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Population Estimation of Proboscis Monkey (*Nasalis larvatus*) in Sarawak, Malaysia

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Population Estimation of Proboscis Monkey (*Nasalis larvatus*) in Sarawak, Malaysia

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DECLARATION

I hereby declare that this dissertation is entirely my original work except for quotations and citations which have been dully acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.



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ABSTRACT

A central practical problem in ecology is the estimation of population size. Last published report on the state-wide survey and population estimation of proboscis monkey (*Nasalis larvatus*) in Sarawak was in 1987. In this study, survey on proboscis monkey population has been conducted at eight selected sites in Sarawak to update the estimation of population size and density of this species. This study have successfully estimated the overall population based on the forest types surveyed which had not been taken into account in any previous studies of proboscis monkey before. Boat survey technique was applied in all survey sites except in Bako National Park within a period of 17 months, starting from April 2015 until August 2016. A cumulative total of 618.6 km of riverbank and 24.14 km of line transect was surveyed. Out of eight surveyed sites, two sites show no presence of proboscis monkey which were Ulu Sebuyau National Park and Rajang Mangrove National Park. A cumulative total of 860 individuals of proboscis monkey comprising of 105 groups was sighted from all surveyed sites. Three types of forests were identified from the eight surveyed sites where the proboscis monkeys were recorded which were mangrove forest, peat swamp forest and tropical heath forest with a sighted distribution of 527, 170 and 163 individuals, respectively. The total population estimation of proboscis monkey in all surveyed sites is 838 individuals. Maludam National Park recorded the highest population estimation with 432 individuals. This was followed by Bako National Park, Samunsam Wildlife Sanctuary, Kuching Wetland National Park, Kuala Lawas Forest Reserve and Limbang Mangrove National Park with estimated population size of 105, 98, 82, 77 and 44 individuals, respectively. The overall population estimation of proboscis monkey in Sarawak based on the data from three types of forests

surveyed was 9,778 individuals. In mangrove forest, the population of proboscis monkey was estimated to be 1,981 individuals with estimated population density of 1.25 individuals/km^2. In peat swamp forest, the population was estimated to be in the number of 6,174 individuals with estimated population density of 0.96 individuals/km^2. While in tropical heath forest, the population was estimated to be 1,623 individuals with 2.76 individuals/km^2 of estimated population density. There was no significant difference between the population density of proboscis monkeys and the forest types ($F = 0.607$, $df = 2$, $P = 0.568$). In addition, the population sizes of proboscis monkeys in different forest types also did not show any significant difference ($P = 0.353$). A comparisons of population estimates from different studies is complicated by their different method of analyses. A standard method of analysis, in lieu of using forest types in the estimation is needed, so that the population estimates and the changes in the population size of the proboscis monkeys can be systematically compared and monitored in the future.

Keywords: Sarawak, proboscis monkey, estimation, population size, population density.

Anggaran Populasi Monyet Belanda* (Nasalis larvatus*) di Sarawak, Malaysia

ABSTRAK

*Masalah praktikal utama dalam ekologi ialah anggaran saiz populasi. Laporan terakhir yang diterbitkan mengenai survei negeri dan anggaran populasi monyet belanda (*Nasalis larvatus*) di Sarawak adalah pada tahun 1987. Dalam kajian ini, survei tentang populasi monyet balanda telah dijalankan di lapan tapak terpilih di Sarawak untuk mengemaskini anggaran saiz populasi dan kepadatan populasi spesis ini. Kajian ini telah berjaya menganggarkan populasi keseluruhan berdasarkan jenis hutan yang disurvei yang tidak diambil kira dalam kajian monyet belanda sebelumnya. Teknik bot survei telah digunapakai di semua tapak survei kecuali di Taman Negara Bako dalam tempoh 17 bulan, bermula dari April 2015 hingga Ogos 2016. Sejumlah kumulatif 618.6 km tebing sungai dan 24.14 km transek talian telah disurvei. Daripada lapan tapak yang disurvei, dua tapak menunjukkan tiada kehadiran monyet belanda iaitu Taman Negara Ulu Sebuyau dan Taman Negara Paya Bakau Rajang. Jumlah kumulatif monyet balanda yang dilihat adalah 860 individu terdiri daripada 105 kumpulan daripada semua tapak yang disurvei. Tiga jenis hutan telah dikenalpasti dari semua tapak yang disurvei di mana monyet belanda direkodkan iaitu hutan paya bakau, hutan paya gambut dan hutan kerangas dengan pengedaran sebanyak 527, 170 dan 163 individu, masing-masing. Jumlah anggaran populasi monyet belanda di semua tapak yang disurvei adalah 838 individu. Taman Negara Maludam mencatatkan anggaran populasi tertinggi dengan 432 individu diikuti Taman Negara Bako, Santuari Hidupan Liar Samunsam, Taman Negara Wetland Kuching, Hutan Simpan Kuala Lawas dan Taman Negara Paya Bakau Limbang dengan*

anggaran populasi 105, 98, 82, 77 dan 44 individu, masing-masing. Anggaran keseluruhan populasi monyet belanda di Sarawak berdasarkan data dari tiga jenis hutan yang disurvei adalah 9,778 individu. Di hutan paya bakau, populasi monyet belanda dianggarkan 1,981 individu dengan anggaran kepadatan populasi 1.25 individu/km^2. Di hutan paya gambut, populasi dianggarkan berjumlah 6,174 individu dengan kepadatan populasi 0.96 individu/km^2. Sementara di hutan kerangas, populasi dianggarkan 1,623 individu dengan kepadatan populasi 2.76 individu/km^2. Tiada perbezaan yang signifikan antara kepadatan populasi monyet belanda dan jenis hutan ($F = 0.607$, $dk = 2$, $P = 0.568$). Di samping itu, saiz population monyet belanda di jenis hutan yang berbeza juga tidak menunjukkan perbezaan yang signifikan ($P = 0.353$). Perbandingan anggaran populasi monyet belanda dari kajian yang berlainan penuh dengan komplikasi disebabkan perbezaan kaedah analisis. Satu kaedah analisis yang standart, sebagai ganti dengan menggunakan jenis hutan dalam anggaran populasi diperlukan, supaya anggaran populasi dan perubahan saiz populasi monyet belanda dapat dibandingkan dan dipantau secara sistematik pada masa akan datang.

Kata kunci: *Sarawak, monyet belanda, anggaran, saiz populasi, kepadatan populasi.*

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TABLE OF CONTENTS

		Page
DECLARATION		i
ACKNOWLEDGEMENT		ii
ABSTRACT		iv
ABSTRAK		vi
TABLE OF CONTENTS		viii
LIST OF TABLES		xii
LIST OF FIGURES		xiv
ABBREVIATIONS		xvi
CHAPTER 1: INTRODUCTION		1
1.1	General Introduction	1
1.2	Problem Statement	4
1.3	Objectives of Study	5
1.4	Hypothesis	5
CHAPTER 2: LITERATURE REVIEW		7
2.1	Morphology of Proboscis Monkey	7
2.2	General Biology and Ecology of Proboscis Monkey	8
	2.2.1 Ranging Behaviour	8
	2.2.2 Feeding Behaviour	10
2.3	Sleeping Site Selection	11
2.4	Social Organisation	13
2.5	Previous Survey and Estimation of Proboscis Monkey	14
2.6	Modelling Population Viability of Proboscis Monkey	17

CHAPTER 3: MATERIAL AND METHOD 19

3.1 Survey Sites 19

3.2 Survey Site Characteristic and Survey Route 21

3.2.1 Samunsam Wildlife Sanctuary 21

3.2.2 Kuching Wetland National Park 22

3.2.3 Bako National Park 23

3.2.4 Ulu Sebuyau National Park 25

3.2.5 Maludam National Park 26

3.2.6 Rajang Mangrove National Park 27

3.2.7 Limbang Mangrove National Park 28

3.2.8 Kuala Lawas Forest Reserve 29

3.3 Boat Survey and Line Transect Survey 30

3.4 Data Analysis 33

3.4.1 Population Density Estimation 33

3.4.2 Population Size Estimation 34

3.4.3 Overall Population Estimation for Whole Area of Sarawak 35

3.5 Vegetation Map and Forest Area Measurement 38

CHAPTER 4: RESULTS 39

4.1 Population Estimation 39

4.1.1 Samunsam Wildlife Sanctuary 39

4.1.2 Kuching Wetland National Park 42

4.1.3 Bako National Park 45

4.1.4 Ulu Sebuyau National Park 48

4.1.5 Maludam National Park 50

4.1.6 Rajang Mangrove National Park 53

4.1.7 Limbang Mangrove National Park 54

4.1.8 Kuala Lawas Forest Reserve 57

4.2 Population Estimation of Proboscis Monkey in Sarawak 60

CHAPTER 5: DISCUSSION 65

5.1 Past and Present Estimation 65

5.2 Population Estimation in Survey Sites and Different Forest Types 67

5.3 Survey Technique Applied 71

5.4 Survey in Bako National Park 72

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS 74

6.1 Conclusion 74

6.2 Recommendation 75

REFERENCES 76

APPENDICES 84

LIST OF TABLES

		Page
Table 3.1	List of surveyed sites with map point, study area (division), area size, forest type, GPS coordinates and survey date (duration).	20
Table 4.1	Area distribution of vegetation in SWS.	39
Table 4.2	Estimated population size of proboscis monkey in SWS.	41
Table 4.3	Area distribution of vegetation in KWNP.	43
Table 4.4	Estimated population size of proboscis monkey in KWNP.	44
Table 4.5	Area distribution of vegetation in BNP.	45
Table 4.6	Estimated population size of proboscis monkey in BNP.	47
Table 4.7	Area distribution of vegetation in USNP.	48
Table 4.8	Area distribution of vegetation in MNP.	51
Table 4.9	Estimated population size of proboscis monkey in MNP.	52
Table 4.10	Area distribution of vegetation in RMNP.	53
Table 4.11	Area distribution of vegetation in LMNP.	54
Table 4.12	Estimated population size of proboscis monkey in LMNP.	56
Table 4.13	Area distribution of vegetation in KLFR.	57
Table 4.14	Estimated population size of proboscis monkey in KLFR.	59
Table 4.15	Estimated population size of proboscis monkey at various localities in Sarawak.	61
Table 4.16	Estimated population size of proboscis monkey at various vegetations in Sarawak	63
Table 4.17	Area distribution of vegetation in Sarawak.	64

