RELATIVE ABUNDANCE, ACTIVITY PATTERNS AND HABITAT USE OF THE ASIAN ELEPHANTS IN THE BELUM-TEMENGOR FOREST COMPLEX, PERAK

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by

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LIST OF SYMBOLS AND ABBREVIATIONS

km	kilometer
p	p-value
km^2	kilometer square
RBSP	Royal Belum State Park
TFR	Temengor Forest Reserve
HEC	Human Elephant Conflict
NECAP	National Elephant Conservation Action Plan
DWNP	Department of Wildlife and National Park
DNA	Deoxyribonucleic acid
BTFC	Belum-Temengor Forest Complex
BFR	Banding Forest Reserve
AFR	Amanjaya Forest Reserve
m	meter
a.s.l.	above sea level
MNS	Malaysian Nature Soceity
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund for Nature
cm	centimeter
RAI	Relative Abundance Index
%	Percentage
p.	page

pp.	paper presentation
GPS	Global Positioning System
NDVI	Normalized Difference Vegetation Index
Dist	Distance trekked
TN	Trap Night
GIS	Geographic Information System
Ψ	Probability of occupancy/use
$\hat{c}$	c-hat
hrs	hours
AIC	Akaike Information Criteria
AICc	Akaike Information Criteria small sample correction
ΔAIC	Delta Akaike Information Criteria
e.g.	example give
i.e	that is

KELIMPAHAN RELATIF, CORAK AKTIVITI DAN PENGGUNAAN HABITAT OLEH GAJAH ASIA DI KOMPLEKS HUTAN BELUM-TEMENGOR, PERAK

ABSTRAK

Ekologi gajah Asia (*Elephas maximus*) di hutan tropika Semenanjung Malaysia tidak dikaji secukupnya walaupun ia merupakan spesis "flagship" yang ikonik di rantau ini. Diklasifikasi sebagai terancam di bawah *IUCN Red List of Threatened Species*, sebanyak 1,223-1,677 gajah Asia liar dianggarkan di Semenanjung Malaysia, yang menghadapi pelbagai ancaman dari fragmentasi, degradasi and penukaran habitat serta konflik gajah manusia, kemalangan jalan raya dan pemburuan haram. Kamera perangkap (21, 263 malam perangkap) and survey kesan tidak langsung (2665 km jarak) telah digunakan untuk menilai kelimpahan relatif, corak aktiviti dan penggunaan habitat oleh gajah Asia di kawasan keutamaan pemuliharaan gajah di Semenanjung Malaysia; Kompleks Hutan Belum-Temengor. Kelimpahan relatif keseluruhan menunjukkan nilai 2.13±0.48. Corak aktiviti gajah Asia didapati "cathemeral" dan berbeza secara ketara ($W=44.50$, $p=0.040$) pada waktu siang di antara dua kawasan di dalam kompleks hutan; Taman Negeri Royal Belum (hutan primer) dan Hutan Simpan Kekal Temengor (hutan sekunder). Penggunaan habitat oleh gajah Asia secara umumnya menunjukkan kepentingan kesan bergabung oleh sungai dan kawasan hutan yang kurang kepadatan tutupan vegetasi. Secara am, kesan bergabung ini kemungkinan besar mencerminkan habitat riparian. Ciri ini lebih ketara di hutan yang

sudah dibalak akibat tumbuhan sekunder yang tumbuh di sepanjang rangkaian sungai seperti yang divisualkan dalam jangkaan penggunaan habitat oleh gajah Asia di Kompleks Hutan Belum-Temengor. Oleh itu, habitat riparian dan hutan yang telah dibalak tidak patut ditukar kepada guna tanah yang lain tanpa mengambil kira impak terhadap taburan gajah Asia di lanskap tersebut.

RELATIVE ABUNDANCE, ACTIVITY PATTERNS AND HABITAT USE OF THE ASIAN ELEPHANTS IN THE BELUM-TEMENGOR FOREST COMPLEX, PERAK

ABSTRACT

The ecology of Asian elephants (*Elephas maximus*) in the tropical forests of Peninsular Malaysia inadequately studied, even though it is an iconic flagship species for the region. Classified as endangered under the IUCN Red List of Threatened Species, a total of 1,223-1,677 wild Asian elephants estimated in Peninsular Malaysia, which are facing various threats from habitat fragmentation, degradation and conversion as well as human elephant conflict, roadkill and poaching. Camera trapping (21, 263 trap nights) and sign survey (2665 km distant) were used to assess relative abundance, activity patterns and habitat use of Asian elephants within priority area for elephant conservation in Peninsular Malaysia; Belum-Temengor Forest Complex. The overall relative abundance index found to be 2.13±0.48. The activity patterns of the Asian elephants was found to be cathemeral and significantly different (W=44.50, p=0.040) only during the daytime between two sites within the forest complex; Royal Belum State Park (a primary forest) and Temengor Forest Reserve (a secondary forest). The habitat use of Asian elephants broadly indicates the importance of the combined effect of rivers and patches of forest that are less dense in vegetative cover. In general, this combined effect is likely to reflect riparian habitats. This feature likely becomes predominant in logged-over forests due to the secondary

growth along networks of rivers as visualized by predicted habitat use of Asian elephants in Belum-Temengor Forest Complex. Therefore, crucial recommendation from this study is to gazette riparian habitats in Belum Temengor Forest Complex for protection from any other land use with a buffer of 1.5 km on each side of the main rivers. The study also recommends that the logged over forest should not be converted to other land uses without taking into account its impact on Asian elephants distribution within this landscape.

CHAPTER 1

INTRODUCTION

1.1 Asian elephant

Listed as Endangered under the IUCN Red List (Choudhury et al., 2008), the Asian elephant (*Elephas maximus)* is one of the few animals celebrated in the Asian region as a cultural symbol among Asian people (Varma, 2006) and has an important historical role in religion throughout the region (Santiapillai & Jackson, 1990). Vedic religions such as Hinduism and Buddhism hold elephant as one of the important figure in their belief system. It is also been given enormous respect in Indo-China region, primarily because of Hindu-Buddhist influence.

In Burmese astrology method *Mahabote*, elephant considered as one of the zodiac. In this zodiac, it has details pertaining tusked and tuskless elephants according to planetary influence (Htin, 1962). This shows the importance of elephants in Burmese culture. Asian elephants are also an important arsenal in wars (Glaize, 2003). The use of war elephants been described in many historical and mythological records.

Thailand celebrates Royal Thai Armed Forces day on January 18th to commemorate the victory of King Naresuan the Great in battle against the vice-king of Burma in 1593. In this battle, both party used war elephants. ("The History," December 2014).

The Asian elephant has been recognized in the conservation field as an umbrella, keystone, and flagship species due to their large ranging areas, importance in ecological roles and their impact on the environment (Choudhury et al., 2008). Smaller than its African counterpart, the Asian elephant is taxonomically divided into three subspecies; *Elephas maximus indicus*, *Elephas maximus maximus*, and *Elephas maximus sumatranus* (Shoshani & Eisenberg, 1982). Interestingly, Lydekker mentioned *Elephas maximus hirsutus* to be a subspecies unique to Peninsular Malaysia (Lydekker, 1914). This designation was based on morphological characteristic alone. However, this has not been accepted and applied in mainstream Asian elephant publications.

In recent years, the Asian elephant population in Borneo has been classified as a separate evolutionary significant unit based on their mitochondrial DNA (Fernando et al., 2003). Thus, with the addition of this new subspecies (*Elephas maximus borneensis*), a total of four subspecies currently exists in Asia (Alfred et al., 2010). For the purpose of this research, elephants found in Peninsular Malaysia are referred to as *Elephas maximus indicus*.

Asian elephants were once distributed from West Asia to East and South East Asia covering over 9 million km^2 (Sukumar, 2003), but currently only occur across 13 countries (Kemf & Santiapillai, 2000; Sukumar, 2003; Blake & Hedges, 2004) covering 878,639 km^2 (Hedges et al., 2009). A decade ago, a global population of 41, 410-52, 345 Asian elephants has been estimated (Sukumar, 2003).

However, Blakes and Hedges (2004) as well as Hedges (2006) argued that these estimates are no more than a rough guess. Even the likely distribution and the very existence of the Asian elephant's range in some of the areas are still questionable. Recent studies using dung count surveys have revealed Malaysia could be the country that has the largest known population of pachyderms among the South East Asian countries (Wildlife Conservation Society, 2009).

1.2 Rational of study

Globally reduced by distribution and numbers, there is an urge for conservation action for this species. In general, there is a lack of ecological information from robust scientific study on the distribution and the population for Asian elephants in Peninsular Malaysia, largely due to lack of resources to conduct rigorous survey. (Khan, 1991; Salman et al., 2011; DWNP, 2013). Under the new National Elephant Conservation

Action Plan (NECAP) three main landscape been identified as priority area for Asian elephant conservation (Belum-Temengor Forest Complex, Taman Negara, Endau-Rompin Complex).

With some ecological studies on Asian elephants had taken place in Taman Negara and Endau Rompin National Park (DWNP, 2013), there is a clear need to get ecological information on this large mammal in Belum-Temengor Forest Complex. Recent studies from Management and Ecology of Malaysian Elephant (MEME) attempts to obtain ecological information such as elephant's impact on the forest structure and biodiversity, effect of translocation on wild elephants, translocated elephant movement (Ning et al., 2016), farmer's perception and attitude towards government's mitigation pertaining elephant via electric fencing (Ponnusamy et al., 2016) have contributed towards improving knowledge towards Asia elephant conservation.

The most relatable occupancy framework based study was on historic elephant distribution that address human dominated areas (Tan, 2017). However, the habitat use of Asian elephants in two of the largest forest blocks within this landscape remain uninvestigated. As a developing nation, competition for agricultural use of land have resulted in Human Elephant Conflict (HEC). Many conflict elephants translocated to forested areas far away from human-dominated landscapes in order to resolve HEC.

One such area is Royal Belum State Park (RBSP), which is part of the Belum-Temengor Forest Complex (Salman & Nasharuddin, 2006). With the current issues of habitat degradation, forest conversion and HEC, the knowledge of Asian elephant ecology in Belum-Temengor Forest Complex becomes extremely crucial for its conservation.

The future of Asian elephant conservation relies on different ecological studies, one of which is resource and habitat utilization (Fernando et al., 2004), which is lacking in Belum-Temengor Forest Complex. In the absence of spatial occurrence and the habitat use of Asian elephants within Belum-Temengor Forest Complex, a comprehensive study on these ecological parameters will not only add to the crucial information about the species for its conservation, it could also be useful in the mitigation of HEC by applying good land use planning.

Apart from that, this study will be in line with fulfilling activities under the NECAP as well as to highlight the conservation value of this landscape. Ultimately, this study aim to predict habitat use for Asian elephants in Belum-Temengor Forest Complex which will help in identification of potential habitat sites that need to be protected.

1.3 Aim of the study

The aim of this study is to increase the ecological knowledge on Asian elephants in order to aid the conservation of the species in Peninsular Malaysia, particularly within Belum-Temengor Forest Complex.

1.4 Objectives

1. To investigate on the relative abundance, activity patterns of Asian elephants.
2. To investigate factors that influence the habitat use of Asian elephants within TFR and RBSP.
3. To identify critical areas for Asian elephant within the Belum-Temengor Forest Complex by creating a habitat suitability map.
4. To explore conservation recommendations to reduce threats to Asian elephants within Belum-Temengor Forest Complex.

1.5 Expected results

The relative abundance of Asian elephant in Temengor Forest Reserve and Royal Belum State Park expected to be different between RBSP and TFR. This is due to the logging activities and subsequent human disturbance to the habitat. Asian elephants reported to be cathemeral hence similar result expected to be observed in the study area.

The habitat use of Asian elephants is likely to be different in the two study sites due to the nature of the forest stand; consisting of primary forest (in Royal Belum State Park) and secondary forest (in Temengor Forest Reserve). Disturbance of natural forests due to logging would create secondary undergrowth that could also be used by elephant for browsing. According to Weerakon *et al*., (2004), disturbed habitat was said to be a preferred habitat for elephants in Sri Lanka.

Observations from DWNP also support this finding (Salman & Nasharuddin, 2006). This scenario is likely to be seen in Temengor Forest Reserve (TFR) since it is a logged-over forest and logging is still active and was during the study. On the other hand, it is known that elephants prefer lowlands (Alfred et al., 2006; Salman & Nasharuddin, 2006; Gopala, et al., 2013) and gentle hills (Alfred et al., 2006; Gopala, et al., 2013) and these features are more prominent in Royal Belum State Park (RBSP) compared to TFR.

In Sabah, elephants were found to be more frequently present in lowland forest with flat ground or gentle slopes, below 400 m a.s.l., most of which is secondary forest (Alfred et al,. 2006). Hence, a combination of availability of lower land and gentle hills coupled with disturbed vegetation are expected to be the likely factors that would influence the habitat use of Asian elephant in Belum-Temengor Forest Complex. Conservation recommendations expected to be focused on management of areas highly used by Asian elephants.

1.6 Flow Chart

The aim of the study is to promote elephant conservation in the Belum-Temengor Forest Complex based on scientifically derived conservation recommendations. The prime ecological factor targeted to be assessed in this study is the habitat use Asian elephant via occupancy framework whereby presence or absence (presence-absence) of the species in the sampling units laid across the study block to investigate against habitat features in order to find out what ecological factors affect utilization of an area by the Asian elephants.

In order to achieve this, rigorous sampling carried out to obtain presence-absence data for Asian elephants over a period of 17 months covering 560 km^2 area via camera trapping and sign surveys. Presence-absence of the species in a sampling unit tested for any relationship with ecological factors via statistical modelling. Best available habitat use model were further explored for conservation recommendations.

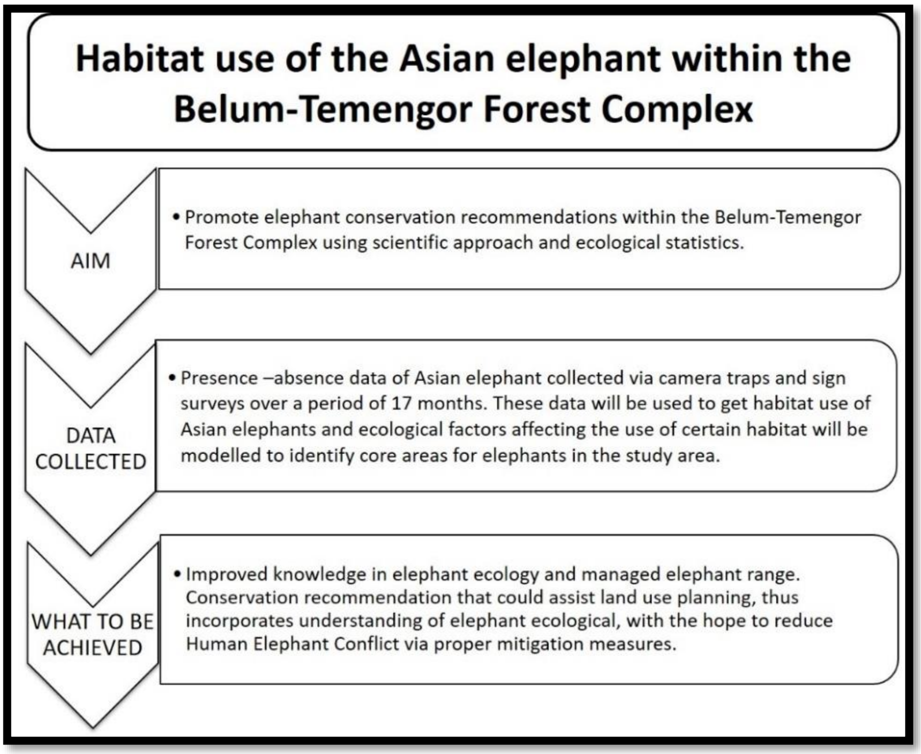

Figure 1.1 Flow of research

1.7 Assumptions and challenges

The assumptions in the framework of occupancy study is that there are no misidentification of Asian elephants especially no false presence in a sampling unit. The detections are also assumed to be independent from one sampling unit to another. This study have closure assumptions whereby occupancy status of a species does not change over the survey season. The individual animal may go in and out of the area of interest. Another assumption is that the probability of occupancy is constant across the sites and differences (if any) modelled using covariates. There is no unmodelled heterogeneity for default model (Mackenzie et al., 2006a).

Among the challenges in this study is to ensure signs of elephants collected were not more than about 1 month old. This is especially a challenge for elephant tracks which may last very long in the forest. Another challenge is spatial independence of a detection in a sampling unit in relation to its adjacent sampling units. Other challenges includes logistics and resource constraints, which result in extended stay in the forest to complete sampling.

CHAPTER 2

LITERATURE REVIEW

2.1 Asian elephant: Taxonomy and Morphology

Taxonomically Asian elephant falls under the Order Proboscidea and there are only two extant species under this order i.e. *Elephas* sp. and *Loxodanta* sp.. Formerly, these groups of large mammals were more diverse but many extinct during and since the Pleistocene period (Corbett & Hill, 1992). Asian elephant placed under Family Elephantidae, under the Genus Elephas (Francis, 2008). Originally described as *Elephas maximus* (Linnaeus, 1758), this Asian elephant were subjected to many suggestions by Blumenbach, (1797), Cuvier (1798), and Temminck (1847) (Shoshani & Eisenberg, 1982).

However, the original description i.e. *Elephas maximus* Linnaeus, 1758 have been largely accepted. Under *Elephas maximus*, three subspecies were recognized by Shoshani and Eisenberg (1982). This recognition was based on Chasen (1940) which concluded that elephant subspecies named as *Elephas maximus indicus* Cuvier, 1798, *Elephas maximus maximus* Linnaeus, 1758, and *Elephas maximus sumtranus* Temminck, 1847 (Shoshani & Eisenberg, 1982). The long debated elephant subspecies of Borneo have been finally resolved via genetic analysis and accepted as the fourth subspecies (*Elephas maximus borneensis*) making altogether four subspecies listed under *Elephas maximus* (Fernando *et. al.*, 2003; Alfred et al., 2010). This study deals with the mainland Asian elephant that is *Elephas maximus indicus*.

Morphologically, elephants are the largest terrestrial mammal that still exist on this planet weighing more than 1,000 kg (Owen-Smith, 1988). These mega herbivores divided into two groups: African elephant and Asian elephant. The main distinguishing character between these two are their size whereby Asian elephants are smaller than African (DWNP, 2013).

The Asian elephant shoulder height is about 1.5 to 3.0 m and weigh up to 5000kg (Francis, 2008). However, there are records of elephant with the height of 3.43 m (Shoshani & Eisenberg, 1982). A large bull in Sri Lanka reported to weigh 5400 kg (Shoshani & Eisenberg, 1982). Although the height and weight may vary, generally male elephants are larger than the females.

In terms of dentation, Asian elephants have two types of teeth. These are the cheek teeth and the iconic tusks. The tusks can be as long as two meters, usually only half of it are visible (Francis, 2008) and weigh up to 50 kg each but such records are hard to observe in recent days (DWNP, 2013). This feature of bearing tusks observed only in male Asian elephants. The females however have tushes, barely protrude beyond the jaw and usually not visible (Linnaeus, 1758; Medway, 1969; Francis, 2008; DWNP, 2013). Record of the tallest bull from early studies on elephants in Peninsular Malaysia comes from a 55 years old bull measured at three meters tall (Khan, 2012). The heaviest of all was a tuskless male, 6133 kg (Khan, 1991).

The tuskless male, are called *makhnas* in Tamil language (Biniwale, Jan 2015; Frontline, October 2015), and they are often bigger than the one with tusks (Kemf & Santiapillai, 2000). Elephant's trunk is a combination of nose and upper lip. This structure allow them to breath, locate scents, drink, and handle objects to extreme delicate and accuracy. Together with tusk, the elephant trunk also used in battles among them (Linnaeus, 1758). Their sense of smell and hearing are acute as oppose to the limited vision capacity. Elephants known to communicate using subsonic sound, which is beyond human hearing. This sound communicated as far as five kilometer in the forest (Jackson, 1990; Kemf & Santiapillai, 2000).

2.2 Ecological significance of Asian elephant

Ecological perspective of Asian elephant identifies the species' crucial role in maintaining the delicate ecosystem (Hazarika et al., 2008). Asian elephants are perfect example of umbrella species. The main criteria of such species is to have a large home range. Asian elephant home ranges are variable, depending on couple of environmental factors such as forest stand, human disturbance level, availability of food and water, sex (Alfred et al., 2012; DWNP, 2013) and in some places it is affected by seasonal change (Shoshani & Eisenberg, 1982; Sukumar 1989).

As an umbrella species, conservation of Asian elephant provides a larger benefit to many other wildlife and the habitat that they depend on (Choudhury et al., 2008). Asian elephant also serves as a flagship species, a charismatic species with high influence and huge fame, this species attain easy attention. Such criteria enables the species to be used for fund raising to aid conservation works. The ecology of Asian elephant is such that is often regarded as keystone species.

By definition, keystone species are that have effect disproportionately that its biomass (Paine, 1995). However, Fernando (2011) mentioned that there is a little evidence to show that Asian elephant serves as a keystone species in seasonally dry tropical forest. Asian elephants are deemed as gardeners in tropical rainforest (Campos-Arceiz et al., 2011) without equal match of existing mega-herbivores in Peninsular Malaysia for seed dispersal of megafaunal-symdrome plants (Campos-Arceiz et al., 2012).

