POPULATION DENSITY, HABITAT, TRAPPING AND TAXONOMY OF THE BORNEAN SLOW LORIS (NYCTICEBUS MENAGENSIS) AND BORNEAN TARSIER (TARSIUS BANCANUS BORNEANUS)

by

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N. menagensis

Image by Helga Schulze
T. b. bancanus

Image by Helga Schulze
ABSTRACT


-Samuel Beckett.

Only two species of nocturnal primates are found in Borneo: the Bornean slow loris *Nycticebus menagensis* and Bornean tarsier (*Tarsius bancanus borneanus*). Both species’ survival is threatened by extensive habitat loss and the illegal wildlife trade, yet no recent research has been done to ascertain their true threat status of Vulnerable (IUCN, 2009). As habitats dwindle these sympatric species will encounter each other more frequently in the wild as they compete for resources. This study was conducted in the Danau Girang Field Centre (DGFC), Sabah, Malaysian Borneo from the 17 March to the 4 September, 2009. The population density of both species was assessed by line transect and point sampling surveys. Vegetation samples were done to determine if they were favouring different micro-habitats to reduce competition. Both were found in low abundances (5.05 lorises/km$^2$; 2.75 tarsiers/km$^2$), with only 8 lorises and 5 tarsiers being sighted. They appear to be reducing competition by favouring different microhabitats. Tarsiers were found in areas with small trees in both height and diameter at breast height (DBH), whereas lorises were mainly found in areas with large trees (both height and DBH). Additionally, trapping methods to improve capture success of Lorisinae and Perodictinae primates were investigated. Improved methods will help researchers collect much needed taxonomic and behavioural data of these primates. Trapping results and a literature review revealed that large, arboreal traps, smelly bait, a long duration and huge effort may increase the probability of success. Finally, facial masks of Bornean lorises were analyzed for differences. Nine facial characteristics were significant in demarcating three groups. Groups were recognizable by the amount of white on the face, plus geographic clustering. Three subspecies were identified, but more research is needed to support this claim. Although small, results from this study improve our understanding of these primates.
I never thought this would actually be completed. Amazingly, with the support from supervisors, colleagues, friends, and, of course, family it has come to its end. Almost three years of my life can be summed up in this dissertation and it would not have happened without the support I received from everyone around me. If I forget to list your name in this small summary of thanks, remember all these individual pieces of paper, painstakingly typed with information, bound in this book form is because of you. Thank you.

Thank you Dr K.A.I. Nekaris. Thank you for your patience, your knowledge, your time, your friendship, and your passion. None of this could be possible if it were not for you striving forward in the night, trying to improve and share your knowledge of these cryptic primates with the world. Thank you for the inspiration.

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Cheers.
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There are times to stay put, and what you want will come to you, and there are times to go out into the world and find such a thing for yourself.

-Lemony Snicket
CHAPTER 1: GENERAL INTRODUCTION

In the end, we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught.
—Baba Dioum

1.1 INTRODUCTION

Over a century has passed since the first primate field research on the great apes was conducted. A few decades after these pioneering studies began, scientists began to spread out and study monkeys as well. Over the years, the public interest in our closest living relatives has increased exponentially thanks to the dedication of a myriad of scientists. Initially observed to help answer questions regarding man’s origin, gradually research expanded to include behavioural and ecological data (Sussman, 2007). The complex lives observed, and the similarity to humans, made primatology a popular field both scientifically and publically. Although this boom has made primates one of the most studied mammal groups, it is still in desperate need of research.

Nocturnal animals are typically studied less than their diurnal counterparts, and this holds true for primates. These little-studied primates comprise a small fraction of the primate species, and are often overlooked by researchers aiming to uncover truths on human origins or behaviour. However, the more we learn about them, the more we realize how much we have to learn.

1.2 PROJECT OVERVIEW

The objectives of this study were to better understand two species of nocturnal primates: the Bornean slow loris (Nycticebus menagensis) and Bornean tarsier (Tarsius bancanus borneanus). The study comprised of field and museum research. The field aspect was
conducted at the Danau Girang Field Centre, Sabah Malaysian Borneo from 17 March- 4 September, 2009. My field aims were to 1) provide an up to date abundance estimate of *N. menagensis* and *T. b. borneanus*, 2) determine if these species are favouring different habitats and therefore avoiding competition 3) create an efficient trapping regime to catch *Nycticebus* spp. for morphological and genetic samples. The museum research was done at the Chicago Field Museum, American Natural History Museum and the Smithsonian. The objective of this research was to examine if facial mask variations in *N. menagensis* can be used to demarcate subspecies or species. The last objective is supported by using GoogleEarth to pinpoint where specific lorises are found to determine if facial mask variation is an individual difference, or if it varies by region.

It was my intention to do a trapping and morphological study on the Bornean tarsier, but several factors prevented such a study. Tarsier museum specimens were measured, photographed and examined, but I was unable to discern key morphological differences between specimens. The bulk of the specimens were from one general region of Borneo, which may explain the difficulty in finding markers to distinguish between individuals or possible subspecies. Tarsier traps were not created due to the lack of time. The design and making of loris traps consumed a huge portion of the study and by the time they were completed only a month remained for a trapping study. Tarsier traps did not seem as pertinent, since methods for catching tarsiers are available. Many researchers are able to catch them by hand, such as in this study, or by the use of mist nets (Crompton & Andau, 1987).
The morphological study relates to past research that Dr Nekaris and I have done on facial mask differences of *Nycticebus* spp. (Nekaris & Munds, 2010). This past study made use of a pre-designed chart (Nekaris & Jaffe, 2007) that covered the facial mask characteristics of lorises. The chart from this past study was useful when designing the chart I created for Bornean subspecies, but modifications were done to address specific Bornean differences (see Chapter 5 for more details).

### 1.3 STUDY SPECIES

Current research on the behaviour and ecology of the Bornean loris and Bornean tarsier is lacking, as our understanding of these primates is primarily based on studies focusing on their congeners. These studies do not provide insights into how Bornean populations are coping with the extensive rate of deforestation occurring throughout Borneo (Rautner & Hardinio, 2005) (see Appendix I on *Tarsius* and *Nycticebus* relatedness and primate taxonomy).

#### 1.3.1 *Tarsius bancanus borneanus* (Fig 1)

Tarsiers (genus *Tarsius* Camel, 1706, cited Yustian, 2007) are classified in the order Primates and debatably in either the suborder Prosimii or Haplorhini (Fleagle, 1999; Schwartz, 2003). The single genus *Tarsius* makes up the infraorder Tarsiiformes. New research has increased the number of species from five to nine (*T. bancanus, T. dentatus, T. lariang, T. pelengensis, T. pumilus, T. sangirensis, T. syrichta, T. tarsier, T. tumpara*) (Gursky, 2007; Shekelle *et al*., 2008). Tarsiers can be found throughout the rainforests of Southeast Asia, and on the islands of
Borneo, Sulawesi, Sumatra, the Philippines and several surrounding smaller islands (Musser & Dagasto 1987; Gursky, 2007; Shekelle et al., 2008). The focal species of this study, the Western tarsier (*Tarsius bancanus*, Horsfield, 1821, cited Yustian, 2007) is found in Southern Sumatra, Borneo, Banka, Belitung, Serasan, Subi and the south Natuna Islands (Brandon-Jones et al., 2004). There are four subspecies of Western tarsiers: the Western tarsier (*Tarsius bancanus bancanus*, Horsfield, 1821); Belitung tarsier (*Tarsius bancanus saltator*, Elliot, 1910); Natuna tarsier (*Tarsius bancanus natunensis*, Chasen, 1940); Bornean tarsier (*Tarsius bancanus borneanus*, Elliot, 1910) (cited from Yustian, 2007). The latter is the focal subspecies for this study.

Unlike most nocturnal primates, tarsiers lack a *tapetum lucidium* (a reflective tissue behind the retina), thus they have no eye shine (Schwartz, 2003). Instead a dull red glare is detected when a light is shined on the eyes (Munds, pers. ob). They are strict undergrowth foragers and are generally seen at heights of 0-11 m, with a median height of 1 m (Niemitz, 1979; Crompton & Andau, 1987; Crompton et al., in press). Tarsiers are described as faunivores, as they are only known to eat prey that they have killed. The majority of tarsier species are strict insectivores, but the Western tarsier is the exception, as it has expanded its diet to include birds, snakes, small reptiles and amphibians, and even small mammals (Niemitz, 1979; Crompton & Andau, 1987; Gursky, 2007). All tarsier species’ primary mode of locomotion is vertical clinging and leaping, and they are capable of leaping up to an astounding three meters (Crompton et al., in press). The Western tarsier has even been observed using their leaping ability to pounce on unsuspecting prey (Crompton & Andau, 1987). Most tarsier species are maintaining healthy populations, even in light of the massive deforestation levels going on throughout Southeast Asia (Merker & Muhlenberg, 2000; Neri-Arboleda, 2002; Yustian, 2007; Yustian et al., 2008; Shekelle & Salim, 2009). Unfortunately,
the last extensive population study on Bornean tarsiers was over 20 years ago. Results indicated a population estimate of 14-80 individuals/km$^2$ (Niemitz, 1984; Crompton & Andau, 1987). A brief study was done on Bornean tarsiers in Central Kalimantan, Indonesian Borneo and yielded a low result of only 0.07 tarsiers/km (Blackham, 2005).

1.3.2 Nycticebus menagensis (Fig 2)

The genus Nycticebus is part of the Order Primates, family Lorisidae, and subfamily Lorisinae. Also included in the Lorisinae is the Asian slender loris (Loris) (Sussman, 1999). All members are characterized as nocturnal, slow movers, although, occasionally, they have been seen to move quickly (McArdle, 1981; Nekaris & Stevens, 2007). The members of the genus Nycticebus, which is comprised of a total of five species (N. bengalensis, N. coucang, N. javanicus, N. menagensis, N. pygmaeus), range throughout the rainforests of South and Southeast Asia and can be found in parts of: Bangladesh, Bhutan, Burma, China, Cambodia, India, Laos, Thailand, Vietnam, Brunei, Malaysia, Indonesia (Nekaris & Bearder, 2007). In particular the focal species of this study, the Bornean loris (N. menagensis) is found on the islands of Banggi, Bangka, Belitung, Borneo, Karimata, Labuan, and the Sulu archipelago (Nekaris & Munds, 2010). Although originally believed to favour heights of the upper canopy, new research is finding that these primates favour all levels of the forest and range from 0-30+ m (Wiens, 2002; Radhakrishna et al., 2005; Nekaris et al., 2008; Nekaris & Munds, 2010; Starr et al., in review). Often they are sighted in the dense parts of the forest and require canopy continuity, lianas and vines to

Fig. 2: Nycticebus menagensis in the Danau Girang Field Centre.
move about the forest, as they are unable to leap (Nekaris & Bearder, 2007). Slow lorises are omnivores, but based on a craniodental study the Bornean loris is postulated to be the most faunivorous of all slow lorises (Ravosa, 1998). No behavioural studies have been conducted on Bornean lorises to determine their diet or other behavioural niches. Only a few population density studies have focused on *N. menagensis*, indicating low abundances (0.02-0.19 individuals/km) (Nekaris *et al*., 2008; Nekaris & Munds, 2010). With no historic data, it is unclear whether these estimates are because they naturally occur at low abundances with large home ranges or they are being caused by deforestation and other anthropogenic threats.

Focusing on the Bornean or Philippine slow loris, the name *menagensis* came from the Menage Scientific expedition to the Philippine islands and Borneo during 1890-1893. From this expedition, the Bornean slow loris was recognized as a new lemur (Menagensis) by Nachtrieb (1892). Nachtrieb did not assign a species name to the newly discovered primate; only unofficially described it (Nachtrieb, 1892; Timm & Birney, 1992). The first person to give a binomial name to the Bornean loris (at the time *Lemur menagensis*) was Lydekker (1893) (cited in Timm & Birney, 1992). This species was later grouped into a highly polymorphic species (*Nycticebus coucang*) and then afterwards recognized as a subspecies within the genus (*Nycticebus coucang menagensis*) (Groves, 1971). Recent research has found evidence supporting the reclassification of the Bornean slow loris as a distinct species (Nekaris & Bearder, 2007). Still being debated by some, evidence such as cranial morphology (Ravosa, 1998), pelage variation (Nekaris & Munds, 2010), and genetics (Roos, 2003; Chen *et al*., 2006) support the recognition of *N. menagensis* as a separate species. For this paper, I will adopt the taxonomy given by Nekaris & Bearder (2007), and will refer to the study species as either *N. menagensis* (Lydekker, 1893) or the Bornean loris.
1.4 NOCTURNAL PRIMATE SPECIATION AND SPECIES CONCEPTS

Table 1: Comparison of diurnal and nocturnal primate studies found on PrimateLit.

<table>
<thead>
<tr>
<th>Family</th>
<th>Number of articles when only searching Family</th>
<th>Number articles when searching with Family and “conservation” term</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diurnal Primates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lemur</td>
<td>5468</td>
<td>821</td>
</tr>
<tr>
<td>Cebidae</td>
<td>28923</td>
<td>2598</td>
</tr>
<tr>
<td>Pongidae</td>
<td>40360</td>
<td>5013</td>
</tr>
<tr>
<td><strong>Nocturnal Primates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aotidae</td>
<td>5794</td>
<td>550</td>
</tr>
<tr>
<td>Cheirogaleidae</td>
<td>4633</td>
<td>1428</td>
</tr>
<tr>
<td>Lepilimuridae</td>
<td>1234</td>
<td>317</td>
</tr>
<tr>
<td>Indriidae (Avahi)</td>
<td>878</td>
<td>245</td>
</tr>
<tr>
<td>Daubentoniidae</td>
<td>1320</td>
<td>376</td>
</tr>
<tr>
<td>Lorisidae</td>
<td>9972</td>
<td>1540</td>
</tr>
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<td>Tarsiidae</td>
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<td></td>
</tr>
<tr>
<td>Galaginace</td>
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<td>441</td>
</tr>
<tr>
<td>Perodicticinae</td>
<td>1912</td>
<td>325</td>
</tr>
<tr>
<td>Lorisinae</td>
<td>3642</td>
<td>774</td>
</tr>
<tr>
<td><strong>Study species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarsius bancanus</td>
<td>597</td>
<td>135</td>
</tr>
<tr>
<td>Nycticebus menagensis</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
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Throughout the years nocturnal primate research across species has lagged behind diurnal studies (Table 1). The lack of technology to aid detection of these primates was the main contributor to the already difficult challenge of undertaking a nocturnal study. With advances in technology, such as improved headlamps and radio-tracking equipment, nocturnal projects began to escalate (Sterling & Radespiel, 2000; Sterling et al., 2000; Martin, 2002).