LIST OF FIGURES

		Page
Figure 3.1	Map of Sarawak showing survey areas. 1= SWS, 2= KWNP, 3= BNP, 4 = USNP, 5= MNP, 6= RMNP, 7= LMNP, 8= KLFR.	19
Figure 3.2	Survey route in SWS (source: Google Earth Pro 7.1.8.3036).	22
Figure 3.3	Survey route in KWNP (source: Google Earth Pro 7.1.8.3036).	23
Figure 3.4	Survey route in BNP (source: Google Earth Pro 7.1.8.3036).	24
Figure 3.5	Survey route in USNP (source: Google Earth Pro 7.1.8.3036).	25
Figure 3.6	Survey route in MNP (source: Google Earth Pro 7.1.8.3036).	27
Figure 3.7	Survey route in RMNP (source: Google Earth Pro 7.1.8.3036).	28
Figure 3.8	Survey route in LMNP (source: Google Earth Pro 7.1.8.3036).	29
Figure 3.9	Survey route in KLFR (source: Google Earth Pro 7.1.8.3036).	30
Figure 3.10	Flow chart summarising the steps in population estimation analysis of proboscis monkey in Sarawak.	37
Figure 4.1	Map showing vegetation types in SWS.	40
Figure 4.2	Map showing vegetation types in KWNP.	42
Figure 4.3	Map showing vegetation types in BNP.	46
Figure 4.4	Map showing vegetation types in USNP.	49
Figure 4.5	*Kumpai* grass (*Panicum* sp.) blocked the entire river in USNP.	49
Figure 4.6	Map showing vegetation types in MNP.	50
Figure 4.7	Map showing vegetation types in RMNP.	53
Figure 4.8	Map showing vegetation types of LMNP.	55
Figure 4.9	Map showing vegetation types in KLFR.	58
Figure 4.10	Map of vegetation in Sarawak	64

LIST OF ABBREVIATIONS

BNP	Bako National Park
ca.	Circa
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
groups/km	Groups per kilometre
groups/km^2	Groups per squared kilometre
Ha	Hectare
individuals/km	Individuals per kilometre
individuals/km^2	Individuals per square kilometre
IUCN	International Union for Conservation of Nature
Kg	Kilogram
Km	Kilometre
km^2	Square kilometre
KLFR	Kuala Lawas Forest Reserve
KWNP	Kuching Wetland National Park
LMNP	Limbang Mangrove National Park
MF	Mangrove forest
MNP	Maludam National Park
PSF	Peat swamp forest
PVA	Population Viability Analysis
RMNP	Rajang Mangrove National Park
SWS	Samunsam Wildlife Sanctuary
THF	Tropical heath forest
USNP	Ulu Sebuyau National Park

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Endemic to the island of Borneo, proboscis monkey (*Nasalis larvatus*) is a large and sexually dimorphic primate from subfamily Colobinae (Bennett and Gombek, 1993). There is no fossil evidence showing proboscis monkey had occurred elsewhere other than in Borneo (Harcourt and Schwartz, 2001; Harrison *et al.*, 2006; Payne and Francis, 2007). Proboscis monkey is distinctive from other primates due its large, red and protruding nose. Within the subfamily Colobinae, proboscis monkey is categorised into the odd nosed monkey group where, none possess similar trait with proboscis monkey (Bennett and Gombek, 1993). They are known to be the largest colobine monkey and the sole member from the genus *Nasalis* (Napier and Napier, 1967; Medway, 1977; Wolfheim, 1983).

The natural habitats of proboscis monkey are restricted to the lowland coastal rainforests including mangroves, riverine, peat and fresh water swamp forest that is always associated with waterways (Kawabe and Mano, 1972; Salter *et al.*, 1985; Bennett and Gombek, 1993; Meijaard and Nijman, 2000). Mangrove trees are the main features in the habitat where the trees are used for resting and sleeping, while the leaves serve as their food (Kawabe and Mano, 1972). During the day, it will forage inland normally less than 1 km away from the riverbank and always return before dusk to sleep (Salter *et al.*, 1985; Bennett and Sebastian, 1988; Yeager, 1989; Matsuda *et. al.*, 2008). Proboscis monkey has their own flexible social structure, for instance one-male with multi-female groups or all-male groups

(Bennett and Sebastian, 1988). Within several groups, a secondary level of social organisation may occur where they may travel and sleep together in close proximity (Boonratana, 2002).

The proboscis monkey is protected by law throughout its range. In Sarawak, proboscis monkey is classified as a totally protected species under the Sarawak Wildlife Protection Ordinance 1988. This primate is classified as endangered in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2017). In the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), this animal is listed in Appendix I. In the year of 2000, the status of this primate was changed from 'vulnerable' to 'endangered' (Meijaard *et al.*, 2008). The combination of hunting, degradation of their habitats by the cause of logging and conversion into agricultural land were identified as the major impact of the declining population of this primate (Meijaard and Nijman, 2000).

In Kalimantan, Indonesia, there are huge differences on the estimations of population size of proboscis monkey. Based on the estimation by MacKinnon (1987), there are more than 250,000 individuals of proboscis monkey within Kalimantan and ca. 25,000 of them are live in protected areas. Yeager and Blondal (1992) suggested that there are less than 5,000 individuals of proboscis monkey reserve in the protected area. Manansang *et al.* (2005) however suggested that the population of proboscis monkey in the Central, West and East Kalimantan was 9,200 individuals. Proboscis monkey population in Kalimantan found to be more widely distributed compared to other regions in Borneo (Meijaard and Nijman, 2000).

In Sabah, based on the state-wide survey of proboscis monkey, the population were estimated to be at least 2,000 individuals (Davies and Payne, 1982). A more recent survey conducted by Sha *et al.* (2008) found that the population was higher than that of recorded previously. The minimum of proboscis monkey population in Sabah were thought to be 5,907 individuals. Population of proboscis monkey in Sabah were found to be highly fragmented with only five major centres of continuous distribution and numerous small isolated populations along the major coastal river of Sabah including Klias Peninsula, Tankarason, Paitan, Sugut, Beluran, Sandakan, Kinabatangan, Segama River, Lahad Datu, Semporna Peninsula and Tawau Bay.

In contrast, the population of proboscis monkey in Sarawak was estimated to be less than 2,000 individuals (Salter and MacKenzie, 1985). A survey by Bennett *et al.* (1987) estimated that the population of proboscis monkey in Sarawak was less than 1,000 individuals. The distributions of proboscis monkey in Sarawak were widely distributed with a huge fragmentation, concentrated at the western part of the state (Salter and MacKenzie, 1985). In Brunei, the population size of proboscis monkey in Brunei Bay was estimated to be less than 300 individuals (Bennett, 1986). However, the population in Brunei Bay is homogenous with the population in Sarawak since it is located between the two divisions of Sarawak, which are Limbang and Lawas. The exact population of proboscis monkey in Brunei Bay were difficult to determine since they are known crossing into Sarawak.

1.2 Problem Statement

There are only a few localities where proboscis monkey are known to occur in Sarawak including Bako National Park, Kuching Wetland National Park, Samunsam Wildlife Sanctuary, Maludam National Park, Limbang Mangrove National Park and Kuala Lawas Forest Reserve. Based on previous studies of proboscis monkey in Sarawak, most were focused on their behaviour and ecology (Salter *et al.*, 1985; Bennett and Sebastian, 1988; Onuma, 2002; Tuen and Pandong, 2007; Pang *et al.*, 2007; Matsuda *et al.*, 2008; Kombi and Abdullah, 2013). Only a few studies have been conducted to estimates their population. Moreover, the estimations were always conducted in localities where proboscis monkey are well established, such as in Bako National Park and Samunsam Wildlife Sanctuary (Brundell *et al.*, 1990; Zaini *et. al.*, 2004; Tuen and Pandong, 2007). A central practical problem in ecology is the estimation of population size (Krebs, 1989). However, this basic information has been ignored in the past, even though the population of proboscis monkey are known to be declining (Chapman and Peres, 2001; Fuller *et al.*, 2004). Till presently, the status of the proboscis monkey in Sarawak still depending on previous data (Salter and MacKenzie, 1985; Bennett *et al.*, 1987). Even though these estimates are known to be out-dated, they are still being cited until today. A population and habitat viability assessment in Indonesia by Manansang *et al.* (2005) was first planned to cover the population of proboscis monkey for the entire range. However, basic data to draw up an accurate range maps and estimate population numbers were insufficient particularly for Malaysia Borneo. Without such information, it is impossible to formulate conservation plan to ensure the survival of proboscis monkey. In this study, a comprehensive and systematic state-wide survey of proboscis monkey population was

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conducted in Sarawak to estimate the population density and population size. The population estimation in this study were analysed based on the type of forests where the proboscis monkey were recorded. Data of the estimation population density from each site were then extrapolated and being used as a representative data to estimate the population of proboscis monkey in each forest type surveyed. There are several assumptions need to be considered in this study. First, all the proboscis monkeys individuals have the same probability for being sighted due to the one-way of survey. Second, all proboscis monkeys individuals within 100 m radius were assumed to be in the same group. Third, the acreage of the forest types from the mapping analysis is considered to be accurate. Lastly, proboscis monkeys in Sarawak is assumed to inhabit only in mangrove, peat swamp and tropical heath forests. This study is important to provide a reliable and updated data in order to access the actual status of the current population of proboscis monkey in Sarawak.