This findings on Asian elephant in parallel to African forest elephant's role in seed dispersal, helping forest health and regeneration (Chapman et al, 1992; White et al., 1993; Blake, 2002). Based on these points, the conservation of Asian elephant is indeed significant for the ecology of many ecosystems, thus ensuring the survival of many species that depend on it, including human race.

2.3 Global distribution of Asian elephant

According to Olivier (1978), the historic range of Asian elephant stretched from the Tigris and Euphrates (45° East) in the west, east through Asia south of Himalaya and north into China at least as far as the Yangste Kiang (30° North) and probably further, covering an area more than nine million km^2 (Sukumar, 2003). Asian elephant have been wiped out almost 90% from their historic range, leaving only 10% (DWNP, 2013) with which they are spread across 13 countries (Kemf & Santiapillai, 2000; Sukumar, 2003; Blake & Hedges, 2004).

According to Choudhury et al., 2008, the 13 countries are Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Sri Lanka, Thailand and Vietnam. In Bangladesh, Asian elephants are restricted to southeast and periodically presence in northeast of the country. The population from the northeast actually shares the neighbouring country India. Most of these areas spared to become elephant habitat due to some level of inaccessibility to human (Choudhury et al., 2008).

In Bhutan, the only area that the species roam are along the Bhutan-India border. The previous movement of the species between Bhutan and India blocked due to habitat loss and fragmentation (DWNP, 2013). In Cambodia, mountains of the southwest; Mondulkiri and Ratanakiri Provinces are stronghold for the species (Pollard et al., 2007). The rest of the Asian elephants in Cambodia exist in small and scattered populations (DWNP, 2013).

In China, this species suffered great extirpation, almost entirely wiped out from this vast land (Kemf & Santiapillai, 2000). This once widespread species in China now restricted to Yunnan Province only. Similar situation observed in India, except that the Asian elephant in India are now restricted to generally four large areas. These areas are the northeast, the central, the northwest and the southern of India. Although the species occur in four large areas, due to human pressure, the Asian elephants in India subjected to fragmented habitat, which leads to isolated population within these four large areas (Sukumar, 1989; DWNP, 2013).

Indonesian elephants are distributed in two different islands of Sumatra and Kalimantan. Sumatra houses *Elephas maximus sumatranus,* which have highly fragmented population, scattered throughout the island (Sukumar, 1989). Some places in Sumatra, the elephants are threatened by habitat loss, poaching due to human elephant conflict (Santiapillai & Jackson, 1990, Hedges et al., 2005).

Bukit Barisan Selatan located in the southern Sumatra identified as highly important area for Asian elephant conservation (DNWP, 2013). Pygmy elephant, *Elephas maximus borneensis* in the Indonesian part of Borneo Island mostly found in northeast Kalimantan. They are recorded to be found in the upper Sembakung river, under Tindung District (Sukumar, 1989; DWNP, 2013).

Laos formerly known as “Lane Xang” literally means the land of a million elephants (Olivier, 1978). Although the species is now widely spread over Laos People’s Democratic Republic, they are only sporadically distributed over the forest along the border of this country, ranging from highland to lowland (Sukumar, 1989; Kemf & Santiapillai, 2000; DWNP, 2013).

The distribution of Asian elephants in Myanmar are poorly known (DWNP, 2013). The species speculated to be widespread in Myanmar based on the forest cover, which is roughly 50% of the country (Kemf & Santiapillai, 2000). The highly fragmented distribution Asian elephants in Myanmar is attributed to five main areas for which are largely at the north and west hill ranges, central, east and the south of the country (Choudhury et al., 2008).

In Nepal, previously Asian elephants found in lowland Terai. In recent years, the distribution are reduced, and they are more likely to be found in the national parks and wildlife reserves of Nepal that borders India (Choudhury et al., 2008). In Sri Lanka, Asian elephant was once widespread. Now, the species are mostly restricted to dry zones of the country.

These are north, south, east, northwest, north central, and southeast of Sri Lanka. The only two wet zones housing Asian elephant in Sri Lanka are the Peak Wilderness Area and Sinharaja Area (Sukumar, 1989; DWNP, 2013). Progress in agriculture in lowlands led to isolation of elephant habitat, termed as "pocketed-herd" phenomenon (Olivier, 1977).

In Thailand, Asian elephants are abundant in mountains bordering Myanmar. The species also found in the southern forest complex bordering Malaysia. Several forest complexes and protected areas in the east and northeast of Thailand also house Asian elephants (Choudhury et al., 2008; DWNP, 2013). In Vietnam, very limited number of Asian elephant populations are sustaining.

In the past, the species distributed nearly throughout the borders of Vietnam with Laos People's Democratic Republic and Cambodia. Drastic decrease in forest cover have resulted in reduction of the species' range (Kemf & Santiapillai, 2000). Asian elephants are no longer present in the north of Vietnam, but this area occasionally receives wanderers from neighbouring country such as Lao People's Democratic Republic Currently Asian elephants distributed in very small-isolated central and southern parts of Vietnam (Choudhury et al., 2008; DWNP, 2013).

2.4 Global population of Asian elephant

Previous global population estimate of Asian elephant subjected to multiple changes. This is largely due to lack thorough scientific research across the distribution of Asian elephants. Olivier estimated a total 28,000 – 42,000 of Asian elephants to exist in late 1970s (Olivier, 1978). In the 21st century a total of 41,410 – 52,345 Asian elephants were estimated (Sukumar, 2003) and this figures which has been regarded as a crude guess is in use for about 25 years (Blake & Hedges, 2004; Hedges, 2006).

Current estimate of Asian elephants are based recent findings from almost all 13 elephant range countries, except Thailand. The result shows that 39,463 – 47,427 Asian elephant to be found in their range (Fernando & Pastorini, 2011). Although the drop for the lower range is only 1,947 individuals since 2003, this recent findings suggest the population trend is indeed declining as what postulated in IUCN Red List for Asian elephants.

2.5 Global threats to Asian elephant

A common set of factors adversely affecting the population of elephants have been known throughout its range. These factors are habitat loss, degradation and fragmentation (Leimgruber et al., 2003; Sukumar, 2003; Hedges, 2006). These factors either singly or in combination have also been known to cause a cascading effect, which often leads to Human Elephant Conflict (HEC). Overall, these threats have isolated them within smaller provinces across Asian countries, likely to affect their long-term survival.

In addition to this, poaching also identified as another major threat to this species (Kemf & Santiapillai, 2000; Dublin et al., 2006; Choudhury et al., 2008). In recent years, major declines in population numbers have mainly been attributed to illegal killing of elephants due to either demand for ivory and body parts (Sukumar et al., 1998; Milliken, 2005) or through retaliatory killing via HEC cases (Sukumar, 1992, 2003; Hedges 2006).

General assumption on Asian elephant is that poaching is not a serious threat in relative to its African counterpart since the ivory trade strongly involves the African elephants. However, poaching on Asian elephant are not entirely to cater ivory market, but also other use such as bushmeat consumption, leather and traditional medicine. Asian elephant population could be more prone to effects due to ivory poaching since only male elephants have tusks. Continuous poaching on male tusker will result in skewed population sex ratio with more female than male elephants. Such scenario have been recorded in different parts of elephant range such as India, Cambodia and Vietnam (Kemf & Santiapillai, 2000; Choudhury et al., 2008). Cases of Asian elephant skin turned into ornamental beads deemed crisis that could affect the species (Akpan, 2018).

2.6 Distribution in Peninsular Malaysia

Based on the literatures, it can be concluded that the distribution of Asian elephant throughout its range have been greatly reduced by human pressure. Similar case observed in Malaysia as well. In Malaysia, there are two species of Asian elephants. These are the mainland population in Peninsular Malaysia (*Elephas maximus indicus*) and the Bornean population in Sabah (*Elephas maximus borneensis*). In Sabah, Bornean elephants occurs in five key managed elephant ranges namely Tabin, Kinabatangan, Central Forest, North Kinabatangan and Ulu Kalumpang (Alfred et al., 2011). The Bornean elephant population estimated to be within the range of 1,184 to 3,652 individuals (Alfred et al., 2010). Central Forest range said to support more than 1,000 individuals whilst the other 4 ranges have less than 1,000 individuals (Alfred et al., 2011).

Literatures reviewed here are mostly from Peninsular Malaysia since this thesis is about the mainland population *Elephas maximus indicus*. Occasionally scientific findings from Bornean population are also included in later part of this thesis. There were no nationwide robust scientific assessment on Asian elephant distribution and many accounts derived from HEC records. Such reliance on HEC records as a proxy to report the species distribution data in official documents would lead to false indication of Asian elephant distribution (DWNP, 2013). Nevertheless, the distribution of the Asian elephant in Peninsular Malaysia reported to reduce over time, in tandem with the loss of their habitat.

According to Flower (1900), Asian elephants were once common everywhere in Peninsular Malaysia except in Penang (Olivier, 1978). Prehistoric Peninsular Malaysia fully covered by few types of natural forest (Salman et al., 2011) and ninety percent of forest was still dominating Peninsular Malaysia in early 1950s (FDTCP, 2007). In less than 60 years, forest cover in Peninsular Malaysia have been reduced to just 37.7% (Miettinen et al., 2011). Expansion of large agricultural scheme driven by the government economic policy has taken vast lowland forests from its existence. These lowland forests, which were once prime habitat for Asian elephants (Fernando, 1989), now replaced with oil palms and rubber trees (Wan, 1985).

A very large chunk of forest have disappeared from Peninsular Malaysia due to large agriculture land scheme. For instance, the oil palm plantations have expended to area more than 21,870 km^2 (Abdullah, 2003), an area larger than the Main Range: the hilly and mountainous forest that stretch from Malaysia-Thailand border to south, covering over five states in Peninsular Malaysia (DWNP, 2008).

This continuous permanent removal of Asian elephant habitat at an alarming rate of 400 km^2 annually (Blair, 1980) which lead by Federal Land Development Agency (FELDA) (Fernando, 1989) have undeniably reduced the distribution of Asian elephant in Peninsular Malaysia.

In a report compiled by Santiapillai and Jackson (1990) for the IUCN/SSC Elephant Conservation Action Plan, a reduction in the distribution of the Asian elephant highlighted. Among the main reason for their reduction is habitat loss, degradation as well as fragmentation (Santiapillai & Jackson, 1990)

According to this report, Asian elephants were recorded in nine states, namely Johor, Kedah, Kelantan, Negeri Sembilan, Pahang, Perak, Perlis, Selangor and Terengganu and absent in the state of Melaka. In 2006, the DWNP management plan for elephants in Peninsular Malaysia reported that elephants were absent in two more states, namely Selangor and Perlis. Partly, due to the practice of translocating Asian elephants out of these two states (Salman & Nasharuddin, 2006).

Distribution of Asian elephants in Peninsular Malaysia states are reduced to 7 out of 11 states according to National Elephant Conservation Action Plan (DWNP, 2013). With the exception of Negeri Sembilan, the states of Perak, Kelantan, Terengganu, Pahang, Johor, and to a lesser extent, Kedah, are thought to sustain the bulk of Peninsular Malaysia's Asian elephant population.

In February 2011, a bull elephant was translocated from Negeri Sembilan to Taman Negara National Park; this individual was suspected to be the last elephant in Negeri Sembilan (Salman et al., 2011). However, presence of elephants in Negeri Sembilan still reported in steering committee of National Elephant Conservation Action Plan (DWNP, 10th February 2015). The elephants suspected to come from neighbouring states such as Pahang.

Without resident population of elephants in Negeri Sembilan state, the Asian elephant has been wiped out from four states of Peninsular Malaysia within a period of slightly more than 100 years, Hence, the long-term survival of Asian elephant in Peninsular Malaysia will be jeopardised if this trend continues to persist.

2.7 Population in Peninsular Malaysia

In Peninsular Malaysia, 681 Asian elephants estimated to be around in 1965 (Medway, 1965). In the 1970's, Olivier (1978) concluded that around 3,000-6,000 Asian elephants may still survive in Malaysia. Entering the new century, 800-3,000 Asian elephants estimated to be present in Malaysia (Sukumar, 2003). Interestingly, Sukumar (2003) quoted using a different population estimate figure in the IUCN Red List for Asian elephants, i.e. 2,100-3,100 (Choudhury et al., 2008).

However, this figure could be inclusive of the elephant population found in Sabah, Malaysian Borneo. In 2006, Sukumar updated the population size of Asian elephants in Peninsular Malaysia as ranging from 1,251-1,466 animals (Sukumar, 2006). A similar figure was estimated in the Management Plan for Peninsular Malaysia Elephants, which is 1,200-1,450 individuals (Salman & Nasharuddin, 2006).

The most recent publication on Asian elephants in Peninsular Malaysia reported a population estimate of 1,223-1,677 individuals (Salman et al., 2011) which derived its number from HEC cases and from footprints in DWNP annual biodiversity inventories (Salman et al., 2011; DWNP, 2013).

Unlike the statistically robust dung count survey method used by WCS (Hedges & Lawson, 2006), the number derived in the year 2011 purely from HEC records as well as footprint counts may not be the best way of estimating the Asian elephant numbers in a particular area. In terms of Asian elephant distributions, the reliance on HEC records as a proxy to report the species distribution data in official documents would lead to false indication of Asian elephant distribution (DWNP, 2013). Unfortunately, this method applied in previous reports of Asian elephant status in Peninsular Malaysia (Khan, 1991).

This give rise to questions on the reliability of the previous accounts of Asian elephants in Peninsular Malaysia, not only in terms of population estimate but also in terms of the accuracy of their distribution. This inaccuracy acknowledged in National Elephant Conservation Action Plan document, which states the reason for such lack of information is due to the constraints in resource to conduct rigorous survey (DWNP, 2013). Starting from 2012, DWNP have decided to use non-invasive genetic mark-recapture method to estimate Asian elephant numbers (Salman et al., 2011). Such method expected to provide robust understanding on the elephant numbers compared to previous studies.

Nevertheless, the overall reducing estimates of Asian elephant population by conservationist indicates clear dwindling of the species in Peninsular Malaysia which halved the size over the past 60 years in tandem with the loss of their habitat, food resource, and retaliatory killing due to HEC, although the later seem to have relatively less records compared to the previous two causes. Table 2.1 shows population estimates of Asian in Peninsular Malaysia from previous studies. Reasons for the decline explored under the sub-chapter 2.8 Threats in Peninsular Malaysia.

Table 2.1: Population estimates of Asian elephants in Peninsular Malaysia from previous studies.

Studies	**Population**
Medway (1965)	1,965
Olivier (1978)	3,000-6,000
Sukumar (2003)	800-3,000
Sukumar (2006)	1,251-1,466
Salman & Nasharuddin, (2006)	1,200-1,450
Salman et al.(2011)	1,223-1,677

There are also population estimate derived from few sites in Peninsular Malaysia, using dung count survey method. This survey was collaboration between DWNP and Wildlife Conservation Society (WCS). For instance, dung count survey conducted in Taman Negara arrived at an estimate of 631 Asian elephants with Confident Intervals of 95 %, ranging from 436 – 915 animals (Hedges et al., 2008). The estimated range of elephant numbers totally differ from DWNP’s estimation, which is 290 – 350 animals in Taman Negara (Salman, 2002).

In Johor, 113 Asian elephant estimated by Hedges et al. (2008), whereas DWNP's estimate from this area was 130-180 animals (Salman, 2002). Although the year of assessment could have contributed to difference in the elephant population estimate derived from both method, it seems the method applied by the DWNP indicates that their biodiversity assessment might underestimate the real population (Salman et al., 2011).

2.8 Threats in Peninsular Malaysia

Although conservation of Asian elephant is recognized to be important, there are challenges for conservation works, mainly due to couple of threats which boils down to one factor, i.e. human pressure. Generally, threats can be divided into two types. These are the direct threats like poaching and indirect threats such as habitat degradation, fragmentation, and conversion, HEC and reduce in genetic diversity (DWNP, 2013).

Other threats faced by Asian elephants are poor management practices mainly to tackle HEC, in some cases small isolated population and possibility of disease from both natural and human induced causes. Similar threats are also concerned to affect the Asian elephants in Peninsular Malaysia (DWNP, 2013).

Based on the previous accounts, a significant decline in both distribution and population size indicates that serious conservation interventions are required in order to safeguard Asian elephants in Peninsular Malaysia. Plate 2.1 shows dead elephant suspected to be poisoned by indigenous villagers within Belum-Temengor Forest Complex during the study period. The elephant found death with bloods in the dung defecated by the individual.

Plate 2.1 Dead elephant found at Rancangan Penempatan Semula Air Banun, Gerik, within Belum-Temengor Forest Complex

2.9 Conservation efforts in Peninsular Malaysia

Asian elephant conservation in Peninsular Malaysia dates back 1970s whereby the first elephant translocation squad formed as an alternative to the shooting and poisoning of conflict elephants. The establishment of elephant centre by DWNP in 1989 at Kuala Gandah as a rehabilitation centre for Asian elephants is also seen as the one of the major step of elephant conservation in Peninsular Malaysia. Since then, the conservation measures to mitigate Human-Elephant conflicts is largely using translocation method.

Although various Asian elephant action plans had been postulated by DWNP, a large-landscape level conservation measures involving various government agencies and conservation NGOs which assures the long term survival of wild Asian elephant in Peninsular Malaysia was still lacking in the 20th century. However, in the 21st century, a major step have been taken on Asian elephant conservation in Peninsular Malaysia whereby a blueprint to save the species have been introduced by Malaysian government (DWNP, 2013).

At the end of 2012, a meeting between the Ministry of Natural Resources and Environment agencies and conservation NGOs was held to draft a National Elephant Conservation Action Plan for Asian elephants in Peninsular Malaysia (WCS News Release, 2013). This effort is a significant local initiative in conserving Asian elephants in Peninsular Malaysia. On the November 27th 2013, National Elephant

Conservation Action Plan (NECAP) was formally launched by Minister of Natural Resources and Environment at Genting, Pahang (Launching of the Malaysia, 2013). Under this plan, three main landscapes have been identified as priority areas for Asian elephant conservation; the Belum-Temengor Forest Complex, Taman Negara National Park and Endau Rompin Forest Complex.

2.10 Asian elephant habitat use

2.10.1 Definition: Habitat use and modelling

Krausman used definition of habitat as per Thomas (1979), whereby habitat referred as the sum of specific resources needed by organisms. He further quoted Leopold (1933) to define habitat as resources such as food, cover, water and species factors needed by a species for survival and reproductive success. Krausman defined habitat as any space that provide organisms with resources for its survival. In summary, corridors used by organisms to migrate and disperse as well as lands that are used by them during breeding and non-breeding season should be considered as habitat (Krausman, 1999). Recent definition also refers to similar defining factors such as place where an organism or a community of organism live which includes all biotic and abiotic surrounding (The Editors, 2017)

Based on this, it can be concluded that habitat is defined as resources and space required for the survival and reproduction of a species. Habitat use refers to the way an animal utilizes the biotic and abiotic elements for various purpose such as forage, refuge, nesting, escape, denning or other behavioral trait in their habitat (Krausman, 1999). In this study, habitat use of Asian elephants within Belum-Temengor Forest Complex were investigated using occupancy framework. Occupancy framework looks at probability of a sampling unit occupied by a species of interest. However, if the sampling unit is smaller than the home range, it cannot the occupied by the species but rather used (Mackenzie et al., 2006a), hence called probability of habitat use.

Occupancy modelling is a framework for mathematical abstraction of real world (Mackenzie et al., 2006a), in this case factors that influence use of an area by Asian elephant. Mathematical model ultimately representative of one or more hypotheses or theories about real world (Mackenzie et al., 2006a). There could be multiple models (Mackenzie et al., 2006a) which can be used to explain, understand or even predict a system of our interest. Top model is the highest-ranking model among the other entire available model.

2.10.2 Analytical method from similar studies

Two studies applied occupancy framework to assess occupancy or habitat use of Asian elephant in India. These are Jathanna et al., 2015 and Lakshminarayanan et al., 2016. Both studies applied sign surveys with spatial replicates to assess factors influencing Asian elephant occupancy in Western Ghats, Karnataka, India. Jathanna et al. (2015) had survey efforts of 4,172 km distance trekked and detected 2,712 elephant signs. There were no indication of efforts from Lakshminarayanan et al. (2016). Jathanna et al. (2015) used grid size (188 km^2) larger than the mean elephant home range data obtained from previous studies in the area. The study focused occupancy rather than habitat use.

In contrast, Lakshminarayanan et al. (2016) had smaller grids (11.75 km^2) as the focus was on habitat use specifically. Both of these studies initially deployed modelling approach as per MacKenzie et al. (2002), followed by test for spatial dependence. Both studies detected significant presence of spatial-dependence and opted to use Hines et al. (2010) modelling approach that explicitly accounts spatial-dependence, which gives a better quantitative result for occupancy or habitat use rate. Statistic model explores which combination of explanatory factors best reliable to infer observation recorded for habitat use assessment. Top occupancy model from Jathanna et al., 2015 includes proportion of livestock signs and NDVI. NDVI found to be negatively correlated to elephant occupancy and this observation is similar to result obtained from habitat use on Asian elephant in BTFC.