Previously, the majority of nocturnal primates were described as solitary, but recent studies have found this assumption inaccurate. These species exhibit an array of social structures, from monogamy to dispersed multi-male systems (Kappeler, 1997; Gursky, 2000; Muller & Thalmann, 2000; Martin, 2002; Wiens, 2002; Pimley et al., 2005; Schulke & Ostner, 2005; Nekaris, 2006; Nekaris et al., 2008). Long-term studies have shed light on a number of issues, regarding their behavioural ecology and conservation status (Nash & Whitten, 1989; Bearder, 1999; Bearder et al., 2003; Wiens & Zitzmann, 2003; Radespiel et al., 2008).
Taxonomic research focusing on the disparities within and between species has revealed a dynamic range of speciation. In 1996, Rowe acknowledged only 50 nocturnal species. Almost a decade later, that number had jumped to 77, with further diversity evident (Campbell et al., 2007). Now, only three years later, the number of species has increased to an astounding 103 (IUCN, 2009). More research will expand our knowledge of these cryptic primates and may even support the recognition of more new species.

The recent diversifications found within many nocturnal primates are that many of them are cryptic species. Defined by Bickford et al., (2006), cryptic species are a group of similar species that have been mistakenly lumped as one. Advancements in understanding have provided new insight into what makes these definitive species. One of the main hindrances when acknowledging them is our inability to agree on an authoritative species definition (Tattersall, 2007). Although there are numerous species concepts (Table 1), the most popular one is the biological species concept (BSC) (Winston, 1999).

**Table 2: Commonly used species concepts**

<table>
<thead>
<tr>
<th>Species Concepts</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological Species: A reproductively isolated group of interbreeding populations</td>
<td>Mayr, 1970</td>
</tr>
<tr>
<td>Ecological Species: Organisms inhabit similar niches and habitats</td>
<td>Winston, 1999</td>
</tr>
<tr>
<td>Evolutionary Species: A population lineage that is evolving its own tendencies and is separate from other groups</td>
<td>Simpson, 1961</td>
</tr>
<tr>
<td>Genetic Species: Genetically compatible, interbreeding and genetically isolated from other groups</td>
<td>Baker &amp; Bradley, 2006</td>
</tr>
<tr>
<td>Recognition Species: The general population of biparental organisms share a common fertilization system.</td>
<td>Paterson, 1985</td>
</tr>
<tr>
<td>Phenetic Species: Smallest groups that is distinct by normal means.</td>
<td>Winston, 1999</td>
</tr>
<tr>
<td>Phylogenetic Species: Parental pattern of ancestry detected and group has own evolved tendencies and outcomes.</td>
<td>Cracraft, 1983</td>
</tr>
</tbody>
</table>
Defined by Mayr (1970), biological species are “a reproductively isolated aggregate of interbreeding populations.” The main drawback when using this parameter is it is difficult to determine what is reproductively isolated. Reproductive isolation is not achieved by geographic barriers; instead it is achieved by the inability of two species to produce a viable offspring (Mayr, 1970). I wanted to better understand the issue of speciation with nocturnal primates, so I chose to focus on one species which is a known enigma. For example, understanding reproductive isolation is difficult to assess, but with *Nycticebus* spp. it is especially problematic as they are capable of hybridizing and producing viable offspring between the currently described species (Schulze & Groves, 2004). Their ability to hybridize causes greater confusion when trying to resolve taxonomic classifications and effective threat statuses. The BSC does not accurately depict the number of *Nycticebus* spp. and other nocturnal primates. Instead of relying on only one concept, such as the BSC, primatologists have started to integrate numerous concepts to define a species, such as: geographic barriers, morphological variations, mate recognition, and genetics (Paterson, 1985; Bearder, 1999; Boinski & Jacobs Cropp, 1999; Thalmann & Geissmann, 2005; Radespiel *et al*., 2008; Shekelle *et al*., 2008). The incorporation of these multiple factors may be the best way to determine speciation patterns within the slow lorises. Studies regarding their behaviours, ranges and effort to collect morphological and genetic data are needed. Information from taxonomic research will also ensure the best conservation action to help protect these species.

**1.5 CONSERVATION**

A poor understanding and the lack of recent research on these species may result in an incorrect conservation status and the application of inadequate conservation action plans. Currently, the majority of *Tarsius* spp. are listed as Vulnerable (VU), Least Concern or Data
Deficient by IUCN; only two are listed as Endangered (*T. pelengensis* & *T. sangirensis*) (IUCN, 2009). Specifically, the Western tarsiers are all classified as VU A2cd (Table 3).

**Table 3: IUCN threat status meanings**

<table>
<thead>
<tr>
<th>Threat category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><em>A reduction in population size is observed based on the following:</em></td>
</tr>
<tr>
<td>2</td>
<td>Reduction in population size. Observed or estimated to have reduced by ≥ 30% over the last 10 years or 3 generations. Reduction cause may be continuing or not it is not understood or is not reversible. Based on c &amp; d below.</td>
</tr>
<tr>
<td>3</td>
<td>Population size has reduction of ≥ 30% projected/suspected to be met within the next 10 years or 3 generations, whichever is longer. Based on c &amp; d below</td>
</tr>
<tr>
<td>c</td>
<td>A decline in area of occupancy, extent of occurrence and/or quality of habitat.</td>
</tr>
<tr>
<td>d</td>
<td>Actual or potential levels of exploitation.</td>
</tr>
</tbody>
</table>

Definitions from IUCN, 2009

Of all slow loris species, only *Nycticebus javanicus* is listed as Endangered by the IUCN, all other species are considered VU, with *N. menagensis* as VU A2cd+3cd (IUCN, 2009). The assessments for both these genera considered all anthropogenic threats, but criteria for the Red List can only account for habitat loss or number of individuals left. The primary threat to most tarsier populations is deforestation, but new research has revealed that they are hunted for human consumption (Shekelle *et al*., 2008) and the illegal wildlife markets (Lee *et al*., 2005). Although all *Tarsius* spp. are listed as Appendix II by CITES, which allows controlled trade of the species (CITES, 2009), it is difficult to determine the affects of the wildlife markets on tarsier populations, as many perish before arrival to the markets due to their restrictive diet (Fitch-Snyder, 2003). Habitat loss influences the low numbers of *Nycticebus* spp, but it is not the only contributor to their low abundance: the illegal wildlife trade is the main factor to their decline. Collected as pets or for use in traditional medicines,
slow lorises are the most commonly found protected primates in the black markets (Nekaris & Nijman, 2007). The dramatic impact these markets are having on slow loris populations raised concern for their survival, and warranted that all *Nycticebus* spp. be transferred to Appendix I on CITES, which permits trade of these species only under exceptional circumstances (Nekaris & Nijman, 2007; CITES, 2009). Only with more population surveys will we be able to assess how serious these anthropogenic threats are affecting their populations.

**1.6 DISSERTATION LAYOUT & CO-AUTHOR CONTRIBUTIONS**

The design of this dissertation is for the quick facilitation of publication. There are three traditionally formatted dissertation chapters that cover all categories of this dissertation (I. Introduction; II. Methods; VI. Conclusion). These traditional chapters are formatted with their own tables, graphs, and works cited pages and are independent from other chapters. Then there are three focal chapters stylized in a specific journal format. These manuscript-styled chapters have their own abstract, keywords, tables and figures, and references attached. By formatting this way, I will be able to expedite the submission process. The styles for each chapter are as follows:

*Chapter 1:* Traditional format: General Introduction

*Chapter 2:* Traditional format: General Methods

*Chapter 3:* For American Journal of Primatology: Bornean loris and tarsier (*Nycticebus menagensis* & *Tarsius bancanus borneanus*) abundance and micro-habitat divergences in a degraded floodplain in Sabah, Malaysian Borneo.

Co-authors for this section provided assistance in the field (R. Ali, N. Roatch), and editing and statistical advice (K.A.I. Nekaris, V. Nijman, and B. Goossens).
Chapter 4: For The Raffles Bulletin of Zoology: Ways not to trap the Lorisinae of Aisa (Loris, Nycticebus) and Africa (Perodicticus, Arctocebus).

Co-authors for this section provided assistance in the field (B.B. Rasake) and editing and statistical advice (B. Goossens, K.A.I. Nekaris)

Chapter 5: For Journal of Mammalogy: Facemask markings used to reveal taxonomic differences in the Bornean slow loris (Nycticebus menagensis)

Co-authors for this section provided editing and statistical advice (K.A.I. Nekaris, S.M. Ford).

Chapter 6: General Conclusion.

REFERENCES


CHAPTER 2: GENERAL METHODS

Whenever you are asked if you can do a job, tell’em, ‘Certainly I can!’ Then get busy and find out how to do it.
- Theodore Roosevelt

2.1 STUDY SITE (Fig. 1)

The Lower Kinabatangan Wildlife Sanctuary (LKWS), (5°20’-5°45’N, 117°40’-118°30’E) located in eastern Sabah, Malaysian Borneo, is one of the few remaining floodplains in SE Asia (Goossens et al., 2005; Davison, 2006). In 2002, it was gazetted under the Land Ordinance 1930 and is comprised of 10 lots that combine to a total of 26,100 ha (Goossens et al., 2005; Davison, 2006). All ten lots are fragmented by oxbow lakes, human encroachment via development, deforestation or oil palm plantations. Additionally the Kinabatangan River divides the area in half. This, the largest river in Sabah at 560 km, has been proven to impede gene flow of various species of wildlife (Goossens et al., 2005; Davison, 2006). The goal of the sanctuary is to act as a corridor and to improve gene flow of the fauna between the mangrove forests found on coastal Sabah and the semi-degraded and primary forests found in the interior of Sabah (Goossens et al., 2005).
Fig 1: The Danau Girang Field Centre based in the Lower Kinabatangan Wildlife Sanctuary, Sabah, Malaysian Borneo.

The LKWS encompasses a mix of different forests: riverine, seasonally inundated, swamp, limestone, dry dipterocarp, estuary nipa, and mangrove (Davison, 2006). Most of the forests have suffered from repeated logging over the years (Ancrenaz et al., 2004) and few trees in the area exceed heights of 35 m. Within the sanctuary numerous species of plants can be found, innumerable insects, over 200 species of birds, and over 50 species of mammals, ten of which are primates. This array of wildlife garners much attention from tourists and researchers alike and supports the need for protecting this biodiversity hotspot (Davison, 2006).
In July 2008 the Danau Girang Field Centre (DGFC) (5°24’ 48” N, 118°02’ 16” E, elevation 15 m asl) opened its doors for researchers, field schools and scientific expeditions. DGFC is a cooperative research facility between the Sabah Wildlife Department and Cardiff University in a common cause to better understand and protect the biodiversity found within DGFC and the LKWS. Based in Lot 6 of the LKWS, the field centre is 123 ha primarily of two forest types: semi-inundated and mixed riparian. Forest density can reach as little as 2 m. Yearly precipitation averages 3000 mm (Ancrenaz et al., 2004). Flooding does occur during the wet season (Nov-Feb), thus the study was delayed until the dry season (Feb-Nov). The wet and dry seasons are not distinctive as the temperature remains steady (21°-34°C) and it rains continuously through the year.

2.2 FIELD METHODS
2.2.1 Surveys Two sampling methods were used in this study: point sampling and line-transect. Surveys were done from 17 March- 4 September 2009. They were conducted between the hours of 18:30-02:00. Five pre-cut trails and transects and two newly cut transects were surveyed a minimum of four times each for line transects and five times each for point sampling. Average trail length was 1.1 km. Typically surveys were done by two to three people. Although the ideal number would be one surveyor, as it would create the least amount of disturbance, for safety reasons this was not possible (Nekaris et al., 2008). Line transect surveys had an average walking speed of 600 m/hr. A 5 m gap was kept between researchers to prevent oversight errors and to remain close enough to avoid counting an animal twice. Point sampling involved selecting five arbitrary points on each transect to survey; each point was surveyed five times. Generally, at the start of each randomly selected point all lights were turned off for 5 minutes. Turning the lights off and standing quietly was believed to encourage animals to approach and not flee from the researchers. After the 5
minutes of darkness, lights would be turned on and 5-10 minutes would be spent surveying the surrounding vicinity. When near the river one light would remain on and fixed on the water for safety reasons, as saltwater crocodiles are found in the area. There was an insignificant amount of sightings with the point sampling method, which made it impossible to compare with line transects, but these data are still useful in showing the difficulty in detecting these two species of primates. Point sampling is considered reliable for surveying highly vocal animals (MacKenzie et al., 2005), which may explain the low rate of detections in this study, as they vocalized rarely.

Typically animals were detected by eye-shine or movement. During surveys, researchers would scan all levels of the forest with a Petzl Myo Zoom 4.5 V headlamp, with a mix of red and white filters (Nekaris, 2003). Preference was given to red filters, as they are less disturbing and increase observation time (Bearder et al., 2006; Nekaris & Nijman, 2007). Most nocturnal primates are detected by their reflective eye shine, which is the result of a layer of tissue found behind the retina known as the *tapetum lucidum* (Bearder et al., 2006). In fact, only two genera of nocturnal primates lack this reflective layer (*Aotus, Tarsius*) (Wright, 1994; Schwartz, 2003). Instead these genera are usually detected by distinct calls or movement (Aquino & Encarnacion, 1994; Gursky, 1998). Unfortunately, Western tarsiers are not known to vocalize regularly and their calls, if never heard before by the researcher, hard to distinguish from insect noise (Niemitz, 1979; Crompton & Andau, 1987; Crompton pers. comm.). However, they were visible by their movement and from a dull red eye glare when a red filter was used.
From each survey the following data were collected: date, start and end time, number of people, length of transect. With each sighting the following data were recorded: number of animals detected on transect, perpendicular distance of animal from transect, animal observer angle, animal height, distance on transect, the time the animal was spotted, and behaviour of the animals upon detection.

2.2.2 Botanical sampling Areas where lorises or tarsiers were found were marked by biodegradable flagging tape. The tape was labelled with a marker indicating which species was found. In case the flagging tape fell off, all areas were recorded in a Garmin GPS and the vegetation surveyed later in the study. A 5 m radius was created around the flagged tree in which the animal had been encountered. For comparison, an outlier group of six plots were randomly selected for sampling. These outlier plots were areas where lorises and tarsiers had not been spotted. In all plots (loris; tarsier; outlier) trees and all saplings above an estimated 1 m in height were measured for their diameter at breast height (DBH) and height. The decision to measure small saplings and trees was based on the assumption that tarsiers preferred using vertical supports with a small DBH and height (Niemitz, 1984; Crompton et al., in press).

