

## POPULATION ESTIMATION OF PROBOSCIS MONKEY, *Nasalis larvatus* WITH NEW ANALYSIS BASED ON FOREST TYPES IN SARAWAK, MALAYSIAN BORNEO

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**Abstract:** A new method of analysis of estimation based on forest types, has been conducted on proboscis monkey to update the out-dated population estimation of this primate in Sarawak. Boat survey technique was applied in all surveyed sites (except in Bako National Park) within a period of 17 months, starting from April 2015 to August 2016. A cumulative riverbank distance of 618.6 km and a line transect of 24.14 km were surveyed. In this study, the estimation was conducted based on the forest types surveyed. Overall, 9,586 individuals of proboscis monkeys were estimated within three forest types, namely, mangrove, peat swamp and tropical heath (*kerangas*) forests. Peat swamp forest has the highest population of 6,174 individuals, with an estimated population density of 0.96 individuals/km<sup>2</sup>. The estimated populations in mangrove and tropical heath forests are 1,789 and 1,623 individuals, and with estimated population densities of 1.13 and 2.76 individuals/km<sup>2</sup>, respectively. A comparison of population estimates from different studies is complicated by their different methods 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: proboscis monkeys, estimation, population size, population density

### Introduction

Endemic to the island of Borneo, proboscis monkeys (*Nasalis larvatus*) are large and sexually dimorphic primates from the subfamily Colobinae (Bennett & Gombek, 1993). There is no fossil evidence to show that proboscis monkeys are found elsewhere other than in Borneo (Harcourt & Schwartz, 2001; Payne & Francis, 2007). Proboscis monkeys are well distinguished from other primates for their large, red and protruding noses (Bennett & Gombek, 1993). Proboscis monkeys are known to be the largest Colobine monkeys and they are the only members of the genus *Nasalis* (Napier & Napier, 1967; Medway, 1977; Wolfheim, 1983).

In Sarawak, a number of efforts to estimate the population of proboscis monkeys have been made since the 1970s (Table 1). In Sarawak, the proboscis monkeys are widely distributed with a huge fragmentation, concentrating at the western part of the state (Salter & MacKenzie, 1985). In 2000, the status of this primate was changed from vulnerable to endangered (Meijaard *et al.*, 2008). Hunting, degradation of their habitats by logging and conversion into agricultural land, were identified as the major factors in the decline of their population (Meijard & Nijman, 2000).

Table 1: Past estimations of proboscis monkey in Sarawak.

	Sarawak Forest Department, (1977)	Salter & MacKenzie, (1985)	Bennett <i>et al.</i> , (1987)	Present Study
Estimated Population Size	6,400	<2,000	<1,000	9,586

Most of the previous researches on the proboscis monkeys in Sarawak were focused on their behaviour and ecology (Salter *et al.*, 1985;

Bennett & Sebastian, 1988; Onuma, 2002; Matsuda *et al.*, 2008; Pang *et al.*, 2007; Kombi & Abdullah, 2013). Only a few studies have been

conducted to estimate their population (Salter & MacKenzie, 1985; Brundell *et al.*, 1990; Zaini *et al.*, 2004; Tuen & Pandong, 2007). Moreover, the estimations were always conducted in localities where proboscis monkeys were well established, such as Bako National Park and Samunsam Wildlife Sanctuary (Salter & MacKenzie, 1985; Brundell *et al.*, 1990; Zaini *et al.*, 2004; Tuen & Pandong, 2007). A central practical problem in ecology is the estimation of population size (Krebs, 1989). However, this basic information has been ignored, even though the population of proboscis monkeys is known to be declining (Chapman & Peres, 2001; Fuller *et al.*, 2004). Till presently, the status of the proboscis monkeys in Sarawak still depending on previous data (Salter & MacKenzie, 1985; Bennett *et al.*, 1987). Even though these estimates are known to be out-dated, they are still being cited until today.

