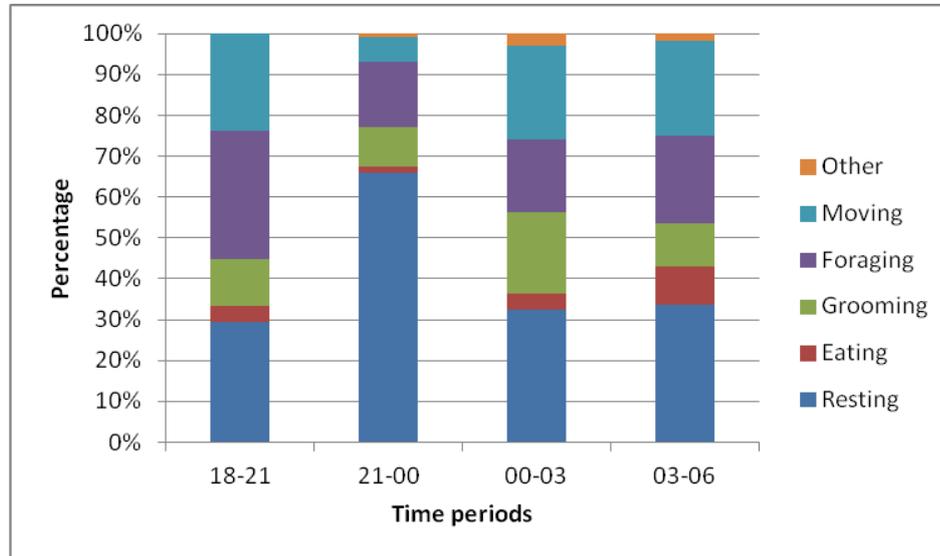


Fig. 7: Female 2 mean percentages of behaviour observed during each 3 hour segment.

New behaviour

The two collared females, as well as a wild male were all seen to perform a regurgitating like behaviour. It involved tilting their head backwards and bringing up food which they retained in their mouths and remasticated. The whole process usually lasted no longer than 10 seconds. Female 1 was first observed to perform this behaviour after 2 months of observations and Female 2, only 2 weeks. From the first observation it regularly reoccurred. Both tarsiers began to retch shortly after eating or grooming, but both were also observed regurgitating and chewing the food when eating and grooming had not been observed beforehand.

Heights observed

There is a significant difference ($W = 96577.5$, $P = <0.001$) between the mean heights of Female 1 (Mean: 1.86 m) and Female 2 (3.75 m) Further analysis of height during different hours of the night (Fig. 8) showed that Female 1 stayed between a mean height of 1.5 m and 3 m. Female 2 however, showed more of a pattern, gradually increasing in mean height at the beginning of the night before peaking to over 7 m at

10 pm. Her mean height then dropped at midnight when it began to gradually decrease towards the end of the night.