2.2.3 Trapping The most challenging and frustrating aspect to the research was the trapping. It was planned that 100 traps would be made, but financial, time and labour restrictions reduced the number of traps to 30. Also, it was intended that trapping would begin in April, but setbacks prevented this from occurring. It was difficult to get people in to make traps, and it was a slow-going process for researchers to make all 30 by hand, so a compromise was made. From 21 March- 15 June 2009, two researchers worked on making traps and from the
12-14 June 2009, four local Malays were brought in to the field site to expedite the making of the last 15 traps, and by early July all 30 traps were built.

Ten traps were made for each of the three types. One trap design was an original design by Joseph Munds, Zainal Abidin Jaafar, and me (Fig. 2). This design was an adapted giant-rat trap, with a falling door. It was light weight, and made from wire-mesh. The other two of the trap designs were interpreted from photographs of traps by Saimon Ambi (Fig 3). Supposedly, these two types were effective in catching lorises. Before actually making the traps, Saimon Ambi gave his approval to recreate his designs. His designs were modified pit-fall type traps. All traps incorporated the use of wire mesh, which can injure a loris. The injuries are sustained when the animal pushes its nose against the wire and cuts it, or when it grabs firmly on the wire. Due to special nerves in the hands and feet, lorises have an extremely firm grip (Charles-Dominique, 1977; Sussmann, 1999). When removing the animal from the wire mesh, nerve damage can occur, thus some traps were lined with plastic mesh. Plastic is a softer material and the tiny mesh holes prevented easy grasping by the lorises. As a bonus, plastic is known to survive the elements of a tropical climate much better than metal. It does not rust and does not require frequent maintenance.
During the months of June and July 2009, three areas were selected and prepared for arboreal trapping (Fig. 4). The three selected locations were based on sightings during the nocturnal surveys. Known areas of activity were used to test the effectiveness of the traps, and not to provide an abundance estimate. Each location was at least 1 km away from the other trapping spots. At the trapping spots, a 200 m trapping line was created that followed a section of a trail. Ten trees were selected along these trails (30 trees total). One tree would be where the loris was spotted and the remaining nine would be spaced at least 10 m apart along either side of the loris tree.
Traps were placed high in the trees using a Jameson Big Shot and fishing rod (Fig. 5). A Jameson Big Shot is a six foot tall sling-shot. It is used mostly by foresters and professional tree climbers to get tree climbing ropes high into the canopy. The fishing rod used a braided fishing line used by deep-sea fishermen that rarely breaks under even the most extreme pressures. One must be careful when using it, for it if wraps around any appendages, such as fingers, when cast it can take the appendage off. Two people were needed to put ropes into the trees. The person who used the Big Shot was the shooter; the person who used the fishing rod was the reeler. A small weight (~50 grams) made of lead shots wrapped with cloth was attached to the braided-fishing line and then set in the pouch of the big shot. The shooter and reeler then aimed towards a desired branch. An example of a desired branch would be a live, sturdy branch that is over several other branches and is surrounded by lianas, vines and other
foliage. The preferred height of such a branch is anything above 25 m. Once a branch was selected, the shooter pulled back on the sling and shot the weight and line into the canopy, over the selected branch. If successful in getting over the branch, the shooter then removed the weight from the line, and attached a 4 mm nylon rope to the braided line. The reeler then reeled the rope in while the shooter pulled and guided it from the bag. Once the rope reached the reeler, it would then be untied from the line and cut from the remaining rope bundle. An equal amount of rope was kept on both sides. The rope was then navigated around obstacles, to fall in a straight line when hoisting the trap. The strength of the branch would be tested by one of the researchers putting all her weight onto the ropes and pulling down. Once all safety tests were done, the rope ends would be tied to a tree. Traps were tied to one end of the rope a few days before trapping began to insure the trap smelled of the jungle. At the bottom of each trap 20 m of additional nylon rope was attached. This was the guide rope, which was used to prevent traps from getting stuck and to help navigate it through the canopy. If the guide rope was too short, the other end of the hoisting rope was tied to the guide rope, creating an extension. The preferred method of getting a trap up was for one person to hoist the trap, while the other steered it. One person could hoist and navigate the trap, but it was easier and faster with two people. Much of the arboreal trapping methodology was inspired by Kays’ (1999) research on kinkajous and olingos.
Months after the original goal to set traps, trapping finally began. From 9 August-13 September 2009, a rigorous slow loris trapping effort was done. Most nights involved the setting of all 30 traps, but on a few nights only 10 traps could be set due to the lack of manpower or because of unfavourable weather such as heavy wind or rain. All traps were hoisted between 8-30 m and suspended nearby or rested on a branch. The height of a trap was only documented when an animal was caught. Traps were set an hour before dusk (17:30). In order to have all traps in all locations set at similar times, two to three teams of researchers were created. Each team had at least two people and was responsible for one location. On nights when only two teams were available, the nearest location to the field centre would be done last and by both teams. This insured that all traps were up by 18:30. At first, it was planned to check traps every four hours (18:00; 22:00; 02:00; 06:00), but it was difficult to get assistance at the 02:00 shift and for safety reasons one researcher could not go alone and check all 30 traps at that hour. Also, there was concern that checking the traps so frequently may deter the animals from visiting the trapping locations. Consequently, traps were checked every six hours (18:00; 00:00; 06:00). This change in time did not seem to affect or cause injury to the few caught animals. It was not necessary to bring traps down when checking. A strong-flashlight or a Petzl Myo Zoom 4.5 V headlamp with a red filter would be shined at the traps. If eye shine or movement was seen, then it was assumed something was in the cage and the trap would be brought down. If nothing was noted, then the traps would remain up until the morning. Checking and bringing traps down was also done in teams. At 06:00 traps were brought down and closed to prevent capture of diurnal animals. The bait used that night was disposed. Traps were only cleaned when contaminated and only with water. It was assumed if cleaned too often and with soap, then the unnatural scent may dissuade the animals from approaching the trap.
Bait selection was random. Each trapping night the type of bait was documented for each location. The favoured baits were types of jack fruits (tarap, durian, jack fruit) endemic to Borneo that have a pungent smell which it was hoped would attract animals. Other baits used were palm fruits, bananas, ficus and cat food. Although cat food is fragrant it also attracted fire ants and other biting ants. This forced the researchers to stop using it in case these ants may seriously injure or kill a caught animal.

2.3 TAXONOMIC METHODS

2.3.1 Face mask analysis Photographs and museum specimens of *N. menagensis* were examined for facemask differences. Requirements for used images and specimens were: a color image, general location is known either by museum tag, personal communication from photographer or website stated where image was photographed, a clear view of the facemask, and a clear view of the top of the head (crown). Features analyzed were provided or inspired from an already published standard. Analyzed features comprised of four groups made up of thirteen specific features: Circumocular patch (patch top, presence of eye rim, eye rim color, patch middle, patch bottom); Interocular stripe (width, shape); Crown (crown and fork shape, ear fur coverage, preauricular hair width); Miscellaneous (mask color, nose color, black and white shade) (Nekaris and Jaffe 2007; Nekaris and Munds 2010). A guide was created for future researchers to easily replicate or expand upon this study (see Appendix I). Of the original 13 features, only 9 were useful to demarcate Bornean loris groups. Thus the following groups and features were tested: Circumocular patch (patch top, patch bottom); Interocular stripe (width, shape); Crown (crown and fork shape, ear fur coverage, preauricular hair width); Miscellaneous (mask color, black and white shade). To avoid biasing the assignment of facial mask characteristics, each image was assigned an arbitrary number to be referred to, instead of the original name of the image, which was often the
location where the loris was found. The results from the analysis were stored in Microsoft Excel and correlated with the number assigned. A master list of photographs of lorises’ number, original name, location and decimal GPS location was created in Microsoft Excel and was referred to after facial mask characteristics were determined for each photograph.

GPS points aided in discerning if clustered loris facemask groups also grouped geographically. GoogleEarth was used to get the decimal GPS latitude and longitude locations of each loris image. For specific facial features examined see Appendix attached at the end of chapter 5.

2.3.2 Museum measurements A lot of data were collected at museums, which will not be analyzed for this dissertation. I still provide the methods used and the data collected in order to share information on what was gathered and to make my procedures known for repeatability. I intend to use the unanalyzed data for a future project.

Table 1: Analyzed specimens of *Nycticebus menagensis* and *Tarsius bancanus*.

<table>
<thead>
<tr>
<th>Museum</th>
<th>Museum Abbreviation</th>
<th>Examined <em>N. menagensis</em> specimens</th>
<th>Examined <em>T. bancanus</em> specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Museum Natural History</td>
<td>AMNH</td>
<td>32649; 106011; 106012; 106013; 17113; 17411; 288/417</td>
<td>106754; 106010; 106649</td>
</tr>
<tr>
<td>Field Museum Natural History</td>
<td>FMNH</td>
<td>17619; 85926; 88277; 89464; 89465; 89466</td>
<td>33466; 76857; 76858; 76860; 76861; 76862; 76863; 76864</td>
</tr>
<tr>
<td>United States National Museum; The Smithsonian</td>
<td>USNM</td>
<td>142232; 142233; 142236; 142237; 142238; 142239; 198267; 198857; 292553; 292554; 317185; 317186; 317187; 317188; 488077; 124907*; 142242*</td>
<td>300916; 300917; 300918; 488081; 488082; 488083; 488084; 124992*; 142242*</td>
</tr>
</tbody>
</table>

*Type specimens

Three museums in the United States were visited between the months of December 2008 to February 2009, and a total of 30 *N. menagensis* and 20 *Tarsius bancanus* specimens were examined (Table 1). Specimens were selected by their species label or by their locality, as
some specimens were found on Borneo but labelled as a different species. Genera were measured for variations in pelage colour and patterns, facial markings, hand and feet sizes, body size, and photographs of hand and feet pads were taken. Most measurements adhered to past study standards (Groves, 1971; Musser & Dagasto, 1987; Ravosa, 1998). Unless otherwise noted, pelage colour was measured using a Munsell Soil Color Chart (MSCC). The use of an MSCC is considered a reliable way of standardizing colour measurements (Carraway & Verts, 2002). Natural lighting was used at all museums, except at USNM where natural lighting was emulated by a specific type of light bulb. Many specimens from various parts of the range are required to quantify any claims of subspecies or species disparities. Unfortunately, only a handful of specimens of T. bancanus were available outside the Sabah area. Thus, the T. bancanus portion of this study will not be discussed. I intend to gather more T. bancanus and N. menagensis data from other parts of their ranges in the future.

All qualitative measurements were done using digital vernier callipers (Faithful Tools 150 mm) and taken in millimetres. In order to reduce human error calliper measurements were repeated two times with a minimum 15 minute interval between measurements; the average was documented. The following features were examined and defined as:
Table 2: Additional museum measurements

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand/foot pad length</td>
<td>From the bottom of the raised areas below the thumb/hallux to the top of the raised area before the second digit (Fig. 6).</td>
</tr>
<tr>
<td>Hallux/third digit on right hand/foot length</td>
<td>Top of the raised based to the tip of the digit. Bent digits were noted, and if bent, several measurements were done on each section and added together.</td>
</tr>
<tr>
<td>Head and body length</td>
<td>Tip of the nose to the base of the tail.</td>
</tr>
<tr>
<td>Muzzle length</td>
<td>Distance from the rhinion to the nasion. Usually taken from the skull, when available, but if not present then from the specimen and noted.</td>
</tr>
<tr>
<td>Tail length</td>
<td>Tip of the tail to the caudal proximal</td>
</tr>
<tr>
<td>Ear length</td>
<td>Distance from the super-aurale to the sub-aurale.</td>
</tr>
</tbody>
</table>

Body skin measurements, defined as anything beyond the back of the head, were broken into four groups: dorsal stripe, skin colour, hair colour, and hair quality. Dorsal stripes are the dark stripe that runs from the head towards the tail of the loris or tarsier. If present, dorsal stripes were measured for their variances of colour, width, lateral stripe enclosures, and start and end points. The location of the start and end points of the dorsal stripe were noted. Start points were considered to be located near the head and the end points were generally located on the lower back or beyond. Color measurements were taken from the middle of the stripe.
A documentation of the general width was noted as narrow or wide. Lateral stripe enclosures are two lighter colour lines surrounding the dorsal stripes. These lines are distinguishable from the rest of the dorsal fur. Not all specimens have these lines and for this study it was noted whether these lines were present. (Schulze, 2009)

Hair colour was measured on both dorsal and ventral sides. The middle of the ventral side was measured for fur coloration. Skin pigmentation was measured from the ventral side without the use of an MSCC. Skin pigmentation was defined as subjective colours: pink, grey, yellow, or cream. The number of dorsal fur colour measurements would range from one to three, depending on the amount of partitions discerned on a specimen. Partitions are defined as distinguishable segments of fur by pattern, quality or colour on the dorsal side (Stump, 2005). The number of partitions would vary from zero to three. In addition, the percent of body covered by the darker dorsal hair was estimated. If frosting, white or silver tipping of fur, was detected I would document where it was found on the body. When possible, tail colour would be measured with an MSCC and the percent of the tip of tail covered by dorsal fur colour would be estimated. Finally, hair quality, on each partition, would be recorded as wavy or woolly.

Hand and foot pad data were collected following an established methodology (Stephenson, 2007). All hand/foot pad digits were examined for nail and claw morphology. Photographs were taken of the right hand and foot of both genera. If the right hand/foot was not available, it was documented and the left was substituted.
REFERENCES


CHAPTER 3:

Bornean loris and tarsier (*Nycticebus menagensis* and *Tarsius bancanus borneanus*) abundance and micro-habitat divergences in a degraded forest in Sabah, Malaysian Borneo.

_Every creature is better alive than dead, men and moose, and pine trees, and he who understands it aright will rather preserve its life than destroy it._

- Henry David Thoreau

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Running title: Bornean slow loris and tarsier abundance
3.1 ABSTRACT
A dramatic loss of habitat and the illegal wildlife trade are affecting the survival of the nocturnal primates of Borneo: the Bornean slow loris (*Nycticebus menagensis*) and tarsier (*Tarsius bancanus borneanus*). As habitats dwindle, competition for diminishing resources may increase between these sympatric faunivores. An understanding of how they are coping with anthropogenic pressures and interspecific competition is needed to conserve them. We conducted line transect survey to estimate density in the Danau Girang Field Center, Sabah, Malaysian Borneo from the 17 March- 4 September 2009. We surveyed a distance of 68.56 km but found only 8 lorises and 5 tarsiers giving a density of of 5.05 lorises/km² and 2.75 tarsiers/km². For the Bornean loris the results coincide with past studies of other *Nycticebus* spp. Results compared to other *Tarsius* spp. are low; Bornean tarsiers studied 20 years ago occurred at densities 7-29 times higher, indicating a much lower density at this site compared to other studies. We then examined micro-habitats to examine the niches exploited by the species. Through analysis of vegetation plots laid around species localities, we found that both tree heights and diameter at breast height (DBH) significantly differed between the species (median heights: loris 6.8 m; tarsier 3.6 m: median DBH: loris 17.8 cm; tarsier 6.2 cm), suggesting that they occupy different niches. Tarsiers occur primarily in the undergrowth on trees and stems less than 5 m, which coincides with other tarsiers species habitat preferences. Lorises were found almost exclusively above 5 m. This result differed significantly from lorises in mainland SE Asia, where they are habitat generalists, using the undergrowth and upper levels of the canopy equally. Such results indicate that competition is driving this niche divergence, but further studies are required to clarify such claims.