However, Jathanna et al., 2015 stressed that anthropogenic factors prevailed natural habitat in determining elephant occupancy. Anthropogenic factors measured in the study was mainly presence of livestock, which grazes in elephant area. The study also mentioned confounding variables related to human that also be related with the livestock, could pose cumulated effect on elephant occupancy.

Lakshminarayan et al. (2016) study provides top model for elephant habitat use consisting distance to river and NDVI. The result shows that Asian elephant habitat use to be affected by both distance to river and NDVI negatively during the dry season in the Western Ghats of India. Distance to the river mentioned as best predictor while low NVDI adds to the effect to elephant habitat use. Lakshminarayan et al. (2016) justifies their observation by quoting findings from Sukumar (1989) and Sukumar (2003) which relates high amount of daily water requirement by elephants to high concentration of elephants in riparian habitat at deciduous forest during dry season.

Other similar studies, without statistically robust analysis also shows similar environmental factors influencing elephant habitat use. Statistically less robust analysis do not include imperfect detections within the method therefore detectability not accounted entirely (Mackenzie et al., 2006a). Rood et al. (2010) carried out ecological niche factor analysis, a method that uses presence only data whereby detection probability are not accounted. However, the study mentioned their result validated via continuous Boyce validation technique, Biomapper software (Hirzel et al., 2006; Pearce & Boyce, 2006).

Result from the study suggest elephant habitat use positively related to vegetation cover and productivity as well as valleys. Rood et al. (2010) proposed that such positive correlation towards productive vegetation and valleys indicates rivers as the water source and natural routes to overcome mountainous terrain. Rood et al. (2010) also suggest elephants mainly utilized forest edges and associates secondary vegetation due to human disturbance provides elephant forage.

Kumar et al. (2010) used sign survey and direct sightings to draw conclusion on elephant habitat use in Annamalai Hill, India. The study compared proportion on habitat type preferred by elephants with the available area and suggested rainforest fragments and riparian habitat as the major features affecting the species' habitat preference. The study also mentioned secondary vegetation in certain rainforest fragments preferred by elephants.

Sitompul et al. (2013) provides insights into Sumatran elephant's habitat use through radio-collar whereby a wild female elephant collared and monitored for about nine months. In general, the elephant and presumably its herd exhibits higher use of medium and open canopy. The high use of such less densely vegetated area supposed to relate to food availability. The closed canopy area were used more during the day and mostly near the forest fringe. The study associated such use of closed canopy area to thermal regulation and shade.

A Global Positioning System (GPS) telemetry study at Belum-Temengor Forest Complex involving 17 local and translocated Asian elephants conducted by Wadey et al. (2018) shows that the animals were attracted to the areas along Gerik-Jeli highway where secondary growth and open habitat are found in abundant. The study modelled habitat selection which explores factors influencing selection of habitat and movement of Asian elephants using Beyer et al. (2016) analytical framework, which calculates probability of "step" from sequential telemetry location from one point to the next by taking into account of available resources and habitat features.

Habitat features included for analysis were slope (degrees), distance to road (km), distance to road squared (km^2), "wetness" (indicator of soil and canopy moisture) obtained using remote sensing data and permeability that indicates whether collared animal crossed the road in any particular "step". The study managed to identify elephant movement paths and reveal habitat features preferred by elephant along the road which are affected by changes in vegetation structure and high food availability.

In Sabah, Alfred et al. (2012) assessed ranging behaviour by overlaying Bornean elephant movement data obtained on the environment layers created using Geographic Information System (GIS) tool, hence no specific modelling carried to scrutinize the relationship between the elephant ranging area and its habitat. Alfred et al. (2012) reported non-fragmented forest area with lowland and gentle hills preferred by Bornean elephants. In addition, availability of food and water sources reported to force elephants to travel adjacent forested area. Jamieson et al., (2012) also used GPS collars to assess correlation between movement of Asian elephants and habitat type in the state of Terengganu and Pahang. However, the attempt failed due to malfunction GPS collars, hence no further information obtained from the study.

Aini et al. (2015) provided information on habitat preferred by two GPS collared translocated elephants in the state of Terengganu and Johor. The study adopted method from Saaty (1980), Analytic Hierarchical Process to predict habitat preferred by Asian elephants. It is important to note that this method is often criticized on procedures which may result to significant degree of uncertainties on output priority (Warren, 2004) and inability to sufficiently handle it (Deng, 1999).

Aini et al. (2015) reported that the collared elephants utilized secondary forest habitat. Results shows profound correlation to water sources as the elephants are generally found within 1.5 km distance from permanent water sources. Similarly, Bahar et al. (2018) attempted to assess relationship between home range and environmental variables using GPS collar fitted on a young bull, which was monitored for almost three months. The study found that the young bull's movement shows high use of medium and open canopy as well as areas with water availability.

Estes et al. (2012) and Reza et al. (2013) developed habitat suitability map for Bornean elephants and large mammals in Selangor respectively. It was carried out based on multi-criteria analysis by expert judgment integrated with GIS as well as literature reviews to determine important environmental factors. Estes et al. (2012) deployed GIS tool namely Corridor Designer (Majka et al., 2007) to determine the available suitable habitat for elephants whereas Reza et al. (2013) used Conefor Sensinode 2.2 (Saura & Torné, 2009) to score connectivity for large mammals in Selangor.

Unlike Reza et al. (2013), Estes et al. (2012) incorporated uncertainty analysis to assess variation in model output in relation to uncertainty in input parameters and had more expertise consulted. Nevertheless, there were no field validation carried out to assess reliability of the predicted suitable habitat map by both studies. In a similar study at Phu Luang Widlife Sanctuary in Thailand, Mongkolsawat & Chanket (2007) carried out field assessment to validate the map output on habitat suitability that were produced using GIS tool. Such cross validation vital given the first attempt of developing such habitat suitability index for large mammals.

The aforementioned four studies (Alfred et al., 2012; Jamieson et al., 2012; Aini et al., 2015 Bahar et al., 2018) explored habitat use and ranging of Asian elephants in Malaysia via GPS collars and were not carried out using occupancy framework. In these studies, relationship of utilization or suitability of habitat by Asian elephants were not explained by applying robust statistical method hence no estimates from correlation test nor habitat modelling with certain degree of precision as oppose to this study in Belum-Temengor Forest Complex.

Whereas Ester et al. (2012) and Reza et al. (2013) focused on predicting suitable habitats whereby the study method assumes important environmental factors affecting wildlife habitat use based on literature review and expert views. Therefore, such method does not elucidate habitat features affecting habitat use.

In general, absence of Asian elephant studies in Malaysia with similar extent, design and analytical method comparable to this study shows the need for ecological research on the species for better understanding as it would facilitate to reduce knowledge gaps and improve conservation of the species. Nevertheless, these studies provide pertinent preliminary understanding on elephant habitat use, suitability and preference in Malaysia.

2.10.3 Application in conservation

As a country with increasing population and economic development, government of Malaysia realized its impact and had taken some initiatives to safeguard threatened wildlife with only a small scale of forested area actively focused and this method ineffective in regional conservation of wildlife (Reza et al., 2013), especially mega-herbivore like Asian elephant that require large roaming areas.

Large forested area has been developed into agricultural plantations. Since 1980s, more 5.01 million ha have been opened for large scheme oil palm plantation (Wahid et al., 2010) and a total of 1.05 million ha area are planted with rubber trees (Malaysia Rubber Board, 2014). This development contributed to encroachment into wildlife habitat, which leads to human elephant conflict in these plantation areas especially at the forest fringe.

Many conflict elephants been poisoned and killed as an illegal measure to resolve the conflict (DWNP, 2013). Failure in good land-use planning and elephant habitat management assisted with scientific knowledge may have attributed to such conflict. Thus, the future of Asian elephant conservation relies on different ecological studies such as resource and habitat utilization (Fernando et al., 2004).

Understanding Asian elephant relationship with habitat is crucial in developing good land-use planning and habitat management guidelines. A study in Meghalaya suggest that elephant crude density is correlated with various habitat variables that are affected by human (Bruce et al., 2011). One of the main anthropogenic effects exerted by human in the landscape is ‘jhum’, a shift cultivation method. The study identified factors that allow Asian elephant’s crude density higher in certain areas than another and it suggested these findings are important in developing habitat management guidelines for the elephants of the region (Bruce et al., 2011).

Another study in India that looks into habitat suitability of elephants that often moves between Chhattisgarh, central India, Orissa and Jharkhand provided an insight on elephant corridors using geospatial modelling. Findings from the study expected to help the state government in India to better manage and minimize HEC in the region (Areendran et al., 2011). Weerakon et al., (2003) identified factors that affect the ranging behavior and habitat utilization of Asian elephant in Sri Lanka and suggestions to reduce human elephant conflict were made based on their study.

It was also mentioned that almost all the management practices executed today are not based on robust scientific findings that ensures long term Asian elephant conservation in the country. Similar effort made to understand the habitat use and ranging of Asian elephant in a fragmented forest at Anamalai Hills, India. The study site is fragmented with tea, coffee and *eucalyptus* plantations. Based on the study, conservation recommendations were made to retain the roaming area for the Asian elephant by protecting rainforest fragments, riparian secondary vegetation and controlled or periodic felling of eucalyptus plant as oppose to clear felling practice. Such recommendations suggested to reduce direct human-elephant encounters, which can result to conflict in this, fragmented wildlife habitat (Kumar et al., 2010).

In Sumatra, spatial and temporal use of Sumatran elephant were investigated using GPS collar in order to provide better insight on managing the fragmented forest to sustain elephants in the area (Sitompul et al., 2013). The study revealed that the collared elephant and its herd used medium-canopy and open-canopy habitat more often, nonetheless the proportion of time spent within the closed-canopy observed to be higher during the day than the nighttime (Sitompul et al., 2013).

Within the closed-canopy area, more time were spent near the forest fringe. As a result of this study, restoration of cleared habitat and provision of forest stand with variety of canopy cover were recommended for effective conservation of the species (Sitompul et al., 2013). Similar research were done in Phu Luang Wildlife Sanctuary, Northeast Thailand. Unlike aforementioned studies, this is a habitat suitability study, which provided management recommendation for Asian elephants within the 900km^2 wildlife sanctuary.

Ground survey and GIS data were used to categorize the habitat suitability of the sanctuary into three levels namely highly suitable (19.15 %), moderate suitable (35.03%), and marginally suitable (45.83%). (Mongkolsawat & Chanket, 2007). Such information are important and relevant for the management to prioritize and allocate resources for the right patch of forest in order to improve wildlife conservation within the sanctuary.

Based on the aforementioned studies, it is conclusive that the ecological knowledge on the Asian elephant habitat use plays an important role in the conservation of the species. Given the fact of rapid decline Malaysian forest cover (Hansen et al., 2013; Butler, 2013) coupled with human elephant conflict cases, efficient habitat management seems to be the best way for human and elephant to co-exist in harmony. Such management can be empowered by the ecological knowledge from this study.

CHAPTER 3

METHODOLOGY

3.1 Study area

Belum-Temengor Forest Complex considered as the oldest rainforest in the world, dating up to 130 million years old (Nasir et al., 2011). Situated in the north of the Main Range, Belum-Temengor Forest Complex comprise of several different forest blocks. Northern section of this forest complex is a protected area known as Royal Belum State Park (RBSP), with a size of 1,175 km^2 (MyBis, 2018). Temengor Forest Reserve (TFR) which is 1488.7 km^2 (Government of Perak, 1991) forms the southernmost part of Belum-Temengor Forest Complex.

Figure 3.1 presents aforementioned geographical locations of Belum-Temengor Forest Complex. Both TFR and RBSP are the two largest forest blocks within this forest complex. TFR is a production forest since 1970s and the second round of logging is currently ongoing in this forest reserve, whereas RBSP is a primary forest (Rayan et al., 2013).

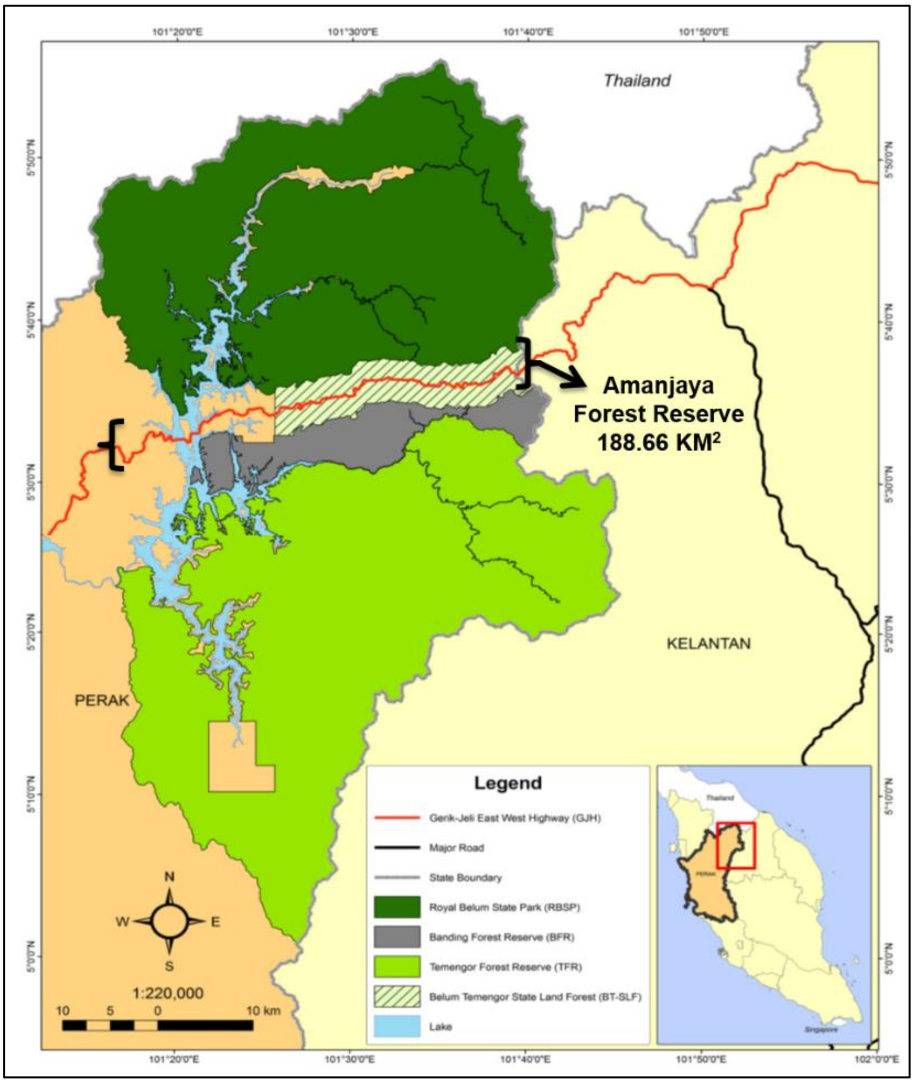

Figure 3.1: Location of Belum-Temengor Forest Complex (BTFC) and forest blocks within it.

Note: Adapted from *Conservation and ecology of tigers in a logged-primary forest mosaic in Peninsular Malaysia* (p. 22), by Darmaraj, 2012, University of Kent, Canterbury, UK. Copyright by Darmaraj (2012). Adapted with permission.

The unique location of RBSP's at the far north of Peninsular Malaysia contains the features of Thai-Burmese flora and fauna (MNS, 2005; WWF-Malaysia, 2011a). This uniqueness shows the conservation significance of the forest complex (WWF-Malaysia, 2011a). Another forest reserves on the west side of RBSP is Gerik Forest Reserve. Amanjaya Forest Reserve (AFR) (188.66 km^2) (Government of Perak, 2013) and Banding Forest Reserve (BFR) (166.67 km^2) (Government of Perak, 2012) situated in between TFR and RBSP. In this thesis, Belum-Temengor Forest Complex (here after BTFC) refers to TFR, RBSP, AFR and BFR. Gerik Forest Reserve is not included in this study due to distant location from sampling site.

There are five different vegetation classes in BTFC, namely lowland dipterocarp, hill dipterocarp, upper dipterocarp, montane ericaceous and oak laurel with elevation ranging from 265-1945 m a.s.l. (Darmaraj, 2012). Areas below this are flooded by the second largest man-made lake in Peninsular Malaysia, Lake Temengor. BTFC falls under the Hulu Perak district of Perak State, contains the origin of Sg. Perak, which is the second longest river in Peninsular Malaysia.

RBSP is the second largest state park after Taman Negara, and TFR is the second largest forest reserve in Peninsular Malaysia (Darmaraj, 2012). Together, RBSP and TFR make up 2663.7 $km^{2,}$ more than half the size of Taman Negara (4343 km^2). This large chunk of forested area houses megafauna such as Asian elephant

(Hubback, 1932; Stevens, 1968; Khan, 1969; Hassan & Mohd Tajuddin, 1994; Ratnam et al., 1995; Norsham et al., 2000) that often recorded to have large roaming area in search for food (Sukumar, 2003). Certain areas within the BTFC proposed as National Park (Stevens, 1968) as it was believed to have outstanding wildlife richness including large mammals (Davison et al., 1995).

Theodore R. Hubback suggested having an expedition to this part of forest complex upon completing his wildlife commission in Malaya (Hubback, 1932). The Department of Wildlife and National Parks (DWNP) then took this suggestion in the year 1960s, which resulted in publications on the biodiversity of the Upper Perak, highlighting large mammals such as elephant, gaur, tapir, and tiger in BTFC (Khan, 1969; Khan, 1992).

DWNP conducted biodiversity assessment in the year 1994 and 2001, mentioned Asian elephant as the most highly encountered large mammals in RBSP and TFR compared to other mammalian species (Hassan & Abdullah, 1994; DWNP, 2001). Subsequent DWNP expedition also highlighted RBSP and TFR as high biodiversity area (DWNP, 2010). It was also noted that, except Stump-tailed Macaque (*Macaca arctoides)*, all large mammals in Peninsular Malaysia can be found in BTFC (DWNP, 2001).

Scientific expeditions by the Malaysian Nature Society (MNS) in certain areas of BTFC highlighted the ecological significant of BTFC via various publications (Davidson et al., 1995; Latiff & Yap, 2000), and Asian elephant was said to be common in the area (Latiff & Yap, 2000). Additionally, BTFC also listed as one of the Important Bird Area (IBA) in Malaysia, believed to have the largest seasonal congregation of hornbills anywhere in the world (MNS, 2005; Yeap et al., 2005).

Summary of notable records from BTFC are 15 endemic palm species, a variety of are orchids, over 100 species of mammals with 13 out 14 are listed as globally threatened and near threatened, possibly higher concentration of large mammals than that of Taman Negara and two rare species of butterflies (MNS, 2005). In 2012, tiger research in BTFC showed that RBSP had the highest tiger density compared to any other previous studies in Peninsular Malaysia (Darmaraj, 2012). Hence, the importance of BTFC as a Malaysian biodiversity hub is undeniable.

Based on these literatures, it can be concluded that BTFC serves as an important habitat for a wide range of fauna, especially the Asian elephants in Peninsular Malaysia. This forest complex is also identified as one of the priority area for national conservation action plans for Malayan tiger and Asian elephant (DWNP, 2008; DWNP, 2013). Inclusion of BTFC in the National Elephant Conservation Action

Plan (NECAP) serves as recognition of this landscape as one of the stronghold habitat for the species in Peninsular Malaysia.

BTFC also is home to the indigenous people of the Jahai and Temiar tribes. The Jahais are more commonly found in RBSP whereas Temiars in TFR (Lim & Jimi, 1995). However, the ethnicity of the indigenous people in TFR and RBSP not sharply established as some areas consist of mixed ethnicity. Most indigenous people in BTFC are self-employed and their livelihood includes agriculture, gathering non-timber forest products, fishing and occasional bush meat hunting (Lim & Jimi, 1995).

Park authority, logging companies and tour operators employs only a few percentage of these indigenous people (WWF-Malaysia, 2011a; WWF-Malaysia, 2011b), thus, it indicates that the indigenous people living within BTFC are still heavily relying on forest resources for their livelihood. Indigenous people of Belum-Temengor are part and important feature of this forest complex and these forest communities must be preserved (MNS, 2005).

3.2 Study design

The data used for this thesis was obtained from a tiger-centric study conducted in TFR and RBSP from 2009-2011, using a combination of camera trapping and sign surveys (Darmaraj, 2012; Rayan et al., 2013). Although the focus of the study was on tigers, critical fine scale ecological information collected during the study is still applicable and would be beneficial for the conservation of Asian elephants within RBSP and TFR and the larger area, which is BTFC. This study would optimize resources spent to achieve greater conservation impact.

This study employed an occupancy framework in which data from sign survey and camera trapping were used to get habitat use of the Asian elephants from the study area. Camera trap data from this study used to obtain the relative abundance index (RAI) and activity patterns of Asian elephant. The camera-traps were set at a height of approximately 45cm above the ground, which were also able to record pictures of Asian elephants. The sign survey data collection method included recording information on all large mammals, which also took into account elephant signs such as tracks, dung, as well as direct sightings.

Thus, the information on Asian elephants detected via this tiger-centric study deemed suitable and applicable to derive ecological parameters mentioned in the objectives. The study adopted sampling based method due to the large size of the study area. The study areas categorized according to five floristic zones; Lowland dipterocarp (0-300 m), Hill dipterocarp (300-750 m), Upper hill dipterocarp (750-1,200 m), Oak laurel forest (1,200-1,500 m) and Montane ericaceous (>1,500 m). In this study, montane ericaceous and oak-laurel zones grouped together as montane forest, making it to four floristic zones as in Whitmore (1984).