In this study, a comprehensive and systematic state-wide survey of the proboscis monkey population was conducted at eight selected sites in Sarawak to provide reliable and updated data to assess the current status of the population. This estimation was analysed based on the forest type surveyed, which had not been taken into account in any previous estimations. Data of the estimated population density from each survey site were then extrapolated and used as representative data to estimate the population

size of proboscis monkeys in each forest type. The primary goal of this study is to suggest a more precise and standard method of analysis in the estimation of proboscis monkey population to obtain a more reliable data. With this standard method of analysis, the various estimates can be compared and the changes in the population can be monitored. Previously, comparisons of the estimates from several studies were complicated by the different methods of analysis being used (Sha *et al.*, 2008).

## Materials and Methods

### Study Sites

In this study, surveys were conducted at eight selected sites in the state of Sarawak. These 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 1). Surveys were made in a period of 17 months, starting from April 2015 to August 2016. At least three days were allocated to each site to allow a minimum of six survey trips. The selection of survey sites was based on a review of the literature and interviews done with a knowledgeable Sarawak Forestry Officer.

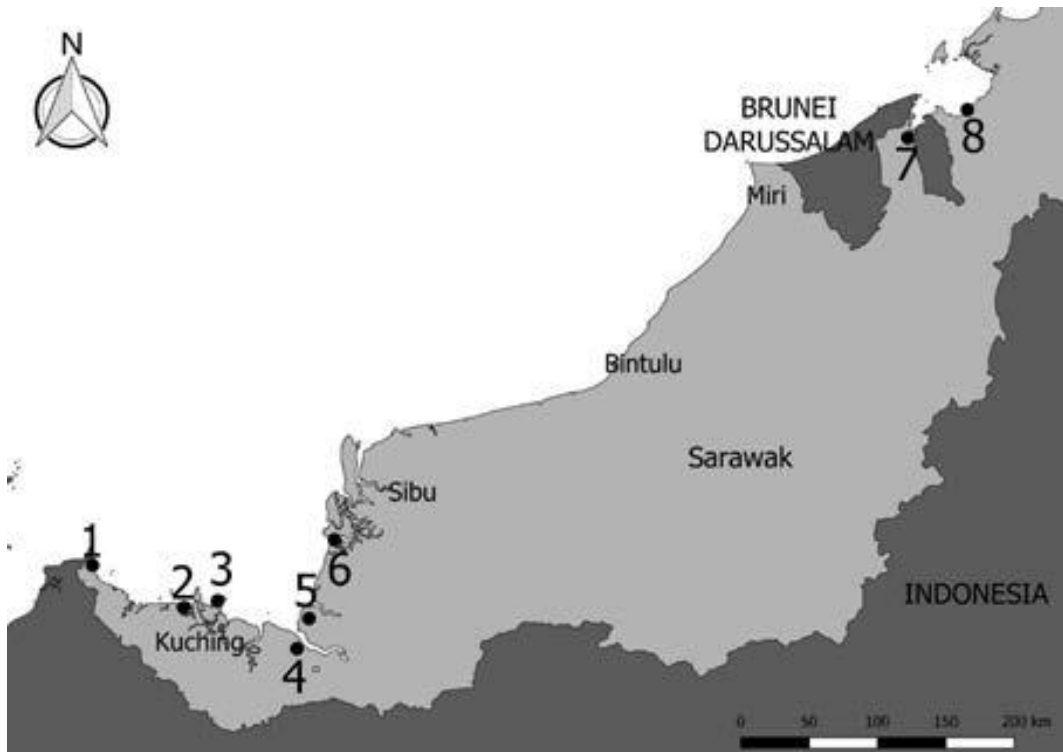


Figure 1: Map of Sarawak showing survey areas. 1= SWS, 2= KWNP, 3= BNP, 4= USNP, 5= MNP, 6= RMNP, 7= LMNP, 8= KLFR. GPS coordinate of each study site are given in Table 4.