3.2 KEY WORDS: *Tarsius bancanus borneanus, Nycticebus menagensis*, niche divergences, abundance, conservation
3.3 INTRODUCTION
Studies of nocturnal primates have increased over the past few decades due to improvements in technology and methodology (Nekaris et al., 2008; Sterling & Radespiel, 2000; Wright, 2003), leading to a better understanding of behavior, general ecology, conservation and taxonomy among these species (Bearder, 1999; Defler, 2001; Rasoloarsion, 2000). For the Southeast Asian species, however, studies are lacking. It was only in the past decade that the highly polymorphic *Nycticebus* was split into five species (*N. bengalensis, N. coucang, N. javanicus, N. menagensis, N. pygmaeus*) (Chen et al., 2001; Groves, 1998; Ravosa, 1998; Roos, 2003), but more taxonomic studies are needed, as diversity within the new taxa are evident (Nekaris & Jaffe, 2007; Nekaris & Munds, in press). Similarly, tarsiers have jumped from three to eight species (Musser & Dagasto 1987; Niemitz, 1984; Shekelle et al., 2008), with more diversity evident (Shekelle & Salim, 2009). A dynamic increase in the number of species has improved conservation efforts in protecting these animals, but additional data on population density, habitat preferences and other behavioral ecological aspects are required to conserve these primates.

Our study focused on the nocturnal primates of Borneo: the Bornean slow loris (*Nycticebus menagensis*) and tarsier (*Tarsius bancanus borneanus*). These two species are currently listed by the IUCN as Vulnerable based solely on habitat loss, but few systematic studies have been conducted to quantify the level of threat. The few recent studies estimated low abundances (Blackham, 2005; Nekaris et al., 2008; Nekaris & Munds, in press). These are not surprising, even based solely on habitat loss, as in under a quarter of a century a third of Borneo’s forests have disappeared due to logging, oil palm plantations, mining, fires and other forms of human development (Rautner & Hardiono, 2005). Habitat loss is not the only threat to the populations of these primates; they are also threatened by hunting, and the pet
and medicinal trade (Lee et al., 2005; Nekaris & Nijman, 2007; Nekaris et al., 2009; Shekelle et al., 2008). A final threat may be the increasing competition between these primates, as they are forced into smaller habitats due to deforestation. Both species share a similar diet, with tarsiers being faunivores (Jablonski & Crompton, 1994) and Bornean lorises omnivores, but being predicted as the most faunivorous of all slow loris species (Nekaris & Bearder, 2007; Ravosa, 1998). Bornean lorises have even been observed attempting to predate on tarsiers (Niemitz, 1979). Some argue that because tarsiers are strict undergrowth foragers, most competition is avoided (Crompton & Andau, 1987; Neimitz, 1984), but all slow loris species are believed to forage at all levels of the forest (Nekaris et al., 2008). No prior studies have attempted to assess if these primates have evolved niche divergences to lessen inter-generic competition. It is unknown how the combined anthropogenic threats and competition between species are affecting the populations of these sympatric primates. Data on habitat preferences and other ecological requirements are needed to assess competition between these species.

In this study, we provide new abundance estimates for the nocturnal primates of Borneo in a degraded floodplain. Additionally, we assess loris and tarsier micro-habitats based on tree/sapling density and size (diameter at breast height (DBH) and height), to determine if these sympatric primates are competing. We predict if competition is present, then there should be no marked differences between the micro-habitats of these primates.
3.4 METHODS

3.4.1 Field site
   See section 2.1

3.4.2 Survey Methods
   See section 2.2.1

3.4.3 Botanical Methods
   See section 2.2.2

3.4.4 Analysis
Abundance was calculated using the following formula: Density= number of animals
observed divided by two times strip half –width x length of trail (D=n/2wl) (Sutherland,
2002). Strip width was obtained by eliminating 10% of the furthest sightings from all
observations.

The program Presence was used to determine the detection probability of the study species in
DGFC. It allows us to assess if animals were difficult to detect because they were not there
and not because of the density of the forest (MacKenzie et al., 2005).

Vegetation data were tested for normality between and within groups, and found to have an
abnormal distribution (Height, D (147) =0.2, p < 0.001 and DBH, D (147) =0.2, p < 0.001); we
thus used non-parametric tests. We used the Kruskal-Wallis analysis of variance to
determine whether variation existed between loris, tarsier and neutral habitats. Mann-
Whitney U tests were used to test differences between two groups. An additional post-hoc
test comparing mean ranks to discern deviation was also used (Seigel & Castellan) as Mann
Whitney U tests are not always reliable as a post-hoc (Field, 2009). All tests were run in
SPSS v 17.0 with a 95% confidence level.
3.5. RESULTS

3.5.1 Survey results
The study yielded a survey effort of 68.56 km. The determined half-width was 10 m, giving a strip width of 20 m. The range of distances from transect for sightings was 0-27 m, with a median range of 3 m. Lorises were sighted at a median height of 15 m with a range of 8.5-30 m. The median tarsier height was 1.25 m with a range of 0.5-3 m. A total of 8 lorises and 5 tarsiers were spotted, resulting in an abundance of 0.1 lorises/km or 5.05 lorises/km² and 0.06 tarsier/km or 2.75 tarsiers/km².

3.5.2 Detectability results
Point sampling resulted in 30 sites being sampled, each on five occasions, resulting in a total of 150 samples. Both lorises and tarsiers were observed only once at separate locations. These results were modeled with the program Presence for a single season, and for both species the probability of detection was 1% for the DGFC area, as only 2 sites were occupied during the study.

3.5.3 Micro-habitat variability results
Comparisons of the three study areas revealed that heights of trees between loris (Median (Mdn) 6.8 m), tarsier (Mdn 3.6 m) and neutral (Mdn 6.1 m) areas differed significantly, $H (2) = 25.92, p < 0.001$. DBH (Mdn: loris 17.8 cm; tarsier 6.2 cm; neutral 12.2 cm) also varied significantly, $H (2) = 19.37, p < 0.001$. 
The post-hoc analyses (Mann Whitney U, Seigel & Castellan) indicated that there were no differences between loris and neutral habitats for both height and DBH: Height, U= 968.5, \( z = -0.31, r = -0.03, ns \); DBH, U= 943.5, \( z = -0.51, r = -0.05, ns \). Conversely tarsier and neutral habitats differed significantly (Height, U= 538.5, \( z = -4.05, r = -0.42, p < 0.001 \); DBH, U= 568, \( z = -3.82, r = -0.4, p < 0.001 \)). Finally, tarsier and loris habitats varied significantly by height (U= 734.5, \( z = -4.54, r = -0.43, p < 0.001 \)) and DBH (U= 877.5, \( z = -3.68, r = -0.35, p < 0.001 \)). Results from the additional post-hoc tests supported the Mann-Whitney U, indicating that areas that support lorises have larger sized trees compared to areas where tarsiers were found.

The precise trees in which lorises and tarsiers were found significantly differed for both height (U=0.0, \( z = -2.611, r = -0.83, p < 0.001 \)) and DBH (U=0.0, \( z = -2.611, r = -0.83, p < 0.001 \)).

Tree density was similar in both loris and tarsier habitats (U=8.5, \( z = -0.84, r = -0.27, ns \)). The median number of trees in loris habitat plots was 8 and in tarsier habitats 11. Tree density averages were: 10.6 (loris plots), 11.2 (tarsier plots) number of trees per plot.

### 3.6 DISCUSSION

#### 3.6.1 Abundance of nocturnal primates

There are more studies of tarsier behavior and home ranges (Crompton & Andau, 1987; Gursky, 1998) than studies of population parameters needed to set conservation priorities. The few studies on tarsier populations indicate that they are uncommon in degraded habitats,
particularly areas where much land conversion is occurring, and they thrive in protected areas and primary forests; although some studies indicate that tarsiers thrive in all habitat types (Merker & Muhlenberg, 2000). Recent Bornean tarsier population densities is of concern, as the densities are extremely low compared to other Tarsius spp. found in degraded forests (Blackham, 2005; this study) (Table 1; see Nekaris et al., 2008 for Nycticebus spp.). When looking at the other Tarsius bancanus sp., only one study was done in a degraded habitat (Yustian, 2007); their results had an estimated population size that was 7-17 times larger than the population found in this study. Compared to congeners in non-deforested habitats, our densities are extremely low. Populations in non-degraded habitats are 7-29 times larger. This may indicate that tarsiers in this area have not recovered from the long-term logging that took place less than twenty years ago. This is corroborated by similar results from the only other recent Bornean tarsier survey by Blackham (2005), which also took place at a site that experienced logging in the last twenty years. Such low rates demonstrate that these primates are sensitive to habitat change and have a slow rate of recovery. The high deforestation

<table>
<thead>
<tr>
<th>Tarsius spp or sp.</th>
<th>Habitat types*</th>
<th>Abundance (individuals/km²)</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. b. borneanus</td>
<td>Improved</td>
<td>80</td>
<td>Niemitz, 1984</td>
</tr>
<tr>
<td>T. b. borneanus</td>
<td>Improved</td>
<td>14-20</td>
<td>Crompton &amp; Andau, 1986</td>
</tr>
<tr>
<td>T. dianae</td>
<td>Improved</td>
<td>13.6 groups/10 ha</td>
<td>Merker &amp; Muhlenberg, 2000</td>
</tr>
<tr>
<td>T. dianae</td>
<td>Improved</td>
<td>57.1 ± 21.5 groups</td>
<td>Yustian et al., 2008</td>
</tr>
<tr>
<td>T. syrichta</td>
<td>Improved</td>
<td>57</td>
<td>Neri-Arboleda, 2002</td>
</tr>
<tr>
<td>T. b. borneanus</td>
<td>Degraded</td>
<td>2.75 (0.06 tarsiers/km)</td>
<td>Munds et al., this study</td>
</tr>
<tr>
<td>T. b. borneanus</td>
<td>Degraded</td>
<td>0.07 tarsiers/km</td>
<td>Blackham, 2005</td>
</tr>
<tr>
<td>T. b. saltator</td>
<td>Degraded</td>
<td>19-46</td>
<td>Yustian, 2007</td>
</tr>
<tr>
<td>T. dianae</td>
<td>Degraded</td>
<td>8.5 groups/10 ha</td>
<td>Merker &amp; Muhlenberg, 2000</td>
</tr>
<tr>
<td>T. dianae</td>
<td>Degraded</td>
<td>32.9 ± 3.1 groups</td>
<td>Yustian et al., 2008</td>
</tr>
<tr>
<td>T. sangirensis</td>
<td>Degraded</td>
<td>1,505-52,734 total population in area of 21.5-532.5 km²</td>
<td>Shekelle &amp; Salim, 2009</td>
</tr>
</tbody>
</table>

*Habitat types: Improved- deforestation has not occurred for 25+years. Degraded: Deforestation activities have occurred (< 24 yrs), or are still continuing.
levels occurring in Borneo threaten tarsier populations and highlight the need for more surveys to assess how many of these primates remain throughout Borneo.

Some argue slow lorises are the most common nocturnal mammal to be sighted in Southeast Asia (Duckworth, 1994), but it is difficult to extend such claims throughout their range when populations for all *Nycticebus* spp. span from 0.03 individuals/km to 4.0 individuals/km (Nekaris *et al*., 2008). Population estimates with 4.0 individuals/km are from sites that were specifically selected for their known plethora of lorises. These sites were not used to provide accurate population densities of lorises (Wiens, 2002; Wiens & Zitzmann, 2003). When these sites are excluded, population densities range from 0.02-1.63 individuals/km (Nekaris *et al*., 2008; Nekaris & Munds, in press). Our results are at the lower end of relative abundance, with 0.1 individuals/km. However, our results do correlate with previous studies on *N. menagensis* in Kalimantan, Borneo, which found them in low numbers, 0.02-0.19 individual/km (Nekaris *et al*., 2008; Nekaris & Munds, in press). Although these past studies focused on degraded habitats, other brief reports found them to be uncommon even in primary forests (Duckworth, 1997; Jenkins, 1971). Such results indicate that Bornean lorises are not abundant, but their populations may be stable. Heavy loss of habitat and the fact that lorises are the most commonly seen primates in the illegal pet and medical markets (Nekaris & Nijman, 2007; Shepard *et al*., 2005) necessitate further studies on how rare these primates are throughout Borneo.
3.6.2 Micro-habitat variability and niche divergences

The hypothesis that lorises and tarsiers were competing was not upheld, as there was a significant difference between the loris and tarsier micro-habitat structures. These sympatric primates favor different habitat niches, which in turn reduces competition. The lack of significant difference between loris and neutral habitats suggest that lorises may lack a defined micro-habitat. Past studies on slow lorises have found them to range in numerous types of environments from plantations and other agricultural areas, to heavily degraded forests and most pristine forests (Elliot & Elliot, 1967; Nekaris et al., 2008; Radhakrishna et al., 2005; Wiens & Zitzmann, 2003). An important limitation for lorises is that they are quadrupedal movers and are incapable of leaping, thus requiring canopy continuity to move easily throughout the forests, although they can move on the ground when necessary (Nekaris & Bearder, 2007). Areas where tarsiers were found lacked the continuity that lorises required, but did provide the necessary substrates for tarsiers: trees with small DBH. Crompton & Andau (1987) and Niemitz (1984) noted that Bornean tarsiers preferred vertical supports smaller than 4 cm DBH. These small vertical substrates, allow for easy grasping which helps with vertical clinging and leaping (VCL) (Crompton et al., 2009). Tarsiers in our study were observed in trees with an average of 4 cm DBH, and the median DBH in tarsier plots was 5 cm. Conversely, lorises were found in trees with a DBH of 40 cm, and the median DBH of loris and neutral plots were twice as large as tarsier plots. Lorises are less selective in their habitats, but it appears they would not often range in preferred tarsier habitats, as the supports required are not available (Pimley, 2002).
An additional niche divergence between these species is height preference. Bornean tarsiers have been observed at a median height of 1 m (range 0-10.7 m) (Crompton et al., 2009), and in this study they were never observed above 3 m. Slow lorises are known to range from the
ground to as high as 30+ m (Wiens & Zitzmann, 2003; Nekaris & Bearder, 2007), but until now almost all studies have been on species that do not share ranges with tarsiers. The median height of Bornean lorises is 15 m (range 8.5-30). The Bornean loris range overlaps the range of the tarsiers, but only 1.5 m. Compared to other Nycticebus spp., the Bornean loris (N. menagensis), appears to favor higher levels of the forest (Table 2).