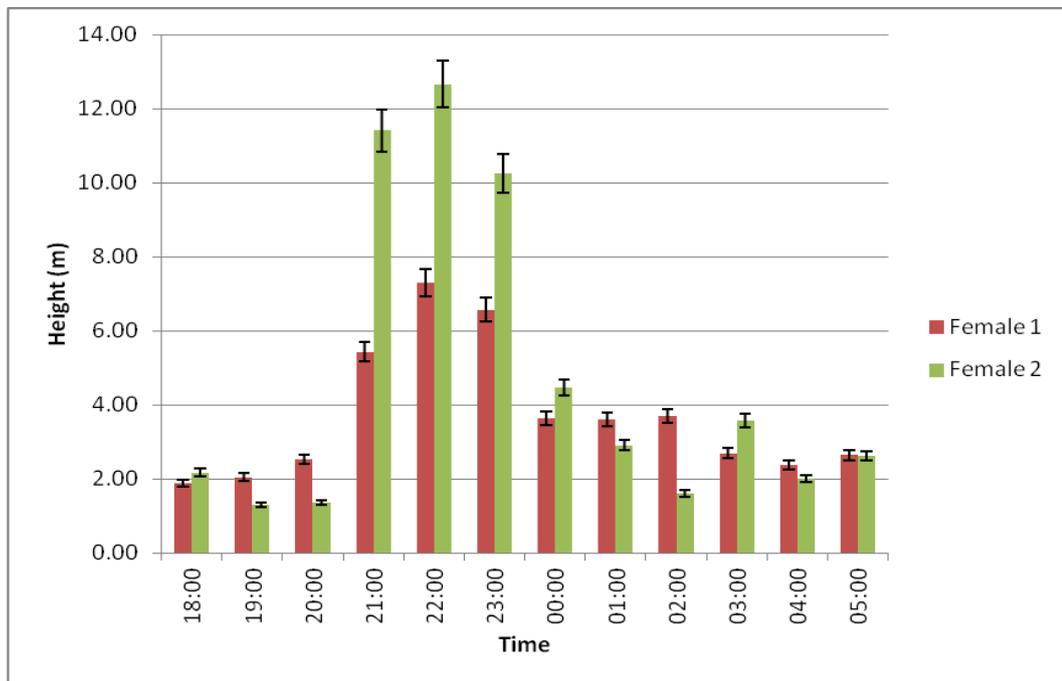


Fig. 8 Mean heights (m) of Females 1 and 2 at different hours of the night.

Distance travelled

The distance travelled over the night varied with each 3 hour segment. Figure 9 shows that both tarsiers travelled a similar distance for different periods of the night. The furthest distance travelled was at the beginning of the night. Activity decreased between 9 pm and 12 am, but increased towards the end of the night, peaking again between 3 am and 6 am.

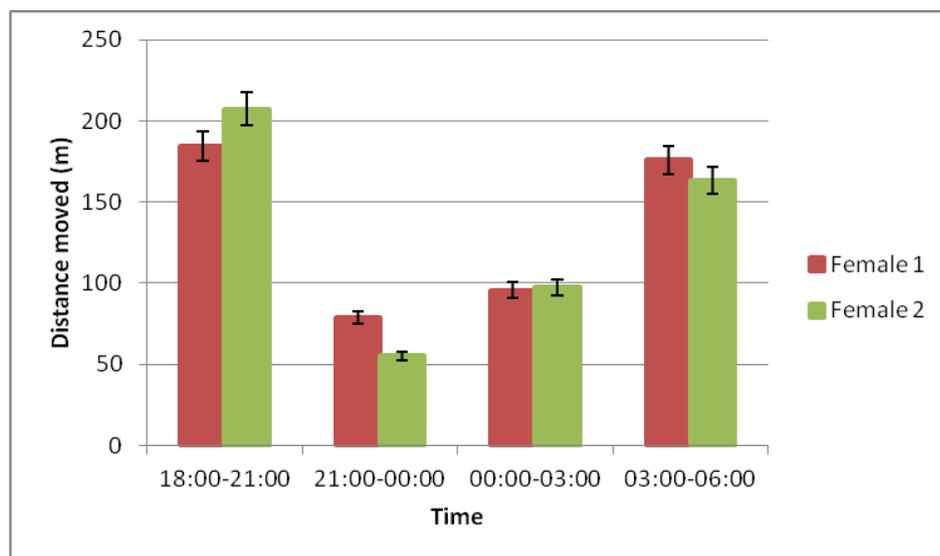


Fig. 9 Mean distance travelled (m) by Females 1 and 2 at different periods of the night.

Home range

Using sleeping site information alone, Female 1's range is 3.76 ha and Female 2's 1.11 ha. Incorporating all of the tracking and sleeping data, the total home range sizes of the tarsiers are of similar sizes (Female 1 = 6.51 ha, Female 2 = 5.48 ha) (Fig. 10). The points are also clustered for both tarsiers; Female 1 spent the majority of her time along the river bank whereas Female 2 was largely concentrated towards the middle of her range.

Seasonal differences

When distance travelled was correlated with rainfall, there was no significant difference for either tarsier (Female 1: $p(27) = 0.381$, $P = 0.493$, Female 2: $p(43) = 0.089$, $P = 0.571$). Distance travelled did not increase as rainfall decreased.

Figure 11 shows the total rainfall was similar during the months of February, March and April and then decreased to around 200 mm in May. During this period, Female 1's home range only increased in size by 0.5 ha. Female 2's range, however, increased much more each month (Fig. 12), with the biggest increase from May to June of 1.52 ha. Between June and the first week of July, her home range increased by another 0.96 ha, almost twice as much as Female 1's increased over 3.5 months.