### Survey Technique

Boat survey technique used in this study followed that of Bennett (1986). This technique involved direct observation of proboscis monkeys by using a boat to observe them at the riverbank. Most researchers viewed this technique as the most acceptable technique in the survey of proboscis monkeys (Bennett & Sebastian, 1988; Rajanathan & Bennett, 1990; Boonratana, 1993; Bernard, 1997; Goossens *et al.*, 2003; Bernard & Hamzah, 2006; Tuen & Pandong, 2007; Ali *et al.*, 2009). The survey was conducted in two sessions per day; morning and evening sessions, depending on the dusk and dawn time of every survey sites. In the morning sessions, 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 & Francis, 2007; Phillipps & Phillipps, 2016). One-way surveys were conducted to prevent double counting of the proboscis monkeys. At least two observers were involved in such survey trip.

Generally, the mangrove waterways in the survey areas are riddled with complex tributaries. It is virtually impossible to conduct the surveys in all the 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 areas in order to cover as much area as possible. For peat swamps and tropical heath forests, the waterway was normally drained by one main river. These surveys were divided into two parts, in lieu of the limited time for each survey trip. Both riverbanks were surveyed simultaneously if the river was less than 250 m wide. At least three replicates of the survey were conducted in every river part. A cumulative distance of 618.6

km of riverbank was surveyed in all surveyed sites, except in BNP. At BNP, the survey was conducted on foot, following Aziz *et al.* (2015). A cumulative distance of 24.14 km line-transect survey was conducted in BNP, along with the existing trails and at the edge of the mangrove area, since there is no waterway for river survey.

When an individual or group of proboscis monkeys were sighted, the boat engine was switched off and the boat was paddled toward the location until its maximum flight zone, which is usually about 50 m to avoid the proboscis monkeys from moving away. The size of the group was recorded and classified by sex and age based on the classification proposed by Bennett and Sebastian (1988). The coordinates of each group of proboscis monkeys were recorded by using the Geographic Positioning System (Garmin 64s). The general forest types were recorded following Hazebroek and Abang

Kashim (2006), with the aids of latest vegetation map available. Binoculars were used for a clearer sighting of the proboscis monkeys. Any individuals within a 50 m radius were considered to be in the same group.

### Data Analysis

The population density of proboscis monkeys at each surveyed site was estimated for every forest type surveyed. The estimated population density was calculated by dividing the cumulative number of proboscis monkeys sighted in each particular forest type surveyed with the total area of the forest type surveyed. The total surveyed area is the cumulative distance of the surveyed riverbank of that particular forest type surveyed multiplied by 0.75 km perpendicular distance from the riverbank. The formulae used are as per below:

$$\text{Population density} = \frac{\text{Cumulative number of individuals sighted}}{\text{Total surveyed area (sq km)}}$$

$$\text{Total surveyed area} = \text{cumulative distance of surveyed riverbank (km)} \times 0.75 \text{ km}$$

To estimate the population density of proboscis monkeys, the information on the home range size of the animals is needed (Bernard & Hamzah, 2006). However, this kind of information needs long-term observation, which is not available in this study. Thus, 0.75 km distance from the riverbank was applied in the analysis of the population density, to estimate the surveyed area used by the proboscis monkeys at all 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 literature (Bernard & 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 (Bennett & Sebastian, 1988; Boonratana, 2000; Bismark, 2010).

The analysis of the estimated population size of proboscis monkeys at each site was correlated to the estimated population density obtained. The estimated population density in a particular forest type was extrapolated by multiplying with the total area of the matched forest type, at that surveyed site to obtain the estimated population size of proboscis monkeys for that particular forest type. The overall estimated population size of proboscis monkeys in each surveyed site was obtained by totalling up the estimated population sizes from every forest type surveyed. The formulae used are as per below:

$$\begin{aligned} \text{Population size} &= \text{Population density} \times \text{total forest area} \\ \text{Cumulative population size} &= \sum \text{Population size}(s) \text{ of all surveyed forest} \end{aligned}$$

