THE DISTRIBUTION AND ABUNDANCE OF SMALL APES IN THE GREATER TAMAN NEGARA PAHANG LANDSCAPE

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by

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LIST OF ABBREVIATIONS

AICc	Hurvich and Tsai's Criterion
asl	above sea level
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
Cm	Centimeter
DBH	Diameter At Breast Height
DEM	Digital Elevation Map
DWNP	Department of Wildlife and National Park
E	East
GFCL	Gross Forest Cover Loss
GIS	Geographic Information System (GIS)
GLAD/UMD	Global Land Analysis & Discovery
GLMM	General linear mixed model
GPS	Global Positioning System
ha	Hectare
IUCN	International Union for Conservation of Nature
km^2	Square Kilometer
LA	Listening Area
Lao PDR	Lao People's Democratic Republic
LP	Listening Post
m	Meter
N	North
NASA	National Aeronautics and Space Administration

NRE	Ministry of Energy and Natural Resources
p(m)	Estimated proportion of groups expected to sing during a sample period of m or 3 days
R^2	Coefficient of determination
RS	Remote sensing
SECR	Spatially explicit capture-recapture
SPSS	Statistical Package for the Social Sciences
UNESCO	United Nations Educational, Scientific and Cultural Organization
VP	Vegetation “speed” Plot

TABURAN DAN KEPADATAN UNGKA DI LANSKAP TAMAN NEGARA PAHANG YANG LEBIH BESAR

ABSTRAK

Terdapat dua spesies ungka yang menghuni Taman Negara Pahang iaitu *Hylobates lar*, dan *Symphalangus syndactylus* dan keduanya disenaraikan sebagai spesies terancam dalam senarai merah IUCN. Walau bagaimanapun, taburan dan kepadatan terkini ungka di Malaysia adalah kurang diketahui. Terdapat empat matlamat utama untuk dicapai dalam kajian ini: 1) untuk menilai ciri-ciri habitat menggunakan data tumbuh-tumbuhan di tanah dan data pengimejan satelit di dalam dan luar Taman Negara, 2) untuk menganggarkan kepadatan kumpulan *H. lar* dan *S. syndactylus* di dalam dan luar sempadan taman, 3) untuk menentukan sama ada terdapat hubungan antara kepadatan dua spesies ungka simpatetik, *H. lar* and *S. syndactylus* di Taman Negara, dan 4) untuk menilai kesan ekologi habitat ke atas kepadatan populasi ungka. Demi mencapai matlamat kajian, dua kaedah umum telah digunakan: 1) sepuluh petak ringkas tumbuh-tumbuhan telah dibina di setiap kawasan pendengaran ungka dan pemboleh ubah habitat direkodkan; bilangan pokok, diameter pada aras dada (DBH), tinggi pokok, peratusan litupan kanopi dan spesies pokok, 2) tinjaun aktif akustik telah dilaksanakan di setiap kawasan pendengaran dengan merekod bunyi ungka daripada tiga pos pendengaran (LP)s yang di tempatkan pada anggaran jarak 300-500 m daripada satu sama lain terletak di dalam dan di luar Taman Negara Pahang. Data dari setiap set LPs direkodkan selama tiga hari berturut-turut dari jam 7 pagi hingga 11 pagi, dan pendengar merekodkan: 1) arah bunyi ungka daripada pendengar di setiap LPs, 2) jangka masa bunyi, dan 3) anggaran jarak bunyi daripada pendengar. Data dipetakan dalam ArcGIS 10.3 dan dianalisis menggunakan kaedah triangulasi untuk mengenal pasti kumpulan ungka bagi menganggarkan kepadatan

kumpulan yang dianggarkan menggunakan formula kepadatan dan pakej untuk *Calculating Gibbon Population Density from Auditory Surveys* oleh Thinh and Rawson (2011). Analisis bukan parametrik telah digunakan dalam kajian ini. Dapatan menunjukkan Taman Negara mempunyai ciri-ciri habitat yang sama di dalam dan di luar sempadannya. Walau bagaimanapun, kepadatan kumpulan kedua-dua spesies ungka didapati rendah (< 2 kumpulan setiap km^2). Kepadatan *H. lar* adalah dalam julat 0.242 hingga 1.711 kumpulan setiap km^2 dan kepadatan *S. syndactylus* berada dalam julat 0 hingga 1.032 kumpulan setiap km^2 merentasi kesemua kawasan pendengaran. Dapatan daripada kajian ini juga mencadangkan bahawa kedua-dua spesies simpatetik mampu wujud bersama di habitat sama tetapi dengan kepadatan rendah keseluruhan. Peratusan litupan kanopi adalah sumber ramalan terbaik yang mempengaruhi kepadatan kedua-dua spesies ungka. Hal ini dapat disimpulkan bahawa, kawasan perlindungan adalah habitat ungka yang penting kerana ungka sangat bergantung kepada kualiti habitat. Tindakan pemuliharaan harus dilaksanakan pada masa hadapan untuk memulihara habitat ungka yang tidak dilindungi di Malaysia, dan dapatan daripada kajian ini dapat memberikan data panduan asas berhubung status pemuliharaan terkini ungka di Semenanjung Malaysia.