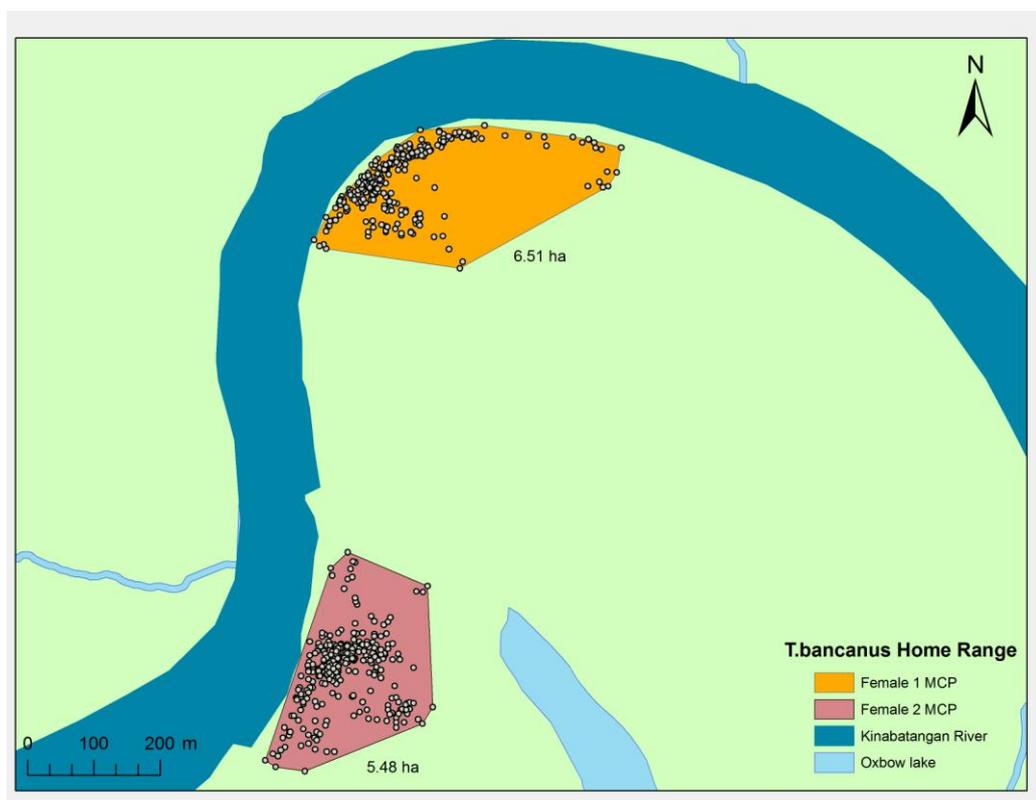


Fig. 10: Minimum convex polygons (MCP) of Females 1 and 2 home ranges based on data collected from tracking and sleeping site locations (white dots).

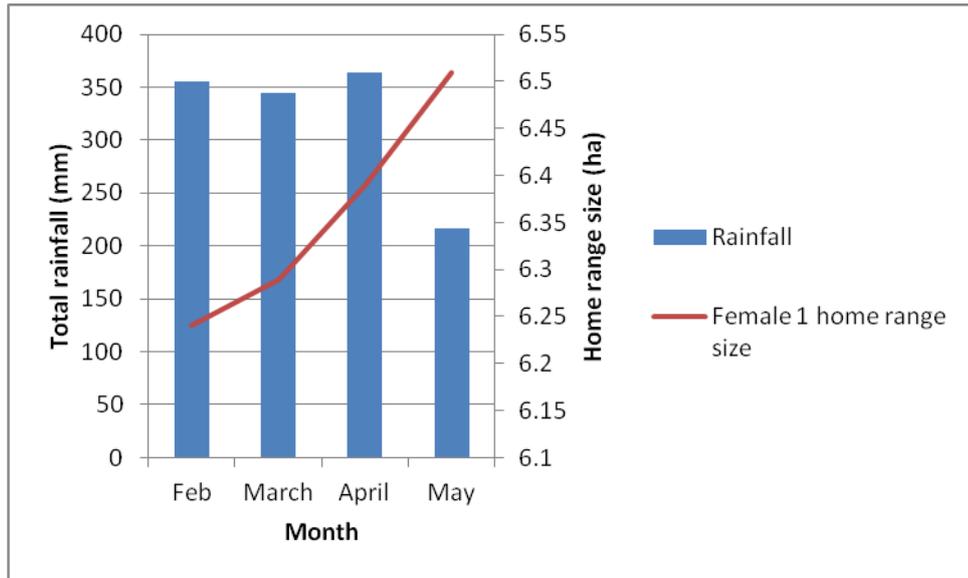


Fig. 11 Total rainfall (mm) each month with home range size calculated each month, based on sleeping site and tracking data.

