The Journal of Animal & Plant Sciences, 24(6): 2014, Page: 1772-1779
ISSN: 1018-7081

POPULATION STRUCTURE ANALYSIS OF MONKEYS IN SELECTED PROTECTED AND NON-PROTECTED AREAS OF PENINSULAR MALAYSIA

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ABSTRACT

Population of monkeys in Peninsular Malaysia has been inconsistent with regards to their numbers. At a certain times they deemed pest because of their large numbers, like *Macaca fascicularis*, a listed protected animal as per local Government jurisdiction. Here we evaluated population status along with recruitments rate, considering three species i.e. Long-tailed Macaques, Dusky-Leaf-Monkeys and Pig-tailed Macaques at seven randomly selected areas in Peninsular Malaysia. For analysis, Generalized Linear Model and Probability Density Function (*pdf*) analyses were conducted. As a result we perceived Kolmogorov values 0.153-0.479 and Anderson statistics 33.258-103.45. The geometric *pdf* ($E« = 1/P, \pm^2 = 1-p/p$ prescribed P = 0.05114) which precisely coincides with the population distribution of the mentioned species. Further, it has been assumed that the smaller number of monkeys posses higher probability as compared with higher numbers in specified colony and vice versa. The results suggested that Bukit Selambau possessed highest parametric frequencies for some of the population indices except the adult male exhibited highest frequencies in Botanical gardens ($\bar{x}$=2.917). Overall, species of Long-tailed Macaques was found predominantly ($\bar{x}$=20.688) among the selected areas. Further, we established the colony size as 1- 17 individuals per group. Generally, the likelihood rate of recruitment index was 0.099 for the three species.

Key words: Rate of recruitment, group size, seasonal effect, geometric *pdf*, adducible, Duncan Multiple range Test.

INTRODUCTION

The status of monkey species available in Peninsular Malaysia has always been inconsistent. At a certain time, they were deemed pest due to their large number (Schweitzer, 2014; Sha *et.al*., 2009). However, species like the *Macaca fascicularis* are listed in the category of protected animals, which cannot be killed nor captured without prior and legal permission from the Department of Wildlife and National Parks, Peninsular Malaysia (Zain, *et., al,* 2011; Sha *et., al*., 2009). The uncertainties of group recruitment on the basis of individual members of monkey are inimical for the appropriate management and its habitat. Previous studies related to monkeys in the Peninsular Malaysia have focused on ecology and management of long-tailed macaques (*Macaca fascicularis*) and their interface with human (Zain, *et., al,* 2011). Further, status and conservation of proboscis monkey (*Nasalis larvatus*) have been studied in Sabah state, East Malaysia (Sha, *et., al,* 2008) along with primate ecology (Clutton-Brock, 1977). However, there is no research study which have been focused on the status evaluation (population) in terms of the sites (protected and non – protected areas), rate of recruitment and weather conditions. Such information's would be useful in future endeavors for the better administrational directions of the monkeys. Generally, a sound and proper protocols would be essential for any natural resources authentication and to evaluate its status for the denizen of natural environment. To overcome the imminent mis-managemental obstacles through considering the previous history and make some comprehensive decisions on the basis of recommended outcomes. Recruitments have been defined as the addition of new individual to a population while rate of recruitment is defined as the number of new organisms/infants reaching a size/age where they would represent a viable target for certain purpose (Martha, *et., al,* 2014). This study posited that a significant difference is existed in the population of monkey at different selected sites of the study; also the population differs according to the prevailing weather conditions. Present study was conducted on three species of monkeys (*Macaca fascicularis*, *Macaca nemestrina* and *Trachypithecus obscurus*) in seven selected areas (Botanical Gardens Penang, Cerok To`kun Penang, Bukit Juru Penang, Gunung Jerai Kedah, Bukit Selambau Kedah, Taiping Zoo Perak and Pondok Tanjung Perak) in the Northern Peninsular Malaysia,

The general objective of this study was to assess the population status of monkeys during different weather conditions at various study sites. While the specific objectives focused concentratedly, to assess the difference between monkeys population in protected and non-protected areas as well as to examine the population

components in term of species and rate of recruitment of monkeys at different sites.