THE DISTRIBUTION AND ABUNDANCE OF SMALL APES IN THE GREATER TAMAN NEGARA PAHANG LANDSCAPE

ABSTRACT

Two species of small apes, or gibbons, inhabit Taman Negara Pahang, *Hylobates lar* and *Symphalangus syndactylus*, and both are listed as Endangered in the IUCN Red List. However, the current distribution and abundance of small apes in Malaysia are not well known. This study had four main goals: 1) to assess the habitat characteristics of small ape habitat using on ground vegetation data and satellite imagery data inside and outside of Taman Negara, 2) to estimate the group density of *H. lar* and *S. syndactylus* inside and outside the park boundaries, 3) to determine whether there is a relationship between the densities of two the sympatric small ape species Taman Negara, 4) to evaluate the effect of habitat ecology on small ape density. To achieve the study goals, two general methods were used: 1) vegetation "speed" plots were established in small ape listening areas and habitat variables were recorded, i.e., the number of trees, tree diameter at breast height (DBH), tree height, percentage of canopy cover, and tree species; 2) active acoustic surveys were conducted in listening areas by recording the small ape calls from three listening posts (LP)s placed ca. 300-500 m from each other located inside and outside of Taman Negara Pahang. Data from each set of LPs were recorded for three consecutive days from 7 am to 11 am, and the listeners recorded: 1) direction of the small ape calls from listeners in each LPs, 2) duration of the calls, and 3) estimated distance of the call from listeners. The data were mapped in ArcGIS 10.3 and analysed using triangulation method to identify small ape groups for group density estimation using the density formula and package for Calculating Gibbon Population Density from Auditory Surveys by Thinh and Rawson (2011). Non-parametric analyses were used in this

study. Findings indicate that Taman Negara had similar habitat characteristics inside and outside its park boundaries. However, the group density for both small ape species was found to be low (< 2 groups per km^2). The density of *H. lar* was in the ranges of 0.242 to 1.711 groups per km^2 and the density of *S. syndactylus* was in the ranges of 0 to 1.032 groups per km^2 across all sampled listening areas. The findings from this study suggest that both sympatric species can coexistence in the same habitat but with overall low densities. The percentage of canopy cover was the best predictor affecting the density of both small ape species. It can be concluded that protected areas are important small ape habitats as they depend on good quality habitat. Future conservation actions should be implemented to conserve unprotected small ape habitats in Malaysia, and findings from this study can provide a baseline for small apes' current conservation status in Peninsular Malaysia.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Protected Forests in Peninsular Malaysia

As one of the mega-diverse countries in the world, Malaysia has a wealth of biological diversity in its terrestrial and marine zones, estimated to contain about 12,500 species of flowering plants, approximately 306 species of mammals (including 25 species of primates), more than 742 species of birds, and 547 species of reptiles, including many endemic species (PERHILITAN, 2016). In Peninsular Malaysia, about 4.81 million ha is categorized as Forest Reserve or reserved as production forest, 0.09 million ha is the proposed permanent Reserved Forest, about 1.83 million ha have been allocated as protected areas (PA), including national parks, wildlife sanctuaries, and nature reserves, and 2.98 million ha as production forest based on forestry statistics in 2019 (Omar et al, 2017; Forestry Department Peninsular Malaysia, 2021).

There are at least four protected area (PA) networks managed by different agencies that are governed by different laws of protection status, gazettement, and de-gazettement procedures (PERHILITAN, 2016). The largest national park in Peninsular Malaysia (Taman Negara in central Peninsular Malaysia) is a totally protected and managed by the Department of Wildlife and National Parks (PERHILITAN). Taman Negara is located in the heart of Peninsular Malaysia and straddles the three states of Pahang (2,477 km^2), Terengganu (853 km^2) and Kelantan (1,013km^2) with a total area of about 4,343 km^2 (Samdin et al, 2013; Tingga et al, 2012; Yahaya & Hassan, 2011). It is also considered one

of the oldest rainforests in the world (more than 130 million years old). It became the first and is still the largest national park gazetted in Malaysia in 1938/39, by then named as the King George V National and declared as ASEAN Heritage Park in the year 1984 (UNESCO, 2014; Ibrahim & Hassan, 2011; DWNP & NRE, 1984) because of its richness in biodiversity as a home for many species of flora and fauna either endemic, rare, vulnerable, or threatened in Peninsular Malaysia. Because of that, Taman Negara is a popular ecotourism attraction to both local and foreign tourists (Chui et al., 2010) who love nature, heritage, and cultural activities offered here.

1.2 Importance of Taman Negara as Protected Area

Hosting the largest population of flora and fauna in Malaysia and being the only World Heritage Site in Peninsular Malaysia (UNESCO, 2014), Taman Negara is also the largest contiguous forest in Peninsular Malaysia covering areas of pristine tropical rainforest with no fire history or disturbance activities, free from any deforestation and supporting high natural levels of diversity, abundance, and richness of tropical terrestrial and aquatic biodiversity (Isa, 2001). A wide river is stretching inside Taman Negara maintaining a healthy overall ecosystem. The three main river systems, Sungai Lebir, Sungai Terengganu, and Sungai Tembeling originating in Taman Negara flow from the tributaries at Banjaran Titiwangsa (Titiwangsa main range) through the states of Kelantan, Terengganu, and Pahang (Yunus et al., 2013) supporting many species of herpetofauna and freshwater fishes, which is important to maintain aquatic species richness and supplying water sources for terrestrial biodiversity (UNESCO, 2014).

Taman Negara plays a fundamental role in maintaining ecological integrity by providing habitat and food sources for terrestrial and aquatic biodiversity and providing home and raw materials (food, water, forest resources etc.) for its indigenous inhabitants, the Batek tribe who are the only people given the privilege to live inside Taman Negara as their ancestral land (Jambari et al., 2019). Taman Negara in the state of Pahang comprises the largest part (57%) of Taman Negara supporting more biodiversity and local communities of indigenous peoples. There are a several Batek communities of living along Sungai Tembeling in Taman Negara Pahang as a semi-nomadic tribe, pursuing, which have been curtailed by intervention of the Malaysian government and the ongoing process of modernization and globalization within the park boundaries (Kamberovic et al., 2018).

Traditionally, Taman Negara provides the food resources (i.e., fruits, herbs, shoots, fish, and small mammals) and forest products (e.g., rattan, bertam and fragrant wood) for the Batek people and to supply to the Malay traders for daily needs (Endicott, 1988). Recently, the addition of cash to their daily life has led to a decreased utilization of wild food sources and increased dependence on commercial foods (e.g., rice, instant food etc.) (Faulstich, 1985). However, collected wild food in the jungle continues to play an important role in the Batek's daily needs, and its availability strongly affects the Batek's movement in the jungle. Besides as the source of food, the freshwater ecosystem plays an important role as water source and forming natural territorial boundaries in Batek life (Faulstich, 1985). Hence, Taman Negara plays an important role by becoming the largest habitat for *in-situ* conservation of both terrestrial and aquatic biodiversity, besides supporting the indigenous community that is impacted by the current development, urbanization, or modernization in Malaysia.