This preference for higher levels of the canopy may be to maintain a stable co-existence with the Bornean tarsiers. Such ecological partitioning by height has been observed in other primate species (Bearder et al., 2003; Fleagle, 1999; Harcourt & Nash, 1986; Heymann & Smith, 2000). A classic canopy division study was done in Gabon on five sympatric nocturnal primates (Charles-Dominique, 1977). These five strepsirrhines shared a habitat, but were able to co-exist because of different requirements, which affected their canopy height preferences. In the Gabon study, the Allen’s bushbaby, a VCL, was partial towards heights of 1-2 m and small, vertical supports of 1-15 cm. Whereas the potto, a quadrupedal primate, spent most of its time in the upper canopy (20-40 m), but was spotted as low as 5 m, and preferred large branches and lianes as supports (Charles-Dominique, 1977). Other studies have had similar results, indicating that height preference can be an outcome of locomotion or ecological needs (Harcourt, 1984; Dagasto & Yamashita, 1998; Pimley, 2002).

Other niche divergences contributing to the cooperative living of these nocturnal primates need to be explored. One is the body size and weight differences. The Bornean loris has a median weight of 420 g (range: 265-682 g) and an average body length of 260 mm. The Western tarsier (all T. bancanus spp.) is found to have a median weight of 115 g (range: 106-
138 g) and an average body length of 160 mm (Munds pers. data; Nekaris & Munds, 2010). The differences in body size may contribute to differences in metabolic rates and dietary requirements. Another observation from this study was flee-behavior. Upon detection it was noted that tarsiers would take flight, quickly leaping from sapling to sapling. The loris would freeze, sometimes hiding its face and eyes from the observer. Different flee responses have been observed in sympatric mouse lemurs (Radespiel et al., 2003), galagos (Bearder & Doyle, 1974) and with pottos and galagos (Charles-Dominique, 1977). These differences are a result of different anti-predator strategies and are another form of niche divergence. Data are needed on various aspects on the ecology of these primates to discern how niche divergences are reducing competition. This study provides a first glimpse of how these primates are living sympatrically and confirms that Bornean lorises and tarsiers are reducing competition by favoring different habitats and canopy heights.

ACKNOWLEDGMENTS
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CHAPTER 4: Ways not to trap the Lorisinae of Asia *(Loris, Nycticebus)* and Perodicticinae of Africa *(Perodicticus, Arctocebus)*.

*I have not failed. I've just found 10,000 ways that won't work.*

-Thomas A. Edison

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4.1 ABSTRACT

A successful live-trapping regime for members of the subfamilies Perodicticinae (pottos) and Lorisinae (lorises) has yet to be devised. Four genera of pottos and lorises range within Africa *(Arctocebus and Perodicticus)* and Asia *(Loris and Nycticebus)*. Our inability to trap consistently prevents us from increasing our understanding about the behaviour and genetics of these elusive primates, which further hinders development of conservation action plans. To help resolve this problem, we conducted a literature review on the past trapping attempts. In addition, we provide an overview of the methods we attempted to trap the Bornean slow loris *(Nycticebus menagensis)*, but which failed. Our study took place in the Lower Kinabatangan Wildlife Sanctuary, Sabah, Malaysian Borneo from August-September 2009. A total of 30 traps were built locally, and then hoisted into the canopy (8-30 m). A 26 trap night study ensued, with an effort of 451 traps set and no lorises caught. Our results coincide
with the literature and information provided by colleagues. Only nine other studies have attempted to trap three of the four genera of lorises, and only four were successful. Success rates were miniscule compared to the effort put in to capture. The *Nycticebus* spp. have received the most effort of 48480 traps set, but a success rate of only 1 capture per 1154 traps set. Effort for *Perodicticus* spp. was 24000 traps set, and a success ratio of 1:800. Finally, a small effort of 660 traps set has been attempted with *Loris* spp. but with no success. Applying arboreal trapping and pungent-smelling bait may assist in increasing the likelihood of catching a loris and decreasing the duration and effort needed. A major concern about developing an efficient trapping regime is it could compromise their survival, as the primary threat for many loris species is the wildlife trade. In order to assist researchers in developing a trapping method and protect lorises, we propose creating an on-line private group for loris-interested researchers to safely share ideas.

**4.2. Key Words:** Arboreal trapping, Lorisinae, Perodicticinae, *Nycticebus menagensis*, wildlife markets

**4.3 INTRODUCTION**

The successful implementation of live-trapping methods has resulted in the better understanding of the behaviour and taxonomy of many once unknown species. Being able to capture these elusive animals allows researchers to radio-collar individuals, to discern home-ranges and other ecological aspects. Additionally, trapping aids taxonomic studies by making it easier to collect morphological measurements (such as weight and head & body length) and tissue samples for genetic research. For instance, in the field of primatology the taxonomic results from trapping studies have resulted in discoveries of many new species or the reclassification of others (Scheffrahn *et al.*, 2000; Li *et al.*, 2007; Thalmann, 2007; Hamada
et al., 2008). The valuable data that can be rendered from live-captures helps conservationists in creating effective protection plans for these species; enabling their survival for the future.

The problem arises when the animal is hard to trap, and few studies are published in regards to the lack of success. Such an examples if found in the primate subfamilies of Lorisinae and Perodicticinae; four genera that are found in Asia (*Loris, Nycticebus*) and Africa (*Perodicticus, Arctocebus*) (Nekaris & Bearder, 2007). They are characterized as cautious, typically slow movers, which favour all levels of the canopy and rarely descend to the ground. Often they are found in the dense parts of the forest, and depend on canopy continuity for ease of locomotion. They have a diet that ranges from omnivorous, including insects, gum, fruit, birds and small mammals, to almost exclusively faunivorous (Charles-Dominique, 1977; Nekaris & Jaywardene, 2003; Nekaris & Bearder, 2007; Nekaris et al., 2008). Due to their ecological preferences, successful trapping is rare. The most successful study was on pottos, with 1 potto trapped per every 800 traps set (Pimley et al., 2005). Unfortunately, it is difficult to improve upon trapping methods when few researchers publish their ineffective results and detail their methods; making it inevitable for future researchers to repeat their mistakes (Coultas, 2000; Nekaris & Pimley, 2002; Wiens, 2002; Bernede, 2003; Davey pers. comm.).

With this study we attempted to trap the elusive Bornean slow loris (*Nycticebus (coucang) menagensis*). Our study used three different trap types and an arboreal trapping method which required us to hoist the traps via ropes into the canopy (Kays, 1999). Furthermore, we gathered unpublished trapping results from colleagues, as well as the few available published trapping results to summarize the previous methods employed for trapping lorises and pottos.
Identifying methods that have met with little success will assist future researchers in developing a successful live-capturing regime for lorises and pottos. Members of the subfamily Lorisinae and Perodicticinae will be referred to as lorises for the remainder of this paper, but when addressing a specific genus, then the scientific nomenclature for the genus will be used.

4.4 MATERIAL AND METHODS

4.4.1 Study species- The Bornean slow loris (N. menagensis) is found on Borneo and several surrounding islands (Banka, Sulu islands, Natuna, Philippines) (Brandon-Jones et al., 2004). Like other Nycticebus spp., the Bornean loris is omnivorous but based solely on a craniodental study it has been postulated to be the most insectivorous of all Nycticebus spp (Ravosa, 1998). There has been no behavioural research on this species. Of the two field studies done on them they were found to be low in abundance (0.02-.19 individuals/km) and ranging from heights of 8.5-30 m (Nekaris et al., 2008; Nekaris & Munds, 2010; Munds et al., in prep). Catching them is necessary to collect tissue samples and morphological measurements, as their taxonomic status is currently being reviewed. Additionally, the rapid deforestation throughout Borneo (Raunter & Hardiono, 2005) highlights the need for detailed behavioural studies to determine their habitat requirements.

4.4.2 Field site- See section 2.1

4.4.3 Preliminary surveys - See section 2.2.1

4.4.4 Trapping placement & procedures- See section 2.2.3
4.4.5 Genera comparison - Trapping data regarding lorises were collected from the literature and various colleagues who never published their trapping attempts. Studies from the literature were difficult to incorporate as few detailed the methods employed. Analyzed data needed to provide trap types, number of traps set, duration of study, location of study, focal species, type of bait, and if any captures occurred. To clear up some ambiguity, trap type refers to a specific brand or type of trap (Tomhawk, Sherman, locally made loris specific). The numbers set is the amount of traps set throughout the entire duration of the study and will also be referred to as the trapping effort. Duration regards the length of the study. Data that did not provide all seven basic precepts were still compiled (Table 1) to assist future researchers.

4.5 RESULTS & DISCUSSION

4.5.1 Effort and duration - For this study an effort of 451 traps was set to no avail. The results are not surprising when compared to the outcomes of the few studies that have attempted to trap lorises (Table 1). Successful captures appear to occur when a high effort is coupled with a long duration. This is a positive correlation, as the more time spent trying to capture will increase the number of traps set during a study. For a successful outcome, efforts must reach a pentagonal figure: the lowest number exceeding 20,000 traps set in a study, and anything beyond will better the chances of capture. These data imply that at least six months is needed in order to obtain such a high effort.
Table 1: Efforts, methods and duration of known Lorisinae and Perodicticinae trapping attempts.

<table>
<thead>
<tr>
<th>Species</th>
<th>Effort</th>
<th>Trap type</th>
<th>Avg height (m)</th>
<th>Primary baits</th>
<th>Duration</th>
<th>Successful capture (Y/N)</th>
<th>Location</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>N. menagensis</em></td>
<td>451</td>
<td>3 different loris specific</td>
<td>15</td>
<td>Jack &amp; palm fruits</td>
<td>26 nights</td>
<td>N</td>
<td>Lower Kinabatangan Floodplain, Sabah, Malaysia, Borneo</td>
<td>This study</td>
</tr>
<tr>
<td><em>N. coucang</em></td>
<td>48000</td>
<td>Wire mesh &amp; Loris specific</td>
<td>NA-arboreal</td>
<td>Banana</td>
<td>800</td>
<td>Y</td>
<td>Manjung District, Perak, Malaysia</td>
<td>Wiens, 2002</td>
</tr>
<tr>
<td><em>N. menagensis</em></td>
<td>46000</td>
<td>Wire mesh</td>
<td>Ground &amp; 13.5</td>
<td>Banana</td>
<td>6 months</td>
<td>Y</td>
<td>Kinabalu National Park, Sabah, Malaysia, Borneo</td>
<td>Wells et al., 2004*1</td>
</tr>
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<td><em>N. bengalensis</em></td>
<td>33</td>
<td>Wire mesh</td>
<td>8</td>
<td>Banana</td>
<td>3 nights</td>
<td>N</td>
<td>Khao Ang Runai Wildlife Sanctuary, Thailand</td>
<td>Pliosungnoen &amp; Savani, 2008</td>
</tr>
<tr>
<td><em>P. p. edwardsi</em></td>
<td>NA</td>
<td>Noose traps &amp; wire mesh</td>
<td>NA-arboreal</td>
<td>Banana</td>
<td>42 months</td>
<td>Y</td>
<td>Makokou, Gabon</td>
<td>Charles-Dominique, 1977*2</td>
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<tr>
<td><em>P. p edwardsi</em></td>
<td>23400</td>
<td>Wire mesh</td>
<td>3-5</td>
<td>Banana &amp; avocado</td>
<td>780</td>
<td>Y</td>
<td>Mount Kupe, Cameroon</td>
<td>Pimley et al., 2005*3</td>
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<tr>
<td><em>P. p edwardsi</em></td>
<td>602</td>
<td>Wire mesh</td>
<td>15</td>
<td>Banana</td>
<td>154</td>
<td>N</td>
<td>NA</td>
<td>Davey, pers comm.</td>
</tr>
<tr>
<td><em>L. tardigradus</em></td>
<td>25</td>
<td>Chardonneret box traps</td>
<td>2-3 m</td>
<td>Banana &amp; treacle honey</td>
<td>5 nights</td>
<td>N</td>
<td>Masmullah Proposed Forest Reserve, Sri Lanka</td>
<td>Coultas, 2002</td>
</tr>
<tr>
<td><em>L. t. tardigradus</em></td>
<td>300</td>
<td>Chardonneret box traps (10) and</td>
<td>1.5-3 m</td>
<td>Banana, treacle honey, cat food,</td>
<td>15 nights</td>
<td>N</td>
<td>Masmullah Proposed Forest Reserve, Sri Lanka</td>
<td>Nekaris and Pimley, 2002, unpub. data.</td>
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<tr>
<td>Species</td>
<td>Trapping Method</td>
<td>Trap Type</td>
<td>Length (m)</td>
<td>Sonation (nights)</td>
<td>Location</td>
<td>Authors, Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------</td>
<td>-----------</td>
<td>------------</td>
<td>-------------------</td>
<td>---------------------------------------</td>
<td>--------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>L. tardigradus</em></td>
<td>Tomhawk traps</td>
<td>(10)</td>
<td>2.6</td>
<td>30 nights</td>
<td>Bangamukande Estate, Galle District, Sri Lanka</td>
<td>Bernede, 2003</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>L. lydekkerianus</em></td>
<td>Tomhawk &amp; havahart</td>
<td>NA</td>
<td></td>
<td>6 months</td>
<td>Mundanthurau Plateau, India</td>
<td>KarGupta, 2007</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These studies did not focus solely on capturing a loris which is why they were not included in the trapping results.

1 Wells et al., (2004) captured a single loris 3 times in the canopy and the ground.
2 70 captures, 20 individuals, were caught; 9 with noose traps and the remainder with wire mesh. An effort was not provided, so results could not be used.
3 Two of the lorises were caught by hand.
4 An effort in hours was given, but this is not comparable to other studies so results could not be used.
Even with high efforts, the proportion between number caught and traps set is exceedingly low (Table 2). An additional two weeks of time is recommended for a trial period. The traps would be baited, but left open, allowing the animal to safely enter and exit the trap. This would habituate the study species to the traps. This type of trial period has been successful in aiding with capturing and re-capturing animals (Bearder pers comm.)