1.3 Objectives of Study

The objectives of this study are:

i. To estimate the current population density of proboscis monkey in Sarawak.

ii. To estimate the current population size of proboscis monkey in Sarawak.

1.4 Hypothesis

H_{O1}: There is no significant difference between the population densities of proboscis monkeys in different forest types.

H_{A1}: There is significant difference between the population densities of proboscis monkey in different forest types.

H_{O2}: There is no significant difference between the population sizes of proboscis monkey in different forest types.

H_{A2}: There is significant difference between the population densities of proboscis monkey in different forest types.

CHAPTER 2

LITERATURE REVIEW

2.1 Morphology of Proboscis Monkey

In the island of Borneo, there are three political divisions, which are bounded by Malaysia (Sabah and Sarawak), Brunei and Indonesia (Kalimantan). Different communities in Borneo named proboscis monkeys differently. In Sarawak, Dayak communities call proboscis monkey as *Rasong* while Malay community calls it as *Orang Belanda* or *Monyet Belanda* (Zaini *et al.*, 2004). Communities in Sabah always known proboscis monkey as *Bayau.* While in Kalimantan, proboscis monkey are often known as *Benkantan* (Zaini *et al.*, 2004).

Proboscis monkey possess a high degree of sexual dimorphism (Bennett, 1986). Between male and female, there are several obvious differences in the morphological appearance. Adult male proboscis monkey larger than female with an average of 20-24 kg while female is lighter than the male with an average half of the male weight, which is about 10-12 kg (Bennett and Gombek, 1993; Phillipps and Phillipps, 2016). An adult male proboscis monkey can be easily identified by a large and pendulous nose. However, an adult female proboscis monkey has smaller and pointed nose. In both sexes, proboscis monkey has reddish-brown fur but male display more striking colour with much thicker, darker mane of hair across their back and have a darker cap on top of their head (Bennett and Gombek, 1993). In both sexes, proboscis monkey have a pair of webbed hind feet, which are likely to aid in swimming and walking on mangrove mud (Harding, 2015). An infant proboscis

monkey is normally born with a dark brown fur and its face is covered with dark blue colour and which begin to disappear as they grow (Bennett and Gombek, 1993; Phillipps and Phillipps, 2016).

Bennett and Sebastian (1988) categorised the age of proboscis monkey into seven classes based on their morphology. An adult male is recognized by the full body size with fully developed nose and their mane hair across back. Sub adult male were categorized with a male proboscis monkey that possess more than 75 % body size of an adult male without fully developed nosed. While adult female were recognized by their body size and the sub adult female possess more than 75 % body size of adult female proboscis monkey. Furthermore, juveniles have body size less than 75 % of adult with no dark coloured on face. Infant were divided into two categories, which are infant I and infant II. Infant I have possess dark brown fur with dark-coloured face and infant II have at least some dark face.

2.2 General Biology and Ecology of Proboscis Monkey

2.2.1 Ranging Behaviour

Home range is defined as the measurement of an area used by an individual or a group during a specific period of time (Boonratana, 1993). The ranging behaviour of proboscis monkey is always associated with many environmental factors. In the case of proboscis monkey, the distribution and abundance of food trees are considered as the major factor that influences the changes in ranging behaviour of proboscis monkey (Matsuda *et al.*, 2008). Besides, ranging behaviour of proboscis monkey was also affected by the water

tidal and seasonal change (Tuen and Pandong, 2007). Riverbank is the core home range for proboscis monkey since it will return to riverside every evening to sleep (Bennett, 1986).

A study by Matsuda *et al.* (2009) on the population of proboscis monkey in Menanggul River at Sabah, revealed that the home range was less than 800 m from the riverbank within a total range of 138.3 ha. The daily range of the groups of proboscis monkey in the area were ranged from 220 m to 1734 m with a mean of 799m. Vegetation survey in 2.15 ha area of 200-500 m of trails in riverine forest conducted found that, during the fruit-abundant season proboscis monkey used smaller range.

Boonratana (2000) in the study at Kinabatangan River, suggested that proboscis monkey is a non-territorial animal. Different groups of proboscis monkey are found to be overlap with one another in their home range use. They are frequently observed to use the same area, sleeping in the same trees, utilise the same food source and travelling in the same route. Based on observation in two sites in Sukau and Abai, the home range size were found to be 220.5 ha and 315 ha, respectively. The perpendicular distance travelled by the proboscis monkey in Sukau was varied with a mean of 910 m from the riverbank. However, the maximum distance of proboscis monkey travelled in Abai found to be shorter with 350 m perpendicularly from the riverbank. The difference in the home range size in Sukau and Abai were suggested due to the different in the type of habitat, which are riverine and mangrove forest, respectively. Higher food availability in Sukau probably is the reason of these differences (Boonratana, 1993).

In another study, Salter *et al.* (1985) surveyed the proboscis monkey ranging behaviour in Samunsam Wildlife Sanctuary. During the survey, maximum number proboscis monkey was found early at the riverside, moving away from the riverside in the morning and return to the riverside to sleep in the evening. The mean distance from the riverside were higher during the day and decreasing as the day approaching evening. During the survey, four groups were trailed on foot for the entire daylight periods and the maximum of the total distance travelled by the proboscis monkey recorded was 1,550 m with a mean of 1,312 m. The maximum perpendicular distance where proboscis monkey travelled from the riverbank was 750 m.

2.2.2 Feeding Behaviour

Proboscis monkey are folivores and frugivores animals (Bennett and Sebastian, 1988; Yeager, 1989). Colobines are characteristically different from other monkey by its enormous stomach. This enormous stomach comprised of several compartment that allows proboscis monkey to digest cellulose which are the main structure of leaves and also the main diet of proboscis monkey (Bauchop and Martucci, 1968; Hladik, 1977; Bauchop, 1978; Bennett and Gombek, 1993).

Previously, study on feeding ecology of proboscis monkey, mangrove leaves always suggested as their primary food (Kawabe and Mano, 1972). However, a recent study shows that the diet of proboscis monkey is actually more diverse than it is expected. There are reports where proboscis monkey consumed non-sweet fruits, flower and seeds (Salter *et al.*, 1985; Bennett and Sebastian, 1988; Yeager, 1989).

In addition, study by Kombi and Abdullah (2013) shows that, the diet of proboscis monkey in Bako National Park has developed adaptive foraging strategy. Proboscis monkey in Bako National Park have changed their diet from mangrove edible plant species to mixed dipterocarp and beach forest species due to the depletion of mangrove in Teluk Assam. Proboscis monkey was recorded feed on sea hibiscus (*Hibiscus tiliaceus*), tapang (*Terminalia catappa*), pandan (*Pandanus utilis*), bintangor (*Calophyllum inophyllum*), bird nest fern (*Asplenium nidus*), putat (*Barringtonia asiatica*), fruit and soft part of the fronds of Nibung Palm (*Oncosperma tigillarium*) and other species.

2.3 Sleeping Site Selection

Most primates spend half of their lives at sleeping sites (Anderson, 1984). The selection of sleeping sites may affect their survival in the natural habitat (Reichard, 1998). The selection may influenced by various factors such as predation threat, risk of injury, intergroup social interactions, and proximity to food sources (Chapman, 1989; Chapman *et al.*, 1989; Reichard, 1998; Day and Elwood, 1999; Anderson, 2000). Primates usually select a tall and large trunked tree with dense vegetation on the ground as anti-predator mechanism especially from terrestrial predator (Cui *et al.*, 2006). The selection of tree with a tough and big crown branches reduce the risk of injury if fallen during windstorm and allow social contact between group members (Anderson, 1984; Anderson, 1998; Di Bitetti *et al.*, 2000). Day and Elwood (1999) suggested that, primate usually select sleeping trees that are close to their foraging sites to reduce travel costs to their food sources.

Bernard *et al.* (2011) suggested that the selection of sleeping trees by proboscis monkey is most likely influenced by the risk of predation or injury, social interaction and efficiency on locomotion. Observation on characteristics of the trees chosen by proboscis monkey were recorded in Garama and Klias River, Sabah. Based on the 16 night observation, the selection of sleeping trees were not based on the species of the tree but depends on the morphology characteristics of the trees itself. Proboscis monkey prefer trees that were closer to the riverbank with larger and taller trunk and greater number of branches. The distance of trees was less than 46 m from the riverbank.