1.3 Small Apes in Taman Negara Pahang

Small apes of the family Hylobatidae are arboreal, frugivorous primates that are remarkable for their long, strong arms, which are associated with the predominance of brachial locomotion (Preuschoft et al., 2016; Bartlett, 2011; Nijman, 2001; Gittins & Raemaker, 1980). Small apes are territorial and live in monogamous family groups consisting of an adult mated pair with none to four offspring of different ages. They produce loud morning calls in duets (female and male singing alternately), which can be heard up to several kilometers, while solo individuals rarely call (mostly only male singing solo) (Nijman, 2001). Small apes produce loud, long bouts and species can easily be identified by their songs; whereby different species of small apes produce different songs (Geissmann, 2000). There are three species of small apes found in Peninsular Malaysia, which are *Hylobates lar* (white-handed gibbon), *Hylobates agilis* (agile gibbon) and *Symphalangus syndactylus* (siamang). Two species of small apes inhabit Taman Negara, which are *H. lar* and *S. syndactylus*. *Hylobates agilis* is distributed in the Northern part of Peninsular Malaysia to south Thailand (near the Malaysian border) and Sumatra, Indonesia (Geissmann et al., 2020) hence the distribution of this species is out of the species distribution range in Taman Negara.

Hylobates lar are sexually monomorphic with black or buff colour-morphs in both sexes, reaching a body mass of 5-6 kg, and females give birth to a single offspring (Reichard & Barelli, 2008; Smith & Jungers 1997). *Hylobates lar* and *H. agilis* are allopatric (Brockelman & Gittins, 1984). Both species are variable in their coat colour, from almost black to pale blonde. *Hylobates lar* is distinguished from *H. agilis* by the

presence of a complete ring of white fur around the face and the solid buff or brownish-black body coloration with white hands and feet (Brockelman & Schilling, 1984). For *Hylobates spp.*, coat colour does not provide a mean for distinguishing the two species and between sexes (Gittins & Raemaekers, 1980). *Hylobates lar* are identified as the most widespread species of small apes in Southeast Asia regarding latitude (Light, 2016; Geissmann, 1995; Raemaekers et al., 1984). Higher latitudes are characterized by higher degrees of seasonal ecological variability whereas different populations of *H. lar* likely experience differences in environmental conditions due to these differences in latitudes (Light, 2016).

Symphalangus syndactylus is also known as black ape, weighing nearly twice (10-12 kg) as *Hylobates spp.* (Preuschoft et al., 2016; Fischer & Geissmann, 1990; Gittins & Raemakers, 1980) with a relatively broader chest, shorter legs (relative to trunk), much longer arms (relative to legs), higher face, and a large throat (Chivers, 1974). The large throat of *S. syndactylus* has a special function; it inflates to act as a resonator while vocalising (Gittins & Raemaeker, 1980) and produces a louder call than other small apes. *Symphalangus syndactylus* lives sympatrically with the two smaller species of hylobatids: *H. lar* and *H. agilis* in Peninsular Malaysia. Their larger body size permits them to consume more food allowing them to have lower daily movement or locomotion (600-800 m compared with the 1,000 – 2,000 m of *H. lar*) (Caldecott, 1980), especially in their favourite trees. This gives them advantage related to relatively lower energy expenditure, which may have allowed *S. syndactylus* to successfully inhabit a broader range of habitats, including higher elevation areas, and thereby may have reduced competition with the

sympatric other small apes (Reichard & Preuschoft, 2016; Elder, 2009; McConkey et al., 2002; Raemaekers, 1984).

1.4 Problem Statement

Since 1950, over half of the pristine forests of Peninsular Malaysia's have been commercialized and converted to other land use, leaving the rest to be increasingly degraded and fragmented (Brook et al., 2003). Declining forest cover is mainly due to urbanization, agricultural fires, forest conversion for agriculture, and logging activities, either legal or illegal (Geographical Association, 2020). Although Taman Negara is a permanently protected area, logging activities seem unstoppable and are happening right up to the border of Taman Negara, based on recent satellite imagery (Figure 1.1). Around the Taman Negara boundaries, there is no proper buffer zone, and this can cause disturbance with human activities approaching so close to the park boundaries (Humphrey, 2019). The areas marked as A, B and C in the map below show the areas experiencing the expansion of development and logging roads with clearing large areas right up to the park boundary.