Seventy cells (each cell measured 2 km x 2 km) allocated to be surveyed in both study sites (TFR and RBSP) according to the floristic proportion of each site to its zone. The percentage of floristic zones in TFR are lowland dipterocarp (4.2%), hill dipterocarp (34.4%), upper dipterocarp (41.7%), montane (19.7%) and for RBSP are: lowland dipterocarp (5.6%), hill dipterocarp (71.5%), upper dipterocarp (20.9%), montane (2.0%). Thus, the 70 cells allocated for TFR were lowland (3 cells), hill dipterocarp (25), upper dipterocarp (28) and montane (14), whereas for RBSP: lowland (3), hill dipterocarp (53) and upper dipterocarp (14).

Figure 3.2 shows configuration of the sampling blocks and the locations of camera traps in relation to four categories of floristic zones. All 70 cells grouped in a single block for each study site, designated as pink blocks.

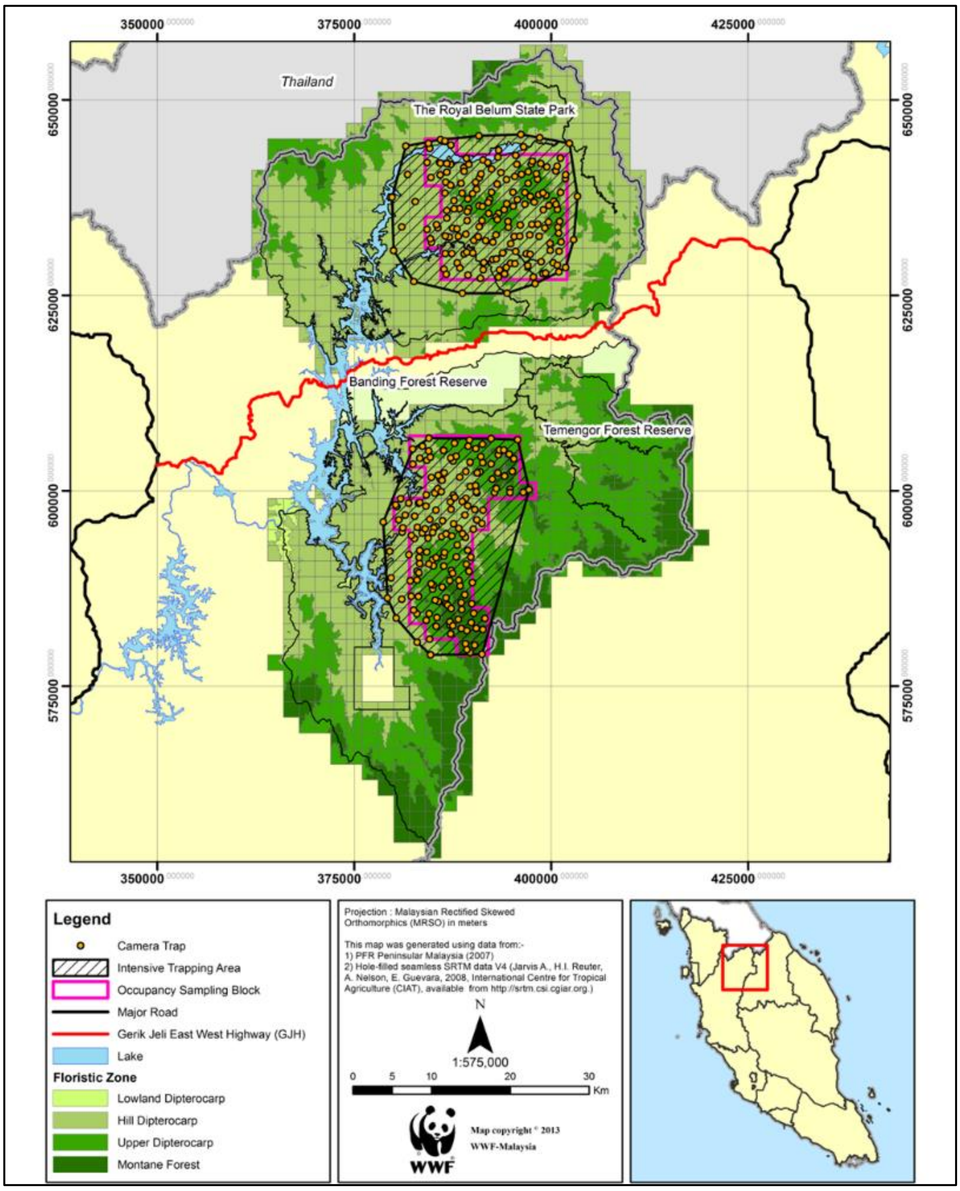

Figure 3.2: Location of study blocks and camera traps in both TFR and RBSP.

Note: Reprinted from *Conservation status of tigers and their prey in the Belum-Temengor Forest Complex* (p. 5), by Rayan, D. M., Mohamad, S., Wong, C., Siwan, E. S., Lau, C. F., Hamirul, M., & Mohamed, A., 2013, Petaling Jaya, Selangor, Malaysia. Copyright by WWF-Malaysia (2013). Reprinted with permission.

The survey cells for montane forest in RBSP are close to Malaysian-Thailand border, which are under patrol by army personnel. Due to safety reason, montane cells were not included for surveys in RBSP study block. Each cell measured 2 x 2 km, further divided into four sub-cells of 1 x 1 km. The selected 70 cells were surveyed using two methods: sign surveys and camera trapping. The size of the survey cells were chosen based the similarity with other tiger prey occupancy surveys (Karanth et al., 2008; Maddox et al., 2007). For occupancy studies, sampling units should be the similarly sized to the home range of the species being studied (Mackenzie et al., 2006a).

Studies done in many landscapes show Asian elephants to have large home range size (Olivier, 1978; Sukumar, 2003; Weerakon et al., 2004 and Alfred et al., 2012). Based on these facts, it is clear that an occupancy estimate for Asian elephant would require a very large study block. The home range of Asian elephants are larger than the sampling units used for this tiger-centric study. Thus, the Asian elephant presence/absence data gathered through this study best suited for habitat use rather than occupancy due to the cell size as per Mackenzie et al. (2006a). A full list of materials used for this study listed in Appendix A.

3.2.1 Sign survey

The core aim of this method is to find indirect signs of large mammal presence (including elephants) based on tracks, dung, and direct sightings. Sign surveys conducted three times (temporal replicate) over a period of eight to nine months, and only signs less than one month old were recorded. Each cell surveyed by three different surveyors. Surveyors were required to trek for at least 1 km in each sub-cell, along trails that were thought to have a higher probability to detect signs of terrestrial wildlife. Upon detection of elephant sign or direct sighting, the location of detection marked using Garmin 60CSx GPS and a photo of the signs (tracks or dung) taken using hand-held camera as a proof of detections. Whenever possible, photo of direct sightings of elephant also taken as seen in Plate 3.1.

Plate 3.1: A bull sighted along Sg. Perak in RBSP

Each detection were recorded in a survey form (Appendix B). Distance trekked and duration used for each sub-cell were also recorded in the form which account for sampling efforts spent by each surveyors. To reduce biasness, an attempt made to cover all locality types present within each cell, should certain species prefer only one or two particular locality types.

The main locality types covered were active logging roads, old logging roads, ridges, forest trails, and streambeds. The first two locality types are not present in RBSP, as it is a primary forest. To ensure independence, a randomly generated patch was placed in each cell and the surveyors were required to pass by this random patch during the survey.

The patch was randomly chosen from 64 equally sized 0.0625 km^2 patches within each cell. Apart from that, surveyors were required to take a random bearing at the start of each sub-cell. A distance of 100 m following this bearing had to be followed before continuing with the planned survey route. Sign survey sampling period for TFR started from 18^{th} August 2009 to 7^{th} May 2010. For RBSP, sign survey commenced from 23^{rd} September 2010 to 20^{th} April 2011.

3.2.2 Camera-trapping

A custom-built camera trap made of Pelican case, Sony P41 camera and Snap Shot Sniper control board were used for this survey. Snap Shot Sniper control board consist heat and motion sensor, which activates the Sony P41 camera to take picture upon triggered by wildlife moving in front of the device. The SONY Memory Stick Pro with a capacity of 500 megabytes to one gigabytes were used for the camera. The camera powered by two units of AA batteries whereas a 9V battery used to power the Snap Shot Sniper control board. Attached picture of the camera trap used for this study (Appendix C). Upon deployment, the camera traps were left to operate 24 hours.

Two different camera-trapping efforts were conducted simultaneously namely "core" camera traps and "additional" camera traps. For "core" camera trapping effort, within each cell, two camera traps placed whereby first camera will be deployed in any sub-cell for two to three months. After this period, data from first camera trapping effort retrieved and the camera trap moved to another sub-cell within the same cell, hence two locations of camera trapping data produced from one cell. "Core" camera trapping effort requires 70 functional unit to be deployed simultaneously across the study block. A total of 280 camera-trap locations were used in this study for both TFR (140 locations) and RBSP (140 locations). Information from these locations used to obtain habitat use value, Relative Abundance Index (RAI) and activity patterns.

For the "additional" camera trapping effort, 35 camera trap locations placed within and around each study blocks. Information from these additional 35 camera traps added into the activity pattern dataset from core camera trapping effort. All camera-traps retrieved from their locations in the third visit, after about 6 months. Information on the camera-trap details, coordinates, microhabitat surrounding the camera stations and the trail condition recorded in a camera-trap form. Combined camera trapping efforts from both "core" and "additional" is expected to provide a good understanding on Asian elephant activity pattern within the BTFC as it increases the chance of detection. Camera trapping for TFR started from 8th August 2009 to 22nd May 2010, whereas for RBSP from 10th August 2010 to 21st April 2011.

3.3 Data organisation

3.3.1 Sign survey data organisation

The sign survey data from TFR and RBSP were arranged in Microsoft Excel 2010 respectively, each dataset with 280 rows correspond to 280 sub-cells (1 km x1 km). Data entry commenced upon completion of each round of survey. The sign survey data consists of three columns representing three replicates of survey. For each detection, inspection carried out on the photos taken using hand-held camera, GPS coordinates and notes on the survey form. Upon completion, the datasheet was shared with three surveyors to detect presence of any errors followed by correction. This ensures the data entered correctly.

3.3.2 Camera trap data organisation

The camera-trap data were imported to WWF-Malaysia Camera-trap database v.261112, which generates the daily capture matrix. Detections regarded as independent event if the gap between each is 30 minutes (O' Brien et al., 2003). Number of animal visible for each detection is entered in the database.

The daily capture matrix provides the daily detection of elephants throughout the duration of sampling for both TFR and RBSP with "0" denoting absence and "1" denoting presence of elephant in each sub-cell. A "-" denotes non functionality or absence of camera trap in a sub-cell due to unit malfunction, stolen, damaged, not-sampled or were not deployed yet. This provides sampling effort for each sub-cell in term of number days where camera traps are operational.

The detections in daily capture matrix for the first 28 days were combined to form the first occasion of camera trapping data, the next 28 days combined as the second occasion and so on. This results in 10 occasions of 28 days for TFR and eight occasions of 28 days for RBSP. The difference is due to shorter sampling period in RBSP compared to TFR. Datasets from both TFR and RBSP combined, results to 560 rows representing 280 sub-cells from TFR and 280 sub-cells from RBSP. The columns were aligned ordinally according to its occasion, i.e. the first occasion from TFR is aligned with the first occasion from RBSP and so on.

The sign survey data from TFR and RBSP were also combined resulting in 560 rows representing the sub-cells and three columns representing the replicates, which serves as occasion. Both sign survey and camera trapping data were then combined whereby the rows representing the sub-cells retained as both methods have the same sub-cell denomination.

The first three columns consist of occasions from sign survey and 4^{th} to 13^{th} column are the occasions from camera trapping survey. Each occasion (i.e. the column) in the dataset represent one month data as the sign survey only recorded for animal signs of about a month old or less whereas the camera-trapping data nested 28 days in one occasion which equates to one month as well.

3.3.3 Habitat covariates

Variance in habitat features may act as factors affecting the habitat use of Asian elephant within BTFC investigated as habitat covariates. The spatial data used in this study extracted from GIS data produced by WWF-Malaysia for tiger-centric study in TFR and RBSP (Darmaraj, 2012). Two major classes of habitat covariates identified namely the nearest distance of a set of habitat features from the sub-cell center followed by habitat features of the sub-cell itself.

The set of identified nearest distance habitat covariates are; distance from the settlements, distance from the lake, distance from the river, distance from the stream, distance from the identified saltlicks and distance from the logging road. All the distance data measured in meter. These sets of distance data are log-transformed using LN in excel-sheet, as the impact of it may not differ much for variations at the further length of space between two points. For example, magnitude of influence factor for distant of river located 10 km away from a sub-cell may not vary much compared to the ones located 10.5 km away.

The habitat covariates of the sub-cell are; normalized difference vegetation index (NDVI), slope in terms of percentage (Slope), mean elevation, the logging intensity and the binary nature of the study site (TFR or RBSP). The formula for NDVI (1.0) which quantifies vegetation by measuring the difference between near-infrared and red light. The near-infrared are strongly reflected by vegetation whereas red light absorbed by vegetation (What is NDVI, 2018)

$$NDVI = \frac{(\text{Near Infrared} - \text{Red})}{(\text{Near Infrared} + \text{Red})} \qquad (1.0)$$

All continuous habitat covariates were standardised using Z-score function in excel-sheet to transform the data at comparable scales. Correlation test were ran in R software environment v3.4.2 (R Development Core Team, 2018) using simple correlation test to eliminate correlated variables. Correlation test result presented in Appendix D. Habitat covariates with correlation of 60% or more discarded (Gaveau et al., 2009). Distance to the lake found to be positively correlated to distance to settlements. Distance to river correlated to logging road negatively whereas positively towards site. Distance to logging road correlated to distance to river and logging intensity. Slope percentage was negatively correlated to site whereas logging intensity positively correlated to logging road and site.

Site covariate found to be correlated to river, logging road, slope percentage and logging intensity. Distance to the steam, elevation, NDVI and saltlick were found to not correlated to any covariates. Seven habitat covariates selected for analysis based on the biological importance for Asian elephants. These are distance from the settlements (Settlements), distance from the river (River), distance from the saltlicks (Saltlick), NDVI, slope in terms of percentage (Slope), mean elevation (Elevation) and site (Site). Habitat covariates data arranged by listing the seven selected TFR and RBSP habitat covariates according to its sub-cells. Sub-cells from TFR and RBSP differentiated by denoting "1" for TFR and "0" RBSP in the last column of the datasheet.

3.3.4 Sampling effort covariates

To account sampling effort's impact on the result, a set of sampling covariates collected and organized. The efforts divided into two categories as per the sampling method; sign survey and camera trapping. Based on observation from the field, surveyors likely to spend more time within sub-cells overgrown with secondary vegetation, which hampers movement. Hence, based on this observation, time spent within each sub-cell were not used for analysis.

Therefore sign survey, distance trekked (Dist) within each sub-cell measured using GPS unit used to measure sampling effort. Camera trapping efforts measured in terms of number of nights the camera traps are functioning denoted as trap nights (TN). Sub-cells from TFR and RBSP differentiated by denoting “1” for TFR and “0” RBSP in the last column of the datasheet.

3.3.5 Datasheet for analysis

Three different datasheets prepared after the data organization namely Asian elephant detection data, habitat covariates data and sampling effort data. Asian elephant detection data comprised of 560 rows representing total sub-cells from TFR and RBSP and 13 columns representing 10 occasions from camera trap data and 3 occasions from sign survey data. The data from sign surveys and camera trapping were combined according to study sites (TFR and RBSP) to reduce false absence.

The combined detection data from two methods; sign survey and camera trapping from both TFR and RBSP presented in Appendix E. Habitat covariates datasheet encompassed of seven columns of habitat covariates with values assigned for respective 560 sub-cells of TFR and RBSP (Appendix F). The sampling effort datasheet contained distance trekked (Dist) for respective 560 sub-cells of TFR and

RBSP as well as trap nights (TN) for each sub-cell bearing camera trap station (Appendix G). Due the long list of rows, only the couple of rows presented for each datasheet in the appendices.

Primary analysis carried out via Programme PRESENCE v11.2 (Hines, 2006). All the datasheets of Asian elephant detection, habitat covariates and sampling efforts were saved as comma separated values (csv) format file. This file were then imported into Programme PRESENCE v11.2. The Asian elephant detection data imported to "Presence/Absence" tab, followed by habitat covariates data to "Site covariates" tab.

Two "Sampling covariates" tabs added to accommodate "Dist" which is the distance trekked for each sub-cell during sign survey and finally "TN" tab to account number of nights the camera traps were functioning in respective sub-cell. Value "-"assigned to sub-cells that do not have a camera trap. Covariates that best explain the observed data investigated by using two-step approach in Programme PRESENCE v11.2 using simple single-season framework. For the first step, a global model for habitat use were utilized which includes all habitat covariates while allowing factors affecting detection probability varies to investigate which covariates of sampling effort have the greatest influence (MacKenzie, 2006b).

This method carried out by modelling detection probability with constant parameters followed by any single parameters of “Dist”, “TN” or “Site” and by any combinations of aforementioned covariates additively which gives 9 different combination of models for first step. Constant parameters for habitat use were also included for the first step.

In the second step, a new Programme Presence window, the best model that explains the detection probability were retained without any other combination of sampling efforts, while modelling for habitat use carried out by running any single habitat covariates i.e. distance from the settlements (Settlements), distance from the river (River), distance from the saltlicks (Saltlick), NDVI, slope in terms of percentage (Slope), mean elevation (Elevation) or site (Site), followed by combinations of it via additive manner. This gives a total of 128 different combinations of models.

3.4 Predicted habitat use map

Predicted habitat use map computed with GIS programme. Grids measuring 1km x 1km laid on RBSP, TFR and BFR. For AFR, habitat use of Asian elephants were produced based on findings from Rayan et al. (2012) as well as Rayan and Linkie

(2015) as this is the only intensive study with the exact methodology ever carried out in AFR which provided habitat use of Asian elephant in the area.

For RBSP, TFR, and BFR, Covariates that best explains the habitat use of Asian elephant from this study selected based on best model from the analysis. Corresponding values of covariates identified in the best model extracted from each 1km x 1km grid within the three abovementioned areas via GIS programme and computed into the best model that explained the habitat use of Asian elephant this study. The output represent habitat use values in logitPsi (Ψ) for each grids that is in logit scale. The logit scale then back-transformed to probability of use by using formula (1.1).

$$P\ (probability\ of\ use) = \frac{e^{logit(Psi)}}{1 + e^{logit(Psi)}} \qquad (1.1)$$

The result provides probability of use by Asian elephant for each 1km x 1km within RBSP, TFR and BFR. The values were then categorized into geometrical intervals for four levels and assigned colour to each intervals, which translates into map that indicate intensity of use in the interested area. Similar method deployed to produce habitat use map for AFR using beta coefficients from Rayan et al. (2012). All results then combined and presented in a single map of predicted Asian elephant habitat use in BTFC.

3.5 Develop conservation recommendations

In order to produce holistic recommendations for Asian elephants in BTFC, conservation recommendations explored from three different aspects; 1) future study, 2) habitat management and 3) species protection. The first two aspects (future studies and habitat management) of conservation recommendations explored based on results obtained from this study. Whereas protection of Asian elephants explored based on incidences and threats recorded during the study period such as roadkill, poaching and death due to HEC. Appendix H

Interviews carried out with conservation NGO personnel like WWF-Malaysia Species coordinator on the 24th October 2018, Senior Programme officer for Community Education & Engagement on the 7th December 2018 and Senior Anti-poaching officer on the 7th December 2018 as well as TRAFFIC-SEA Senior officer on the 29th October 2018. Interview were also carried out with principal investigator of Management and Ecology of Malaysian Elephant (MEME) on the 1st November 2018. From Department of Wildlife and National Parks (DWNP), interviews carried out with the Director of My Gajah Working Group steering committee that oversees implementation of NECAP at national level was interviewed on the 16th November 2018 and DWNP Senior officers of Perak state on the 14th December 2018.

CHAPTER 4

RESULT

4.1 General results

Out of the overall 560 sub-cells, 299 of it have Asian elephant detection thus providing naïve occupancy of 53%. Through a combination of sign survey and camera traps, lowest and highest elevation of Asian elephant detected were from 277m a.s.l. to 1945m a.s.l. Sign survey effort, which is the distance trekked by surveyors amounts to 1,410 km for TFR and 1,255 km for RBSP. In terms for camera-trapping survey effort, a sum of 10,779 trap nights with 236 detections of Asian elephant recorded in TFR and 10,484 trap nights with 273 detections of Asian elephant in RBSP. Summary of the sampling period and the efforts presented in Table 4.1.