### Table 2: Combined trapping results of each genus

<table>
<thead>
<tr>
<th>Genus</th>
<th>Effort (number traps set)</th>
<th>Number caught (animals caught/traps set)</th>
<th>Success rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctocebus</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Loris</td>
<td>660</td>
<td>0</td>
<td>0:660</td>
</tr>
<tr>
<td>Nycticebus</td>
<td>48480</td>
<td>42</td>
<td>1:1154</td>
</tr>
<tr>
<td>Perodicticus</td>
<td>24000</td>
<td>30*</td>
<td>1:800</td>
</tr>
</tbody>
</table>

*Not clarified by Pimley *et al* (2005) what amount of captures were caught by hand or trap.

The problem is such a long time investment is a major deterrent for many researchers who wish to implement and finish a study in six to 12 months. Additionally, the long-time in the field may force geneticists who wish to clarify the species debate within these primates to use less reliable tissue samples from museum specimens. To assist the dedicated loris researchers we provide a few synopses that will hopefully offer some inspiration in developing a trapping regime that will require less time and effort.

**4.5.2 Arboreal trapping and heights**- We define an arboreal trapping method as a procedure that lifts traps at least 0.5 m off the ground. The traps do not have to be in the canopy, but should be placed at heights where the study species are found. All loris are found from heights of 0-30+ m, but rarely descend to the ground (Charles-Dominique, 1977; Wiens, 2002;
Nekaris & Jaywardene, 2003; Munds et al., in prep); making arboreal trapping a key element for a successful trapping regime. For our study, we attempted to remain in the height preference of *Nycticebus menagensis* (Nekaris et al., 2008; Munds et al., in prep), therefore all trap types were put at different levels of the canopy, between 8-30 m, with an average height estimate of 15 m. The arboreal method we employed was quick and safe, as it did not require climbing into the canopy and it allowed ~15 trap-hoisting ropes to be put up in two hours. The downfall came with branch selection and trap-stability. Lorises tend to favour areas of dense liana and foliage coverage (Charles-Dominique, 1977; Wiens, 2002; Nekaris & Jaywardene, 2003; Pimley et al., 2005), but these areas do not ensure a safe branch to support the weight of a trap. Plus it is difficult to determine how alive the branch is when it is covered with vines. Thus we were forced to place our ropes near tangles of vines. Climbing into trees to place our ropes would have placed the ropes in more loris suitable habitats, but it would have compromised our safety, so we opted against it. Trap-stability was less of a concern, as most arboreal mammals are used to the sway of a branch, so a swaying trap should not be a problem (Kays, 1999). We ensured the trap would not bang against trees or branches, or get stuck in the canopy by attaching a guide rope to the bottom of it. This provided more control of the trap and its location in the canopy (Kays, 1999). Alternatively, attaching traps to branches or a pole and setting it near branches, and making the traps part of the loris normal travel is another method that has been successful (Pimley et al., 2005). Arboreal trapping has been semi-successful with past loris studies and should be further explored to determine its effectiveness with other loris species.

4.5.3 Bait- One of the major problems with lorises is trying to find effective bait, albeit most people rely on bananas. Of the ten studies examined, and the nine that detailed the type of bait used, all but this study favoured banana. Ripe banana was considered to be smelly bait
(Charles-Dominique, 1977; Davey, pers comm., 2009), but with other options available we considered banana to be one of the least fragrant items. Borneo yields a host of pungent-smelling fruit: several species of jack fruits including the infamous fish-like smell of durian. Our study demonstrates that banana was not as successful in luring animals into the traps. Out of an effort of 60 attempts with banana as the bait, only twice (3%) was it stolen. Durian had an effort of 30, and eight baits (27%) were stolen. Similarly, jack fruit was used 65 times and was stolen 14 times (22%). Although, a loris may have not stolen the fruit, this example reveals that there are other baits available that are more appealing. On the one occasion from this study where a loris was seen to be approaching a trap, jack fruit was the bait; unfortunately the loris was not caught.

As an omnivorous species, bait is a critical issue. For lorises as a whole, to determine a definitive food item is impossible. Each genus favours a different diet (Table 3), and even within a genus, diets of species vary (Nekaris & Bearder, 2007). The genera Loris and Arctocebus, have had the lowest trapping effort because of their primarily faunivorous diet (Charles-Dominique, 1977; Nekaris, 2001; Nekaris & Jayewardene, 2003). Charles-Dominique (1977) deposed his trapping study of Arctocebus due to the challenge of finding an attractant for the species. This dietary preference explains why no one has successfully trapped a member of either of these genera. For these genera, we propose using live-insects as bait, by attaching a string through the abdomen of a large insect and tying it, whilst alive, to the cage. Such a method has been attempted before, but effort and details regarding if insects were kept alive was not recorded (Bernede, 2003). Likewise, Nycticebus and Perodicticus have a broad diet, which makes it difficult to find ideal bait. To the researchers’ advantage, both consume fruit and in higher proportions than their thinner cousins. More so, the diet of Perodicticus spp. is dominated by fruit, thus making it appropriate bait (Charles-
We encourage the use of different fruits to determine if one has more positive results than others. The Nycticebus spp. may be a true omnivore, with a diet that has near equal parts of fruit, gum and nectar, and various animals (Wiens, 2002; Wiens & Zitzmann, 2003; Nekaris & Bearder, 2007; Striecher et al., in press). Hard-boiled eggs, which are strong-smelling, may be an excellent bait to use. In recent research, these sweet looking creatures show a ravenous appetite for birds (Striecher et al., in press), and wild slow lorises have been observed eating eggs (Nekaris & Bearder, 2007). Other loris bait proposals are provided (Table 3).

Table 3: Food preferences and bait suggestions

<table>
<thead>
<tr>
<th>Genus</th>
<th>Main food items</th>
<th>Bait suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctocebus, Loris</td>
<td>Animal prey &amp; fruit</td>
<td>Insects (crickets, grasshoppers, caterpillars), eggs, cat food, sap</td>
</tr>
<tr>
<td>Perodicticus</td>
<td>Fruit, animal prey, sap &amp; nectar</td>
<td>Eggs, insects, fragrant fruits, cat food, sap</td>
</tr>
</tbody>
</table>

4.5.4 Trap types & locomotion- Commercial traps (Sherman, Tomahawk) are designed based on an animal’s size and weight. Trap producers do not consider an animal’s locomotion, as typically it is not necessary because many animals, including many nocturnal primates, are easily caught by standard traps (Harcourt & Nash, 1986; Kays, 1999; Radespiel et al., 2003; Schulke & Kappeler, 2003; Munshi-South, 2006). Some species are more problematic due to their mode of locomotion. Such an example is found with lorises, which are cautious and hold on to a branch with a back leg, while they stretch their body to get the bait inside the trap (McArdle, 1981; Nekaris, 2001; Nekaris, pers. comm.). Rarely will they put their entire body in a small trap (Nekaris, pers. comm.). Commercial traps for the size and weight of lorises are too short in length when factoring in the loris’s stretch. If a larger trap is used, the small body size of a loris will not set off the trigger. Loris-specific traps are difficult to
design, because one has to factor weight, size and stretch; making a trigger sensitive enough to detect a loris, but not too sensitive to fall from the weight of the trap is difficult. Traps without triggers (i.e. modified pit-falls) result in the capture of undesired animals, or leave a hole in the trap which encourages predators. Loris-specific traps need to be large enough to persuade the loris to enter, but not have vast space inside the trap, as that will stress a loris. Instead of having the animal stand on a platform to set the trigger, like most traps, a study on pottos has found requiring animals to remove the bait from a platform to set off the trigger is more successful for capture (Pimley, pers comm.). This trap design may be useful when attempting to trap other lorises. Designing a perfect, stress-free trap is impossible, but to reduce stress and increase safety and comfort of the animals, we suggest placing branches inside and around the trap, and make it with soft materials, like plastic mesh (Schulze, 2009; Nekaris, pers. comm.).

4.5.5 Other methods- Other forms to capture lorises without traps have been done. Opportunistic hand-catching is done when a loris is within reach (Wiens, 2002; Nekaris & Jaywardene, 2003; Pimley et al., 2005; Starr, 2010), but the height preferences of some species make such an opportunity rare. Some researchers have opted to shake lorises out of trees, but we discourage this because it is stressful to the animals. Others have suggested darting them with an anaesthetic and a fast acting-muscle relaxant. Obvious problems with this method are the fall to the ground or poor aim could cause serious injury. If the study requires tissue samples, non-invasive methods have been developed. One that may be useful to incorporate was developed by Amendo-Pimenta et al. (2009) for howler monkeys. They created a sticky blow-dart that once shot could be drawn back with hair and follicles attached to the dart. Another method is noose-catching favoured by local hunters in Indonesia.
(Nekaris & Munds, 2010) although this could be more labour intensive. Charles-Dominique (1977) was successful with this method when catching Perodicticus spp. There are many advantages to live-capture, but if a successful trapping methodology cannot be created for lorises, then the way forward may depend on using one of these creative methods.

4.5.6 Problems of trapping, conservation & the future- Understandably, few researchers want to make public a successful trapping regime when the main threat to most lorises is the pet and medicinal trade (Nekaris et al., 2009). Additional threats include the rapid loss of habitat and hunting for human consumption (Raunter & Hardiono, 2005; Laurence et al., 2006). Results that can benefit multiple studies, but harm the survival of a species, put loris-scientists in a quagmire when it comes to openly sharing ideas, and explains with good reason why trap types are often described in vague terms as “loris-specific” and “wire-mesh”.

Sharing too much information may not only benefit the researcher who wants to know how to trap a loris, but it also benefits the pet-trader. Even we decided not to show images of the unsuccessful traps. Perhaps the best way to protect these species and improve trapping would be to create a private online group for loris-interested researchers to share methodology. Working with each other, openly discussing ideas, will help in creating a trapping regime that will take less time and produce more positive results.

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observing protocols set out by the American Society of Mammalogists.

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CHAPTER 5: Facial mask markings used to reveal taxonomic differences in the bornean slow loris (*Nycticebus menagensis*)

*There is nothing like looking if you want to find something. You certainly usually find something, if you look, but it is not always quite the something you were after.*

- *J.R.R. Tolkien.*

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Suggested running head: Bornean loris facemask differences

Title: Facemask markings used to reveal taxonomic differences in the Bornean slow loris

(*Nycticebus menagensis*)

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5.1 ABSTRACT
More species of nocturnal primates exist than originally believed, because many were cryptic species. Subtle morphological disparities, such as pelage pattern and color variation, vocal cues, and genetics have aided in elucidating the true number of species in a taxon. The slow lorises (genus *Nycticebus*) were once comprised of only two species, but taxonomic studies revealed an array of speciation which resulted in the recognition of three additional species, but diversity is still noted in the newly described species. The Bornean loris (*N. menagensis*) is such an example. Extreme differences in adult facial masks and the geographical barriers that this primate encounters justified an investigation of their taxonomy. Influenced by the amount of white on the face, similar facemask patterns significantly clustered together by geographic regions ($\Lambda = 0.07$, $F (14, 88) = 17.5, p \leq .05$). Based on facemask differences and geographic boundaries, our results support the classification of three subspecies of Bornean lorises.

5.2 Key words: *Nycticebus menagensis*, cryptic species, morphology, sympatric, allopatric

5.3 INTRODUCTION
Technological advances have improved our knowledge about several nocturnal mammals; many of these nocturnal mammals were cryptic species that were falsely lumped together as one species (Bickford *et al* 2006). With a better understanding of what differentiates these cryptic mammals, new species have been recognized (Bearder 1999; Yoder *et al* 2000; Jacobs *et al* 2006; Munshi-South 2006). Many were distinguished by their unique calls (Niemitz 1984; Bearder 1999; Jacobs *et al* 2006), others by variation in sexual anatomy (Anderson 2000), subtle and obvious pelage variations (Ford 1994; Bearder 1999; Carraway and Verts 2000; Bradley and Mundy 2008), and the increased use of genetics has resulted in the

Although the number of recognized species of primates has more than doubled in the past 25 years and our understanding of what defines a species has improved, some species, particularly the nocturnal ones remain hidden. Many compounding variables contribute to the poor understanding of these species: difficulty of distinguishing between allopatric species, inability to collect genetic tissue, subtle morphological cues, and disagreements on what defines a species (Isaac et al 2000; Tattersall 2007; Bradley and Mundy 2008; Nekaris and Munds 2010). Here we examine geographic variation in the Bornean slow loris (Nycticebus menagensis, Lydekker 1893). A small taxonomic study has been done which found diversity within the species (Nekaris and Munds 2010), but no thorough investigation has been conducted.

Until recently, the genus Nycticebus (Boddaert 1785, cited from Groves 1971) was comprised of two species, the pygmy loris (N. pygmaeus) and the polymorphic slow loris (N. coucang), which was consisted of four subspecies (Groves 1971). Only in 1998 was one of the subspecies of N. coucang recognized as a distinct species (N. bengalensis) (Groves 1998). More than a decade after the first split in the genus, the three remaining subspecies of N. coucang have been classified as distinct, based on genetic and morphological research (Ravosa 1998; Roos 2003; Chen et al. 2006; Nekaris et al. 2008). More taxonomic research is required, as there is variation within these newly recognized species (Nekaris and Jaffe 2007; Nekaris and Munds 2010).
Slow lorises are found in a multitude of habitats from the heavily degraded to the pristine rainforests, plantations, and lowland and montane forests (Wiens 2003; Nekaris et al. 2008; Thorn et al. 2008). They are estimated to have an altitudinal limit of ~1000 m asl (Thorn et al. 2008). The smallest of the slow lorises, the Bornean loris, is found throughout Borneo and several surrounding islands. Based on cranio-dental analyzes the Bornean loris is speculated to be the most faunivorous of all the slow lorises (Ravosa 1998). They are listed as Vulnerable by the IUCN. Habitat loss and the illegal wildlife trade are affecting the survival of the Bornean loris (Nekaris and Nijman 2007; IUCN 2010). Borneo has lost a third of its forest in less than 25 years (Rautner and Hardino 2005) and Nycticebus spp. are the most commonly seen protected primate in the wildlife markets (Nekaris and Nijman 2007; Shepherd et al. 2005). As there is still much phenotypic variation detected within N. menagensis (Nekaris and Munds 2010), studies are needed to elucidate additional subspecies, as such research would assist conservationists in creating appropriate action plans to protect this primate.