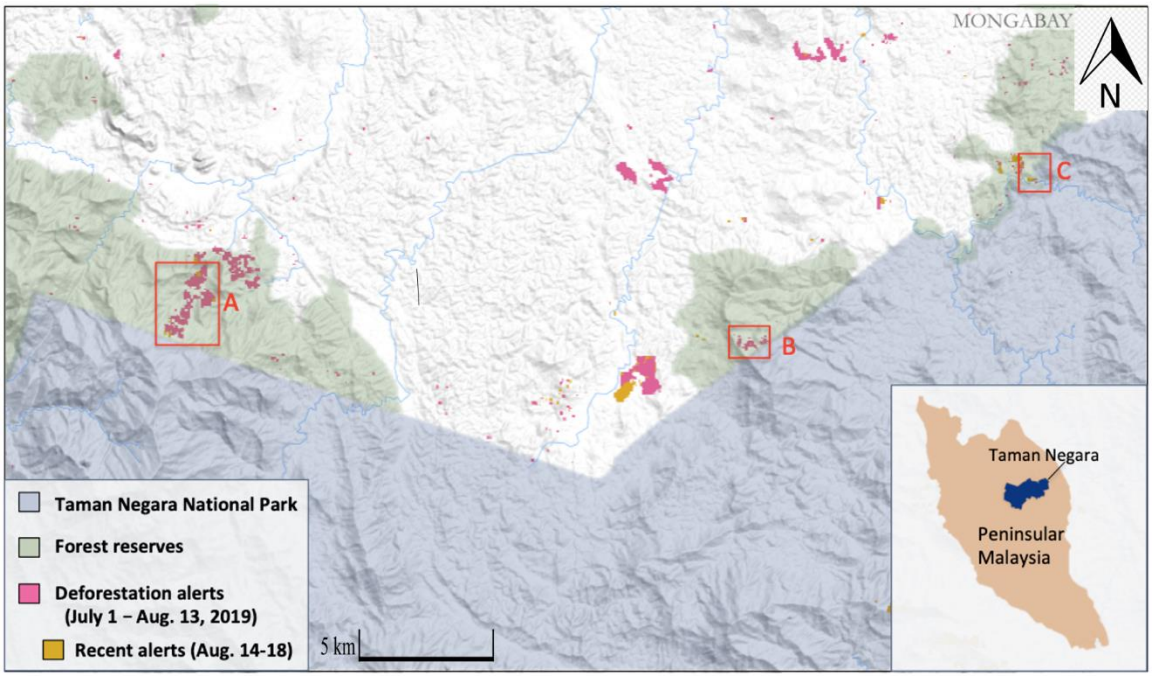

Figure 1.1. Satellite data from the University of Maryland shows large areas of recent tree cover loss (2014-18 and 2019) in forest reserves the border of Taman Negara.

Sources: GLAD/UMD, accessed through Global Forest Watch; forest reserve boundaries are from Forest Trends (Main News, 2019); adopted from Mongabay.com.

Deforestation activities cause detrimental impacts on wildlife because of the habitat loss and decrease of food source availability. Reduction in the density of primate populations, especially in small apes, has been reviewed as reflecting a reduction in the food availability caused by logging or deforestation activities (Johns, 1986). Rapid development in certain areas in Peninsular Malaysia has introduced small ape populations to disturbed environments, causing small ape-human interactions to become more frequent. Some populations of small apes might migrate further into the forest while some may stay and try to adapt to the surrounding disturbed environment. However, small apes have specific habitat requirements, including continuous canopy cover, and they respond poorly to habitat conversion and fragmentation (Lappan & Whittaker, 2009). Human disturbance

is a major threat to the Malaysian small ape population by threatening these species with extinction. The decrease of small ape populations is accelerated by hunting (mainly for medicine, and the illegal pet trade where online pet trade is becoming more prevalent) and logging activities, which have become a concerning issue (Ni et al., 2018; Nijman, 2009; Chapman & Peres, 2001)

While all three species of small apes in Peninsular Malaysia are currently listed as Endangered (IUCN, 2020) and persist in most protected areas including Taman Negara, their distribution and population densities in Taman Negara, and all of Malaysia, have not been adequately mapped. Historically, in the shadow of Malaysia's charismatic great ape, the orangutan, small apes have received little scientific attention and are generally overlooked by the public. The local conservationists and scientific community have deemed them the "forgotten" or "neglected apes" (Fan & Bartlett, 2017; Malone et al., 2014; Whittaker & Lappan, 2009). Currently, there are limited recent studies on small apes, especially about their distribution and population density in Peninsular Malaysia, whereby the most recent studies were conducted in the 1980s (Caldecott, 1980; Chivers, 1980). Since then, no systematic follow up assessment of these species was conducted, hence the actual conservation status of small apes in Peninsular Malaysia currently is not well known.

This study was conducted to assess the group density of the two small ape species, *H. lar* and *S. syndactylus*, inhabiting Taman Negara Pahang as part of an ongoing assessment of the distribution and abundance of small apes in Peninsular Malaysia. The ultimate goal of this study was to fill this knowledge gap by updating the current density of small apes in Taman Negara. Besides, this study also aimed to assess the habitat characteristics preferred by the small apes and to understand how small apes react to the

disturbances for future population trend assessments and for more effective conservation planning and management.

1.5 Objectives, Hypotheses, and Research Questions

This study aimed to achieve four main goals:

1.5.1. Habitat Characteristics

A habitat assessment was conducted inside and outside of Taman Negara Pahang based on vegetation data and satellite imagery data inside and outside of Taman Negara.

The two objectives of this study aim were:

1.1) To assess small ape habitat characteristics using on ground vegetation data and to identify any differences across defined forest categories.

1.2) To monitor past and present habitat characteristics and their changes by using satellite imagery data and to determine the proportion of forest loss inside and outside of Taman Negara.

Hypothesis Objective 1.1:

Null hypothesis: There is no difference between the habitat characteristics inside and outside the Taman Negara.

Alternative hypothesis: There habitat characteristics inside Taman Negara are different from outside of Taman Negara whereby high-quality habitat is more frequent inside the Taman Negara boundaries than outside.

Hypothesis Objective 1.2:

Null hypothesis: There is no difference between habitat characteristic changes inside and outside of Taman Negara for the past and present years.

Alternative hypothesis: Habitat characteristics outside Taman Negara changed significant differently from inside of Taman in the past and present years.

The two research questions are:

1.1) What is the difference in small ape habitat characteristics across defined forest categories inside and outside Taman Negara Pahang?

1.2) What is the difference between the past and present habitat characteristics inside and outside of Taman Negara?

1.5.2 Small Ape Group Densities

This study goal aimed to estimate the group density of the two species, *H. lar* and *S. syndactylus* inside and outside the park boundaries.

The two objectives of this goal were:

2.1) To estimate the group density of *Hylobates lar* and *Symphalangus syndactylus* based on calling probability and identified groups inside and outside Taman Negara;

2.2) To estimate the group density of *H. lar* and *S. syndactylus* based on distance to Batek villages.

Hypothesis Objective 2.1:

Null hypothesis: The density of *H. lar* and *S. syndactylus* are low inside and outside of Taman Negara based on calling probability.