The population of proboscis monkeys for the whole area of Sarawak was estimated from the results of the estimated population size for every surveyed site. The results were used as representative data to estimate the population size of the proboscis monkeys in the whole area of Sarawak. Results of the estimated population size from each forest type from all surveyed site were totalled up before dividing by the total area

of the respective forest type from all surveyed site to obtain the average population density of proboscis monkeys in that particular forests type. The average population density was then multiplied with the total area of that forest type in Sarawak, to obtain the population size estimate for that forest type for the whole area of Sarawak. The formulae used are as per below:

$$\text{Population Estimation} = \frac{\sum \alpha_1 + \alpha_2 + \alpha_3 + \dots + \alpha_n}{\sum \beta_1 + \beta_2 + \beta_3 + \dots + \beta_n} \times \text{Total forest area in Sarawak}$$

where,

$\alpha$  = estimated population size in respective forest type from every surveyed site

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

### **Vegetation Map and Forest Area Measurement**

Geographic Information System software programme (QGIS version 2.14.10) was used to illustrate the vegetation cover map of Sarawak (Figure 2). The same software programme was used to estimate the area of each forest type (Table 2). Soil map of Sarawak 1968 from Agriculture Department of Sarawak was used as the main reference to generate the latest vegetation cover map. The process of illustrating the map was rectified and updated with the latest forest cover that were obtained from the satellite images of Landsat 8, Sentinel 2, MODIS 2016 and SRTM 1 arc-second. Other maps that were utilised as supplementary references are the land use map acquired from the Department of Survey and Mapping Sarawak, a 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 on 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 & 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 in the use of land in Sarawak.

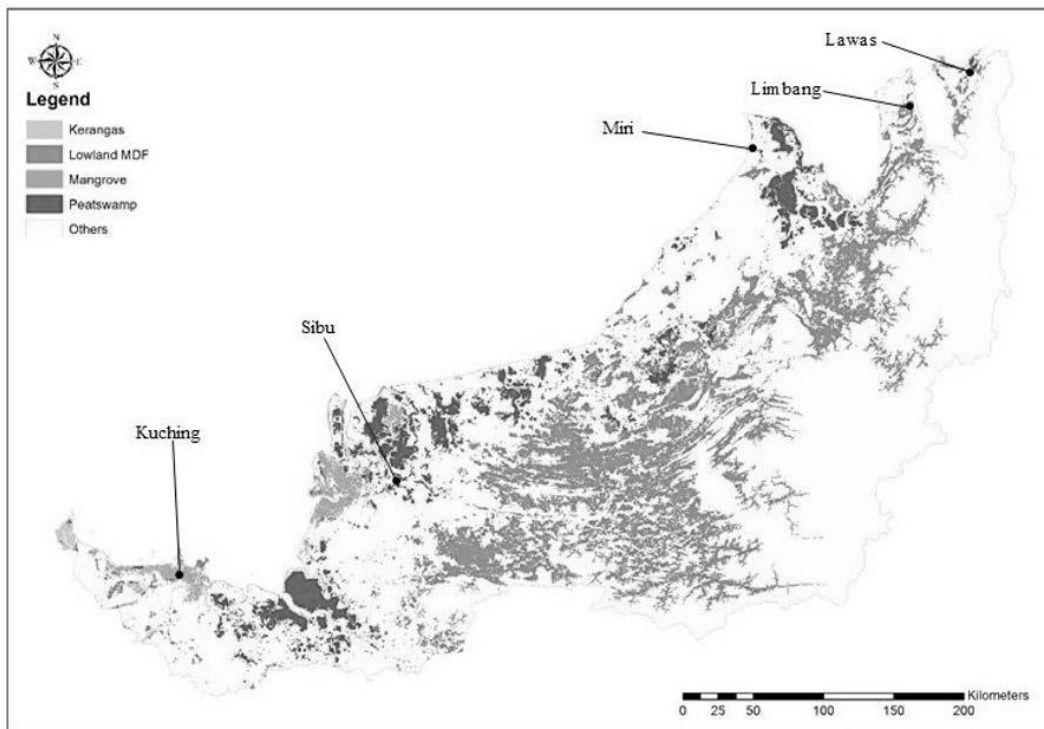


Figure 2: Map of vegetation in Sarawak.

Table 2: Area distribution of forest types in Sarawak.