However, Matsuda *et al.* (2008) suggested that the sleeping sites of proboscis monkey are always associated with the river crossing sites of proboscis monkey. Observation from May 2005 to May 2006 at Menanggul River, Kinabatangan found that proboscis monkey choose to cross the river at the location where the narrower distance between the longest tree branches extending over the river and the bank of river on each side. They choose location where they did not need to swim to cross the river. The sleeping sites were frequently recorded at the same location of their crossing sites as it may provide a good escape routes from the predator and were considered as one of their anti-predator mechanism.

Another study by Matsuda *et al.* (2010) provides information on the effect of water level on the sleeping site of proboscis monkey in Menanggul River, Kinabatangan, Sabah. Results from the observation during the flooded month shows that proboscis monkey do not sleep at the riverbank like usual when the forest floor are covered with more than 1 m of water depth for more than 700 m inland. The proboscis monkey was found to sleep

further inside the forest when this situation occurred. Matsuda *et al.* (2010) suggested that, the sleeping sites of the focal group were not influenced by the food availability since there is not much different during flooded and non-flooded month. Matsuda *et al.* (2008) suggested that their sleeping behaviour avoid or reduce terrestrial predator attack.

2.4 Social Organisation

The basic social unit of proboscis monkey is a harem group that consist of an adult male, several females and their offspring (Bennett and Sebastian, 1988). A harem group of proboscis monkey typically stable over time and more flexible compared to any other primates (Bennett and Gombek, 1993). Within several groups, a secondary level of social organisation called bands maybe formed where they may travel and sleep in close proximity together (Bennett and Sebastian, 1988). A young male is kicked out from the harem once it reaches an age that is old enough to fend itself either by living solitary or forming an all-male group (Bennett and Sebastian, 1988; Boonratana, 2002). However solitary males were rarely reported (Bennett and Sebastian 1988; Yeager, 1995; Boonratana, 2002; Murai, 2004). Size of a group of proboscis monkey reported typically in the range of 3-23 individuals and can form association within other groups up to 60 individuals (Bennett and Sebastian, 1988; Yeager, 1990; Yeager, 1991; Yeager, 1993).

Murai *et al.* (2007) reported transfer incidence of female proboscis monkey from their natal group to another group during the 32 months field observation in the tributary of Kinabatangan River, Sabah. The transfer involved of both adult female and sub adult female. When an adult female trying to shift to another group, the adult male of the natal

group will make an uttered sound without any physical attack. Adult female with an infant found to leave her son in all male group before she joined another group. While transfer of sub adult female always starts with copulation by mounted with the adult male in the group that she joined. Adult male of the natal groups did not show any threatened reaction with the transfer of an adult female to another group.

2.5 Previous Survey and Estimation

In the survey of proboscis monkey, boat survey method was widely used (Salter and MacKenzie, 1985; Bennett, 1986; Bernard and Hamzah, 2006; Tuen and Pandong, 2007; Sha *et al.*, 2008). This method involved a direct census on the proboscis monkey early in the morning and late evening where proboscis monkey is known to be by the riverside to sleep (Bennett, 1986). This method of survey has been accepted as the most accurate technique in the survey of proboscis monkey (Bennett and Sebastian, 1988; Rajanathan and Bennett, 1990; Boonratana, 1993; Rajanathan, 1995; Bernard, 1997; Goossens *et al.*, 2003).

Based on the survey by Bernard and Hamzah (2006) in Klias Peninsula, Sabah, the population size of proboscis monkey was estimated to be at least 65 groups with a total of 569 individuals. Population density in Klias Peninsula were estimated to be 0.5 groups/km^2 or 4.4 individuals/km^2. At least three replication of one way surveys were conducted in each survey route. Group of proboscis monkey were defined as all the individuals within 50 m to each other. The population size in this study was estimated as the highest number of counted individuals or groups in any of one of the survey trips. While the population

density was obtained by dividing the maximum number of individuals or groups of proboscis monkey with the estimated survey area. The estimated survey area was gained by multiplying the total length of the river surveyed with 500 m width perpendicular distance for each side of riverbank.

Sha *et al.* (2008) conducted a state-wide survey in Sabah. The survey recorded 5,907 individuals of proboscis monkey from 435 harem groups, 31 all male groups and 12 single male individuals. Survey site was selected based on the information gained from the questionnaire of the wildlife officer and knowledgeable local residents. The survey route was largely random and covered as much rivers as possible in every session. Due to the large survey effort, the surveyed were conducted only once in each survey route. River and tributaries that are close together were covered in the same survey session in order to reduce the probability of double counting individuals of proboscis monkey.

Survey by Bennett and Sebastian (1988) in Samunsam Wildlife Sanctuary resulted in the population estimation of 160 individuals within 12 groups including 30 individuals from all male groups and solo male. The population density was estimated at 2.63 individuals/km^2 and 0.22 groups/km^2. In this study, the population size was estimated by the direct count of the proboscis monkey encountered. While the population density was calculated by dividing directly the number of proboscis monkey with the total area of Samunsam Wildlife Sanctuary, which was 60 km^2 at that time. The survey was conducted for 16 month, so the proboscis monkey became habituated with the presence of the observer and the identification of proboscis monkey group can be made.

In another survey in Samunsam Wildlife Sanctuary by Tuen and Pandong (2007), estimate the population density as number of proboscis monkey sighted per kilometre surveyed. The cumulative total of proboscis monkey sighted during the six trips of survey was divided by the total distance of surveyed. In each survey trip, 8.7 km distance of river was surveyed. The total distance was calculated as the distance of surveyed times with the frequency of surveyed. Survey was done twice at different period to represent wet and dry season. In each period, six replication trips of survey were conducted. During the dry season, the population density was found to be 0.08 groups/km with 0.48 individuals/km. While during the wet season, the population density was 0.27 groups/km with 1.34 individuals/km.

Aziz *et al.* (2015) in their survey of proboscis monkey in Bako National Park suggested that the population size was 311 individuals with estimated population density of 1.13 individuals/km^2. Line transect method was used in this survey. This method involved a slow and quiet walking along the line transects. In every 50 m interval, the surrounding areas were visually scanned and any vocalisation made by the proboscis monkeys were carefully listened. Two trails covering an area of 182 ha were surveyed which are Telok Paku-Telok Delima Trails and Telok Paku-Bukit Tambi Trails. Any individuals within 50 m radius were considered as same group. One-way survey was conducted to prevent double counting of proboscis monkey groups or individuals

The status of the proboscis monkey in Sarawak was assessed during 1980-1981 by boat survey started on June 1980 (Salter and MacKenzie, 1985). The estimation was conducted based on the on total number of proboscis monkey individuals counted in the selected sites,

extrapolation of population density in mangrove vegetation and projection estimation from the surveyed area. Based on the extrapolation of the population density in the surveyed sites, the population of proboscis monkey at mangrove vegetation in Sarawak was estimated to be 680 individuals. The sum of the estimated population size of proboscis monkey from the survey area and the extrapolation data of the total mangrove area in Sarawak was estimated to be 946 individuals. After taking into account the remaining part of the unsurveyed area, the total population of proboscis monkey in Sarawak were assumed to be approximately of 2000 animals. In Samunsam Wildlife Sanctuary and Maludam River, the population size was estimated based of the maximum counts of the proboscis monkey individuals or groups. While the population density was estimated as per km^2 area. These areas were obtained by multiplying length of the survey river with 750 m of each side of the riverbank. Both riverbank were survey simultaneously if the width of the river was less than 250 m. Any individuals in the range of 100m to each other were considered as same groups. In Bako National Park, search for proboscis monkey were conducted intensively on foot along the existing trails and along the edge of mangrove vegetation. In four of the deltaic mangrove sites which are Sematan Mangrove, Rajang Delta, Limbang-Lawas Mangrove and Sarawak Mangrove Forest Reserve (now known as Kuching Wetland National Park), data of the population density were extrapolated to estimate the population size of proboscis monkey in the undisturbed mangrove vegetation in Sarawak.

2.6 Modelling Population Viability of Proboscis Monkey

Stark *et al.* (2012) conducted a modelling population viability analysis (PVA) of proboscis monkey populations in Sabah and Kalimantan. Three largest proboscis monkey

populations in Borneo were chosen to be analysed in the PVA, which are Lower Kinabatangan Wildlife Sanctuary, Balikpapan Bay and Danau Sentarum National Park. This model predicted that the Malaysian population of proboscis monkey in Sabah will remain stable even without any management. However, in Kalimantan Indonesia, the two populations under study were predicted to decrease more than half and the smallest population were estimated to be effectively extinct in 30 years. In Indonesia, fire had been identified as the greatest impact on the Indonesia populations.

Manansang *et al.* (2005) in the final report of the population viability analysis of proboscis monkey in Indonesia suggested that the number of proboscis monkey in Kalimantan are more than 10,000 individuals. The population are found to be entirely too small and highly isolated from each other. Unsustainable rate of deforestation, which was mainly illegal and forest fire due to anthropogenic activities had become the main threats towards the proboscis monkey in Kalimantan, Indonesia. To ensure the future survival of proboscis monkey, the current habitat destruction due to the illegal logging within the area was by reduced as low as 20 %.