Alternative hypothesis: The density of *H. lar* and *S. syndactylus* are high inside and outside of Taman Negara based on calling probability.

Hypothesis Objective 2.2:

Null hypothesis: There is no different in the density of *H. lar* and *S. syndactylus* based on distance to Batek village.

Alternative hypothesis: The density of *H. lar* and *S. syndactylus* are lower when close to Batek Village and higher when medium close or far from Batek village.

The two research questions are:

2.1) What is the density of *H. lar* and *S. syndactylus* inside and outside of Taman Negara?

2.2) What is the density of *H. lar* and *S. syndactylus* in relation to the distance from Batek villages?

1.5.3 Effect of Sympatry on Small Ape Biomass

This study goal aimed to determine whether there is an inverse relationship between the biomass of two sympatric small ape species, *H. lar* and *S. syndactylus* in Taman Negara by assessing how the interaction between both sympatric species affect their respective group biomass. This may provide a better understanding of the reaction between the two

sympatric small apes in terms of how the presence one species can affect the other species or whether both species can tolerate each other although sharing the same habitat.

The two objectives of this goal were:

3.1) To determine the effect of *S. syndactylus* presence in Taman Negara Pahang on the *H. lar* biomass.

3.2) To determine the effect of *H. lar* biomass on the biomass of *S. syndactylus*.

Hypothesis Objective 3.1:

Null hypothesis: The biomass of *H. lar* is the same in the presence and absence of *S. syndactylus*.

Alternative hypothesis: The biomass of *H. lar* is higher in the absence of *S. syndactylus* (and vice versa).

Hypothesis Objective 3.2:

Null hypothesis: The biomass of *S. syndactylus* does not affect the biomass of *H. lar*.

Alternative hypothesis: The biomass of *S. syndactylus* affects the biomass of *H. lar*,

The two research questions:

3.1) Is there any effect on the biomass of *H. lar* when in the presence or absence of the *S. syndactylus*?

3.2) Is there any effect on the biomass of *S. syndactylus* to the biomass of *H. lar*?

1.5.4 Effect of Habitat Characteristics on Small Ape Group Densities And Biomass

This study goal aims to determine effect of habitat characteristics on small ape group density. These objectives aimed to assess the influence of habitat characteristics, i.e., vegetation variables, disturbance variables, and current forest cover and past forest cover losses on small ape group density to determine whether the density of small apes correlate with the habitat characteristics, and which predictors variable can affect the group density of both species.

There are four objectives to achieve in this goal:

4.1) To determine the effect of habitat characteristics on the group density of *H. lar* inside and outside of Taman Negara.

4.2) To determine the effect of habitat characteristics on the group density of *S. syndactylus* inside and outside of Taman Negara.

4.3) To determine the effect of habitat characteristics on the biomass of both species inside and outside of Taman Negara landscape

4.4) To identify the best model of predictors for the group density of both small ape species inside and outside of Taman Negara landscape.

Hypothesis Objective 4.1:

Null hypothesis: There is no significant effect of habitat characteristics on the density of *H. lar* inside and outside the Taman Negara boundaries.

Alternative hypothesis: There is a significant effect of habitat characteristics on the density of *H. lar* inside and outside of the Taman Negara boundaries.

Hypothesis Objective 4.2:

Null hypothesis: There is no significant effect of habitat characteristics on the density of *S. syndactylus* inside and outside of the Taman Negara park boundaries.

Alternative hypothesis: There is a significant effect of habitat characteristics on the density of *S. syndactylus* inside and outside of the Taman Negara park boundaries.

Hypothesis Objective 4.3:

Null hypothesis: There is no significant effect of habitat characteristics on the biomass of both species of small ape inside and outside of Taman Negara.

Alternative hypothesis: There is significant effect of habitat characteristics on the biomass of both species of small ape inside and outside of Taman Negara.

Hypothesis Objective 4.4:

Null hypothesis: There are no habitat characteristics variable can predict the density of both small ape species inside and outside of Taman Negara.

Alternative hypothesis: There are habitat can predict the density of both small ape species inside and outside of Taman Negara.

The four research questions:

4.1) Which habitat characteristics affect the density of *H. lar*?

4.2) Which habitat characteristics affect the density of *S. syndactylus*?

4.3) What is the effect of habitat characteristics on the biomass of both species, *H. lar* and *S. syndactylus*, in the greater Taman Negara landscape?

4.4) What is the best predictor model for the group density of both small ape species in Taman Negara?

1.6 Thesis Structure

This thesis has eight chapters, which cover all topics of the study as outlined in Table 1.1. Chapter Four to Seven are written as stand-alone manuscripts. There are repetitions in the information that might appear in certain portions of thesis to properly guide the reader.

Table 1.1. Thesis structure

Thesis Chapter	Description
Chapter 1	This chapter covers a general overview of protected forests as crucial small ape habitat in Malaysia and introduces the two small ape species (Hylobatidae) that can be found in Taman Negara Pahang, followed by problem statements, objectives, hypotheses, and research questions of this study.
Chapter 2	This chapter consists of the literature review on small apes, the distribution of small ape species, their habitat preference, songs and calling probability, home ranges, estimation of small ape density, preferred habitat types and impact of disturbance affecting small ape density, sympatric relationships between small ape species, monitoring forest cover change using satellite imagery analysis, and threats to small ape populations.

(cont.) **Table 1.1.** Thesis structure

Thesis Chapter	Description
Chapter 3	This chapter thoroughly describes the study site and sampling areas, listening posts (LPs) and listening areas (LAs), vegetation speed plots, population and density assessment, and training of field assistants for data collection.
Chapter 4	This chapter describes the habitat characteristics across the forest types inside and outside of Taman Negara, including disturbance variables, forest cover in the year 2000, and forest loss between 2000 to 2019.
Chapter 5	This chapter describes the estimation of group density of *Hylobates lar* and *Symphalangus syndactylus* inside and outside of Taman Negara Pahang.
Chapter 6	This chapter covers the sympatric relationship between *Hylobates lar* and *Symphalangus syndactylus* in Taman Negara. The sympatric relationship between these two species was expected to be inversely related where the biomass of *Hylobates lar* and to increase when the biomass of *Symphalangus syndactylus* decreases, and vice versa.