Vegetation	Total area (km <sup>2</sup> )	Percentage (%)
Tropical Heath	588.32	0.47
Lowland MDF	22610.54	18.17
Mangrove	1587.73	1.28
Peat Swamp	6432.21	5.17
Others	93231.20	74.91
<b>Total</b>	<b>124450</b>	<b>100</b>

**Results**

A cumulative total of 860 individuals of proboscis monkeys from 105 groups, including harem groups, all male groups and solitary males, were recorded from all surveyed sites. Out of eight surveyed sites, two sites, RMNP and USNP, showed no presence of proboscis monkeys, during the survey. Proboscis monkeys

were recorded in mangrove forest at SWS, KWNP, BNP, LMNP and KLFR. While in peat swamp forest, proboscis monkeys were recorded only in MNP. In tropical heath forest, proboscis monkeys were recorded in SWS and BNP. Table 3 shows in detailed the cumulative number of individuals and groups sighted in different forest type from all surveyed sites.

Table 3: Cumulative total of proboscis monkey individuals and groups sighted in different forest types from all surveyed sites.

Type of Forest	Locality	Number of individuals	Number of groups
Mangrove	SWS	60	8
	KWNP	158	19
	BNP	84	9
	LMNP	141	15
	KLFR	84	6
Peat Swamp	MNP	170	25
Tropical Heath	SWS	109	11
	BNP	54	12
Total		860	105

The estimated population sizes in all surveyed sites are shown in Table 4. The total estimate of proboscis monkeys in all surveyed sites is 838 individuals. Among the six surveyed sites with the presence of proboscis monkeys, MNP shows

the highest estimated population size with 432 individuals, followed by BNP, SWS, KWNP, KLFR and LMNP with estimated population sizes of 105, 98, 82, 77 and 44 individuals, respectively.

Table 4: Estimated population size of proboscis monkey at various localities in Sarawak.

Locality	GPS Coordinate	Cumulative distance of surveyed riverbank (km)	Cumulative surveyed area (km <sup>2</sup> )	Cumulative number of individuals sighted	Cumulative number of groups sighted	Estimated population size
SWS	1°57'3.03"N 109°38'42.81"E	83.19	62.39	169	19	98
KWNP	1°40'24.96"N 110°14'39.40"E	128.91	96.68	158	19	82
BNP	1°42'59.37"N 110°26'38.72"E	*24.14	18.11	138	21	105
USNP	1°24'12.42"N 110°59'23.04"E	41.96	31.47	-	-	-
MNP	1°36'6.18"N 111°4'6.49"E	129.48	97.11	170	25	432
RMNP	2°7'4.53"N 111°14'9.28"E	88.24	66.18	-	-	-
LMNP	4°45'28.18"N 115°0'20.79"E	71.96	53.97	141	15	44
KLFR	4°56'30.23"N 115°23'47.01"E	74.86	56.14	84	6	77
Total		642.74	482.05	860	105	838

Note: \*Survey in BNP was conducted on foot followed as Aziz *et al.*, (2015). The distance of the survey was based on the line transect surveyed.

The overall population of proboscis monkeys at these three vegetation types in Sarawak was estimated to be 9,586 individuals (Table 5). This estimation refers to the sum of the population

estimation in mangrove forest, peat swamp forest and tropical heath forest, with estimated population sizes of 1,789, 6,174 and 1,623 individuals, respectively.

Table 5: Population estimation of proboscis monkey at various forest types in Sarawak.

Vegetation type	Cumulative estimated population size	Total forest area in all surveyed site (km <sup>2</sup> )	Total forest area in Sarawak (km <sup>2</sup> )	Estimated population density (individuals/km <sup>2</sup> )	Estimated population size
Mangrove	234	207.69	1587.73	1.13	1789
Peat Swamp	432	450.08	6432.21	0.96	6174
Tropical Heath	172	62.35	588.32	2.76	1623
Total	838	720.12	5608.26	-	9586

**Discussion**

This study estimates the population of proboscis monkeys in Sarawak to be 9,586 individuals. This estimate is higher than previous estimates. In 1977, the Sarawak Forestry Department reported that the estimation of proboscis monkeys at that time was 6,400 individuals, based on the extrapolation of population density data in BNP and SWS. While Salter and MacKenzie (1985) estimated the population of proboscis monkey at that time to be less than 2,000 individuals in Sarawak. Bennett *et al.* (1987), from their state-wide survey, suggested that the population size of proboscis monkeys may be as low as 1,000 individuals.