CHAPTER 3

MATERIAL AND METHOD

3.1 Survey Sites

A total of eight sites were selected to be surveyed in the state of Sarawak. These sites include Samunsam Wildlife Sanctuary (SWS), Kuching Wetland National Park (KWNP), Bako National Park (BNP), Ulu Sebuyau National Park (USNP), Maludam National Park (MNP), Rajang Mangrove National Park (RMNP), Limbang Mangrove National Park (LMNP) and Kuala Lawas Forest Reserve (KLFR) (Figure 3.1). Surveys were made within a period of 17 months, starting from April 2015 until August 2016 (Table 3.1). The selection of survey sites was based on literatures and interviews were done with knowledgeable Sarawak Forestry Officers.



Figure 3.1: Map of Sarawak showing survey areas. 1= SWS, 2= KWNP, 3= BNP, 4 = USNP, 5= MNP, 6= RMNP, 7= LMNP, 8= KLFR.

Table 3.1: List of surveyed sites with map point, study area (division), area size, forest type, GPS coordinates and survey date (duration).

Map Point	Study Area (Division)	Study Site	Area Size (km^2)	*Forest Type	GPS Coordinate	Survey Date (Duration)
1	Kuching	Samunsam Wildlife Sanctuary	63.89	MF, THF	1°57'3.03"N 109°38'42.81"E	21-24 November 2015 (4 days)
2	Kuching	Kuching Wetland National Park	73.06	MF	1°40'24.96"N 110°14'39.40"E	30 September-2 October 2015, 11-13 January 2016 (6 days)
3	Kuching	Bako National Park	27.95	MF,THF	1°42'59.37"N 110°26'38.72"E	15-18 April 2015, 15-18 May 2015 (8 days)
4	Samarahan	Ulu Sebuyau National Park	182.20	PSF	1°24'12.42"N 110°59'23.04"E	15-16 October 2015 (2 days)
5	Sri Aman	Maludam National Park	420.78	PSF	1°36'6.18"N 111°4'6.49"E	27-29 February 2016 (3 days)
6	Sarikei	Rajang Mangrove National Park	100.84	MF	2°7'4.53"N 111°14'9.28"E	18-20 April 2016 (2 days)
7	Limbang	Limbang Mangrove National Park	43.53	MF	4°45'28.18"N 115°0'20.79"E	25-27 May 2016 (3 days)
8	Limbang	Kuala Lawas Forest Reserve	230.88	MF, PSF	4°56'30.23"N 115°23'47.01"E	3-6 August 2016 (4 days)

Note: Forest type was recorded based on the surveyed vegetation. MF= mangrove forest, PSF= peat swamp forest, THF= tropical heath forest.

3.2 Survey Site Characteristic and Survey Route

3.2.1 Samunsam Wildlife Sanctuary

SWS is located at the western tip of Sarawak (1°57'3.03"N 109°38'42.81"E). SWS was gazetted in 1979 and is the first wildlife sanctuary established in Sarawak. This sanctuary was established with the goal for the conservation of proboscis monkey. It covers an area of about 61 km^2 with four main forests types which are mangrove forest, riverine forest, tropical heath forest and mixed dipterocarp forest. The area is drained by the Samunsam River at the central of the sanctuary. This sanctuary is not open to visitors and requires a journey about two hours using boat from the jetty in the small town of Sematan.

During the four days survey period in SWS, a cumulative total of 83.19 km of riverbank was surveyed (Figure 3.2). In each trip, approximately 10.40 km of the river was surveyed, starting from the jetty near the river mouth of Samunsam River. This is the maximum distance that can be access during the survey due to the water tidal and short time frame of the survey. Many floating stumps along the river slower the surveys process since the boat had to move slowly to avoid collision. A cumulative total distance of 18.12 km and 65.08 km of mangrove and tropical heath forests riverbanks were surveyed. Tropical heath forest is the dominant vegetation in this sanctuary. Mangrove forest found to occur about 2 km upriver from the river mouth.



Figure 3.2: Survey route in SWS (source: Google Earth Pro 7.1.8.3036).

3.2.2 Kuching Wetland National Park

KWNP is located approximately 15 km from Kuching City at 1°40'24.96"N latitude 110°14'39.40"E longitude. Previously, this park is known as Sarawak Mangrove Forest Reserve before it gazetted in 2000 with a total area of about 6,610 ha. This park is predominantly covered by mangrove vegetation (ca.70 %). On November 2005, KWNP was listed as the first Ramsar site in Sarawak under the Ramsar Convention. KWNP is the only area in Sarawak that remains as refuge for mangrove flora and fauna (Bennett and Reynolds, 1993).

Approximately 128.91 km of mangrove riverbank was surveyed during the 6-days survey (Figure 3.3). In order to cover a large mangrove area in KWNP, the survey was designated into two parts. Each part, three days were allocated to allow at least six trips. During the

first part which is on 30 September–2 October 2015, the survey were covered the western part of the park mainly in Sungai Sibu Laut. The second part of survey was conducted on 11 January- 13 January 2016. At this time, survey covered the east part of the park, specifically along the Batang Salak.



Figure 3.3: Survey route in KWNP (source: Google Earth Pro 7.1.8.3036).

3.2.3 Bako National Park

BNP is located at Muara Tebas Peninsula, about 30 km from the Kuching City (1°42'59.37"N, 110°26'38.72"E). BNP was gazetted in 1957 with a total area of 2,727 ha and is the oldest national park in Sarawak. This park consists of at least seven types of vegetation namely, beach forest, cliff vegetation, mangrove forest, tropical heath forest (*kerangas* forest), mixed dipterocarp forest, open shrub land vegetation and peat swamp forest (Ashton, 1971; Hazebroek and Abang Kashim, 2006). With the diverse of vegetation that exist, BNP serve as a healthy habitat not only for the proboscis monkeys but also

forother 224 species coexist comprising of insecta, herpetofauna, aves and mammals (Zahidin *et al.*, 2016). The richness of the flora and fauna in this park make it as one of the most popular ecotourism attraction in Sarawak.

Survey in BNP was conducted in two trails, which are Teluk Asam-Teluk Paku Trails and Teluk Asam-Teluk Delima Trails. A cumulative total distance of 24.14 km of transect were surveyed during the six days survey period (Figure 3.4). This distance consists a distance of 5.24 km of mangrove forest and 18.90 km of tropical heath forest. Survey in BNP was divided into two part of period. On the first part, the survey was conducted along Teluk Assam-Teluk Delima Trails on 15-18 April 2015.While in the second part, the survey covered the trails along Teluk Assam-Teluk Delima that was conducted on 15-18 May 2015.



Figure 3.4: Survey route in BNP (source: Google Earth Pro 7.1.8.3036).

3.2.4 Ulu Sebuyau National Park

USNP located in Samarahan Division (1°24'12.42"N, 110°59'23.04"E). This park was gazetted on March 2010 with an area about 18,278 ha. Generally, USNP is predominantly covered by peat swamp forest. USNP is adjacent to Maludam National Park separated by the Batang (river) Lupar. There is no road access to USNP. Two-hour journey along Sebuyau River by using boat from the Sebuyau Town are needed to reach USNP. There are Iban villages adjacent to the river about 6 km from the Sebuyau Jetty. Two days of surveyed was conducted in USNP covered a cumulative total distance of 41.96 km riverbank. Survey was start at the base camp and finish at the both end point 1 and 2 (Figure 3.5).



Figure 3.5: Survey route in USNP (source: Google Earth Pro 7.1.8.3036).

3.2.5 Maludam National Park

MNP is located in Betong Division (1°36'6.18"N latitude 111°4'6.49"Elongitude). This park was gazetted in May 2000 with a total area of 43,147 ha where peat swamp forest is the main vegetation. MNP boundary covered almost the entire Maludam Peninsula that was confined by the Saribas and Lupar Rivers on the north and south, respectively. At the central of the park lies a small long river known as Maludam River. There are Malay villages and Iban longhouses that can be found around the river mouth of Maludam River.

Survey in MNP covered approximately 13.64 km of the Maludam River. The survey river were divided into two halves since the river that needs to be covered were too long to be surveyed within one trip (Figure 3.6). The condition of Maludam River that is about 50 m width, ease the surveyed processes but slower the movement of the boat. On the first halves, the survey covered about 7.94 km of Maludam River starting from the Park HQ to the Ranger Station. The second halves of the survey is the continuous of the first halves, starting from the Ranger Station to about 5.70 km inland of the Maludam River. A total of six and three series of survey were conducted on the first and second halves, respectively.



Figure 3.6: Survey route in MNP (source: Google Earth Pro 7.1.8.3036).

3.2.6 Rajang Mangrove National Park

This national park is located in Sarikei Division at the coordinate 2°7'4.53"N latitude 111°14'9.28"E longitude. This park was gazetted in August 2000 with a total area of 9,373 ha and predominantly occupied with mangrove forest. There are two ways to go to this park by either boat or plane since there is no accessible road and the land of this park is not interconnected with mainland. RMNP is situated at the busy waterway by cargo ships that anchored at the Tanjung Manis Port. Survey in RMNP covered a total distance of 88.24 km riverbank. All the tributaries were being surveyed (Figure 3.7).



Figure 3.7: Survey route in RMNP (source: Google Earth Pro 7.1.8.3036).

3.2.7 Limbang Mangrove National Park

Located at the Limbang Division, LMNP (4°47'51.21"N, 115°1'30.38"E) was gazetted on July 2013. This park covered an area of 4,360 ha with mangrove are the dominant vegetation. LMNP is surrounded by the developing area and villages around Limbang Town. This national park is just adjacent to the Limbang Airport. This park is also boundary with the State of Brunei which is bounded by the Limbang River.A total of 71.96 km of mangrove riverbank was surveyed within the three days survey period. Survey was focused on Sungai Limbang, around Pulau Limpaku Pinang, Sungai Rangau until Kampung Pati Ambun (Figure 3.8).