(cont.) **Table 1.1.** Thesis structure

Thesis Chapter	Description
Chapter 7	This chapter describes the effects of the habitat characteristics, vegetation variables, disturbance variables, forest cover in the year 2000, and forest loss between 2000 and 2019 on the density of *Hylobates lar* and *Symphalangus syndactylus* biomass. Then, the predictor models using AICc model of habitat characteristics on the biomass of small ape were determined.
Chapter 8	This chapter discusses all findings of the study and gives several recommendations regarding potential research methods to identify the occurrence of small ape species, and to gain a better understanding of small ape behavior by utilizing the indigenous local knowledge and potential method to use for estimation of small ape density.

CHAPTER 2

LITERATURE REVIEW

2.1 Small Apes

Small apes (family of Hylobatidae) are identified under the superfamily of Hominoidea, together with humans and the great apes (Thompson, 2007). Small apes live in evergreen forests throughout Southeast Asia, are arboreal and organized in strict territorial family groups (Fan & Bartlett, 2017; Geissmann, 2000). Small apes are socially monogamous primates with a pair of an adult male and female and up to four associated offspring (Light, 2016; Bartlett, 2011; Brockelman 2009). Being highly frugivorous, small apes are high quality seed-dispersers that play an important role in forest regeneration to maintain a healthy forest ecosystem (Fan & Bartlett, 2017; Buckley et al., 2004). Small apes mainly feed on fruits, which make up 75% of their diet, and figs are their favourite, but they may also eat varying proportion of leaves, flowers, insects, and bird eggs as well as young birds to supplement their diet (Encyclopaedia Britannica, 2020; Leisure, 2020; National Geographic, 2020; Smithsonian National Zoological Park, 2020; Bradford, 2015).

All small ape species including *Symphalangus syndactylus*, the siamang, are also known as gibbons, even though *S. syndactylus* most of the time is not referred to as gibbon. Most adult small apes are about 3 feet (90 cm) tall when standing upright and weigh 12 to 20 pounds (5.5 to 9 kg) (Leisure, 2020). The biggest small ape species is *S. syndactylus*, with a significant size difference between sexes and different enough from the other small ape species to be in their own genus (O'Neil, 2020). Small apes are not as strong as great

apes, but their powerful arms, hook-like hands and specialised shoulder joints help them swinging through the high canopies a specialized form of locomotion called brachiation (Smithsonian National Zoological Park, 2020; Pennock, 2013). Besides being known as the ”singing apes”, small apes are also known as “true brachiators” as they can move through the jungle at speeds of up to 56 km per hour, bridging gaps between the canopies as wide as 15 metres with a single swinging leap (National Geographic, 2020; Bradford, 2015). In addition, small apes are perfectly adapted to life in the canopies as highly arboreal species, and they rarely descent to the ground, even though they are good walkers (Leisure, 2020).

There are four genera of small apes, which are *Hylobates, Nomascus, Symphalangus,* and *Hoolock* (previously identified as *Bunopithecus*) (IUCN, 2020; Lappan & Whittaker, 2009; Thompson, 2007), and up to 20 recognized species. Based on the latest update by IUCN (2020), five species of small apes are classified as Critically Endangered (CR), one species as Vulnerable (VU), and the rest of 16 are species classified as Endangered (EN), hence the population of small ape species is on the brink of extinction. Small apes exhibit distinct colour differentiations between males and females in the *Nomascus* and *Hoolock* genera but not in *Hylobates* and *Symphalangus,* where colour variation is unrelated to sex. However, the different vocalization patterns of males and females is another genuine way to distinguish sexes because males and females have unique sex-specific patterns of vocalizations for each species of small ape (Geissmann, 1995; Haimoff, 1984; Marshall and Marshall, 1976). Thus, it is easier to distinguish between male and female calls in the same species than to differentiate between *H. lar* and *H. agilis* who have almost similar female great calls but slightly different in male calls.

2. 2 Distribution of Small Ape Species

Small apes are distributed in the rainforest and monsoon forest in Southeast Asian throughout India, China, Laos, Vietnam, Indonesia, Sumatera, Myanmar, and Borneo (Leisure, 2020). Figure 2.1 illustrates the distribution of small apes based on genus in Southeast Asian.