MATERIALS AND METHODS

Study area: This study was conducted between January 2012 and December 2013 in Northern Peninsular Malaysia. Which is located near to north Singapore border along with Southern Thailand, and eastern part of the Indonesian isle (Sumatra) between 99^o to 105^o east and 1^o to 7^o north having total land area of 131,587 km^2. It is composed of highlands, shore zones, tidal plains (Fuentes *et al*., 2011), also carry the tropical rain forest, peat swamp timberlands with mangrove forests and dipterocarp forests (Mohd-Azlan, 2006). Present study was carried out in seven randomly selected areas of peninsular Malaysia i.e. Penang Botanical Gardens, Cerok To`kun Penang, Bukit Juru Penang, Gunung Jerai Kedah, Bukit Selambau Kedah, Taiping Zoo Perak and Pondok Tanjung Perak (Figure 1). The study sites were further divided into protected and non-protected areas. The climatic condition is tropical humid and worm around the year with temperature ranges 21^{o}C to 32^{o}C. Rainfall occurs in two rainy seasons that linked with Southwest Monsoon from May to September and Northeast Monsoon from November to March (Suhaila and Jemain, 2009).

The data were randomly and continuously collected in the above seven different habitats located in three states of Peninsular Malaysia. The selected seven study sites were further subdivided in protected and non-protected habitat. The protected habitat consisted of four locations i.e. “Botanical Gardens Penang, “Cerok To’kun Penang”, “Gunung Jerai Kedah” and “Taiping Zoo Perak”. While, the non-protected habitat composed on three locations which were; “Bukit Juru, Penang”, “Bukit Selambau, Kedah” and “Pondok Tanjung, Perak”. Further detail regarding the selected study sites with geographical positioning data and particular of monkey’s species habitation are given in table 1.

Study subjects and Data collection: The data were collected from 8.00am to 6.00pm and sampling sub-session was fifteen observations per hour. Three species of monkeys were studied including *Macaca fascicularis, Macaca nemestrina* and *Trachypithecus obscurus*, which were commonly distributed in most of study areas. The opportunity of counting and recognizing was higher in *Macaca fascicularis* and *Macaca nemestrina*, because they usually approached to took food from human habitations. *Trachypithecus obscures* spent most of their time in trees and rarely comedown to ground. Data with respect to the number of monkeys in a group consisted; number of males, number of females, number of juveniles (male/female), number of sub-adults (male/female) and adults were considered.

Data analysis: The data collected were analyzed using summary statistics (like means, standard error of mean and variance). The total frequency of the encountered monkeys species was tested for five different probability distributions, including, Uniform, geometric, logarithmic, negative binomial and poisson probability distribution function. The most parsimonious of the pdf was selected using both Kolmogorov and Anderson test (Hubert 1967). Hypothesis was tested using generalized linear models, while the mean of the significantly different frequencies was separated using both Duncan Multiple Range Test (DMRT) and Least Significance Difference (LSD). The recruitment rate index (RRI) (Lima and Rodrigues-de-Paula 2013) was obtained using;

$$RRI = f_i / f_t$$

Where f_i = number of the infant and f_t = number of the individuals encountered in the study site. Both SAS version 8 and Easy Fit were deployed in this study.

RESULTS

Among different age groups of monkeys, both male and female consisting juvenile, sub-adult and adult age groups possessed highest mean frequency at Bukit Selambau in non-protected area (Table 2). The corresponding mean frequencies for male were 3.967 (juvenile), 2.667 (sub-adult), 2.917 (adult) and for female were 5.567 (juvenile), 3.7 (sub-adult), 4.667 (adult) respectively (Table 2). Whereas, the likelihood frequencies in case of infant age groups were dissimilar irrespective of gender, in the non-protected areas of Bukit Selambau. But, the highest mean frequency in case of infant (2.083) was obtained at Cerok To’kun, Penang. Further, the interpretation of these results suggest that (i) highest population of the monkeys were obtainable at Bukit Selambau on the basis of population size and (ii) the higher frequencies of monkeys at any sites, the greater will be the chance of variability (increase) in population and vice versa. The data analysis pertaining to distribution function (pdf) of the total frequency with regards to monkeys exhibited the responding Kolmogorov statistics between 0.153 and 0.479 while the Anderson statistics were ranged between 33.258 and 103.45. Based on ranking of the mentioned statistical tests, the geometric probability density (Figure 2A) suits best to the distribution of the total frequencies, as given below;

$$(\Pr(X = K) = 1 - P)^{k-1} p$$

The expected value of this (pdf) is $1/P$, the variance is $1-P/P$ and the parametric P is 0.05114. While both the K and Anderson statistics both concluded a lesser pdf value (Table 6). It have been justified that the probability of appreance is maximum for the number of monkeys ranged between 1-17 individuals in a group

whereas the minimum probability of appearance will be accessed if the number of monkeys ranged between 25 – 44 individuals in a group.