Figure 3.8: Survey route in LMNP (source: Google Earth Pro 7.1.8.3036).

3.2.8 Kuala Lawas Forest Reserve

KLFR is located about 15 km from Lawas Town (4°56'30.23"N latitude 115° 23'47.01"E longitude). Based on the record from Sarawak Forestry Department, the area of KLFR only covered the sea body. However, survey in this site was conducted in the land area in front of the sea body boundary of this forest reserve. This survey site was predominantly vegetated with mangrove forest and peat swamp forest with some of the areas were planted alternately with palm oil trees.

Based on the record from the Sarawak Forestry Department, KLFR only covered the water body that face to the land area in Kuala Lawas. The survey was conducted at the east side of Kuala Lawas until approaching boundary of Sabah. Survey in this site covered mostly the main river. Start from Bukit Sari, the survey through Merapok River until Kampung

Bankatan. On the western side, the survey covered along Sungai Murut near Pulau Perepat and through Kampung Labik Labik (Figure 3.9).

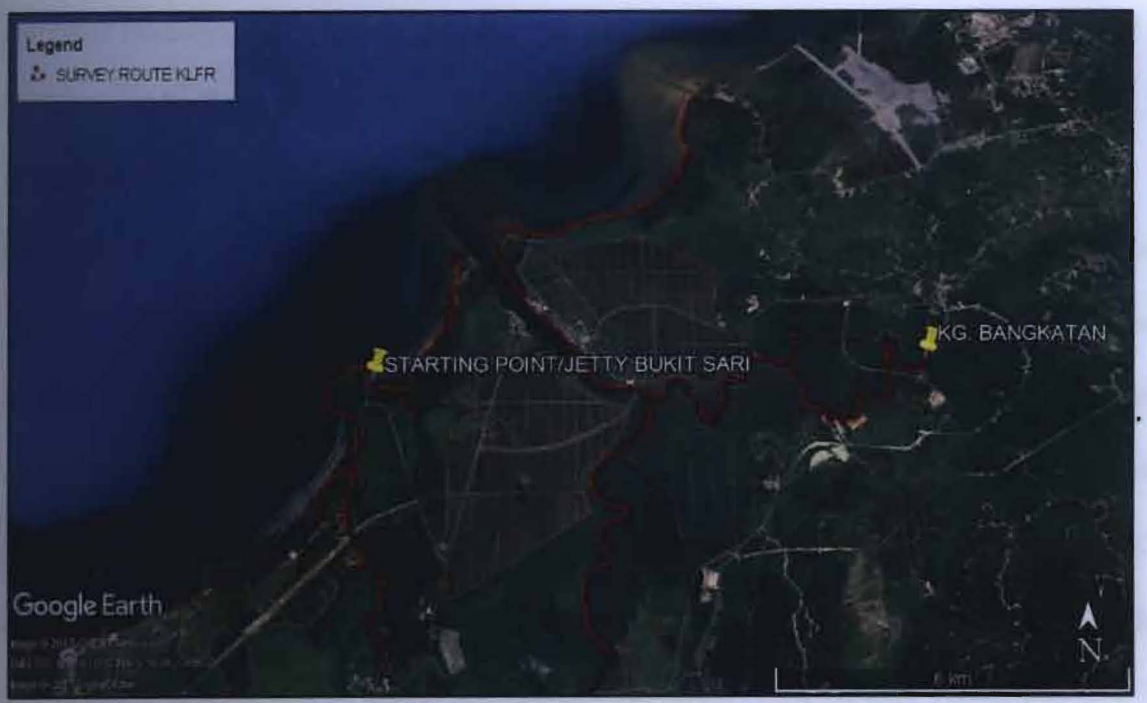


Figure 3.9: Survey route in KLFR (source: Google Earth Pro 7.1.8.3036).

3.3 Boat Survey and Line Transect Survey

Survey technique used in this study was following that of Bennett (1986). This survey involved a direct observation by using a boat observing at the riverbank in the morning and evening. This survey technique was widely used by other researchers and has been accepted as the most acceptable technique in the proboscis monkey survey (Bennett and Sebastian, 1988; Rajanathan and Bennett, 1990; Boonratana, 1993; Bernard, 1997; Goossens *et al.*, 2003; Tuen and Pandong, 2007). Boat survey technique was applied in all sites except in BNP. Survey was conducted two sessions per day; morning and evening session, depending on the dusk and dawn time of every survey sites. In the morning

session, the surveys start at dawn and finish about 90 minutes later. While in the evening sessions, the surveys were conducted 75-90 minutes before dusk. Surveys were conducted only within these limited periods of time, so as to adapt to the natural behaviour of proboscis monkeys that sleeps at the riverbank (Bennett, 1986; Payne and Francis, 2007; Phillipps and Phillipps, 2016).

Generally, in mangrove areas, the waterways are riddle with complex tributaries. It is virtually impossible to conduct the surveys in all tributaries. Surveys in this kind of waterway were focused on the main river and the nearest tributaries. In each trip, the survey was conducted at different parts of the area in order to covers as much areas as possible. For peat swamps and tropical heath forests, the waterway was normally drained by one main river. These surveys were divided into two part if the route were too long since there is limited time of survey for each survey trips. A cumulative distance of 618.6 km riverbank was surveyed in all sites except BNP. Both riverbanks were surveyed simultaneously if the river were less than 250 m in width. At least three replications of survey were conducted in every river parts. One-way surveys were conducted to prevent double counting of the proboscis monkey. At least two observers were involved in such survey trip.

When an individual or group of proboscis monkeys were sighted, the boat engine was switched off and paddled towards the location of the group or individual until its maximum flight zone which is usually about 50 m to avoid the proboscis monkey moving away from the location. Following Bennett and Sebastian (1988), the size of the group was recorded and classified into sex and age classes. The coordinate of each group were recorded by

using Geographic Positioning System (Garmin 64s). The vegetation type occupied by these groups were recorded following Hazebroek and Abang Kashim (2006), with the aids of the latest vegetation map obtained from the mapping analysis (sub-chapter 3.6). During the survey, a binocular (Bushnell 16x50) were used to provide a clearer sighting of proboscis monkey. Any individuals of proboscis monkey sighted within 100 m radius were considered as the same group (Bernad and Hamzah, 2006).

At BNP, the survey was conducted on foot followed as Aziz *et al.* (2015). Survey was conducted along the existing trails and at the edge of mangrove area since there is no representative waterway for river survey. The survey was focused on two trails, which are Teluk Asam-Teluk Paku Trails and Teluk Asam-Teluk Delima Trails. These two trails are known with the existence of proboscis monkey based on the interviews with the park rangers in BNP. Survey in BNP involved a slow and quiet walking along the surveyed trails. In every 50 m interval of transect, the surrounding areas were visually scanned and any vocalisation made by the proboscis monkey were carefully listened. A cumulative distance of 24.14 km of line transect survey was conducted during the six days survey period. This distance was calculated for both sides of transects surveyed consist a distance of 5.24 km and 18.90 km of mangrove forest and tropical heath forest, respectively. In this kind of survey, same data was collected as the data that were collected during the boat survey.

3.4 Data Analysis

3.4.1 Population Density Estimation

The population density of proboscis monkey at each surveyed sites was estimated for every forest type surveyed. Estimated population density was calculated by dividing the cumulative total number of proboscis monkeys sighted in each particular forest type surveyed with the total surveyed area of the forest type respectively. The total surveyed area is the length of the riverbank of that particular forest type surveyed multiplied with 0.75 km perpendicular distance from the riverbank. The formulas used are as the following:

$$Population\ density = \frac{Cumulative\ total\ number\ of\ individual\ sighted}{Total\ surveyed\ area\ (sq\ km)} \quad (1)$$

$$Total\ surveyed\ area = length\ of\ riverbank\ surveyed\ (km) \times 0.75\ km \quad (2)$$

In order to conduct a study on the estimation population density of proboscis monkey, the information on the home range size of the animals are needed (Bernard and Hamzah, 2006). However, this kind of information need a long-term observation, which is not be able to be conducted in this study. Thus, 0.75 km perpendicular distance from the riverbank was applied in the analysis of the population density, to estimate the surveyed area used by the proboscis monkeys in the surveyed sites. The distance of 0.75 km was taken as the maximum perpendicular distance from the riverbank where the proboscis monkeys might travel from their sleeping sites. This figure was first proposed by

Nightingale (1981), which was supported by Salter *et al.* (1985) in their study of the ranging behaviour of proboscis monkeys in SWS and BNP.

Other studies utilised a different ranging distance of 0.50 km in their estimation analysis of population density in Klias Peninsula, Sabah, which were also based on previous literatures (Bernard and Hamzah, 2006; Ali *et al.*, 2009). Since the actual home range of proboscis monkeys is not available for each surveyed sites, the distance of 0.75 km was applied in the analysis of this study to standardise the ranging distance used by the proboscis monkeys in each surveyed site. Besides, this is the closest and available ranging distance that was recorded in Sarawak. In addition, this ranging distance is acceptable since it is still in the range of the daily movement of proboscis monkeys that had been reported which is less than 1 km from the riverbank (Medway, 1977; Salter and MacKenzie, 1985; Bennett and Sebastian, 1988; Yeager, 1991; Boonratana, 2000; Meijaard and Nijman, 2000; Matsuda, 2008; Bismark, 2010).