Table 4.1: Summary of sampling period and efforts for Asian elephant habitat use using sign survey and camera trapping

Site	Sign survey period	Camera-trapping period	Distance trekked	Trap nights	Camera trap detections
TFR	18/8/2009 - 7/5/2010	18/8/2009 - 22/5/2010	1,410 km	10,779	236
RBSP	23/9/2010 - 20/4/2011	10/8/2009 - 21/4/2010	1,255 km	10,484	273

4.2 Relative Abundance Index

The Relative Abundance Index (RAI) counted based on average photo-trapping rate across all camera-trapping location along with the associated standard errors. The Asian elephant detection divided with the sampling effort for each location before multiplied with 100 respectively. Subsequently the values from each locations averaged to get RAI value with standard errors. Table 4.2 shows overall RAI value and for each study site.

Table 4.2: Relative abundance Index (RAI) values generated from camera trap.

Site	Detections	RAI	SE
TFR	236	2.20	0.75
RBSP	273	2.07	0.62
Overall	509	2.13	0.48

4.3 Activity patterns and class

4.3.1 Activity patterns

Total number of Asian elephants detected for every hour according to its site presented in Appendix I. The activity patterns for TFR and RBSP were compared for any differences using Wilcoxon rank sum test in R software environment v3.4.2 (R Development Core Team, 2010). There was significant difference in the activity patterns of Asian elephants between TFR and RBSP (W=192.00, p=0.047).

Separate analysis for daytime (07:00 – 19:00) and nighttime (19:00 - 07:00) carried out to investigate deeper understanding that could attribute to this difference. Our result shows the Asian elephant activity patterns were found to be different during the daytime (W=44.50, p=0.040). However, during the nighttime, the result of test were not significant between TFR and RBSP (W=50, p=0.509).

Further analysis to test difference in activity patterns between morning sessions (07:00-12:00) of TFR and RBSP Asian elephants were carried out. The test repeated for evening sessions (12:00-19:00) between two sites. There were no significant difference between activity patterns of Asian elephants from the two sites for both morning (W=6.5, p=0.076) and evening (W=17, p=0.362) sessions. R script and result for the test presented in Appendix J.

4.3.2 Activity class

Out of 509 detections across TFR and RBSP, 259 (51%) detections were diurnal whereas 250 (49%) were nocturnal. With almost equal percentage for both day and night detections, the overall activity class of Asian elephants for these categorized as cathemeral. Figure 4.1 summarize activity patterns and class of the Asian elephant from both sites.

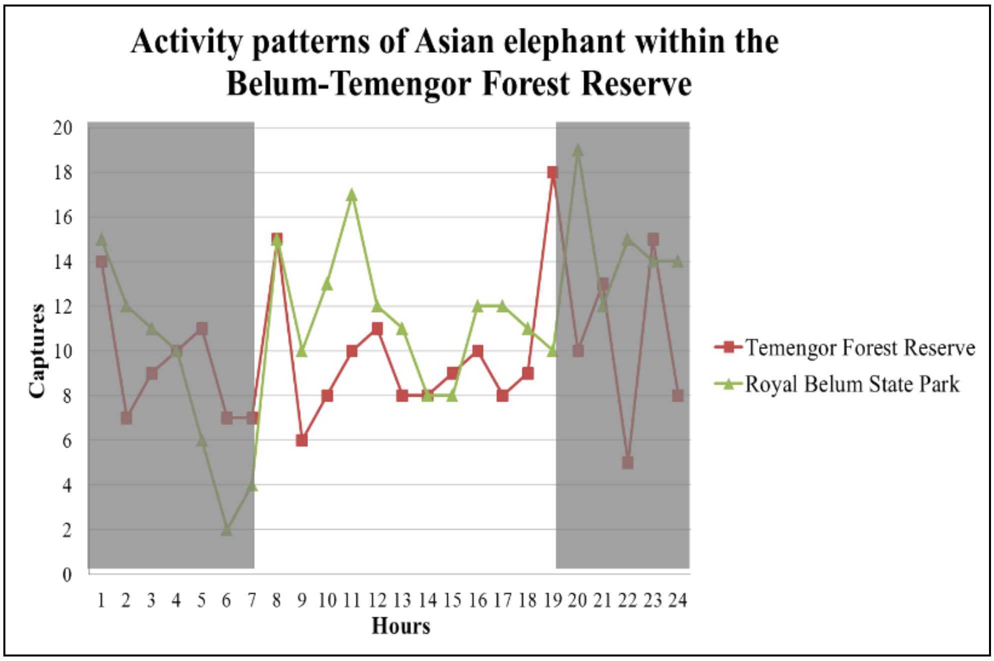

Figure 4.1: Activity class of Asian elephants in TFR and RBSP

4.4 Habitat use

4.4.1 First step: Detection probability

Although data obtained from two methods i.e. sign survey and camera trapping, there are no requirements to assume lack of independence between these two methods (Long et al., 2011) hence single-season, multi-method framework is not applied (Darmaraj, 2012). For the first step of modelling detection probability, a total of 9 models were ran and presented in Table 4.3

Table 4.3 BTFC Asian elephant detection probability

Model	AIC	Δ AIC	AIC weight	Model Likelihood	no.Par	-2*LogLike
psi(FULL), p(Site+TN+Dist)	2360.82	0	0.9896	1	14	2332.82
psi(FULL), p(Site+TN)	2370.57	9.75	0.0076	0.0076	13	2344.57
psi(FULL), p(Site+Dist)	2373.51	12.69	0.0017	0.0018	13	2347.51
psi(FULL), p(TN+Dist)	2374.49	13.67	0.0011	0.0011	12	2350.49
psi(FULL), p(Site)	2383.29	22.47	0	0	12	2359.29
psi(FULL), p(TN)	2384.9	24.08	0	0	11	2362.9
psi(FULL), p(Dist)	2387.28	26.46	0	0	11	2365.28
psi(FULL),p(.)	2397.72	36.9	0	0	10	2377.72
psi(.),p(.)	2444.39	83.57	0	0	3	2438.39

Δ=delta, No. Par.=Number of Parameter

The top model are the most likely to explain the data with Akaike's Criterion (AIC) for Selection, with AIC value of 2360.82 faring a difference of 9.75 in relation to the second model. This first step identified the best model that affects the detection probability for Asian elephants and it is used for the second step in order to identify habitat covariates that affects the habitat use.

4.4.2 Second step: Probability of habitat use

For second step, a total of 128 models were ran to assess the best combination of habitat covariates that explain habitat use of Asian elephants while retaining best detection probability model obtained from the first step. Small-sample size correction to AIC was accounted by changing effective sample size to 560 as per the sub-cell numbers to rank the models (Burnham & Anderson, 2002), indicated by an addition of "c" in AIC and delta AIC column.

Model fit assessed by comparing statistics from the Pearson chi-square from the global model with chi-square from 10,000 simulated parametric bootstrap datasets (MacKenzie & Bailey, 2004). Estimated overdispersion parameter generally should be within ($1 \leq \hat{c} \leq 4$) (Burnham & Anderson, 2002). Model fit found to be poor ($\hat{c}$= 1.89) and it was accounted by changing c-hat value to 1.0, which did not result to any changes in model ranking.

Ranked models according to AICc presented in Table 4.4 for delta AICc less than the value two. Distance to the river and NDVI listed as the top model which explains the habitat use of Asian elephant with an AIC weight of 0.1995.

Table 4.4 Models <2 Δ AICc value

Model	AICc	Δ AICc	AIC weight	Model Likelihood	No. Par.	-2*LogLike
Ψ (River+NDVI), p(Site+Dist+TN)	2352.17	0	0.1995	1.000	09	2333.84
Ψ (River+NDVI+Site), p(Site+Dist+TN)	2353.95	1.78	0.0819	0.4107	10	2333.55
Ψ(River+Settlements+NDVI), p(Site+Dist+TN)	2354.12	1.95	0.0753	0.3772	10	2333.72

Δ=delta, No. Par.=Number of Parameter

4.5 Predicted habitat use map

Grids (1km x 1km) amounting to 3135 overlaid across TFR, RBSP, AFR, and BFR. Based on the top model, values for covariates; "River" and "NDVI" values extracted using GIS programme from TFR, RBSP and BFR whereas for AFR, distance to the road were used as per the top model of elephant habitat use reported by Rayan et al. (2012). For distance to the road data generated for AFR, values were converted to natural log before as per the reason mentioned in methodology.

Appendix K shows datasheet used to predict habitat use for TFR, RBSP and BFR. Whereas Appendix L shows datasheet to predict Asian elephant habitat use in AFR. Using Microsoft Excel 2016, these values transformed into standardised z-scores, which were then plugged into the equation from the best model together with its beta coefficients (1.2) to produce values of habitat use for each grids. These values, which are on logit scale (negative infinity to positive infinity), were than back-transformed using equation (1.1) to provide habitat use values in the form of probability(zero to one).

$$\text{logitPsi}\ (\Psi) = B_0 + B_{River}*\text{River} + B_{NDVI}*\ \text{NDVI} \qquad (1.2)$$

$$\textit{Beta coefficients: } B_{0=}\ 1.89_;\ B_{River=}\ -\ 0.99_;\ B_{NDVI=}\ -2.06$$

Probability of the habitat use for each grids plugged into GIS software to produce maps of Asian elephant habitat use within BTFC with geometrical interval of the probability of use value as this type of interval provides best visualization of the habitat use with relatively good distinguishing colour variation for this study. Features such as rivers, roads, logging roads and known indigenous village within BTFC also plotted on the same map (Figure 4.2).

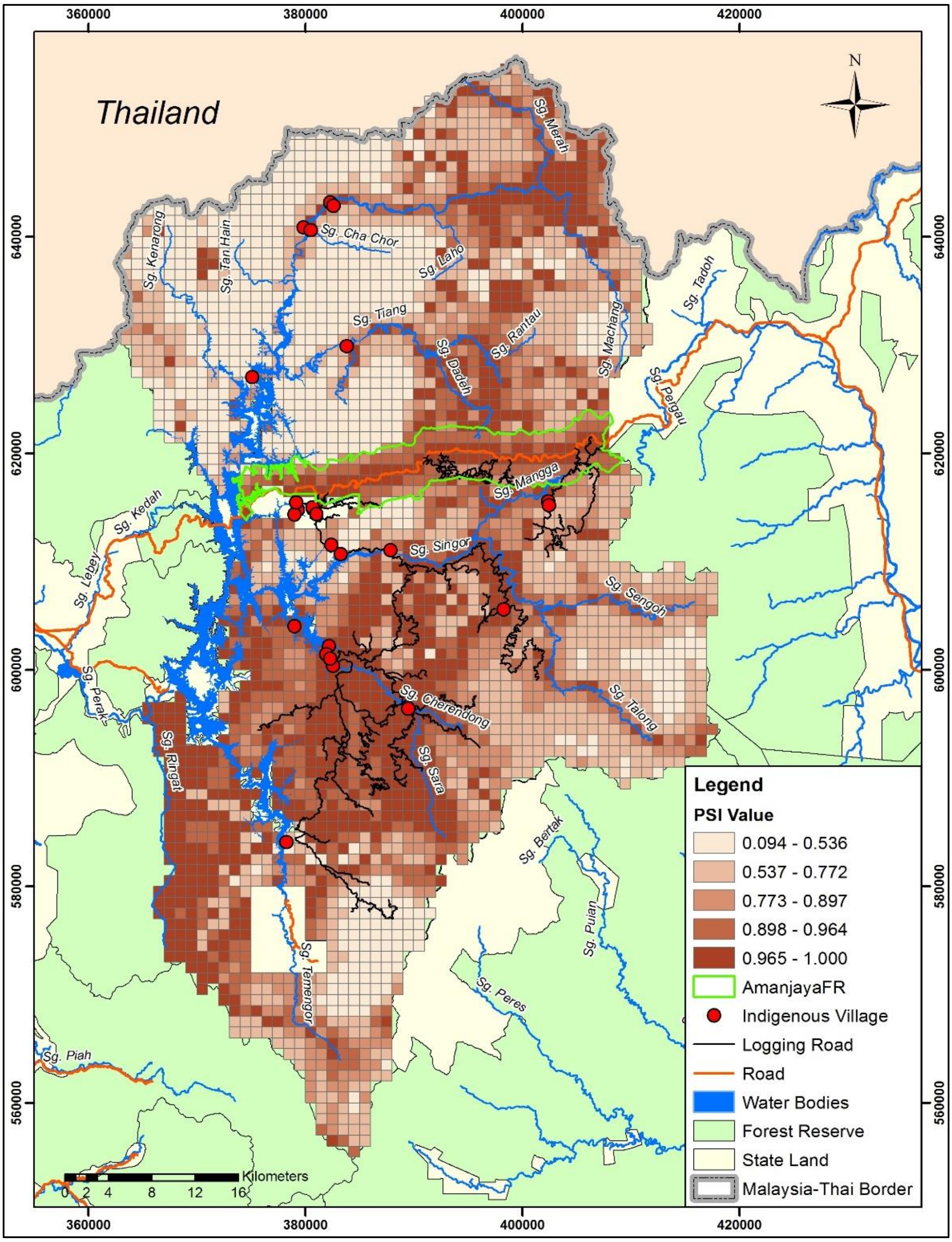

Figure 4.2: Predicted habitat use intensity of Asian elephant within BTFC.

4.6 Explore conservation recommendations

Result from this study shared with experts to obtain feedback recommendation for Asian elephant conservation. Recommendations to reduce direct threats to Asian elephants detected during the study period we also explored. All senior officers and experts agreed on the importance of riparian habitat for Asian elephants in BTFC. Protection of riparian habitat deemed important as it can hinder other land use practices in these areas, hence reducing chances of HEC.

As for the threats from poaching, strategic roadblocks at roads that leads to BTFC agreed as good method to hinder poachers accessing the landscape. Existing anti-poaching activities such as patrolling along the road that traverse BTFC as well as patrolling in the forest emphasized as important to curb poaching in general which will benefit Asian elephants.

Given the scarce resource to guard the entrances with government staffs all the time, empowering indigenous community living next to forest may serve as the good strategy for holistic anti-poaching measure. As such, empowerment of indigenous community to be present at logging road entrances into forest reserves also recommended as a way to gather information of vehicles that enters the forest and their presence may serve as hindrance to poachers.

In order to reduce possibility of Asian elephant roadkill, enforcement of speed limits were suggested. Apart from that, having more signboards and beacon lights at areas where the species are commonly sighted along the road were suggested as means to increase road user’s attention, hence possibly reduce chances of roadkill.

CHAPTER 5

DISCUSSION

This study has a considerably large sampling effort with a trekking distance of 2,665 km for sign survey method and 21,263 trap nights for camera trapping method. Total minimum convex polygon from both TFR and RBSP amounts to 815 km^2, larger than the size of Singapore (722.5 km^2) (Government of Singapore, 2018). To my knowledge, this is the first large scale (560 km^2) intensive occupancy framework based assessment ever carried out on wild elephants within tropical rainforest of Malaysia.

It provides valuable insights on Asian elephant relative abundance, activity patterns and habitat use within BTFC. Similar study on Asian elephant conducted in AFR at a smaller scale of 156 km^2 (Rayan et al., 2012) under the same tiger-centric project of WWF-Malaysia. The only other available large-scale occupancy survey on Asian elephant in Malaysia conducted in human-occupied landscape (Tan, 2016) which are not within the forest reserves or parks.

5.1 Relative abundance in BTFC

The RAI range for TFR and RBSP overlaps almost entirely, suggesting no major difference in relative abundance of Asian elephants between the two sites. The overall RAI value for Asian elephant in BTFC is 2.13±0.48. This figure is relatively similar to some other RAI values of Asian elephant camera trapping study in Asia. Camera trapping study in Phnom Prich Wildlife Sanctuary, Cambodia with 2717 trap nights recorded 84 detections of elephants giving RAI of 3.10 (Gray & Phan, 2011).

With smaller number of trap nights, difference between the values RAI of Asian elephant from Phnom Prich Wildlife Sanctuary shows the high proportion of detections of the species in the area compared to BTFC. However, Gray and Phan (2011) used 20 minutes interval to define independent detection following (Yasuda, 2004; Phan & Gray, 2010), as oppose to my study which used 30 minutes (O' Brien et al., 2003).

This could lead to higher number of independent events as the pooling of the data differs by 10 minutes, hence increasing the RAI value. Palei et al. (2016) provides RAI value of 2.09 for Asian elephants, highest among the threatened species found within the Simipal Tiger Reserve in India. In general, the RAI value for Asian elephants in Phnom Prich Wildlife Sanctuary, Cambodia and Simipal Tiger Reserve, India are similar to the value generated from my study.

However, there are some extreme values of RAI for Asian elephants recorded in across Asian landscape. Kuldiha Wildlife Sanctuary, eastern India (Debata & Swain, 2018) recorded RAI value of 9.72 for Asian elephants. Asian elephant abundance was the highest recorded among all the other species in the study and the study attributed such observation to large home range, frequency of movement as well as the large body of the species that can easily captured by camera traps. Chaiyarat et al. (2015) recorded high RAI value of 10.30 for Asian elephants in Salakpra Wildlife Sanctuary in Thailand. The study associated the high RAI value to increasing elephant population density, which surpasses population limit predicted by their model.

Low RAI values have also reported from Thailand at Khao Yai National Park (Jenks et al., 2011) with only 0.42 of relative abundance for Asian elephants. Naing et al. (2015) camera trapping study at Hukaung Valley of Northern Myanmar recorded extremely low RAI value of 0.13. Both Jenks et al. (2011) and Naing et al. (2015) links human activity as the major factor contributing to low RAI values of Asian elephant in the area and emphasized importance of managing human activity in these areas.

Relative abundance of Asian elephant in BTFC appears to be moderate among the other available studies, as the index does not fall within the two extreme ends. In terms of camera trapping efforts, BTFC data have the highest trap nights compared to all the above-mentioned studies suggesting a good sampling effort and reliable estimates of RAI. Unlike Gray & Phan (2011), studies from India, Myanmar and Thailand (Jenks et al., 2011; Chaiyarat et al., 2015; Palei et al., 2016; Debata & Swain, 2018) used 30 minutes interval to define the independent detections, hence the RAI value are more relevant to be compared to BTFC Asian elephant.

However, comparison of wildlife abundance using relative abundance index has its limitations (Sollmann et al., 2013). Factors such as survey efforts, study designs (Sollmann et al., 2013) and difference in home ranges of a species across the region (Mcloughlin et al., 2000) may affect the significance of comparing Asian elephant RAI values. Nevertheless, comparison of RAI values over time under the same survey effort and design might be more meaningful if research carried out within the same study area. Table 5.1 summarizes the details from these studies.

Table 5.1: Summary of camera trapping studies used for comparison in terms of RAI.

Studies	This study	Gray & Phan (2011)	Debata & Swain (2018)	Palei et al. 2016.	Naing et al. (2015).	Chaiyarat et al. (2015).	Jenks et al. (2011).
Study area	BTFC	PPWS	KWS	STR	HK	SWS	KYNP
Camera trap locations	280	40	65	187	260	32	34
Trap nights/days	21,263	2717	916	6413	7,452	1,391	1,017
Detections	509	84	89 (photos)	134 (photos)	N/A	143	N/A
RAI	2.13±0.48	3.10	9.72	2.09	0.13	10.30	0.42

PPWS: Phnom Prich Wildlife Sanctuary, Cambodia; KWS-Kuldiha Wildlife Sanctuary, India; STR-Simipal Tiger Reserve, India; HK-Hukuang Valley, Myanmar; SWS-Salakpra Wildlife Sanctuary, Thailand; KYNP-Khao Yai National Park, Thailand.

5.2 Activity patterns and class

The activity patterns derived from reliable number of sample size for each site (detection $\geq$ 100) (Lashely et al., 2017). The activity patterns of Asian elephants in TFR and RBSP show significant difference although the general trend-lines from both sites appears similar. Separate analysis between the activity patterns for daytime and nighttime provides better understanding for the difference between TFR and RBSP. Difference on activity patterns only detected during the daytime. Closer inspection on the activity pattern's trend-line during the daytime appears similar between the two sites during the start of the day.

However, between the periods of 16:00 hrs to 18:00 hrs there was marked difference in terms of the trend-line of activity patterns for TFR and RBSP. Hence, further test between the two sites for morning session (07:00 hrs-12:00 hrs) and evening session (12:00 hrs-19:00 hrs) carried out to understand whether the difference in the daytime could be caused by evening session (12:00 hrs-19:00 hrs) which encompass detections from 16:00 hrs -18:00 hrs. However, there were no significant difference detected for Asian elephant activity patterns between TFR and RBSP for evening session (12:00 hrs-19:00 hrs) (Appendix J) and this could be due to low number of data points after the detections separated to different sessions i.e. morning and evening.

Although statistical test do not show significant difference between activity patterns from both sites from 12:00 hrs to 19:00 hrs, the slight visible difference noted in the trend-lines from 16:00 hrs to 18:00 hrs between TFR and RBSP elephants could be related to human activity. Logging operations and access created by the process believed to have increased human activity in TFR in comparison to RBSP.

According to Darmaraj (2012), there were no significant difference in human activities between RBSP and TFR except vehicular presence. Hence, the disturbance effect from logging related vehicular noise could likely affect elephant activity in TFR. Logging operation could start at staggered time but in general, the loggers would return to logging camp by evening, before dark. Thus, the slight visible difference could be attributed to this.