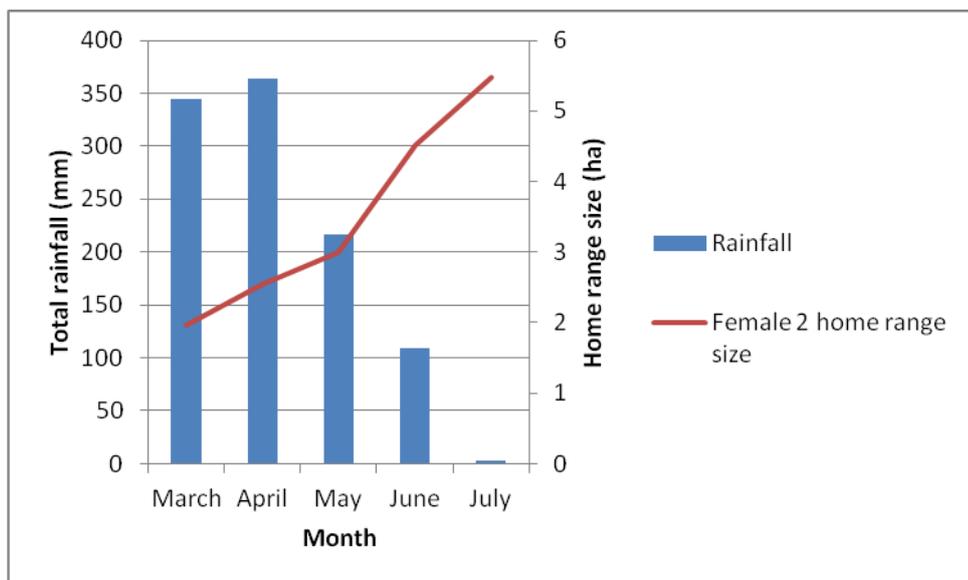


Fig.12. Total rainfall (mm) each month versus Female 2's home range estimate based on tracking and sleeping site locations.

Discussion

Our estimates of the two adult female home ranges (6.51 ha and 5.48 ha) are similar to the findings of the last Bornean tarsier home range study. Crompton and Andau (1987) found two adult female home range sizes to be 4.5 ha and 9.5 ha. Similarly, it was found in this study that the home range estimates using sleeping locations alone were much smaller, also supporting Crompton & Andau's (1987) findings. To date, only Gursky (2000) found seasonal differences in the home ranges of spectral tarsiers

by looking at distance travelled. We found no significant difference in distance travelled versus rainfall. However, one big drawback of our study was that it only covered the months of February to the beginning of July, incorporating just one month during the wet season (Scott, 1989). Other primate studies focusing on seasonality and home range were at least one year long (Gursky, 2000; Sylviane *et al.*, 2011), thus a longer study covering full seasons may produce different results. Our results did show that the tarsiers' home ranges increased, but this is likely to be due to the accumulation of data as the study progressed. Female 2's home range however did increase twice as much when the rainfall troughed in May, hinting that rainfall may have caused this. However, the following factors could also have played a role. Tracking of Female 1 had ceased at this time, thus location data was only collected from Female 2, and Female 2's infant was also becoming more independent, thus she may have been able to travel further away from it. A different method of estimating home range size may also produce more reliable results. The MCP method of measuring home range is useful to compare size to other studies, but it has been criticised of overestimating home range sizes (Kie *et al.*, 2010; Richard & Powell, 2008). MCPs use outlying location points, thus areas which a tarsier was never observed in could be included. This is visible in figure 10 of our tarsiers' range. Mechanistic models have been suggested by Kie *et al.* (2010) which incorporate 'animal movement behaviour' which better represent the intensity of space used by the animal, as well reflecting how an animal responds to any changes in its environment.

The tarsiers were found to be primarily solitary, but males were observed within the ranges of both females, supporting the findings of other studies that home ranges overlap (Crompton & Andau, 1987; Niemitz, 1984). Males were also seen travelling with the females during tracking and Female 2 was observed with a male on more than one occasion. Crompton & Andau (1987) never observed two tarsiers together during the night and Fogden (1974) observed it only 8 times between 2 tarsiers over 2 years.