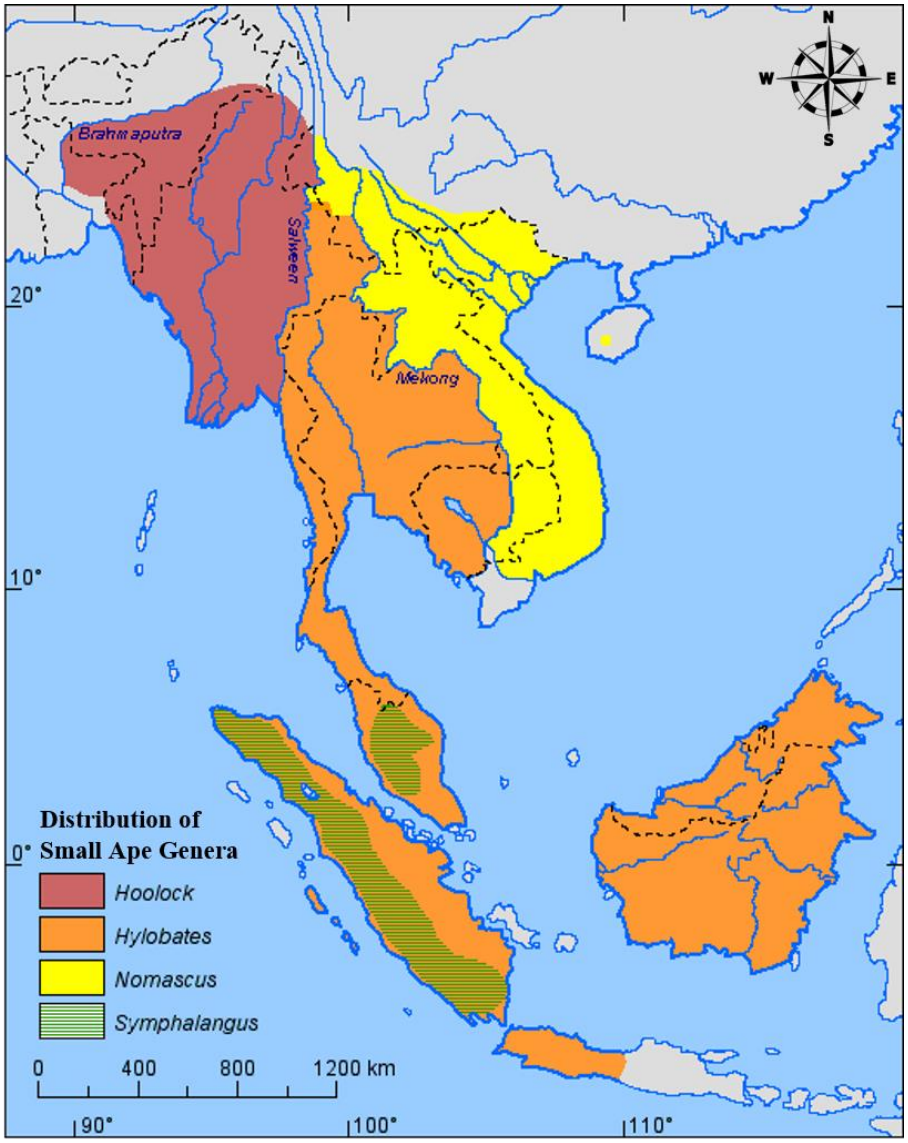

Figure 2.1. Distribution map of all the four genera of small apes (Geissmann, 2003).

Hylobates is the widest distributed genus and constitutes the most species of small ape compared to the other genera. This genus spans from Yunnan, China to Borneo (Encyclopaedia Britannica, 2020). Under the genus of *Hylobates*, the agile or black-handed gibbons are the smallest. *Hylobates agilis* is found in Sumatra, Indonesia (southeast of Lake Toba and the Singkil River), Peninsular Malaysia (from Mudah and Thepha Rivers in the north to the Perak and Kelantan Rivers in the south), and south of Thailand (near the Malaysia border, east of the Thepha River watershed) (Sultan et al., 2009; Groves, 2001; Marshall and Sugardjito, 1986; Gittins, 1979).

Hylobates lar or the white-handed gibbon is found in northern Sumatra (Indonesia), throughout Peninsular Malaysia (except for the area between the Perak and Mudah Rivers, where *H. agilis* occurs), north to southern and eastern Myanmar (east of the Salween River), most of the Thailand (except in the north-east, Marshall et al., 1972), and expanding to southern China, where now declared as local extinction there (Grueter et al., 2009). *Hylobates pileatus* ranges in southeastern Thailand, a portion of southwestern Lao PDR (west of the Mekong), and western Cambodia (west of the Mekong) (IUCN, 2020). *Hylobates klossii* is endemic to the four Mentawai Islands of Siberut, Sipora, North Pagai and South Pagai of the west coast of Sumatra, Indonesia (Groves, 2001; Geissmann, 1995; Marshall and Sugardjito, 1986).

Hylobates moloch is endemic to Java (Indonesia) and mostly restricted to Java's western provinces (Banten and West Java), but also present in Central Java, spanning to the Dieng Mountains (Smith et al., 2018; Setiawan et al., 2012; Supriatna et al., 1994; Kappeler, 1981). Meanwhile in Borneo, there are four species of small apes, *H. albibarbis* (West Kalimantan and Central Kalimantan provinces of Indonesia – South of the Kapuas

River and west of the Barito River (Cheyne et al., 2016; Groves, 2001; Marshall & Sugardjito, 1986), *H. funereus* (north and northeast Borneo – from Sabah south to the Mahakam River in East Kalimantan Province, perhaps west to Baram District and IV Division of Sarawak State (IUCN, 2020), *H. abbotti* (southwest Borneo – south Sarawak and West Kalimantan Province, north of Kapuas River and as far east as Saribas in District of Sarawak (IUCN, 2020), and *H. muelleri* (southeast Kalimantan, Indonesia – approximately south of the Mahakam River and east of the Barito River (Groves, 2001; Mitani, 1984).

Nomascus is distributed from Southern China across Laos, Cambodia, and Vietnam. *Nomascus concolor* occurs discontinuously in southwestern China, north-western Lao PDR and northern Vietnam (Geissmann et al., 2000). *Nomascus leucogenys* occurs in northwestern Vietnam, northern Lao PDR, and southwestern China. In Vietnam, this species occurs in west and south of the Black River, has been local extinct in several areas from which it was previously recorded and is currently only known from a few localities in the north-west and north-central parts of the country (Rawson et al., 2011; Geissmann et al., 2000). *Nomascus siki* occurs in central Lao PDR, east of the Mekong River, and central Vietnam (Rawson et al., 2011). However, the limits of distribution of this species have been significantly reduced after the description of *N. annamensis* to the south, which is now recognized to include much of the formerly recognized range of *N. siki* (Van Ngoc Thinh et al., 2010). The ranges of *N. gabriellae* includes northeastern Cambodia, southeastern Lao PDR, and southern Vietnam, south of Bach Ma (Rawson et al., 2011; Channa & Gray, 2009; Traeholt et al., 2005; Geissmann et al., 2000; Groves, 2001).