Camera trapping study at a saltlick in TFR by Hii (2016) shows clear avoidance to human during daytime. A study by Jathanna et al. (2015) shows detection probability of Asian elephant are affected by human disturbance whereas Jenks et al. (2011) and Naing et al. (2015) attributed human activity to the low number of Asian elephant RAI generated by their camera traps. Asian elephants known to be sensitive to sounds due to their large ears (Shoshani & Eisenberg, 1982; EleAid, 2018). Hence, there is a logical assumption to believe vehicular noise causes the difference in activity between the two sites, whereby a slight drop noticed in TFR elephant activity patterns from 16:00 hrs to 18:00 hrs. Future study on the effects of noise made by vehicles heading back to logging camp may help in clarifying the assumption.

Asian elephants in the study area fall within activity class of cathemeral. Unlike diurnal (active during the daytime) or nocturnal (active during the nighttime), wildlife with cathemeral activity class do not have specific active period. Cathemerality of Asian elephants in BTFC are consistent with other camera trapping studies, which also records the species to show irregular active period at any point of time (van Schaik & Griffiths, 1996; Grassman et al., 2006; Gray & Phan, 2011; Ramesh et al., 2015). This characteristic also observed in African elephant (Shoshani et al., 2004). It has been reported that wildlife activity to be associated to their body mass (Lindstedt et al., 1986; Owen-Smith, 1988; Ramesh et al., 2015) as mega-herbivores like Asian elephants tend to spend longer period of time to find sufficient food without being limited to any specific time (van Schaik & Griffiths, 1996).

However, Hii (2016) found that elephants visiting particular saltlick (Sira Gajah) in TFR were more active during the night and associated this observation to possible adaption to human activity. The study reported elephants leaving the saltlick (Sira Gajah) silently before the arrival of tourists or researchers. Two of my personal observations made at another saltlick in TFR (Sira Tubung) also shows wild elephants leaving after noticing my arrival. Hii (2016) noted that this observation at the saltlick were not evident as in the studies on African elephant which clearly shows such adaptations in activity class with regards to human presence (Lewis, 1986; Ruggiero, 1990, Shoshani et al., 2004; Graham et al., 2009; Gunn et al., 2009; Wrege et al., 2010).

It is important to note that these are localized observations at saltlicks, which are not representative of overall activity class of Asian elephants across the tropical rainforest of BTFC. Other available camera trapping studies on Asian elephants (Azlan, 2006; Jenks et al., 2011; Chaiyarat, 2015; Palei et al., 2016; Debata & Swain, 2018) did not produce results on activity patterns or class due to different focus of the research.

5.3 Asian elephant habitat use

This study used occupancy framework, which incorporates detection probability, derived from presence and absence data. Sub-cells detected with Asian elephants confirms presence of the species within the sampling units. Absence or precisely non-detection of a species at a sub-cell does not imply that the species is absent unless the probability of detection is one (MacKenzie et al., 2002). Given the probability of detection is impossible to be 100%, the surveyor or camera traps could miss Asian elephant due to various factors.

In this study, detection probability of the Asian elephant found to be influenced by factors such as study area (TFR or RBSP), distance trekked (Dist) in each sub-cell for sign survey and number of trap nights (TN) for camera trapping. Detection probability of Asian elephants varied between study areas and positively related to survey efforts as per the beta coefficients; p (Dist) = 0.21 ± 0.06, and p (TN) = 0.05 ± 0.01. This suggest increase in survey efforts escalates the chance of detecting the species in a sampling unit. Incorporation of detection probability improves modelling to understand habitat use of Asian elephant.

Combination of TFR and RBSP data into a single dataset including detections from both sign surveys and camera traps increase data points and optimizes species detections for habitat use analysis (Darmaraj, 2012). The best habitat use model that explains data recorded from this study is Ψ (River+NDVI) whereby "River" is the distance to the river from the mid-point of the sub-cell and "NDVI" describes on how dense is vegetation cover of a sub-cell on average. Both habitat covariates appeared in the top model with beta coefficients indicate negative correlation (Ψ (River) = - 0.99 ± 0.28 and Ψ (NDVI) = - 2.06 ± 0.35) to habitat use of Asian elephants.

Model with either of habitat covariates performed poorly as the delta AIC (ΔAIC) values are very large; Ψ (River), ΔAIC=54.98 and Ψ (NDVI), ΔAIC=16.33. This indicates singular habitat covariates of neither "River" nor "NDVI" affects habitat use of Asian elephants within study area. In contrast, all the three top models have combinations of "River" and "NDVI" habitat covariates. Hence, combination of distance to river and density of vegetation cover appears to be the best model to explain Asian elephant habitat use in BTFC.

Based on observation in the field during data collection in BTFC from 2009-2011, canopy covers are usually thick with not much light penetrating into the forest floor. This observation area prominent at the hills and inland which area away from rivers. However, more light enters forest floor gradually as the distance to the river decreases until it becomes bright under the day light where sky is visible at the river.

Based on understanding that NDVI calculated by measuring spectral reflectance and brighter light intensity found near rivers due to less vegetation cover, it is reasonable to believe that this observation in the field most likely mirrors riparian habitat. Therefore, riparian habitat believed to be the explanation behind the top model, which influence Asian elephant habitat use in BTFC.

5.4 Synthesis from habitat use studies

Only two studies used occupancy framework to investigate environmental factors affecting elephant habitat use (Jathanna et al., 2015; Lakshminarayanan et al., 2016) and these are the most similar studies to be compared that applied robust statistical analysis. Findings from these studies have profound influence in understanding habitat use of Asian elephants from BTFC especially from Lakshminarayan et al. (2016). However, given my study design with large single block for each sites in TFR and RBSP, using fine scale sampling units of one km^2 in relation to Asian elephant large home range (Alfred et al., 2012; Bahar et al., 2018), detections across the sub-cells inevitably expected to be spatially dependent.

This is the major analytical difference between the abovementioned (Jathanna et al., 2015; Lakshminarayanan et al., 2016) studies compared to my study whereby habitat use modelling was carried out using MacKenzie et al. (2002) modelling approach. This study focused on qualitative aspects of Asian elephant habitat use instead of quantification habitat use rate.

Although this study incorporated detection probability in habitat use modelling as per MacKenzie et al. (2002) approach which provide statistically robust result, it should be noted that spatial-dependence is not accounted as done by Jathanna et al. (2015) and Lakshminarayan et al. (2016) which used Hines et al. (2010) modelling approach. Nevertheless, the qualitative aspects found to be affecting habitat use of Asian elephants by Jathanna et al., 2015 and Lakshminarayanan et al., 2016 are similar to findings from BTFC.

Some key assumptions made to synthesize information from all similar studies on Asian elephant habitat use mentioned in literature review. The assumptions made to assist understanding of Asian elephant habitat use within the context of BTFC as this study draws information from various sources with slight variation in terminology.

Firstly, environmental factors reported to affect elephant habitat use, which are water (Alfred et al., 2012) or permanent water source (Aini et al., 2015), assumed to represent river in the case of BTFC. Secondly, mentions on secondary vegetation (Kumar et al., 2010; Rood et al., 2010), secondary forest (Aini et al., 2015), forest edges (Rood et al., 2010), medium and open canopy (Sitompul et al., 2013; Bahar et al., 2018) assumed to be related to environmental features with less dense vegetation cover in the context of BTFC.

In general, environmental factors affecting Asian elephant habitat use, which are river (Alfred et al., 2012; Aini et al., 2015) and less densely vegetated area (Kumar et al., 2010; Rood et al., 2010; Sitompul et al., 2013; Jathanna et al., 2015; Aini et al., 2015; Lakshminaratan et al., 2016) were associated to riparian habitat (Kumar et al., 2010; Rood et al., 2010; Lakshminarayan et al., 2016). Studies by English et al. (2014a, 2014b) recommended riparian area to be prioritized for Bornean elephant conservation based on the species preference towards plants and time spent in the area.

Therefore, findings from these studies are parallel with postulation from my study, which suggests high use of riparian habitat in BTFC by Asian elephants. Riparian habitat consist of unique areas between the transition of terrestrial and aquatic system (Naiman & Décamps, 1990; Malanson, 1993) and defined as the area of land adjacent to water, which includes floodplains (Riparian vegetation, 2018).

Such unique system in tropical rainforest found to be contributing to both alpha and beta diversity (Drucker et al., 2008). Alpha diversity termed as complexity related to community's richness in species whereas beta diversity referred to as the extent of species replacement or biotic change along environmental gradients (Whittaker, 1972). According to Naiman et al. (1993), riparian areas reflected as among the most rich and productive system.

It is preferred by megafauna like elephants for green forage (Dudgeon, 2000) as the species is attracted to highly productive and diverse flora with palatable plant particularly bamboos, grasses, sedges and browse (Karanth & Sunquist, 1992). In Sabah, English et al. (2014a) mentioned grasses and bamboos are very common in the riparian areas and the diet of Bornean elephants are predominantly consist of the two aforementioned water loving plant types.

Postulation on riparian habitat as the overarching environmental factors of both “River” and “NDVI” affecting elephant habitat use becomes evident in RBSP based on map produced using the best model (Figure 4.2). Obvious high intensity of use observed in the map along the riparian habitat of the two major rivers in RBSP, which are Sg. Perak and Sg. Tiang as well as the smaller tributaries (e.g. Sg. Machang, Sg. Merah, Sg. Rantau, Sg. Laho, Sg. Mangga, and Sg. Uu Tiang) within the state park.

Within an unaltered habitat of primary forest (RBSP) riparian habitat were highly used by Asian elephants and easily predicted using the model to develop habitat use map. The landscape level information provided by this map on RBSP expected to be greatly useful in managing elephant high use areas within the state park.

However, at the finer scale, there were questionable intensity of use in RBSP. Highest use by Asian elephant reflected mostly in the interior part of RBSP near the smaller rivers at the upstream, more than the larger rivers downstream. Closer inspection on the data used for computation reveals low values of NDVI in these areas. The areas surrounding Sg. Machang and Sg. Merah are upper dipterocarp primary forest without any vegetation clearance. The low amount of NDVI value in Sg. Machang and Sg. Merah areas suspected due to cloud cover in the highland, which have significant impact on remote sensing image interpretation (Roy et al., 2010; Zhu et al., 2015).

Measure to overcome the cloud cover effect carried out by masking and mosaic of satellite images from 2008 to 2011 prior to computation. However, certain grids still produced lower NDVI values due to some aspects of cloud cover especially area in higher elevation. The NVDI values inversely correlated to habitat use value as per the formula (1.1). Hence, the high use of elephants predicted surrounding area of upstream of Sg. Merah and Sg. Macang could possibly be associated to low NDVI values due to cloud cover.

Effects of NVDI on predicted elephant habitat use are more visible in TFR, which is secondary forest with ongoing logging operations. The map shows overwhelming habitat use of Asian elephants across large blocks of forest without distinguishing features of riparian and terrestrial habitat. Such observation suspected due to logging activity followed by secondary growth in TFR, which are reported to have steep slopes and hills with networks of streams and rivers in reticulating patterns (Davison et al., 1995).

According to Yamamoto-Ebina et al. (2016) elephants along the Gerik-Jeli roadside prefer grasses. Their study also shows non-grass monocots such as ginger plants and palms are important for elephants in primary and secondary forest of RBSP and TFR respectively. However, it was mentioned in their study that such observation from RBSP and TFR could be due sampling effect whereby the samples were collected near Temenggor Lake. Yamamoto-Ebina et al. (2016) suggested that their observation strengthen elephant's preference for opening in canopy and forest fringe where plants optimizing availability of gap and disturbed habitat like gingers and palms grow easily.

Wadey et al. (2018) shows elephant habitat preference largely in AFR affected by similar features of secondary growth and open habitat which also similar to findings reported by Rayan et al. (2012). Highlighted areas by these studies areas are not riparian in nature and yet shows preference by Asian elephants. Such observation largely attributed to availability of food source due to secondary growth (Yamamoto-Ebina et al., 2016; Wadey et al., 2018).

Invasion of bamboos and ginger shrubs as a result of gaps after tree falling mentioned by Yamamoto-Ebina et al. (2016). Secondary forest with limited disturbance preferred by elephants due to presence of secondary vegetation with good food source (Shoshani & Eisenberg 1982; Sukumar, 1989; Alfred et al., 2012).

The relationship with logging activity becomes apparent when logging roads overlaid on the same map (Figure 4.2) which shows most areas with logging road networks indicated to have highest use by Asian elephants. Logging roads mentioned to influence habitat use of an area by Asian elephants due to ease of movement (Alfred et al., 2012; Arzaimran, personal communication, December 14th 2018) and this features are found in TFR. Tar roads present within Gunung Basor Forest Reserve also reported to be used by elephants for moving from one place to another (Jayaraj et al., 2019). Growth of secondary forest and presence of logging roads due to human interventions raise concern on frequency of HEC. Changes in natural Asian elephant habitat due to human activities may escalate HEC as both species may come into contact more often due to high use of common area.

Therefore, it is pertinent to understand that disturbed habitat which are preferred by Asian elephants may pose challenge to humans in the same area to co-exist without conflict. Based on the Figure 4.2, intense use of riparian habitat in TFR are not distinctly highlighted as much as RBSP.

However, predicted habitat use map still shows high use of riparian habitat by Asian elephants at unlogged areas in TFR such as upper reaches of Sg. Sengoh and Sg. Talong which are far away from logging activity. Selective logging method reported to have potential to alter riparian habitat (Azliza et al., 2012) and known to physically change forest environment due to the heavy use of machines to fall tress and build logging roads (Wyatt-Smith & Foenander, 1962; Burgess, 1971; Cannon et al., 1994).

Apart from that, regeneration of secondary forest creates complex land cover mosaics, which affects riparian vegetation (Aide et al., 1995, 2000; Zimmerman et al., 1995; Roth et al., 1996; Allan et al., 1997; Wisssmar & Beschta 1998). Since riparian habitat in indicated as high use area by Asian elephants, understanding of these habitat features need to be improved in logged over forest. Unfortunately, there were no study on riparian plant, composition and structure in Malaysia (Azliza et al., 2012) and in BTFC.

5.5 Explored aspects of conservation recommendations

5.5.1 Limitations and future study recommendations

Use of NDVI and interpretation of it were cautioned due to the ambiguity of measurement of the parameter since cloud cover can influence it. NDVI also do not reflect the true condition of vegetation quality. Interpretation of predicted habitat use map based on NDVI suggested to be carefully used. This study did not account for spatial – correlation which requires greater statistical and analytical knowledge. Another limitation of this study is use of single large study block, which covers continuous range of floristic zones that could pose edge effect at the transition of different zones.

5.5.2 Habitat management for Asian elephants

Given the importance of riparian habitat for Asian elephant, all experts agreed this area should be prioritized for Asian elephant in BTFC. Although RBSP is a protected area, growing numbers of visitors (WWF-Malaysia, 2018) may increase interest to create more infrastructures to cater tourist demand. Most development of infrastructures tend to occur along the major rivers as seen in the map produced in a study by WWF-Malaysia (WWF-Malaysia, 2018). The choice of the locations near rivers provides easy accessibility and availability of water source for eco-tourism based activities.

Forest reserves like TFR and BFR that had and still undergoing logging requires special attention for habitat management. This is because logging impact said to be highest on riparian habitat and structure if harvest carried out up to the stream banks (Naiman & Décamps, 1997). Logging activity alters the nature and long-term composition riparian habitat even with implementation of buffer zones especially during building of logging road and skidder trail near rivers (Azliza et al., 2012). The rugged terrain of TFR and BFR yet to be studied for impacts from logging on riparian habitat.

A study by Ohnuki et al. (2010) at Bukit Tarek Experimental Watershed, shows 20 m buffer zones were partially adequate to prevent sediment discharge. However, this width is not enough to reduce impacts from logging road in areas that are steep with concave slopes. Hence, riparian habitat protection recommended along major rivers in RBSP, TFR and BFR as these areas prone for other land use such as infrastructure development or logging activities.

5.5.3 Protection of Asian elephants

Since this study did not collect any data on direct threats to Asian elephants, most recommendation on this species protection explored at minimal depth. Hii (2016) quoted DWNP personnel from Perak state on records of Asian elephant poaching involving 24 carcasses from 2013 to 2015 related to three threats i.e. roadkill, poaching, and poisoning. Out the three threats, roadkill and poaching were explored for conservation recommendation as these are the commonly reported and easily available information.

There were three elephant roadkills reported in BTFC (Loh, 2011; Baby elephant killed, 2017; Tour bus runs over elephant, 2017). WWF-Malaysia's recorded poaching activity in RBSP and TFR since 2007 (Sukor & John, 2011). However, there were minimal signs on elephant poaching that were detected in relation to other wildlife. Hii (2016) mentioned five elephants collared by MEME for tracking purpose were poached. Three of it are young males with small tusks, which shows serious threats to elephants even with small tusks. Providentially, seven elephant poachers caught in February 2017 at Gua Musang, Kelantan (Hamdan, 2017) which neighbours Perak.

The operation recovered two elephant tusks, dried elephant meat and other wildlife parts. In March 2018 (A gang of ivory poachers, 2018), four local poachers caught by joint team of Royal Malaysian Police and DWNP near a village at within Gerik district. The poachers reported to responsible for killing 20 wild elephants for the past 10 years in areas within and surrounding BTFC.

In 2010 Belum-Temengor Joint Enforcement Taskforce (BT-JETF) was set up to curb poaching threats to wildlife in Belum-Temengor Forest Complex. This taskforce comprised of the Royal Malaysian Police, The Perak State National Security Council, Royal Malaysian Customs, The Hulu Perak District and Land Office, DWNP Perak, Anti-Smuggling Unit, Gerik Forestry Department, Perak State Park Corporation, Fisheries Department and People's Volunteer Cops.

The taskforce coordinated by Gerik District Security Council (Clements et al., 2010; Sukor & John, 2011). Apart from roadblocks, the taskforce carry out patrols and raids. However, such operations requires resource, which are often scarce (Sukor & John, 2011) and leads to inactive operation. Revival of this taskforce in 2014 brought success in apprehending 12 people including 10 Vietnamese involved in illegal agarwood extraction from BTFC (Sharma, 2014) and more of such inter-agency enforcement activity demanded by Traffic South-East Asia, an agency that monitors illegal wildlife trade called for more of such efforts (Lai, 2014).

In the past and even now, presence of indigenous communities via involvement with WWF-Malaysia reported to be useful in deterring encroachers into forest reserve as well as for reporting of vehicles details into the forest reserve. It is difficult to determine whether these encroachers into forest reserves are poachers, but the mere presence of indigenous communities with NGOs possibly helped in deterring encroachment (Umi A'Zuhrah Abdul Rahman, personal communication, December 8th 2018). Apart from that, such activity provides indigenous communities a platform to communicate with possible intruders into the forest and share the information on government laws pertaining to wildlife.

A success story of empowered indigenous community in BTFC landscape can be observed from Kampung Semelor within BFR whereby 16 men carries out patrolling activity on their own with the support of WWF-Malaysia. WWF-Malaysia provides support in terms of GPS device, batteries, motorbike fuel expenses, and part of their ration cost. These men channels information collected during their patrols to WWF-Malaysia, which later directed to enforcement authorities.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study achieved its objective whereby important ecological information of Asian elephants such as RAI, activity patterns, ecological factors influencing the species' habitat use and predicted habitat use map were produced. As such, this study provides the first robust occupancy framework based ecological information for Asian elephants within TFR and RBSP. In an area of 560 km^2 of intensive sampling, more than half of the area (53%) shows Asian elephant detection.

In the beginning of the study, RAI value between TFR and RBSP was expected to be different. However, the result shows that the RAI are of the similar values between TFR and RBSP. The Asian elephants of TFR and RBPS indeed falls within the cathemeral class as in expected outcome of this study. The hypothesized combined effect of lowland and disturbed habitat reveals somewhat similar result in this study as the lowlands harbour rivers, indicating high use in both TFR and RBSP in riparian habitat. Whereas visible high intensity of use by Asian elephants in logged over area of TFR. Therefore, the expected outcome for Asian elephant habitat use is not identical but rather complexly fits into the result obtained in this study.

This large-scale study strengthens the importance of Belum-Temengor Forest Complex as priority area for Asian elephant conservation in Peninsular Malaysia. Apart from that, predicted habitat use by Asian elephants produced in this study expected to boost conservation management of the species. This study maximises information obtained from tiger-centric occupancy framework research to create greater conservation impact. Given the limited resource in wildlife conservation, exploration of data of non-target species could be optimized using robust statistical analysis in order to produce grander conservation impact as showed in this study.

During the process of consultation with experts, critical information obtained from this study were indirectly shared with experts involved in wildlife conservation in the area especially government officers and conservationist working on BTFC. Such sharing believed to contribute to conservation action on the ground by equipping right individuals for better management actions pertaining to Asian elephants in BTFC.

6.2 Recommendations

Incorporating spatial auto-correlation and accounting edge effect into the future studies on Asian elephant habitat use in BTFC recommended for greater statistical robustness. Instead of NDVI, use of Enhanced Vegetation Index (EVI) recommended (Sukumar, personal communication, June 5th 2018) in future studies pertaining to investigation related to vegetation cover. Due to limitation in NDVI, which affects habitat use map, field validation recommended as future study to assess areas predicted with highest habitat use intensity area by Asian elephants in order to gauge true quality of the habitat especially in secondary forest. Same caution was also mentioned by Lakshinarayan et al. (2016) which obtained identical habitat use result to this study.