We found both tarsiers to sleep on exposed tree trunks and branches, often in dense vegetation, similar to other studies (Crompton & Andau, 1987; Niemitz, 1979). Our findings suggest that the tarsiers favoured sleeping trees with certain characteristics, e.g. increased tree number, however the characteristics varied with tarsier. A large proportion of time is spent on a sleeping site and it has been found that sleeping sites

can play a role in 'predator defence, thermoregulation and their distribution can affect breeding and social system' (Lutermann *et al.*, 2010). It is perhaps no surprise that each tarsier's sleeping site was distinguishable from other trees within their range and that they often returned to them. Average sleeping height showed both tarsiers slept lower than other findings (Fogden, 1974; Niemitz, 1979; Niemitz, 1984; Crompton & Andau, 1987), although this could solely be down to habitat characteristics as the heights between the two tarsiers also significantly differed. Other wild tarsiers were never seen to sleep with the two female tarsiers, although one tarsier was seen on a tree within 2 m of Female 2. Crompton & Andau (1987) reported that they often saw a male and female sleep within 50 m of each other. Our findings on the sleeping behaviour of Female 2 and her infant support that of Roberts (1994).

During the night, our results showed slight cyclicity in the heights and distance travelled at different parts of the night, similar to Crompton & Andau's (1987) findings. Our results also suggest that, although distance travelled throughout the night was similar, behaviour and average heights between the two tarsiers differed. This suggests that, as they inhabited slightly different habitats, tarsiers adapt to their environment, thus habitats affect their movements and how they forage. Merker and Mühlenberg (2005) found that habitat quality influences home range size and foraging behaviour in Dian's tarsier (*Tarsius diana*). Considering that these Bornean tarsiers live in a fragmented and highly disturbed environment, perhaps seasonality should not be the main focus of future studies, but solely the habitat.

The most significant find from our study is a new behaviour, which we believe has not been seen before in any tarsier species. Our two collared females, as well as a wild male were all observed to exhibit regurgitation and reingestion (R/R) behaviour. R/R is the 'voluntary retrograde movement of food and/or fluid from the oesophagus or stomach into the mouth, the hands, or a substrate, followed by the subsequent consumption of the regurgitant' (Gould & Bres, 1986; Lukas, 1999). R/R occurs consistently in ruminant animals such as cattle and sheep, and is well documented in captive gorillas (*Gorilla gorilla gorilla*) (Lukas, 1999). The cause of this behaviour is unknown for these gorillas and is often documented as a 'stereotypic behaviour'; of which it has 'no obvious goal or purpose' (Odberg, 1987). Stereotypic behaviour is often reported in captive animals e.g. pacing in carnivores (Carlstead & Seidensticker, 1991), presumably to help the animal cope with stress (Rushen, 1993). R/R is considered abnormal behaviour and 'indicates sub-optimal welfare' in captive gorillas

(Bloomsmith *et al.*, 1989), thus we are led to assume the same for tarsiers. Theories surrounding R/R suggest that it may be ‘an adaptive response to boredom, diet, stress, space restriction or lack of control’ (Lukas, 1999). This may explain why R/R is rare in free ranging animals, where they are constantly being stimulated by their environment. It has, however, been reported in wild species such as koalas (*Phascolarctos cinereus*) as a result of tooth wear (Logan, 2003), but the first naturally occurring behaviour documented in primates was in the proboscis monkey (*Nasalis larvatus*) by Matsuda *et al.* (2011). He hypothesises that the behaviour could possibly allow increased food intake or to help with the foregut fermenting process. Tarsiers are completely carnivorous and do not have compartmentalised stomachs, thus it is interesting to what is causing this behaviour. However, R/R cannot be stated as a ‘behavioural tradition’ in tarsiers, but the repetitive nature and the fact it was observed by two tarsiers which were not in contact with each other, implies that it may serve some function (Lukas, 1999). As stress is associated with the behaviour, we cannot rule out the possibility that the presence of observers may have contributed to the behaviour.

Although there are many difficulties associated with studying nocturnal species (Wiens & Zitzmann, 2003) and this study resulted in being only short term, it has still provided an updated insight in to the home range, habitat usage and behaviour of Bornean tarsiers. Future work of incorporating different habitat types and a larger sample number, will tell us much more about the effect habitat quality has on tarsiers. Our study also reflects the importance of continued behavioural studies on this species, as in just a short period of time we witnessed new behaviour. By continuing and improving the home ranging and behavioural studies on the Bornean tarsier, knowledge about these cryptic species and how they are surviving and adapting in their fragmented habitat can be gained.

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Appendix I

Female 1 sleeping site selection

Shapiro-Wilk normality test

$W = 0.7016$, $p\text{-value} = 1.826e-10$ (Abnormal, transformations tried but not effective).

GLM – What climatic variables affect where Female 1 will sleep?