The analysis of Generalized Linear Model (GLM) resulted that the animals frequency by weather were significantly different in case of infants, juveniles, sub-adults and adults. The corresponding F-statistics mean were; infants (6.500), juveniles (9.16, 4.53), sub-adults (6.36, 3.45) and adults (6.21, 3.04) (Table 3). The mean values exhibited the effect of weather have a heterogeneous impact upon the population structure. Further, the Duncan Multiple Range Test (DMRT) concluded that the mean frequencies for sunshine were maximum ($P<0.01$) than the cloudy and rainy weather for infant, Juvenile and sub-adult. However, the one category i.e; adult possessed the highest mean frequencies ($P<0.05$) in case of raining (Male: 2.56, Female: 4.12) followed by cloudy weather (Male:1.951, Female: 3.044) (Table2). The result illustrated that the differences pertaining to weather conditions impacted various structural frequencies in different classes of monkeys. The aged monkeys were adopted to rain as compared with the infant and juvenile. Regarding the study site, statistical analysis (GLM) for the monkey's number per site were significantly varied. The corresponding F-statistics were 12.47 (Infants), 4.47 (Juvenile males), 6.19 (Juvenile females), 6.21 (Sub-adult males), 8.21 (Sub-adult females), 10.40 (adult males) and 5.91 (adult females) which was greater than $F_{(6, 253)} = 3.67$ (Table 4). The DMRT revealed that the mean numbers in monkey population were highest at Bukit Selambau in case of juvenile, sub adult and adult for both gender (male and female), Which was higher than Cerok To'kun for the corresponding means numbers in monkey's population. The study site Gunung Jerai consisted of maximum mean frequencies for male sub-adult where Botanical gardens exhibited highest mean frequencies for female sub-adult. Further we assumed that there were no regularity in numbers of group members in speficied population. However, Bukit Selambau, Cerok To,kun and Botanical gardens revealed highest mean frequencies of monkeys. From the results, it is clear that Bukit Selambau, a non-protected area, possessed highest mean frequencies of monkeys. In addition, the remained two; Cerok To'kun and Botanical gardens consisted the maximum frequencies of monkeys, which were announced as the protected areas (Table 4).

The mean (GLM) frequencies of monkeys' in a population according to species illustrated significant differences in term of male and female for juveniles, sub-adults, adults.. The corresponding F-statistics values were 5.820, 7.790 for juvenile, 21.800, 3.210 for sub-adult and 31.530, 24.160 for adult (Table 5). The DMRT grouping showed that the frequencies of *Macaca fascicularis* were significantly higher than *Macaca nemestrina* followed by the least significant species; *Trachypithecu sobscurus* (Table 5). The mean rate of recruitment index (*RRI*) was 0.099 with maximum value 0.500 which indicate that the animals during the study period could be turned or recruited through the birth half of the population for a specific site. Similarly, RRI decreases in case of *Macaca nemestrina;* the maximum, to *Trachypithecus obscurus; the minimum*, showed variation in the rate of recruitment across the species, considering the study sites (Figure 3). Highest *RRI* was obtained with sunshine while raining condition returned the least *RRI* (Figure 3). This conclude that the animals possessed the capability of maximum recruitment rate, ultimately explode their population and warranting the Ministry of Wildlife and National Park for controlled harvesting (Schweitzer 2014).