With reference to riparian habitat as which was identified as important area for Asian elephants in BTFC, studies on riparian plant, composition, community and structure recommended especially in logged over forests such as TFR and BFR. This provides valid ground information pertaining to quality of habitat in secondary forest that might serve as precursor to rehabilitate riparian habitat should the area badly affected by logging activity.

Apart from ground assessment on riparian plant composition, community and structure, a study on elephant diet in the interiors of BTFC using microhistological analysis also recommended. Existing first study on elephant diet using microhistological analysis at BTFC by Yamamoto-Ebina et al. (2016) explained elephant food habit in the area but the study mentioned probable sampling effect due to data collection nearby lake at RBSP for their primary forest site. Hence, both riparian plant composition, community and structure assessment together with elephant diet at the interiors of TFR and RSBP will deepen the knowledge on the types of riparian plants in the landscape which can be crosschecked with plants preferred Asian elephant.

Recommended major rivers for protection are Sg. Perak, Sg. Machang, Sg. Merah, Sg. Tiang, Sg. Dadeh, Sg. Rantau, Sg. Singor, Sg. Mangga, Sg. Talong, Sg. Sengoh, Sg. Sara and Sg. Cherendong. AFR is not included in this recommendation as it does not share the same environmental factors that affect Asian elephant habitat use (Rayan et al., 2012). A riparian buffer zone measuring 1.5 km each side from the river recommended (Figure 6.1) based on findings from Aini et al. (2015).

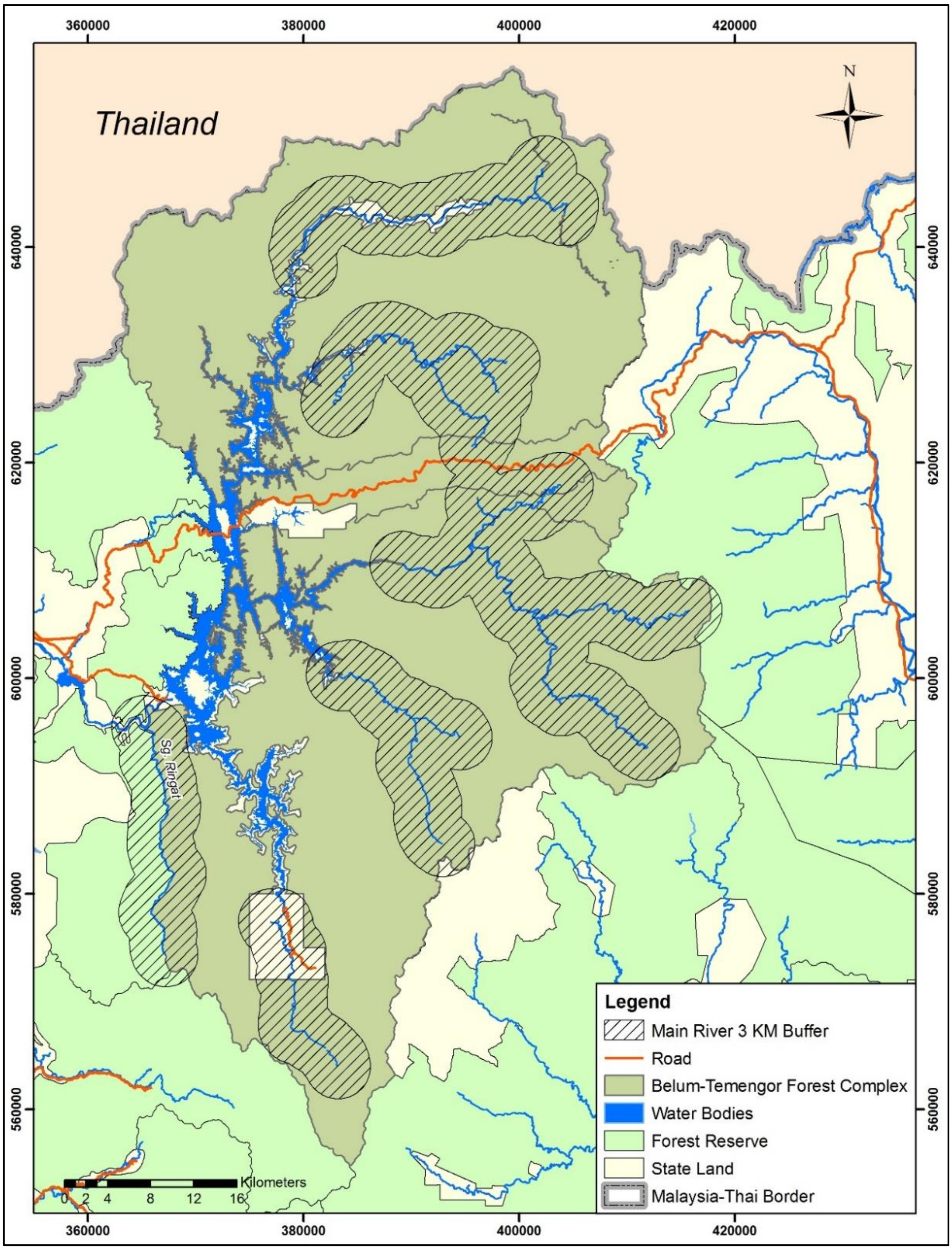

Figure 6.1: Proposed riparian buffer zone for Asian elephant protection

This buffer zone should be labelled as riparian buffer zones for Asian elephant protection. The proposed riparian buffer zones recommended to be gazetted as protected zones from any other land use. Development such as plantations or infrastructures for tourism activities tend to occur closer to water source and relatively flat area alongside river. By avoiding other land uses in the proposed riparian buffer zones for the species, chances of human coming in contact with Asian elephants could be reduced hence helps in limiting HEC.

In general, riparian habitat in BTFC suggested to be managed based on information from scientific studies. Future studies suggested in previous section such as riparian plant community, composition and structure assessment may help to provide baseline information on the health of riparian habitat. Collaboration with local universities highly recommended as it benefits both academia and forestry departments. Rehabilitation of degraded riparian habitat recommended to help regeneration of this important zones back to its natural condition. Reference towards natural condition on riparian habitat can be made by looking into unlogged riparian area within TFR or the RBSP. Riparian habitat are not only important for Asian elephants, as this area will also help other mega-herbivores like gaurs, which are also threatened under the IUCN Red List.

In order to reduce roadkill, increase in signboards and beacon light suggested by experts as possible means to increase road-user's attention in areas where elephants are commonly sighted. DWNP has applied the usage of blue beacon light in some locations along the Gerik-Jeli Highway as a measure to increase alertness. Although it is deemed helpful, this initiative face challenge due to theft (Dr. Pazil, personal communication, 26th November 2018).

Wildlife signboards were applied in Tasmania as a measure to reduce road kill (Magnus et al., 2004) thought to be helpful in reducing roadkill if signage are properly placed (Bond & Jones, 2013). Apart from wildlife signboards, expert also recommended to enforce speed limit to reduce risk of Asian elephant roadkill. This suggestion shown to reduce roadkill in Tasmania, Australia (Hobday, 2010) and was brought up by Tan Sri Lee Lam Thye (Lee, 2018). Wadey et al. (2018) also recommended to reduce and enforce speed limit along Gerik-Jeli highway.

In relevance to past effort by inter-agency to reduce poaching, all experts agreed that having roadblocks at the entrances to BTFC would be good deterring factor to reduce poachers from accessing this area. East-West Highway or more commonly known as Gerik-Jeli Highway is the only road that leads into the BTFC and it connects Gerik town in the state of Perak and Jeli town in the state of Kelantan.

Geographically Sg. Lebey an area that is the last stop from Gerik before the road leads into the large forested landscape, hence inter-agency managed roadblocks highly recommended at this area. Similarly, roadblocks at the Perak-Kelantan border for vehicles coming from Jeli town also recommended in order to deter poachers entering BTFC from Kelantan side. The suggested locations for roadblocks showed in Figure 6.2. The coordinates for the locations are at QT 360249 605334 (Sg. Lebey) and QU 407489 620832 (border of Perak-Kelantan).

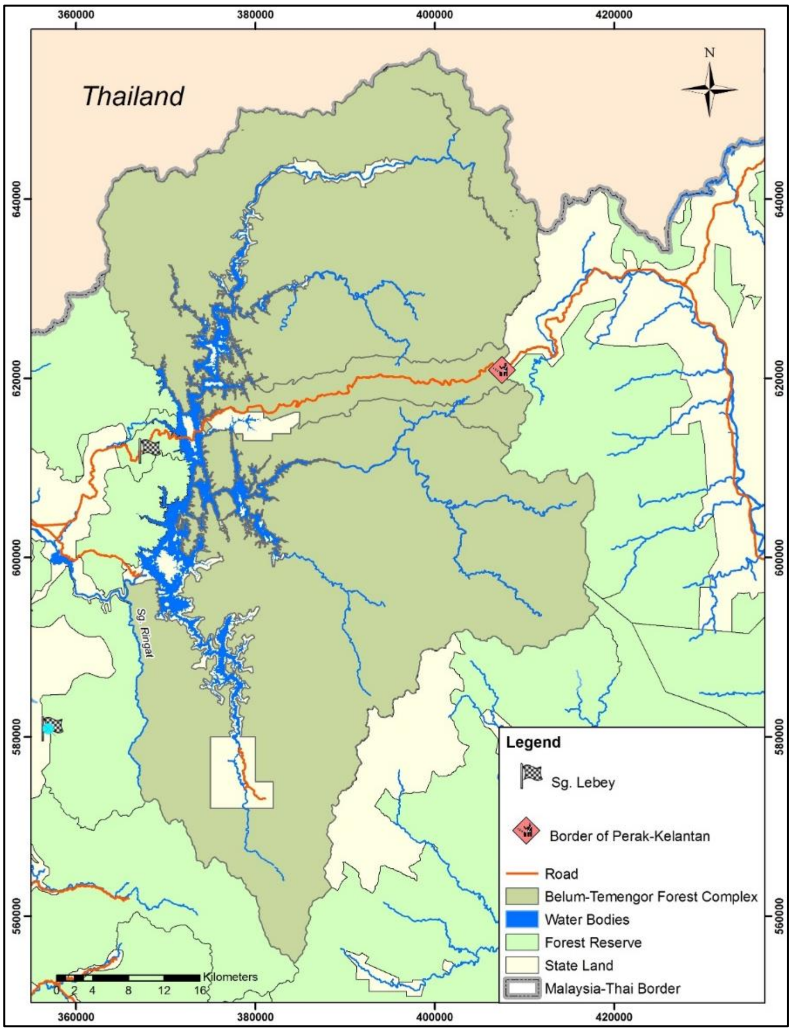

Figure 6.2: Proposed locations for roadblocks

This recommendation done in consideration of efforts and resources spent on the ground for patrolling and difficulty in tracking poachers in the vast jungle of BTFC. Diversion of some resources from patrolling activities to roadblocks at the access points in Figure 6.2 agreed by experts as a strategic method to deter poaching entering BTFC in the first place. Apart from that, existing patrolling along the Gerik-Jeli Highway and in the forest deemed helpful in reducing poaching threats to elephants hence need to be retained.

Diversifying anti-poaching activities, such as community patrolling were also recommended whereby indigenous community living adjacent to forest suggested to be empowered in order for these communities regulate entrance into forest reserves. Empowering indigenous community has started in 2018 within BTFC and still lacks buy-in from the community due to various factors such as safety and lack of leadership among them. Finally, this approach of empowering indigenous community said to be successful only if the information channelled by the communities acted upon by authorities as this will motivates these passionate indigenous community to continue their patrolling (Lau Ching Fong & Umi A'Zuhrah Abdul Rahman personal communication, Dec 8th 2018).

6.3 Succinct conservation recommendations

Below are the list of summary of major recommendations produced from this study.

a) Conduct future study on riparian plant community along the major rivers of BTFC.

b) Conduct future study on elephant diet in the interior parts of BTFC.

c) Conduct ground truthing to validate Asian elephant habitat use map obtained from this study.

d) Protection of riparian habitat along the major rivers within BTFC, which spans 3km in width i.e. 1.5km to the left and right of the river.

e) Rehabilitation of degraded riparian habitat.

f) Wildlife signage and beacon light to increase alertness of Gerik-Jeli Highway road users in order to reduce elephant roadkill.

g) Reduce and enforce speed limit in order to lessen risk of Asian elephant roadkill.

h) Joint enforcement by authorities to conduct roadblocks at the two strategic locations along Gerik-Jeli Highway i.e. Sg. Lebey and border of Perak-Kelantan in order to reduce Asian elephant poaching.

i) Empowerment of indigenous community to collect information on poaching in the area.

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Appendix A

SURVEY EQUIPMENTS

GPS

Digital camera

Compass

Rulers

Pens /marker pens

Track guides

Occupancy forms

Habitat assessment forms

Camera-trap forms for prey

Species detection form

Scat collection forms

Random bearings list

Field schedule

Camera-trap

Cable lock

Cable lock keys for prey

Spare 9V battery

Toiletries

Towel Maps (laminated & full-scale)

Ziplock bags

Torchlight / headlamp

CAMPING EQUIPMENTS

Hammocks /tent

Flysheets

Food rations

Cooking utensils

Detergent / sponge

Campingaz head &gas

Candles

Hexamine tablets

Raffia string / rope

Duct tape

Sleeping bag

Tupperware / cup

Extra clothes

Rubbish bags

Poncho / rain cover

Satellite phone

AA batteries &memory stick

Habitat assessment kit

Daypack

First aid kit

Appendix B

WWF-Malaysia Tigers Alive III

OCCUPANCY FORM

STUDY AREA:	**SURVEY NO.**	**BEARING:**

Gridcell ID: A B C D   Date: _______ Observers: ___________________________ Rainfall in past 24 hrs: Heavy / Medium / Light / None

Start time: _________ Start point: Q _________ WMR _________

End time: _________ End point: Q _________ WMR _________

Estimated time spent on foot: ____+____ hours ____+____minutes

GPS odometer reading: ________+________ km

Locality types covered	Detections (photo ID = detected, *blank* = not detected); *< 1 month old*																							
	ELE			TAP			GAU			SAM			SER			WIL			BAR			TIG		
	S	*T*	*D*	*S*	*T*	*D*	*S*	*T*	*D*	*S*	*T*	*D*	*S*	*T*	*D*	*S*	*T*	*D*	*S*	*T*	*D*	*S*	*T*	*D*
Active logging road (A)																								
Old logging road (O)																								
Ridge (R)																								
Forest trail (F)																								
Stream bed (S)																								
No clear trail (N)																								

Locality types covered	Detections (photo ID = detected, *blank* = not detected); *< 1 month old*																							Detected = 1		
	LEO		CLO		GOL		CAT		DHO		SUN			MOU		POR		UNG		PRI		ENC	POA	LOG		
	S	*T*	*S*	*T*	*S*	*T*	*S*	*T*	*S*	*T*	*S*	*T*	*C*	*S*	*T*	*S*	*T*	*T*	*D*	*T*	*S*					
Active logging road (A)																										
Old logging road (O)																										
Ridge (R)																										
Forest trail (F)																										
Stream bed (S)																										
No clear trail (N)																										

Notes:

FIELD PROCEDURES FOR OCCUPANCY SURVEY

- A minimum of 1 km needs to be spent looking for animal signs in each sub-gridcell.
- Survey in places with a high probability of finding animal signs - forest trails, ridges, streambeds and logging roads. Try to encompass a range of these features within each cell – if possible a minimum of 500 m for each locality within each cell.
- For verification purposes, take a photograph of each sign detection, along with the appropriate measurement scale. Take one photo with flash, one without. Fill in the occupancy form based on the photo ID number (in playback mode).
- For each sub-gridcell, surveyors must start with a random bearing of 100 m (refer to random bearing form).
- Surveyors must also pass within 125 m of a random point within each gridcell.
- Write down details of encroachment, poaching signs and recent logging activities in the section behind.
- Cross-check GPS waypoints from each sub-gridcell with data from occupancy forms, and check for accuracy, every night!

GPS PROCEDURES FOR OCCUPANCY SURVEY

- Reset trip data (odometer) before surveying each sub-gridcell.
- Turn off GPS when resting to reduce odometer error, except in places with bad satellite reception.
- Turn off tracks when not carrying out occupancy survey.
- Mark beginning of each sub-gridcell route, as well as species detection locations.
  Example: For Gaur (GAU) dung (D) detected on a ridge (R) in subgridcell U16A during survey no.1 (S1):
  - Mark start of each sub-gridcell: ***U16AS1 St***
  - Mark waypoint of detection: ***GAU D U16AS1R***
- Mark every fig tree detection **FIG U16AS1 01**, tree marking (symbol or word): **TRE U16AS1 01**, poaching sign: **POA U16AS1 01** and active argus pheasant dancing ground: **ARG U16AS1 01**

ELE - Asian elephant; **TAP** - Asian tapir; **GAU** - Gaur; **SAM** - Sambar deer; **SER** - Serow; **WIL** - Wild boar; **BAR** - Barking deer; **TIG** - Tiger; **LEO** - Leopard; **CLO** - Clouded leopard; **GOL** - Golden cat; **CAT** - Leopard cat; **DHO** - Dhole; **SUN** - Sun bear; **MOU** - Mouse deer; **POR** - Porcupine; **PRI** - Primate; **UNG** - Ungulate; **ENC** - Encroachment signs; **POA** - Poaching signs; **LOG** - Recent logging signs (<1 year)

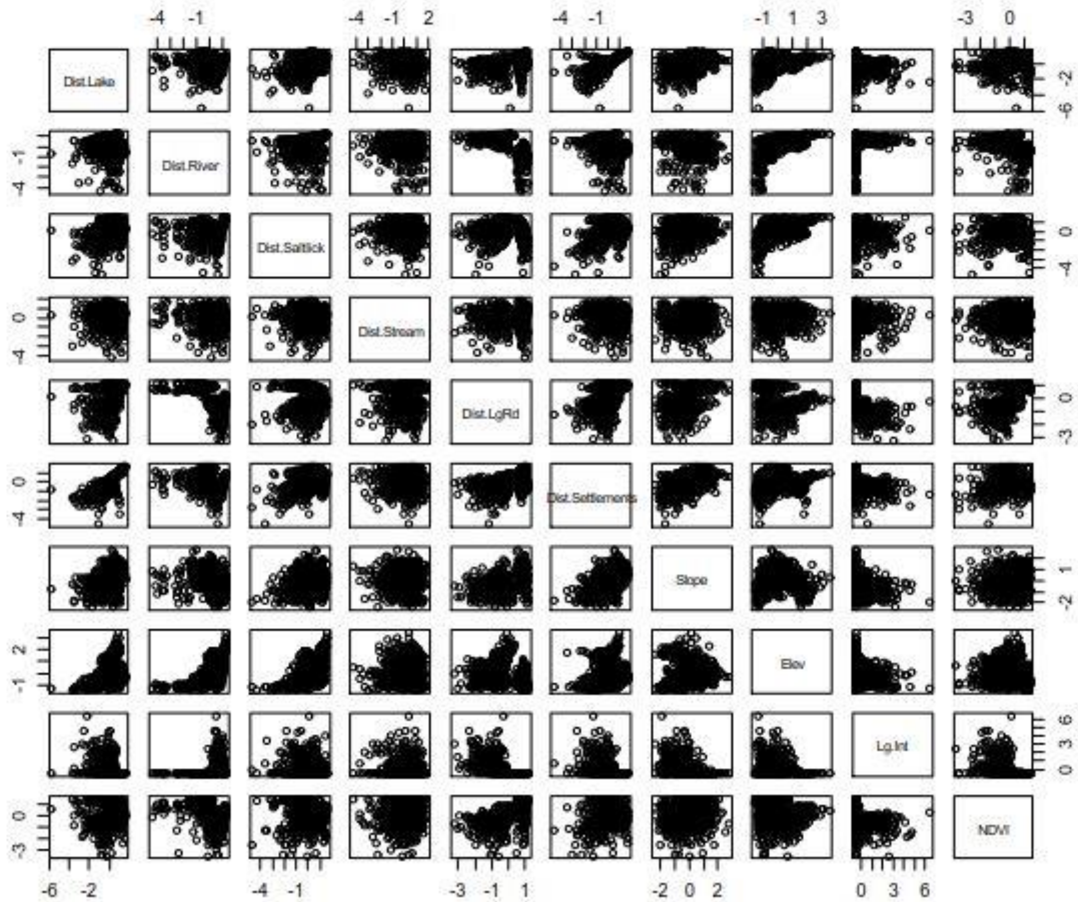
S - Sighting; **T** - Tracks; **D** - Dung; **C** - Claw marks

Survey form

Appendix C

Photo of custom made camera trap

Appendix D



Correlation test result

Appendix E

Sub-cell	Sign survey 1	Sign survey 2	Sign survey 3	Occasion 1	Occasion 2	Occasion 3	Occasion 4	Occasion 5	Occasion 6	Occasion 7	Occasion 8	Occasion 9
U001A	0	0	0	-	-	-	-	-	-	-	-	-
U001B	0	1	0	-	-	-	-	-	-	-	-	-
U001C	0	0	0	-	-	-	-	0	0	0	-	-
U001D	0	0	0	-	-	-	-	-	-	0	0	1
U002A	0	1	0	-	-	-	-	-	-	-	-	-
U002B	0	0	0	-	-	-	-	-	-	-	-	-
U002C	0	1	0	-	-	-	-	-	-	0	0	1
U002D	0	0	0	-	-	-	-	-	-	-	-	-
U003A	0	1	0	-	-	-	-	-	-	-	-	-
U003B	0	1	0	-	-	-	-	0	1	-	-	-
U003C	0	0	0	-	-	-	-	-	-	0	0	0
U003D	0	0	0	-	-	-	-	-	-	-	-	-
U004A	1	0	0	-	-	-	-	-	-	-	-	-
U004B	0	0	1	-	-	-	-	-	-	1	0	0
U004C	1	0	1	-	-	-	-	-	-	-	-	-
U004D	0	0	0	-	-	-	-	0	0	1	-	-
U005A	0	1	0	-	-	-	-	-	-	-	-	-
U005B	0	1	0	-	-	-	-	-	-	-	-	-
U005C	0	0	0	-	-	0	0	1	-	-	-	-
U005D	1	1	1	-	-	-	-	-	-	-	0	0
U006A	0	1	0	-	-	-	-	-	-	-	-	-
U006B	0	0	1	-	-	-	-	-	-	0	0	0
U006C	0	1	0	-	-	-	-	-	-	-	-	-
U006D	1	0	0	-	-	-	-	0	1	0	-	-
U007A	0	0	0	-	-	-	-	-	-	-	-	-
U007B	0	1	0	-	-	-	-	-	-	0	0	0
U007C	1	0	0	-	-	-	-	0	0	0	-	-
U007D	1	0	0	-	-	-	-	-	-	-	-	-
U008A	0	0	0	-	-	-	-	-	-	-	-	-
U008B	0	0	0	-	-	-	-	0	0	0	-	-
U008C	0	0	0	-	-	-	-	-	-	0	0	0
U008D	0	0	0	-	-	-	-	-	-	-	-	-
U009A	0	1	0	-	-	-	-	0	0	0	-	-
U009B	1	0	0	-	-	-	-	-	-	-	-	-
U009C	0	0	0	-	-	-	-	-	-	0	0	1
U009D	0	0	0	-	-	-	-	-	-	-	-	-
U010A	0	0	0	-	-	-	-	-	-	-	-	-
U010B	0	1	0	-	-	-	-	0	0	0	-	-
U010C	0	0	0	-	-	-	-	-	-	-	-	-
U010D	0	0	0	-	-	-	-	-	-	0	0	0
U011A	0	0	0	-	-	-	-	-	-	0	1	-
U011B	0	0	0	-	-	-	-	-	-	-	-	-
U011C	0	0	0	-	-	-	-	-	-	-	-	-
U011D	0	1	0	-	-	-	-	0	0	0	-	-
U012A	0	1	0	-	-	-	-	-	-	-	-	-
U012B	1	1	0	-	-	-	-	-	1	-	-	-
U012C	0	0	0	-	-	-	-	-	-	-	-	-
U012D	1	1	0	-	-	-	-	-	-	-	0	0
U013A	1	0	0	-	-	-	-	-	-	-	-	-
U013B	1	1	1	-	-	-	-	-	-	0	0	0
U013C	0	0	0	-	-	-	-	0	0	0	-	-

Detection history datasheet.