3.4.2 Population Size Estimation

The analysis in the estimated population size of proboscis monkey in each site were correlated with the results of the estimated population density obtained. The estimated population density of the particular forest type was multiplied with the total area of the respective forest type to obtain the estimated population size of proboscis monkey in that particular forest type. Overall estimated population size of proboscis monkey in the each surveyed site was obtained by totalling up the estimated population size from each forest type. The formulas used are as the following:

$$Population\ size = Population\ density \times total\ area\ forest\ (km^2) \quad (3)$$

$$Cumulative\ population\ size = \sum Population\ sizes\ of\ all\ surveyed\ forest \quad (4)$$

3.4.3 Overall Population Estimation for Whole Area of Sarawak

The overall population estimation of proboscis monkeys for the whole area of Sarawak was derived from the projection of the estimated population density of every forest types surveyed. Results of the estimated population size from each forest type from all surveyed sites were total up before dividing by the total area of the respective forest type from all surveyed site, to obtain the average population density of proboscis monkey in that particular forests type. The average population density was then extrapolated to the whole area of Sarawak by multiplying with the total area of the respective forest type in Sarawak, to obtain the population size estimate for that forest type for the whole area of Sarawak. Sum of the estimated population size from all forest type in Sarawak represent the total estimation of proboscis monkey in Sarawak. The flow chart of the steps of analysis of the population estimations is shown in Figure 3.10. The formulas used are as the following:

$$Population\ Estimation = \frac{\sum \alpha 1 + \alpha 2 + \alpha 3 + \cdots n}{\sum \beta 1 + \beta 2 + \beta 3 + \ldots n} \times Total\ forest\ area\ in\ Sarawak \quad (5)$$

Where:

$$a = estimated\ population\ size\ in\ respective\ forest\ type\ in\ each\ surveyed\ sites$$

$$\beta = total\ area\ of\ particular\ forest\ type\ from\ every\ surveyed\ sites$$

One-way Analysis of Variance (ANOVA) was applied to test for a relationship between population density of proboscis monkey and the forest types where the proboscis monkey were recorded. Meanwhile, Kruskal-Wallis Test was conducted to examine the differences on population size according to the types of forest. Statistical significant level was set at $\alpha = 0.05$. All tests were calculated using the Statistical Package for the Social Science (SPSS) software Version 21.0.

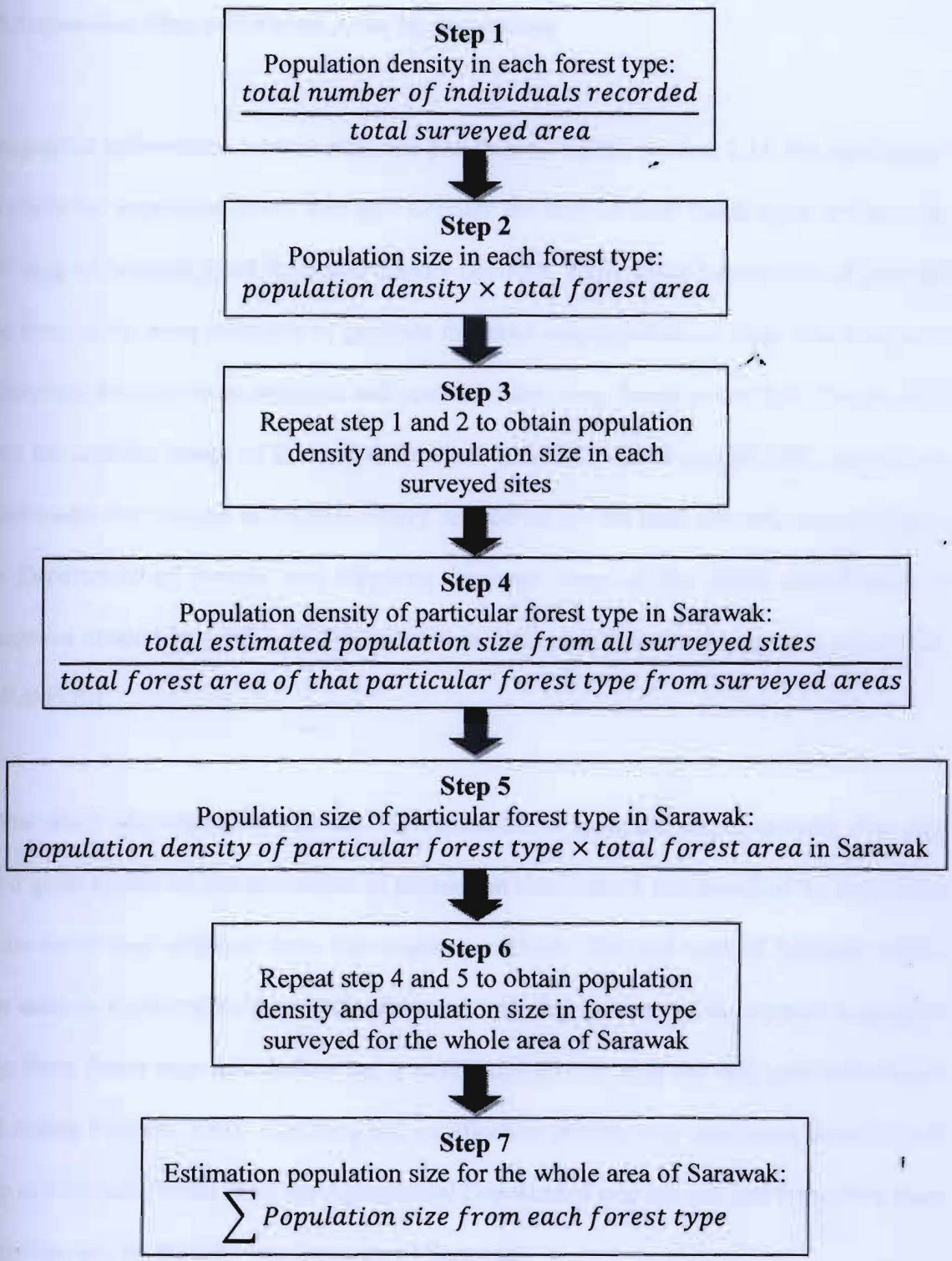


Figure 3.10: Flow chart summarising the steps in population estimation analysis of proboscis monkey in Sarawak.

3.5 Vegetation Map and Forest Area Measurement

Geographic Information System software programme (QGIS version 2.14.10) was used to illustrate the vegetation cover map and estimate the area of each forest types in Sarawak. Soil map of Sarawak 1968 from Soil Survey Division, Agriculture Department of Sarawak was used as the main reference to generate the latest vegetation cover map. The process of illustrating the map were rectified and updated with latest forest cover that was obtained from the satellite image of Landsat 8, Sentinel 2, MODIS 2016 and SRTM 1-arcsecond. Other maps that utilised as supplementary references are the land use map acquired from the Department of Survey and Mapping Sarawak, map of the global distribution of mangrove created by UNEP-WCMC-Global in 2011 and Sarawak topography map series DNMM5201.

In this study, the vegetation map and the estimation of areas are very important. The map has a great impact on the estimation of population size since it was based of the projection of the forest area obtained from this mapping analysis. The soil map of Sarawak (1968) was used as a referral in the rectification and updating process of the current vegetation map since forest type distribution has a strong correlation with the soil type (Hazebroek and Abang Kashim, 2006). Updating and rectification process was conducted since the soil map of Sarawak (1968) from the Agricultural Department was too old and there have been many changes on the land use scenarios of Sarawak.

CHAPTER 4

RESULTS

4.1 Population Estimation

4.1.1 Samunsam Wildlife Sanctuary

In SWS, a cumulative total 169 individuals of proboscis monkey within 19 groups was recorded. Out of the total individuals of proboscis monkey sighted in SWS, 60 of them were recorded in mangrove forest within eight groups while another 109 individuals were recorded in tropical heath forest within 11 groups (Appendix A). The area size of the mangrove and tropical heath forest in SWS were estimated at 1.10 km^2 and 41.56 km^2, respectively (Table 4.1; Figure 4.1). This resulted the population density of proboscis monkey in mangrove vegetation with an estimation of 4.42 individuals/km^2 or 0.59 groups/km^2. Meanwhile, in tropical heath forest, the population density was estimated at 2.23 individuals/km^2 or 0.23 groups/km^2. The estimated population size of proboscis monkey for the whole reserve area was 98 individuals. The composition of the estimation in mangrove and tropical heath forest are 5 and 93 individuals, respectively (Table 4.2).

Table 4.1: Area distribution of vegetation in SWS.