Hoolock is distributed from Myanmar to Bangladesh. *Hoolock hoolock* is found in eastern Bangladesh, north-eastern India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura), and north-western Myanmar (west of the Chindwin River) (IUCN, 2020). *Symphalangus*, the genus which only has one species, i.e., *Symphalangus syndactylus*, inhabits the forests of Sumatra and the Malay Peninsula. This species is found in Indonesia (Barisan Mountains of west-central Sumatra and region of eastern Sumatra), Malaysia (mountains of Peninsular Malaysia south of the Perak River), and a small area of southern Thailand (Lappan, 2007; Gittins & Raemaekers, 1980; Chivers et al., 1975; Chivers, 1974). Figure 2.2 shows the distribution map of small apes in Malaysia. Figure 2.3 to Figure 2.6 show the photos of each species of small apes present in Malaysia.

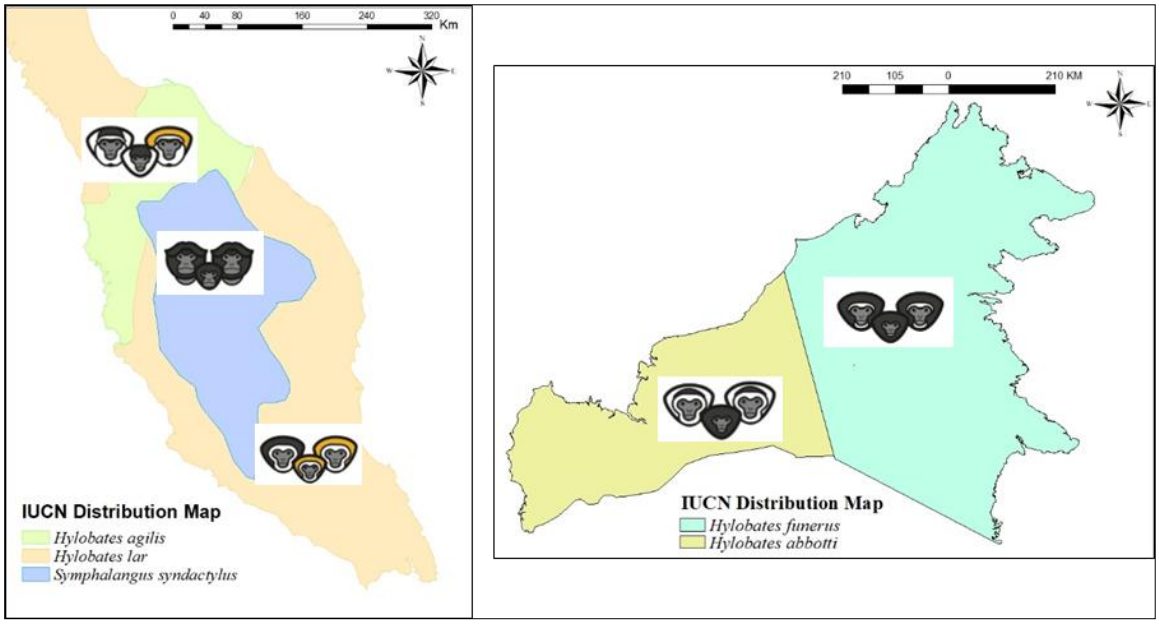

Figure 2.2. The distribution map for all five small ape species recognized in Malaysia by The International Union for Conservation of Nature (IUCN).

Figure 2.3. *Hylobates lar*, buff colour morph, female with offspring (Vargtak, 2020).

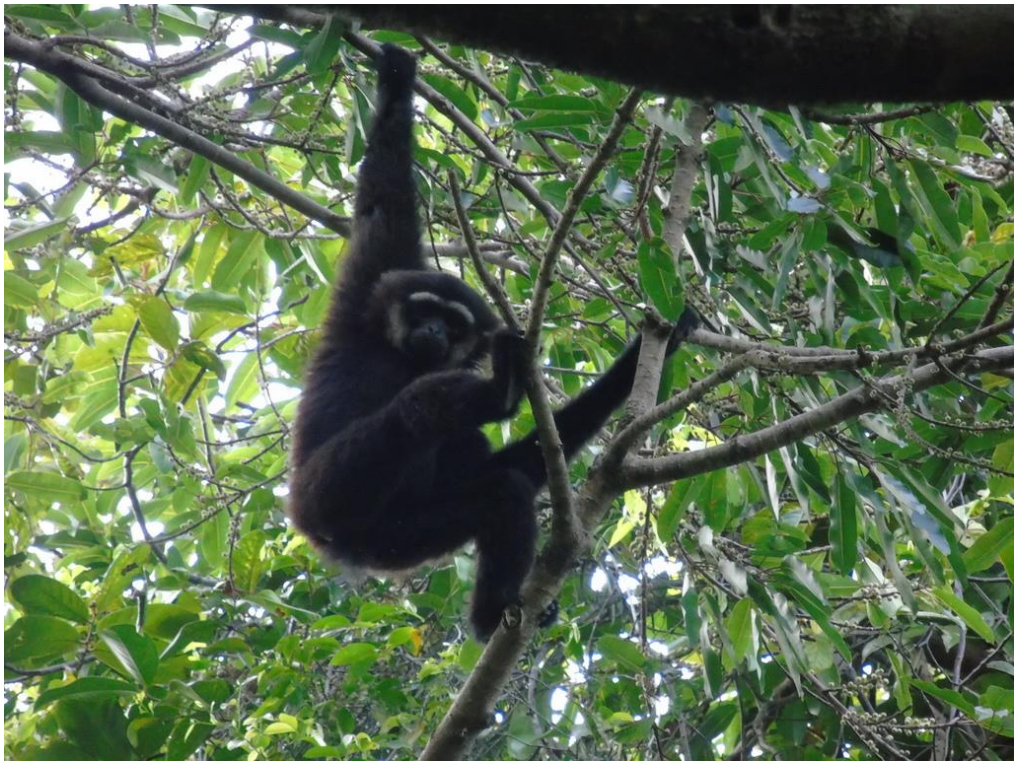

Figure 2.4. *Hylobates agilis*, dark colour morph in Perak, Malaysia (Holzner, 2018).