Here we examine the external pelage variability of N. menagensis. Studies on other nocturnal primates have indicated that differences in pelage, particular the amount of white, have an influence on species recognition (Ford 1994; Bearder 1999; Bradley and Mundy 2008). By examining photographs and museum specimens of N. menagensis, we hope to reveal a greater diversity within this species than originally presumed. We propose, like other Bornean mammals and nocturnal primates, morphological disparities may result in the classification of subspecies.
5.4 METHODS

See section 2.3.1

5.4.1 Analysis
SPSS v. 17.0 was used to analyze differences between lorises. A cluster analysis (CA) divided the examined Bornean lorises into groups. To strengthen the CA findings, a discriminate analysis (DA) was run. The DA determined which of the nine facial features were more important to use to distinguish between the CA/DA groups. We used GoogleEarth 2010 to obtain the precise decimal latitude and longitude (GPS points) of analyzed lorises, which allowed us to assess if groups were clustered by geographic regions. Outlier lorises were re-examined and moved into appropriate groups based on the DA facial features and geographic location. Once we were confident with the groupings, a functional MANOVA tested for significance differences between the groups and facial features. Pair-wise comparisons between the groups were analyzed with MANOVA. Additionally, Pearson’s Chi-squares tested for significance between groups and analyzed facial features. A 95% confidence level was used.
<table>
<thead>
<tr>
<th>Characters</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Circumocular Patch</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patch Top</td>
<td>D: 100%</td>
<td>D: 9%</td>
<td>D: 50%</td>
</tr>
<tr>
<td></td>
<td>P: 19%</td>
<td></td>
<td>R: 50%</td>
</tr>
<tr>
<td></td>
<td>R: 72%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patch Bottom</td>
<td>BE: 29%</td>
<td>BE: 16%</td>
<td>BE: 50%</td>
</tr>
<tr>
<td></td>
<td>AZ: 71%</td>
<td>AZ: 31%</td>
<td>AZ: 21%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UZ: 53%</td>
<td>UZ: 29%</td>
</tr>
<tr>
<td><strong>Interocular Stripe</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>W: 100%</td>
<td>N: 81%</td>
<td>N: 100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W: 19%</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>R: 100%</td>
<td>B: 25%</td>
<td>R: 100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H: 6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: 69%</td>
<td></td>
</tr>
<tr>
<td><strong>Crown</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crown/fork</td>
<td>D: 100%</td>
<td>B: 25%</td>
<td>B: 7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D: 37.5%</td>
<td>D: 93%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: 37.5%</td>
<td></td>
</tr>
<tr>
<td>Ear fur coverage</td>
<td>A: 14%</td>
<td>A: 6%</td>
<td>A: 71%</td>
</tr>
<tr>
<td></td>
<td>P: 86%</td>
<td>P: 94%</td>
<td>P: 29%</td>
</tr>
<tr>
<td>Preauricular hair width</td>
<td>N: 86%</td>
<td>N: 6%</td>
<td>N: 21.5%</td>
</tr>
<tr>
<td></td>
<td>M: 14%</td>
<td>M: 47%</td>
<td>M: 21.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W: 47%</td>
<td>W: 57%</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mask color</td>
<td>O: 71%</td>
<td>B: 13%</td>
<td>O: 36%</td>
</tr>
<tr>
<td></td>
<td>R: 14%</td>
<td>O: 81%</td>
<td>Y: 64%</td>
</tr>
<tr>
<td></td>
<td>Y: 14%</td>
<td>R: 3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y: 3%</td>
<td></td>
</tr>
<tr>
<td>Black and white shade</td>
<td>L: 100%</td>
<td>D: 94%</td>
<td>D: 7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: 6%</td>
<td>L: 93%</td>
</tr>
</tbody>
</table>

*Patch top:* D-diffused, P-pointed, R-round; *Patch bottom:* BE-below eye, AZ-above zygomatic arch; UZ-under zygomatic arch; *Width:* N-narrow, W-wide; *Shape:* B-bulb, H-hourglass, R-round; *Crown/fork:* B-band, D-diffused, R-round; *Ear fur coverage:* A-absent, P-present; *Preauricular hair width:* N-narrow, M-medium, W-wide; *Mask color:* B-brown, O-orange, R-red, Y-yellow; *Black and white shade:* L-light, D-dark.

### 5.5 RESULTS

A hierarchical cluster analysis (CA) divided the 53 lorises into 3 primary groups and an outlier group. The discriminate analysis supported the CA division and revealed the outlier group aligned with group 2, thus outliers were placed in group 2. A Levene’s test of equality
of error variances denoted mask color ($p \leq 0.3$) and black and white shade ($p \leq 0.2$) to be insignificant indicators to demarcate lorises. This result supported the removal of the aforementioned features from the remainder of the tests. Although not all were significant, the nine features did vary between the groups (Table 1).

From the DA, a canonical discriminate function showed two outliers belonging to group 3 that aligned more with group 2. We re-examined the data and noted that one of group 3 outliers was mistakenly clustered due to its light face mask color. When face mask color and shade were discarded this loris clustered better with group 2, thus it was moved. The other outlier could not be determined, but even with this one outlier, 98.1% of lorises were clustered correctly (Fig. 1).

![Canonical Discriminant Functions](image)

**Fig 1:** Canonical discriminate function showing the clustering of the three groups of *N. menagensis.*
A factorial MANOVA showed significance between all 3 groups (Wilks’ Lambda statistic: $\Lambda = 0.07$, $F(14, 88) = 17.5, p \leq 0.05$). A Bartlett’s test of sphericity was significant (df=27, $p \leq 0.001$) as were pair-wise comparisons between groups (Wilks’ Lambda: $p \leq 0.05$).

According to the Levene’s test of equality of error variances, all tested facial features were significant when demarcating groups. The circumocular patch bottom was the closest to being insignificant ($p = 0.05$).

Pearson’s chi-squares tests found circumocular patch top, circumocular patch bottom, crown forks and preauricular hair width was significant between groups ($\chi^2 (4) = p \leq 0.01$). Interocular stripe width and ear fur coverage was significant ($\chi^2 (2) = p \leq 0.001$). Only interocular stripe shape was insignificant ($\chi^2 (4) = p = 0.08$).

The GPS locations (i.e. city, sanctuary, park) for analyzed lorises were placed in GoogleEarth 2010 to determine if divisions were geographical. Group1 centered on the island of Banka and possibly parts of lowland southern Borneo (West and South Kalimantan). Group2 dominated the majority of Borneo. Group 3 ranged in parts of northern lowland Borneo (Brunei, parts of Sabah, and East Kalimantan) and the Philippines.

5.6 DISCUSSION

Our results found significant differences within the Bornean loris. Three groups were distinguishable based both on cluster and discriminate analyses. Slow lorises, like other nocturnal primates, possess dichromatic vision, therefore white, contrasting colors and patterns are easily distinguishable between species and individuals (Surridge et al 2003; Bradley and Mundy 2008). So it should not be surprising that facemask variety may be useful in distinguishing between species, as vision may have a greater role in the lives of
nocturnal primates than originally presumed (Bearder et al 2006). Thus our results make sense because the significant features influencing the division of these groups were ones affecting the amount of white on the face and enhancing visual cues. Other nocturnal primates, like galagos, mouse lemurs, slender lorises, and owl monkeys, have also been noted to have distinct facial masks, influenced by contrasting colors that are used as individual and species markers (Ford 1994; Bearder 1999; Yoder et al 2000; Bearder et al. 2006).

It is possible to discern differences between the three groups just by looking at facemask images (Fig 2). Group 2, made of central Bornean lorises, stands out amongst the other two groups due to more distinctive white markings on the face. The primary features that stand out are the patch bottom which descends to or below the zygomatic arch, and the preauricular hair is far more distinguished in this group. Although it was not deemed a significant feature, Group 2 is dominated by having a dark black and white facemask shade. The dark shade aide in making the facemask noticeable and distinctive compared to the two sympatric groups that surround Group 2. Sympatric species are hypothesized to appear more color divergent as a way to easily signal species differences and mate compatibility (Bradley and Mundy 2008). As seen here with Bornean lorises, color divergence has also been noted in other slow loris species, galagos, lemurs and other nocturnal primates (Ford 1994; Bearder et al 1995;
Bearder 1999; Nekaris and Jaffe 2007; Nekaris and Munds 2010). The main challenge when interpreting Group 2, as a whole, is the noted variety of Group 2. The observed differences may be a result of kin recognition, or an anti-predator strategy (Brockelman 2004; Bradley and Mundy 2008). It could also be a sign that more subspecies exist, but additional research would be needed to quantify any of the aforementioned hypotheses.

When comparing Group 1 and Group 3 in Table 1, we noticed these two groups have quite a few similar features, like patch top, interocular shape, and a diffused crown/fork, but these shared features have a minute impact on species differences. Understandably, these two populations may appear morphologically similar because they are allopatric, and thus have not evolved the markings to readily distinguish between each other (Bradley and Mundy 2008). Yet, it is the subtle, different markings between these plausible subspecies that have a huge affect on recognition. These differences are interocular stripe width and preauricular hair width; both features affect the amount of white on the face. But the main, obvious factor dividing these two populations is the geographic separation: Group 1 in the south and on Banka and Group 3 being north and on the Philippine islands. This barrier is not influencing morphological divergences, but it may be affecting genetic divergence.

Although there are known geographic differences between the groups, exact locations of examined lorises must be taken with caution. We were able to gather the general locale, which gives us an idea that these clustered groups were geographically biased. The wide variety of facial characteristics in Group 2 could be due to altitude differences, but this is difficult to quantify. The majority of examined images were from museum specimens. These specimens were often from major cities, so precise altitudinal and original location of the specimen is unknown. The examined photographs are slightly more reliable, but some of the
images were taken in cities or of lorises being released into the wild, once again their initial
point of origin is unknown. Although, exact origins of examined lorises are not available we
are confident that the clustering of these lorises signify an influence of geographic boundaries
which are dividing the populations. Particularly, the geographic split between Group 1 and
Group 3 is quite distinctive and warrants these two populations to be recognized as
subspecies of *N. menagensis*.

### Table 2: Taxonomy of *N. menagensis* sp.

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Taxonomic nomenclature</th>
<th>Range</th>
<th>Type specimen location &amp; cat. number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td><em>N. m. bancanus</em> (Lyon 1906)</td>
<td>Banka and possible parts of lowland southern Borneo (West and South Kalimantan)</td>
<td>USNM: 124907</td>
</tr>
<tr>
<td>Group 2</td>
<td><em>N. m. borneanus</em> (Lyon 1906)</td>
<td>Borneo, except parts of northern Borneo (above)</td>
<td>USNM: 142234</td>
</tr>
<tr>
<td>Group 3</td>
<td><em>N. m. menagensis</em> (Lydekker 1893)</td>
<td>Philippine islands, lowland northern Borneo (East Kalimantan, Sabah, Brunei)</td>
<td>MMNH or FMNH: Type not available*</td>
</tr>
</tbody>
</table>

USNM=United States National Museum or the Smithsonian

*Specimens from this region are housed at the Bell Museum of Natural History, Minneapolis (MMNH) and the Field Museum of Natural History, Chicago (FMNH). Specimens with pelage are only at FMNH.

### 5.6.1 Taxonomy-
Based on known geographical boundaries of Borneo and the face mask variations discerned we recognize three subspecies of *N. menagensis* (Table 2). Past taxonomic studies of *Nycticebus* spp. and other nocturnal primates have shown that facial features are strong indicators to demarcate species and subspecies (Ford 1994; Bearder 1999; Nekaris and Jaffe 2007). Many of these newly recognized nocturnal primates were once considered distinct and the three discerned from this study are the same (Osman Hill 1953). Ours is not the first study to recognize differences between the Bornean and Banka population of lorises. Results from a previous study support our findings of differences between the populations (Nekaris and Munds 2010). Additional taxonomic investigations of
N. menagensis are needed to justify our claim, or to support the recognition of full species status between the populations.

To summarize, our findings show that facemasks can influence species diversity and are corroborated with past studies on other nocturnal primates (Ford 1994; Bearder 1999; Yoder et al 2000; Nekaris and Jaffe 2007). Some researchers claim there is no significant diversity within Bornean lorises because they share a similar cranial morphology and the absence of an upper second incisor, and pelage variability within taxa is only a small part to recognizing different species (Groves 1971; Groves and Maryanto 2008). Yet it is known that many smaller primates exhibit shared cranial features that are not important when recognizing species. What has been considered more important in distinguishing species within these smaller primates is the pelage color or pattern or other external morphological features (Charles-Dominique et al 1980). It should not be surprising if such features were also significant in dividing the Bornean lorises, as this study has demonstrated. What has assisted these past studies in supporting the taxonomic upgrading of a species is genetics, and such a procedure should be implemented to better understand the Bornean loris diversity.

ACKNOWLEDGEMENTS
We thank the following museums and curators: W. Stanley (Field Museum of Natural History), R. Thorington, L. Gordon (National Museum of Natural History) and G. Musser (American Museum Natural History). Danica Stark and Leah Schein are appreciated for their comments. We are grateful for the support provided by the Primate Society of Great Britain, Primate Action Fund, Primate Conservation Inc., Columbus Zoo and Aquarium, Cleveland Zoo, and The Margot Marsh Biodiversity grant.


CHAPTER 6: General conclusion

“Unless someone like you cares a whole awful lot, nothing is going to get better. It’s not.”

-Dr Seuss

The nocturnal primates of Borneo were prime examples of species lacking up to date research. The Bornean loris (Nycticebus menagensis) and Bornean tarsier (Tarsius bancanus borneanus) are considered Vulnerable by the IUCN (2009), yet no systematic studies had been done to determine the accuracy of their statuses. This study was designed to address the lack of research on these two species. My aims were 1) to provide a current abundance estimate of both species in the Danau Girang Field Centre (DGFC), Lower Kinabatangan Wildlife Sanctuary (LKWS), Sabah, Malaysian Borneo, 2) to understand niche divergences between the species, 3) to improve trapping methods of Lorisinae and Perodictinae, and 4) to determine the role of facial mask characters in demarcating (sub) species of Bornean lorises.