Vegetation	Total area (km^2)	Percentage (%)
Tropical Heath	41.56	65.05
Lowland Mixed Dipterocarp	10.80	16.89
Mangrove	1.10	1.72
Open Shrubland	10.43	16.32
Riverine	0.017	0.03
Total	**63.89**	**100**

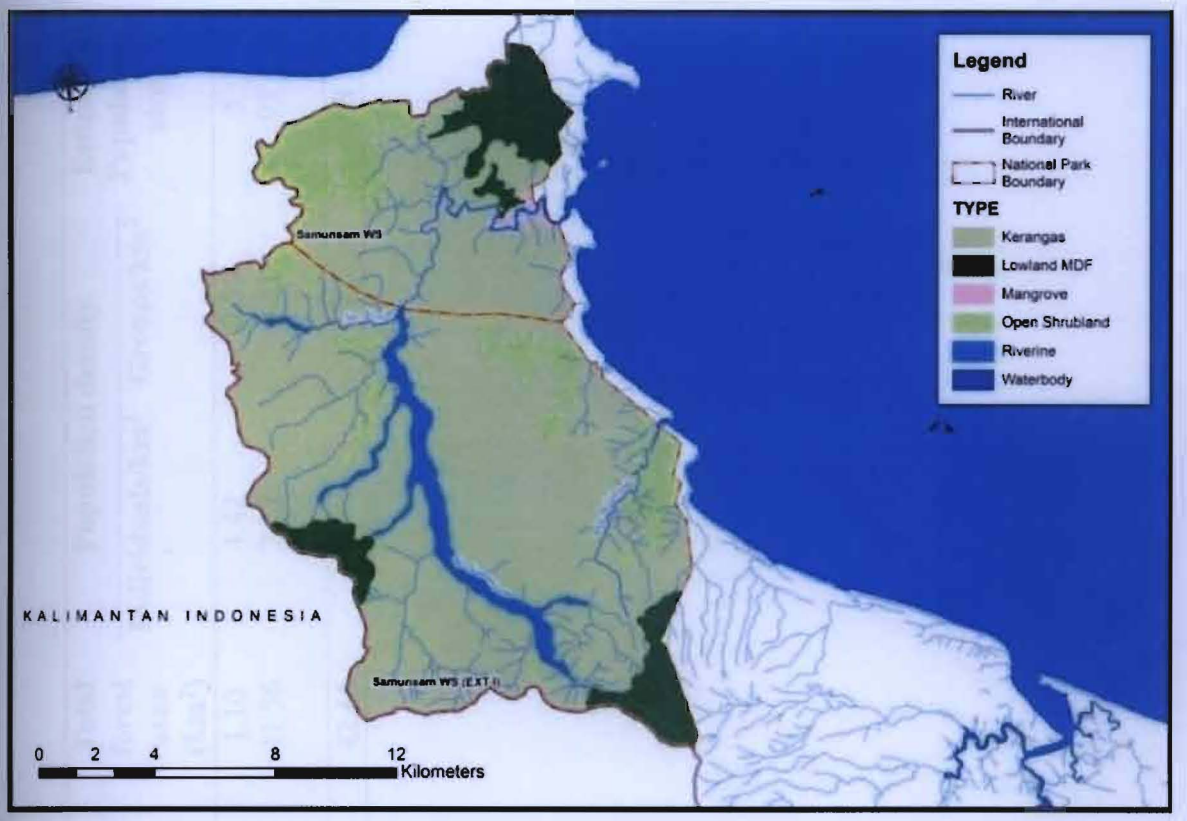


Figure 4.1: Map showing vegetation types in SWS.

Table 4.2: Estimated population size of proboscis monkey in SWS.

Vegetation Type	Number of individuals sighted	Number of groups sighted	Length of riverbank surveyed (km)	Total surveyed area (km^2)	Total forest area (km^2)	Population density		Estimated Population size
						Individuals/km^2	Groups/km^2	
Mangrove	60	8	18.12	13.59	1.10	4.42	0.59	5
Tropical Heath	109	11	65.08	48.81	41.56	2.23	0.23	93
Total	**169**	**19**	**83.19**	**62.39**	**42.65**	-	-	**98**

4.1.2 Kuching Wetland National Park

A cumulative total of 158 individuals from 19 groups and solitary males of proboscis monkey were recorded during the survey done in KWNP (Appendix B). The population size of the proboscis monkey in KWNP was estimated to be 82 individuals with estimated population density of 1.63 individuals/km^2 or 0.20 groups/km^2 (Table 4.4). All the proboscis monkeys were sighted only in mangrove vegetation since mangrove is the dominant vegetation with about 68 % covered of the whole area of this park (Figure 4.2; Table 4.3).

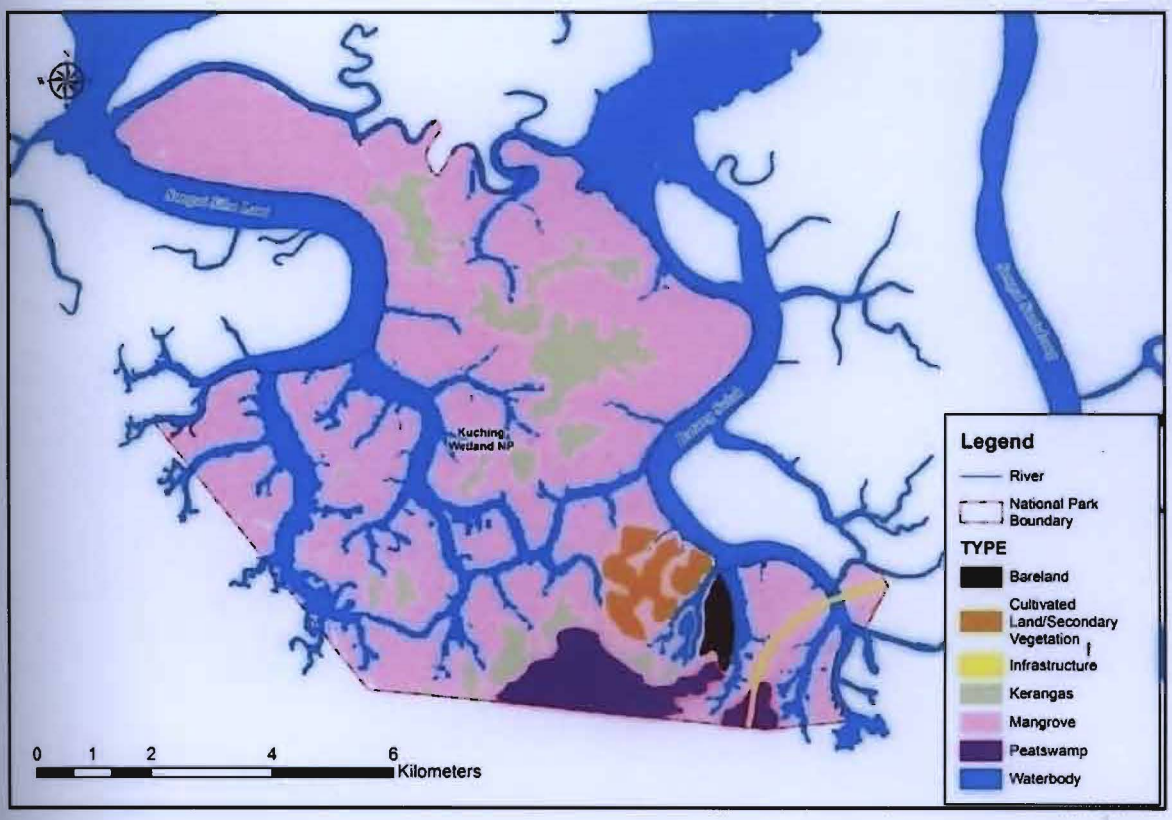


Figure 4.2: Map showing vegetation types in KWNP.

Table 4.3: Area distribution of vegetation in KWNP.

Vegetation Type	Total Area (km^2)	Percentage (%)
Bareland	0.60	0.82
Cultivated Land/Secondary Vegetation	1.61	2.20
Infrastructure/ HQ	0.37	0.50
Tropical Heath	7.47	10.23
Mangrove	49.97	68.40
Peat Swamp	3.04	4.17
Water body	10.00	13.68
Total	**73.06**	**100**

Table 4.4: Estimated population size of proboscis monkey in KWNP.

Vegetation type	Number of individuals sighted	Number of groups sighted	Length of riverbank surveyed (km)	Total surveyed area (km^2)	Total forest area (km^2)	Estimated population density		Estimated population size
						Individuals/km^2	Groups/km^2	
Mangrove	158	19	128.91	96.68	49.97	1.63	0.20	82
Total	**158**	**19**	**128.91**	**96.68**	**49.97**	-	-	**82**

4.1.3 Bako National Park

In BNP, a cumulative total of 138 individuals from 21 groups were recorded (Appendix C). Proboscis monkey was sighted in two different forest types, which are mangrove forest and tropical heath forest. The area size of the mangrove and tropical heath forests in BNP were 1.23 km^2 and 20.79 km^2, respectively (Figure 4.3; Table 4.5). In the mangrove forest, 84 individuals of proboscis monkey were recorded resulted in population density of 21.36 individuals/km^2 or 2.29 groups/km^2. While in tropical heath forest, 54 individuals of proboscis monkey were recorded with estimated population density of 3.81 individuals/km^2or 0.85 groups/km^2 (Table 4.6). In both forest types, the population were estimated to be 105 individuals with a distribution of 26 and 79 individuals in mangrove and tropical forest, respectively.

Table 4.5: Area distribution of vegetation in BNP.

Vegetation type	Total area (km^2)	Percentage (%)
Infrastructure/HQ	0.12	0.42
Cultivated Land/Secondary Vegetation	0.41	1.46
Tropical Heath	20.79	74.40
Lowland Mixed Dipterocarp	1.74	6.22
Mangrove	1.23	4.39
Open Shrubland	3.74	13.38
Total	**27.95**	**100**