Note: Not all rows presented due to limitation in space and data confidentiality.

Appendix F

	River	Saltlick	Settlements	Slope	Elev	NDVI	Site
U01A	-0.631	0.115	-0.729	-0.726	-1.341	0.48	1
U01B	-0.32	0.002	-0.686	0.071	-0.891	0.099	1
U01C	-0.425	-0.07	-1.081	0.265	-0.709	0.344	1
U01D	-0.205	-0.226	-0.993	-0.127	-1.046	-0.028	1
U02A	-0.143	-0.083	-0.64	-0.393	-0.519	-0.456	1
U02B	-0.005	-0.126	-0.524	0.129	0.119	-0.713	1
U02C	-0.028	-0.351	-0.819	0.317	-0.309	-0.497	1
U02D	0.111	-0.417	-0.667	-0.017	-0.123	-0.893	1
U03A	0.009	-0.116	-0.486	-0.34	0.891	-0.822	1
U03B	0.013	-0.057	-0.555	-0.395	1.102	0.512	1
U03C	0.165	-0.403	-0.474	-0.448	0.332	-0.146	1
U03D	0.154	-0.313	-0.324	0.931	0.883	-0.923	1
U04A	-0.06	0.039	-0.556	-1.04	1.137	-1.508	1
U04B	-0.103	0.158	-0.562	-1.24	1.281	-1.765	1
U04C	0.104	-0.173	-0.258	-0.338	0.935	-1.575	1
U04D	0.075	-0.013	-0.355	-0.383	1.176	-1.37	1
U05A	-0.113	0.287	-0.83	-0.277	1.097	-1.396	1
U05B	-0.197	0.333	-1.09	-0.202	1.386	-0.499	1
U05C	0.052	0.151	-0.55	-0.407	1.379	-1.098	1
U05D	0	0.309	-0.719	-1.783	1.434	-0.433	1
U06A	-0.224	0.155	-1.275	-0.288	1.468	-1.892	1
U06B	-0.183	-0.042	-1.301	-0.004	0.635	-3.602	1
U06C	-0.016	0.258	-0.828	-0.88	1.611	0.213	1
U06D	0.008	0.094	-0.842	-0.211	1.305	-1.631	1
U07A	-0.089	-0.261	-1.152	-0.452	0.591	-0.506	1
U07B	-0.13	-0.492	-1.242	-0.145	1.027	0.798	1
U07C	0.067	-0.076	-0.829	-0.438	1.253	0.136	1
U07D	-0.029	-0.241	-1.285	-0.986	1.397	0.861	1
U08A	-0.218	-0.261	-1.637	-0.603	-0.542	0.547	1
U08B	-0.076	-0.482	-1.464	-0.464	-0.496	0.065	1
U08C	-0.042	-0.442	-2.517	-0.822	-1.05	0.227	1
U08D	0.057	-0.755	-2.066	-0.045	-0.482	-0.403	1
U09A	0.064	-0.68	-1.241	-0.437	-0.358	-0.792	1
U09B	0.188	-0.794	-0.993	-0.106	0.074	-0.513	1
U09C	0.16	-1.09	-1.782	-0.408	-0.301	-1.029	1
U09D	0.261	-1.329	-1.342	-0.401	-0.611	-1.326	1
U10A	0.294	-0.768	-0.713	-0.564	-0.012	-1.994	1
U10B	0.276	-0.617	-0.631	0.542	0.294	-1.642	1
U10C	0.357	-1.27	-1.063	-0.381	-0.504	-2.473	1
U10D	0.383	-0.975	-1.014	-0.059	-0.149	-2.43	1
U11A	0.241	-0.405	-0.531	-0.294	0.562	-1.072	1
U11B	0.219	-0.185	-0.383	-0.248	0.487	-0.904	1
U11C	0.356	-0.641	-0.854	-0.25	-0.153	-1.302	1
U11D	0.34	-0.343	-0.637	0.073	0.113	-0.78	1
U12A	0.191	0.022	-0.293	-0.291	0.927	-0.954	1
U12B	0.157	0.203	-0.41	-1.815	1.462	0.456	1

Habitat covariates datasheet

Note: Not all rows presented due to limitation in space and data confidentiality.

Appendix G

	ODO 1	ODO 2	ODO 3	TN1	TN2	TN3	TN4	TN5	TN6	TN7	TN8	TN9	TN10	Site
U001A	-0.357	-1.333	-1.256	-	-	-	-	-	-	-	-	-	-	1
U001B	-0.758	-0.77	-0.535	-	-	-	-	-	-	-	-	-	-	1
U001C	0.56	1.232	-0.19	0	0	0	0	6	28	25	0	0	0	1
U001D	0.517	-0.028	0.32	0	0	0	0	0	0	4	28	28	17	1
U002A	-0.333	-0.378	-1.261	0	0	0	0	0	0	0	0	0	0	1
U002B	-1.065	-0.993	-0.609	-	-	-	-	-	-	-	-	-	-	1
U002C	1.082	1.247	0.905	0	0	0	0	0	0	4	28	28	17	1
U002D	-0.9	1.659	-0.746	-	-	-	-	-	-	-	-	-	-	1
U003A	-1.43	0.801	-1.041	-	-	-	-	-	-	-	-	-	-	1
U003B	-1.046	-0.946	-0.447	0	0	0	0	5	16	0	0	0	0	1
U003C	0.227	-0.428	-0.303	0	0	0	0	0	0	2	28	28	19	1
U003D	-0.167	-0.85	-0.53	-	-	-	-	-	-	-	-	-	-	1
U004A	-0.207	-0.028	1.105	-	-	-	-	-	-	-	-	-	-	1
U004B	-0.161	1.082	0.653	0	0	0	0	0	0	2	28	28	19	1
U004C	0.248	0.458	0.095	-	-	-	-	-	-	-	-	-	-	1
U004D	-0.569	0.378	-0.781	0	0	0	0	5	28	9	0	0	0	1
U005A	-0.774	0.409	-0.695	-	-	-	-	-	-	-	-	-	-	1
U005B	0.747	0.471	0.495	-	-	-	-	-	-	-	-	-	-	1
U005C	1.846	0.76	0.261	0	0	8	28	26	0	0	0	0	0	1
U005D	-0.016	-1.194	0.996	0	0	0	0	0	0	0	28	28	17	1
U006A	-0.905	1.175	0.333	-	-	-	-	-	-	-	-	-	-	1
U006B	0.126	-0.435	-0.312	0	0	0	0	0	0	4	28	28	19	1
U006C	1.43	0.196	-0.242	-	-	-	-	-	-	-	-	-	-	1
U006D	0.116	1.241	3.143	0	0	0	0	2	28	24	0	0	0	1
U007A	-0.748	-0.008	1.02	-	-	-	-	-	-	-	-	-	-	1
U007B	-1.221	0.319	0.276	0	0	0	0	0	0	3	28	28	19	1
U007C	-0.806	2.012	-0.731	0	0	0	0	2	28	26	0	0	0	1
U007D	-0.828	-0.846	-0.796	-	-	-	-	-	-	-	-	-	-	1
U008A	-0.423	-0.455	-0.412	-	-	-	-	-	-	-	-	-	-	1
U008B	2.565	-0.778	0.388	0	0	0	0	7	28	25	0	0	0	1
U008C	-1.018	-0.578	-0.665	0	0	0	0	0	0	4	28	28	17	1
U008D	-0.016	-0.697	-0.566	-	-	-	-	-	-	-	-	-	-	1
U009A	-1.067	2.574	1.044	0	0	0	0	7	28	25	0	0	0	1
U009B	0.521	0.597	-0.636	-	-	-	-	-	-	-	-	-	-	1
U009C	-0.124	-0.074	1.338	0	0	0	0	0	0	5	28	28	16	1
U009D	-0.875	-0.801	0.606	-	-	-	-	-	-	-	-	-	-	1
U010A	-0.724	-0.087	-0.811	-	-	-	-	-	-	-	-	-	-	1
U010B	-0.28	-0.859	-0.904	0	0	0	0	6	28	28	0	0	0	1
U010C	-0.932	0.834	2.199	-	-	-	-	-	-	-	-	-	-	1
U010D	-0.281	-0.337	0.331	0	0	0	0	0	0	1	28	28	18	1
U011A	-0.833	2.816	1.457	0	0	0	0	0	0	3	16	0	0	1
U011B	1.109	3.021	0.01	-	-	-	-	-	-	-	-	-	-	1
U011C	0.909	1.908	0.356	-	-	-	-	-	-	-	-	-	-	1
U011D	0.11	0.688	-0.43	0	0	0	0	6	28	26	0	0	0	1
U012A	0.858	1.81	1.814	-	-	-	-	-	-	-	-	-	-	1
U012B	0.656	0.035	9.101	0	0	0	0	0	27	0	0	0	0	1
U012C	0.429	6.377	5.601	-	-	-	-	-	-	-	-	-	-	1
U012D	0.429	0.125	-0.806	0	0	0	0	0	0	0	28	28	17	1
U013A	-0.818	-1.078	-0.844	-	-	-	-	-	-	-	-	-	-	1
U013B	0.205	1.675	1.662	0	0	0	0	0	0	4	28	28	20	1
U013C	0.579	1.612	-0.269	0	0	0	0	2	28	25	0	0	0	1
U013D	-1.212	-0.297	-0.798	-	-	-	-	-	-	-	-	-	-	1
U014A	-0.444	0.244	0.328	0	0	0	0	0	0	2	28	28	19	1
U014B	-1.226	0.41	0.297	0	0	0	0	2	28	27	0	0	0	1

Sampling effort datasheet

Note: Not all rows presented due to limitation in space and data confidentiality.

Appendix H

Section 1: Future study

1) Based on the limitation identified in this study design, what are the recommendation to future study that you would like to provide for improvement?

2) Result of this study shows habitat use of Asian elephants influenced by riparian habitat. What you is your opinion on this?

Section 2: Habitat management

1) Given the result of this study on importance of riparian habitat for Asian elephants, are you agreeable on the following recommendations?
   i) Protection of riparian habitat along the major river within BTFC, which spans 3 km in with i.e. 1.5 km to the left and right of the river
   ii) Rehabilitation of degraded riparian habitat

2) Is there any additional suggestions or point to take note?

Section 3: Species protection

1) Considering elephant roadkill along Gerik-Jeli highway, are you supportive of?
   i) Having wildlife signage and beacon to increase alertness of Gerik-Jeli Highway road users
   ii) Reduce and enforce speed limit

2) Is there any additional suggestions or point to take note?

3) Considering poaching threats in BTFC, what is your opinion on having roadblocks at strategic location that leads to BTFC landscape? Is there any additional suggestions or point to take note?

Appendix I

Hours	Detections	
	TFR	RBSP
0	14	15
1	7	12
2	9	11
3	10	10
4	11	6
5	7	2
6	7	4
7	15	15
8	6	10
9	8	13
10	10	17
11	11	12
12	8	11
13	8	8
14	9	8
15	10	12
16	8	12
17	9	11
18	18	10
19	10	19
20	13	12
21	5	15
22	15	14
23	8	14

Asian elephant hourly detections for TFR and RBSP

Note: Not all rows presented due to limitation in space and data confidentiality.

Appendix J

```
> AP <- read.csv("AP test.csv", header=TRUE)
> TFR <- AP$Temengor     #TFR
> RBSP <- AP$Belum       #RBSP
> TFR_AM <- TFR[8:20]    #TFR morning detections
> RBSP_AM <- RBSP[8:20]  #RBSP morning detections
> TFR_mor_AM <- c(15,6,8,10,11,8)         #TFR morning session 07:00-12:00
> TFR_eve_AM <- c(8,9,10,8,9,18,10)       #TFR evening session 12:00-19:00
> RBSP_mor_AM <- c(15,10,13,17,12,11)     #RBSP morning session 07:00-12:00
> RBSP_eve_AM <- c(8,8,12,12,11,10,19)    #RBSP evening session 12:00-19:00
> TFR_1PM <- TFR[1:7]
> TFR_2PM <- TFR[21:24]
> TFR_PM <- c(TFR_1PM,TFR_2PM)    #TFR night detections
> RBSP_1PM <- RBSP[1:7]
> RBSP_2PM <- RBSP[21:24]
> RBSP_PM <- c(RBSP_1PM,RBSP_2PM) #RBSP night detections

> wilcox.test(TFR,RBSP)             #TFR vs RBSP
        Wilcoxon rank sum test with continuity correction
data:  TFR and RBSP
W = 192, p-value = 0.04779
alternative hypothesis: true location shift is not equal to 0
Warning message:
In wilcox.test.default(TFR, RBSP) : cannot compute exact p-value with ties

> wilcox.test(TFR_AM,RBSP_AM)        #TFR morning detections vs RBSP morning detections
        Wilcoxon rank sum test with continuity correction
data:  TFR_AM and RBSP_AM
W = 44.5, p-value = 0.04051
alternative hypothesis: true location shift is not equal to 0
Warning message:
In wilcox.test.default(TFR_AM, RBSP_AM) :  cannot compute exact p-value with ties

> wilcox.test(TFR_PM,RBSP_PM)        #TFR night detections vs RBSP night detections
        Wilcoxon rank sum test with continuity correction
data:  TFR_PM and RBSP_PM
W = 50, p-value = 0.5096
alternative hypothesis: true location shift is not equal to 0
Warning message:
In wilcox.test.default(TFR_PM, RBSP_PM) :  cannot compute exact p-value with ties

> wilcox.test(TFR_mor_AM,RBSP_mor_AM) #TFR morning session vs RBSP morning session
        Wilcoxon rank sum test with continuity correction
data:  TFR_mor_AM and RBSP_mor_AM
W = 6.5, p-value = 0.07609
alternative hypothesis: true location shift is not equal to 0
Warning message: In wilcox.test.default(TFR_mor_AM, RBSP_mor_AM) : cannot compute exact p-value with ties

> wilcox.test(TFR_eve_AM,RBSP_eve_AM) #TFR evening session vs RBSP evening session
        Wilcoxon rank sum test with continuity correction
data:  TFR_eve_AM and RBSP_eve_AM
W = 17, p-value = 0.3625
alternative hypothesis: true location shift is not equal to 0
Warning message: In wilcox.test.default(TFR_eve_AM, RBSP_eve_AM) :  cannot compute exact p-value with ties
```

Appendix K

OBJECTID	FID_	MEAN	NEAR_DIST	PSI
1	0	0.873	6481.780	0.657
2	1	0.848	7172.873	0.830
3	2	0.845	10449.718	0.802
4	3	0.857	11341.659	0.691
5	4	0.879	12250.300	0.457
6	5	0.841	13172.186	0.793
7	6	0.891	6045.348	0.490
8	7	0.884	6323.200	0.546
9	8	0.881	6739.397	0.567
10	9	0.858	7270.220	0.762
11	10	0.843	7892.574	0.848
12	11	0.855	8586.580	0.755
13	12	0.852	9336.272	0.769
14	13	0.814	10129.294	0.937
15	14	0.861	10956.241	0.661
16	15	0.876	11809.990	0.504
17	16	0.883	12685.128	0.409
18	17	0.888	13577.522	0.354
19	18	0.887	14483.982	0.346
20	19	0.899	15305.104	0.232
21	20	0.895	15386.074	0.262
22	21	0.777	0.421	1.000
23	22	0.791	122.620	0.999
24	23	0.896	6924.755	0.402
25	24	0.882	7027.720	0.551
26	25	0.864	7268.114	0.710
27	26	0.863	7632.962	0.711
28	27	0.862	8105.475	0.712
29	28	0.803	8668.065	0.964
30	29	0.857	9304.406	0.724
31	30	0.863	10000.430	0.658
32	31	0.863	10744.544	0.645
33	32	0.867	11527.439	0.596
34	33	0.878	12341.737	0.467
35	34	0.886	13181.620	0.377
36	35	0.893	14042.497	0.297
37	36	0.888	14289.402	0.340
38	37	0.835	14306.364	0.819
39	38	0.854	14392.953	0.672
40	39	0.888	14547.926	0.333
41	40	0.760	847.238	0.999
42	41	0.831	521.930	0.989
43	42	0.826	63.356	0.999
44	43	0.773	137.320	1.000
45	44	0.744	432.034	1.000

Datasheet for BTFC habitat use prediction

Note: Not all rows presented due to limitation in space and data confidentiality.

Appendix L

ORIG_FID	NEAR_DIST	STANDARDIZED	Logit psi	PSI
0	1038.531	-0.032	2.860	0.946
1	1717.686	1.011	2.088	0.890
2	2520.841	2.245	1.499	0.817
3	303.891	-1.161	4.745	0.991
4	1204.224	0.223	2.633	0.933
5	2188.570	1.735	1.716	0.848
6	947.228	-0.172	3.001	0.953
7	771.959	-0.442	3.315	0.965
8	1753.648	1.067	2.056	0.887
9	358.080	-1.077	4.493	0.989
10	1004.032	-0.085	2.912	0.948
11	1831.680	1.186	1.989	0.880
12	332.333	-1.117	4.607	0.990
13	661.868	-0.611	3.551	0.972
14	1657.470	0.919	2.143	0.895
15	304.409	-1.160	4.742	0.991
16	516.189	-0.835	3.932	0.981
17	1514.439	0.699	2.281	0.907
18	630.042	-0.660	3.626	0.974
19	350.982	-1.088	4.524	0.989
20	1028.006	-0.048	2.875	0.947
21	1799.972	1.138	2.016	0.882
22	128.981	-1.429	6.059	0.998
23	456.063	-0.927	4.122	0.984
24	1425.078	0.562	2.374	0.915
25	449.233	-0.937	4.145	0.984
26	518.836	-0.830	3.924	0.981
27	1312.960	0.390	2.500	0.924
28	2189.410	1.736	1.716	0.848
29	342.822	-1.101	4.560	0.990
30	31.780	-1.579	8.208	1.000
31	1029.226	-0.046	2.874	0.947
32	2026.497	1.486	1.834	0.862
33	1573.218	0.789	2.223	0.902
34	816.419	-0.373	3.229	0.962
35	36.210	-1.572	8.008	1.000
36	783.579	-0.424	3.292	0.964
37	1767.437	1.088	2.044	0.885
38	2020.955	1.477	1.839	0.863
39	1021.532	-0.058	2.885	0.947

Datasheet for AFR habitat use prediction

Note: Not all rows presented due to limitation in space and data confidentiality.