The Bornean loris was estimated to have a population size of 5.05 individuals/km$^2$. These results align with past studies on other Nycticebus spp.. The Bornean tarsier population is lower in the DGFC, with abundance estimates of only 2.75 individuals/km$^2$. Studies done decades ago on other populations of tarsiers found much higher abundances (14-80 individuals/km$^2$) (Niemitz, 1984; Crompton & Andau 1987). These low results are concerning, as past studies on different species of tarsiers have indicated these primates do not always thrive well in heavily degraded habitats. My results support that it is safe to say, both species are Vulnerable, but if no protective measures are taken to protect their populations, these species could become Endangered.
The low abundances found in these species is unsettling, but animal sightings in the Danau Girang Field Centre (DGFC) were low (Table 1). These low sightings could also be contributed to the active deforestation going on around the field site. Also, it was less than 25 years ago that logging was occurring within the field site area, thus the animals and habitat may still be recovering from the prior logging activity. The diversity of animals sighted does support that the DGFC and the Lower Kinabatangan Wildlife Sanctuary (LKWS) is host to a score of wildlife and it is important to protect this area. In time animal abundance may increase as the DGFC and the LKWS recuperate from the massive logging that occurred years back.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Number of sightings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bornean slow loris</td>
<td>Nycticebus menagensis</td>
<td>9</td>
</tr>
<tr>
<td>Bornean tarsier</td>
<td>Tarsius bancanus borneanus</td>
<td>6</td>
</tr>
<tr>
<td>Banded palm civet</td>
<td>Hemigalus derbyanus</td>
<td>9</td>
</tr>
<tr>
<td>Barking deer</td>
<td>Muntiacus muntjac</td>
<td>1</td>
</tr>
<tr>
<td>Colugo</td>
<td>Cynocephalus variegatus</td>
<td>1</td>
</tr>
<tr>
<td>Common palm civet</td>
<td>Paradoxurus hermaphroditus</td>
<td>11</td>
</tr>
<tr>
<td>Hose’s civet</td>
<td>Hemigalus hosei</td>
<td>1</td>
</tr>
<tr>
<td>Banded linsang</td>
<td>Prionodon linsang</td>
<td>1</td>
</tr>
<tr>
<td>Malay badger</td>
<td>Mydaus javanensis</td>
<td>4</td>
</tr>
<tr>
<td>Malay civet</td>
<td>Viverra tangalunga</td>
<td>8</td>
</tr>
<tr>
<td>Pen tailed tree shrew</td>
<td>Ptilocercus lowii</td>
<td>17</td>
</tr>
<tr>
<td>Sambar deer</td>
<td>Cervus unicolor</td>
<td>2</td>
</tr>
<tr>
<td>Small toothed palm civet</td>
<td>Arctogalidia trivirgata</td>
<td>6</td>
</tr>
</tbody>
</table>

This was the first study to investigate if these species have evolved niche divergences to reduce intergeneric competition. The Bornean tarsier favours habitats with small trees in both height and diameter at breast height (DBH). The Bornean loris lacked a definitive habitat preference, but appeared to prefer areas which had extensive canopy continuity and much larger trees (height and DBH). Another factor reducing competition is the median height which the Bornean loris (mdn height 15 m) and tarsiers (mdn 1.25 m) were spotted.

Additional studies are needed to assess niche divergences influencing the stable co-existence of these two species.
Trapping attempts were not done on the Bornean tarsier. Studies on tarsiers have shown mist nets are successful in capturing these species (Crompton & Andau, 1987; Gursky 1998). To use a mist net, one should be fully trained. If not the incorrect removal of bats, birds, or tarsiers could result in the damage of limbs or death. By the time the study started, I had not received the appropriate training and felt it best not to risk the safety of the animals.

I attempted to trap Bornean lorises, but none were caught. A literature review of Lorisinae and Perodictinae revealed it is generally difficult to capture these species. A high trapping effort and a long duration are required with little success (1 capture: 800 traps set in 780 nights; Pimley et al., 2005). Trap size and locomotion are problematic, as commercially produced traps do not consider the stretch movement of the lorises. Their reach allows them to get the bait and not be caught. Specially designed traps are costly, time consuming to make, and not always reliable or safe. Bait is another complicated matter as many of these species are omnivorous or insectivorous, which makes it difficult to find a bait that would encourage them to enter a trap. Height preferences of loris species vary, but all of them are arboreal, so the best height should be determined for the specific loris species. Arboreal trapping is not easy, and although it has worked for some studies (Pimley et al., 2005; Wiens, 2002), it did not work for this one. Placing a trap in a good location is difficult, as lorises prefer dense vine areas, or on a horizontal limb. I do believe that arboreal trapping will work better than ground traps, but more studies are needed to devise the best method. Finally, the problem with the development of a successful trapping regime is how does one safely share it with the scientific community without it being used for the illegal pet or medicinal trade? Lorises are the most commonly seen protected primate in the wildlife markets (Nekaris and Nijman, 2007), and the development of a successful trapping regime could hinder the survival of these species. Trapping is necessary to further elucidate the taxonomy and
improve understanding of the behavioural ecology of these primates, and trapping ideas should be shared with the utmost privacy.

Facemask differences were considered a powerful morphological measurement to assess differences between potential subspecies of Bornean lorises. I discerned three subspecies of Bornean lorises (N. m. menagensis; N. m. bancanus; N. m. borneanus). These findings were based on results of a cluster and discriminate analysis which divided 53 lorises into three groups. These groups appeared to favour different geographic regions of Borneo and surrounding islands. Characteristics that divided the groups had an impact on the amount of white seen on the face. Past studies on other species of nocturnal primates noted similar results regarding the affect of dark and light markings in species recognition (Ford 1994; Bearder 1999; Bearder et al., 2006). More research involving genetics and other morphologic characteristics should be done to support the recognition of these subspecies.

The research from this study is preliminary, but we have a better understanding of their abundance, niche divergences and the challenges of trapping and taxonomy in these primates. Future research needs to address many facets to improve our knowledge. An understanding of their behavioural ecology is needed to determine their requirements for survival. A successful trapping regime needs to be designed, before we can radio-collar or collect taxonomic and genetics samples. Failed trapping studies need to be published, or made available to the public, so past mistakes are not repeated. Knowledge of what has not worked, will allow us to design a regime that will work. Only when a satisfactory regime has been designed, can we move forward in our better understanding of these primates. We hope to radio-collar these animals in order to assess their home ranges and ecological needs in the Lower Kinabatangan Wildlife Sanctuary (LKWS). The genetic and taxonomic data will
improve our knowledge of their speciation throughout Borneo and in the LKWS. A study on the affects of forest fragmentation will be done to determine how the mass loss of forest is affecting the genetic diversity of these primates, in the LKWS and Borneo. All these future studies will enable researchers and conservationists to create the best action plan to conserve the Bornean loris and tarsier for the future.

REFERENCES


Appendix I:
Primate taxonomy & Nycitcebous & Tarsius species

Fig 1: Cladogram of primate taxonomy. Lorises are part of the Lorisoida superfamily and depending on the taxonomy used, they are considered prosimian or strepsirhini, but are always placed with lemurs. Conversely, tarsiers are in the genera Tarsius and depending on the taxonomic category used, are placed with the lemurs and lorises as prosimians, or placed with monkeys and apes as haplorhini. The relatedness of tarsiers to lorises and lemurs and monkeys is still questionable, which makes it difficult for taxonomists to agree on where to place tarsiers*

Table 1: Strepsirhini, tarsiers, haplorhini similarities and differences.

<table>
<thead>
<tr>
<th></th>
<th>Strepsirhini</th>
<th>Tarsiers</th>
<th>Haplorhini</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-orbital bar</td>
<td></td>
<td>?</td>
<td>Post-orbital plate</td>
</tr>
<tr>
<td>Wet nose</td>
<td></td>
<td>Dry nose</td>
<td>Dry nose</td>
</tr>
<tr>
<td>Attached upper lip</td>
<td></td>
<td>Unattached upper lip</td>
<td>Unattached upper lip</td>
</tr>
<tr>
<td>Dental comb</td>
<td></td>
<td>Vertical incisors</td>
<td>Vertical incisors</td>
</tr>
<tr>
<td>Grooming claw</td>
<td></td>
<td>Two grooming claws</td>
<td>Nails</td>
</tr>
<tr>
<td>Tapetum lucidium</td>
<td></td>
<td>No tapetum lucidium</td>
<td>No tapetum lucidium</td>
</tr>
<tr>
<td>Bicornate uterus</td>
<td></td>
<td>Unicorne uterus</td>
<td>Unicorne uterus</td>
</tr>
</tbody>
</table>

Table 2: *Nycticebus* taxonomy

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Subspecies</th>
<th>Range</th>
<th>Threat Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>N. bengalensis</em></td>
<td>Bengal slow loris</td>
<td>None recognized</td>
<td>Bangladesh; Cambodia; China; India; Lao People's Democratic Republic; Myanmar; Thailand; Viet Nam</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>N. coucang</em></td>
<td>Greater slow loris</td>
<td><em>N. c. natunae</em></td>
<td>Sumatera; Peninsular Malaysia; Singapore; Thailand</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>N. javanicus</em></td>
<td>Javan slow loris</td>
<td>Possibly two</td>
<td>Java</td>
<td>Endangered</td>
</tr>
<tr>
<td><em>N. menagensis</em></td>
<td>Bornean slow loris</td>
<td>Possibly two</td>
<td>Borneo; Philippines</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>N. pygmaeus</em></td>
<td>Pygmy slow loris</td>
<td>None recognized</td>
<td>Cambodia; Lao People's Democratic Republic; Viet Nam</td>
<td>Vulnerable</td>
</tr>
</tbody>
</table>


Table 3: *Tarsius* taxonomy

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Subspecies</th>
<th>Range</th>
<th>Threat Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. bancanus</em></td>
<td>Western tarsier</td>
<td><em>T. b. bancanus; T. b. borneanus; T. b. natunensis; T. b. saltator</em></td>
<td>Bangka, Belitung, Karimata, southeastern Sumatra, Serasen in the South Natuna Islands, and Borneo.</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>T. dentatus</em></td>
<td>Dian’s tarsier</td>
<td>None recognized</td>
<td>Eastern portion Sulawesi</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>T. lariang</em></td>
<td>Lariang tarsier</td>
<td>None recognized</td>
<td>Western portion Sulawesi</td>
<td>Data deficient</td>
</tr>
<tr>
<td><em>T. pelengensis</em></td>
<td>Peleng tarsier</td>
<td>None recognized</td>
<td>Peleng island</td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. pumilus</em></td>
<td>Pygmy tarsier</td>
<td>None recognized</td>
<td>Southern and central Sulawesi</td>
<td>Data deficient</td>
</tr>
<tr>
<td><em>T. sangirensis</em></td>
<td>Sangihe tarsier</td>
<td>None recognized</td>
<td>Sangihe Island</td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. syrichta</em></td>
<td>Philippine tarsier</td>
<td>Possibly two subspecies</td>
<td>Philippines</td>
<td>Threatened</td>
</tr>
<tr>
<td><em>T. tarsier</em></td>
<td>Spectral tarsier</td>
<td>None recognized</td>
<td>Sulawesi</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>T. tumpara</em></td>
<td>Siau island tarsier</td>
<td>None recognized</td>
<td>Sulu island</td>
<td>Critically Endangered</td>
</tr>
</tbody>
</table>


APPENDIX II: Facial mask guide for Bornean lorises

*CIRCUMOCULAR EYE PATCH*: A distinct furred area around the eyes creating a mask. They are divided by lighter patches (the interocular stripe and preauricular stripes, defined below).

![Facial mask guide diagram]

**Patch top**: The part of eye patch nearest the top of the head
- Pointed: Narrow to absent in width, similar to the tip of a triangle.
- Round: Medium width, rectangular in shape, distinct from the crown patch.
- Diffused: Wide, no distinct shape and blends with crown.

**Eye rim**: The narrow, furred area that surrounds just around the eye.
- Absent: Rim is a non-contrasting color of eye patch.
- Present: Rim is a contrasting color of eye patch (i.e. White rim with black fur)
- Rim color: Black or white

**Patch middle**: The part of the eye patch that circles around the eye or eye rim.
- Broad: Extends towards cheek, well away from eye.
- Narrow: Hugs around the eye.

**Patch bottom**: The part of the eye patch found below eye.
- Under eye: Narrow line that ends just below the eye.
- Above/on zygomatic arch (cheekbone): Medium line which extends above or directly on top of the cheekbone.
- Below zygomatic arch: Wide/long line that extends below the arch, sometimes to the chin.
**INTEROCULAR STRIPE**: The light, often white, stripe that runs down the center of the loris face and separates the eye patches. It runs from where the eye patch tops connect to the start of the nose.

![Interocular stripe](image)

**Interocular width**: Measured between the eyes (middle eye patch section).

- Narrow: The eye patch tops appear to lean towards each before reaching the crown; width approximately less than 10 mm.
- Wide: The eye patch tops seem to lean away from each other, and never connect or connect after crown (if crown is present); width approximately more than 10 mm.

**Interocular shape**:

- Diamond: A pointed top where eye patch tops meet, widest part often right above or parallel with the eyes, and part between middle and bottom eye section is a straight bar running to the nose.
- Rectangle: A straight bar that runs between all sections of the eye patches. The bar remains almost the same size from top to bottom.
- Hourglass: A straight bar in the middle which flares outwards on the end of each section, creating a waist-like appearance.
- Bulb: A round top between where the eye patch topes meet, and part between middle area is a straight bar running to the nose.
**CROWN**: Area on the top of the head, beyond the circumocular patch. The crown features also include the auricularea.

**Crown/fork**:

<table>
<thead>
<tr>
<th>Round</th>
<th>Band</th>
<th>Diffused</th>
</tr>
</thead>
</table>

  Round: The crown is circular and only on center of head. Ear forks are present, but often blend into fur or the majority of head is covered with crown. Ear forks are not visible.

  Band: Rectangular strip spans from ear to ear. No crown is truly visible.

  Diffused (the “other” category): No shape is noticeable, it blends in with the body fur.

**Ear coverage**: The presence or absence of tufts of ear on the tip of ear. The ear is also considered covered if it is hidden from view (difficult to note on museums specimens).

  Present: Small hair tufts are on the tip of the ear. Often ears are easily seen beyond the body fur. Or the ears are covered by fur.

  Absent: Ears are naked and typically hidden by the body fur.

**Preauricular hair**: The lighter patch of fur that runs between the ear forks and circumocular patches.

  Wide: A broad gap between the two darker furs of the ear forks and circumocular patch.

  Medium: A small, but distinctive stripe between the ear forks and circumocular patch.

  Narrow/Absent: A barely visible to no stripe separating the ear forks and circumocular patch.
MISCELLANEOUS CATEGORIES:

Mask color: Mask is the crown, ear forks, preauricular hair, and circumocular patches.

*Colors are subjective. First row is from museum specimen picture furs, second row is an extra set of colors to assist in assigning the appropriate color.

- **Black:**
- **Brown:**
- **Red:**
- **Orange:**
- **Yellow:**

Black and white mask shade: Image set to black and white saturation, then examined to determine how distinct the facemask stands out from the rest of the facial patterns.

- Dark-facemask (eye patches & crown) stands out distinctively from the rest of the face
- Light –facemask blends with the rest of the facial patterns, hard to notice.

Nose color:

- Pink: Lightest color
- Mixed: Color neutral color, neither black nor pink.
- Black: Darkest color, dark brown to black.