Distance_river vs Moon_phase

Df Deviance AIC scaled dev. Pr(Chi)

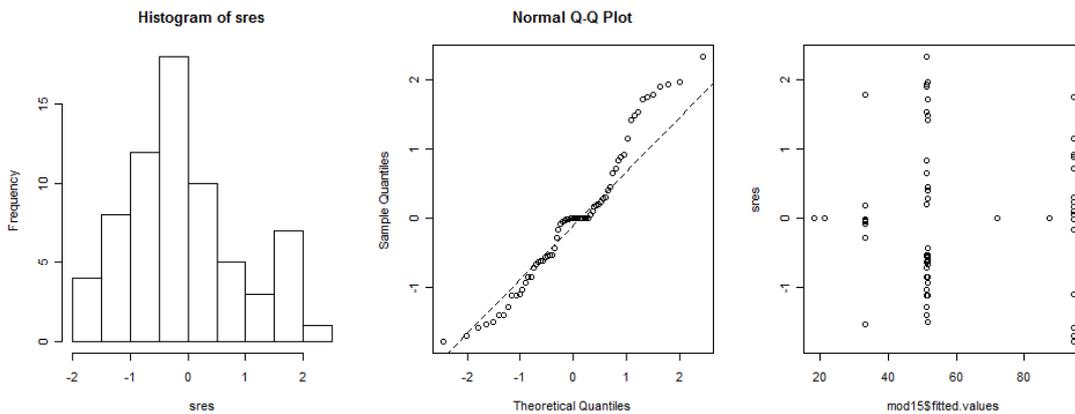
<none> 142019 730.78

Moon_phase 7 180198 732.97 16.191 **0.02343** *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Moon phase significant for Female 1 and the distance from the river she sleeps.

However, residuals not normally distributed.



Predictions

Prediction of moon phase and thus the distance to river Female 1 will sleep. During the waxing crescent and last quarter phase she will sleep further away from the river compared to full moon and first quarter phase.

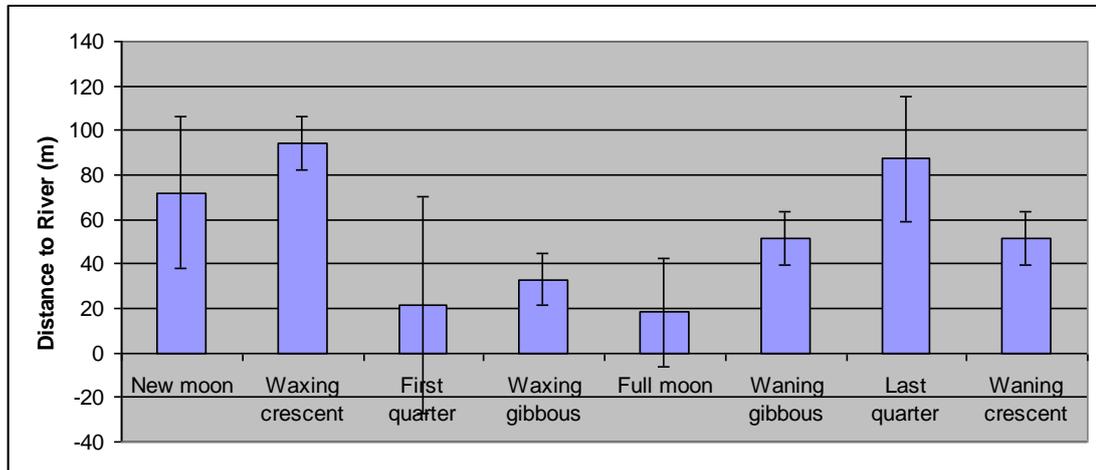


Fig.13: Predicted distance from the river Female 1 will sleep depending on the moon phase.

What habitat variables effect where Female 1 will sleep?

Site vs height

Df Deviance AIC scaled dev. Pr(Chi)

<none> 381.11 272.31

height 1 459.71 280.81 10.501 0.001193 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Tree height of the plot is highly significant in Female 1's selection of a sleeping site (W = 0.9259, P = 0.002).

Female 2 sleeping site selection

Climatic variables:

-No significance with climatic variables.

Habitat variables:

Site vs dbh + canopy

	Df	Deviance	AIC	scaled dev.	Pr(Chi)
<none>		149.92	267.70		
dbh	1	293.05	314.63	48.926	2.658e-12 ***
canopy	1	187.14	281.89	16.186	5.743e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

DBH and canopy cover are significant for Female 2 determining where she would sleep. However, residuals are not normally distributed.