Even though most of the researchers used the same technique in the surveys, the differences in time, methods of analysis and survey efforts are the main obstacles before a comparison can be made (Sha *et al.*, 2008). Probably, the higher value of the estimates in this study is due to the more comprehensive survey and detailed analysis, which is based on the type of forest surveyed compared to the previous estimations. The Sarawak Forest Department used extrapolation data of population density from only two sites to represent an area as large as Sarawak. Estimates by Salter and MacKenzie (1985) were doubtful because of the inconsistency of the methodologies applied. This estimation was actually acquired from the results of estimation using several methods of analyses. First is the extrapolation of population density data of proboscis monkey from undisturbed mangrove forest. Second is the estimation from direct census from the surveyed area and last is the estimation based

on the projection of the unsurveyed areas. The last method used in the analysis is considered inappropriate because there is no basis to guess the number of the population size in the unsurveyed areas. Even if the first and second methods of analyses applied in the estimation by Salter and MacKenzie (1985) were considered as reliable, the consistency of the results that came from different analyses needs to be considered. Meanwhile, Bennett *et al.* (1987) obtained the figure of 1,000 individuals in their estimation based on projections, which was supported by their survey without taking into account the forest types. Thus, by comparing all these estimates, we are still not able to determine whether the population are actually increasing or declining due to the different method of analyses used in separate studies. Most importantly, this primate is an endangered species; every effort should be made to conserve its threatened existence.

In this study, the results of the estimation were derived from more complete data and detailed analysis compared to previous estimations. The estimation of the population size actually came from extrapolation of the estimated population density from all surveyed sites, including all the forest types where proboscis monkeys possibly exist. Since the survey was conducted in early morning and late evening to adapt to the natural behaviour of proboscis monkeys that sleep next to the river, the forest types where the proboscis monkeys were recorded were taken as the vegetation of its habitat (Bennett, 1986; Yeager, 1989; Boonratana, 2000; Matsuda, 2008). The population density was assessed based on forest type to allow extrapolation of the population density for each forest type. This kind of analysis is found to be more precise



because the estimation by extrapolation of the population density data was conducted based on the forest types of their natural habitats including mangrove, peat swamp and tropical heath forests, where the proboscis monkeys probably exist rather than randomly extrapolating the population density data to the whole area of Sarawak (Bennett & Gombek, 1993; Meijaard & Nijman, 2000).

Bennett (1986) mentioned that, due to the different arrangement of waterways in different forest types, a comparable estimation cannot be made. In peat swamp and tropical heath forests, the areas are usually drained by one main river. By surveying along the river, most of the proboscis monkeys in that area can be sighted. However, in mangrove forest, that area is connected by a complex network of tributaries. Searching of proboscis monkeys in mangrove forest needs an extra effort since they may probably sleep at any of the creeks rather than returning at the main rivers (Bennett & Sebastian, 1988). Even though the number of individuals sighted in these two different waterways was almost the same, the population density in mangrove forest might be lower due to more survey efforts needed and lesser rate of detection, in mangrove waterways. Thus, it is impossible to compare the estimated results for different forest type, because of the possibility of biasedness.

## Conclusion

To our knowledge, this is the first study on the estimation of proboscis monkey population that was conducted based on the forest types in Sarawak. This kind of analysis is found to be systematic, precise and reliable compared to previous studies, in providing a more detailed estimation. A similar analysis should be applied in future studies in order to monitor the changes in the population size and population density of proboscis monkeys. Without such information, it is impossible to construct an effective conservation plan to ensure the survival of this endangered species. In the future, as studies on the home range are updated, the maximum ranging distance used in this analysis may be

updated. Other potential sites should be included in future studies to obtain a larger sample size. It is also recommended that the survey period to be extended and covering a larger area with more replications.

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