Figure 1. Map of the study sites, modified from Google map

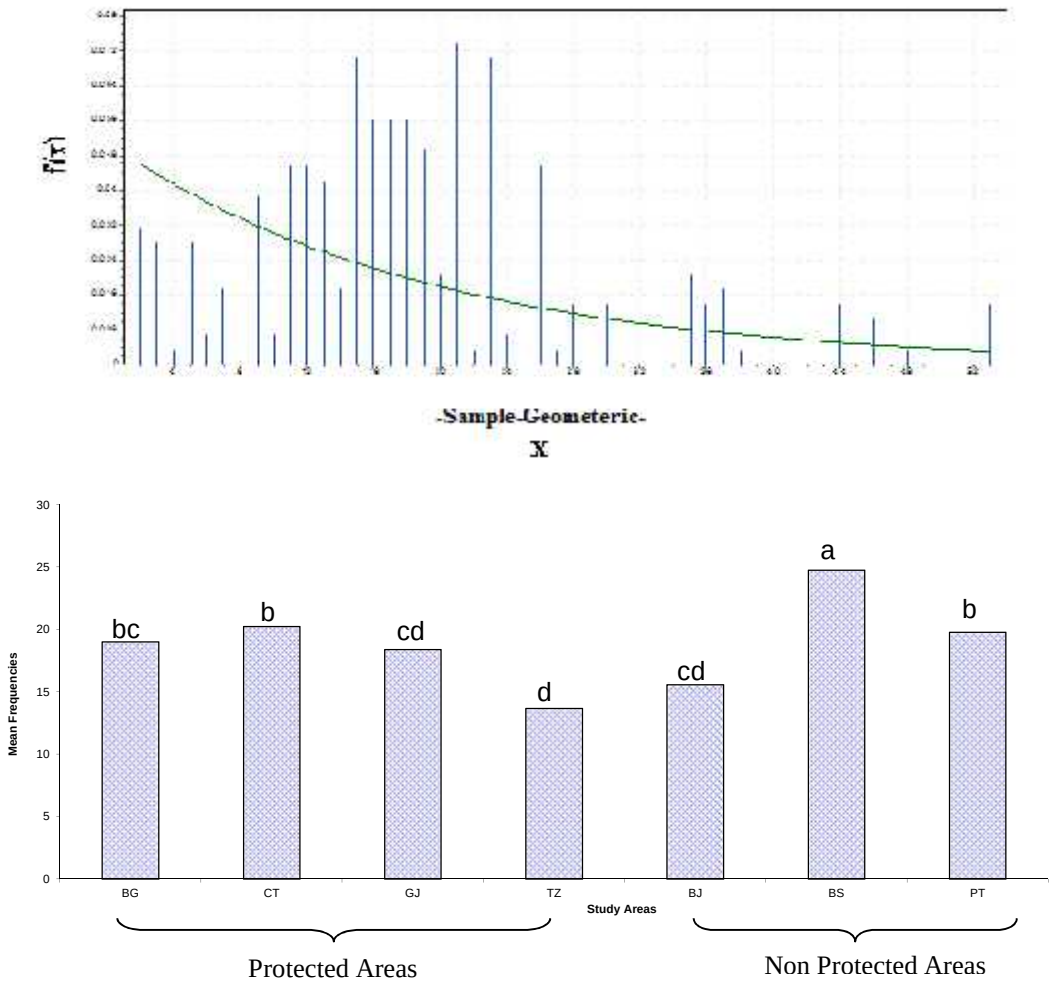

Figure 2. Geometric Probability Density function (A) and Mean Separation (B) for the total frequency of the Monkeys.

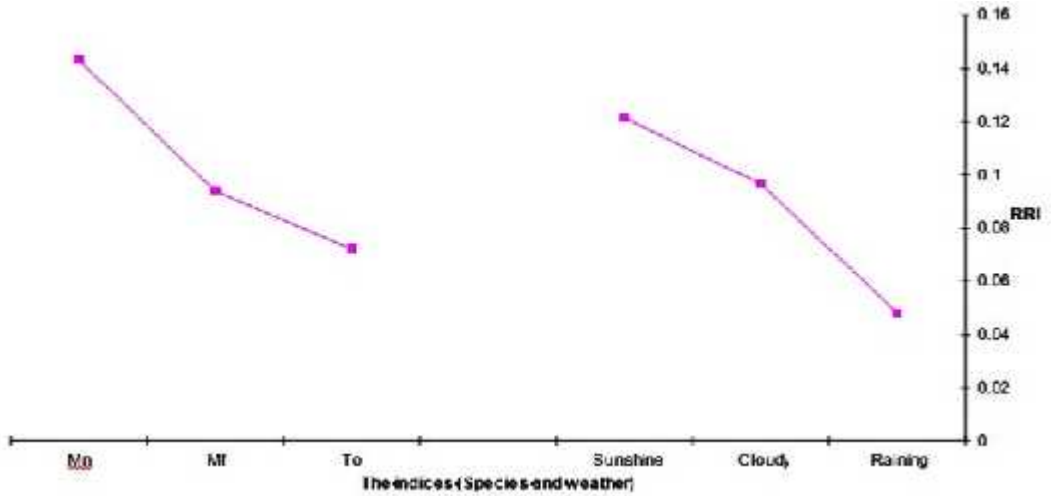

Figure 3. Rate of Recruitment Index for both weather and Species. Mn=*Macaca nemestrina*, Mf= *Macaca fascicularis* and To= *Trachypithecus obscurus*

Table 1. Geographical co-ordination (GPS) within study areas of the three monkeys species

	Study Areas	Land Areas (KM^2)	Geographical Positional System (GPS)	Species
Protected areas	Botanical Gardens	2.4	05° 26.265" N 100° 17.437"E	*Macaca fascicularis* and *Trachypithecus obscurus*
	Cerok To`kun Penang	3.5	05° 21.522"N 100° 29.606"E	*Macaca fascicularis* and *Macaca nemestrina*
	Gunung Jerai Kedah	5.2	05° 49.716"N 100°27.517"E	*Macaca fascicularis* and *Macaca nemestrina*
	Taiping Zoo Perak	1.8	04° 51.285"N 100° 44.989"E	*Macaca fascicularis*, *Macaca nemestrina* and *Trachypithecus obscurus*
Non-protected Areas	Bukit Juru Penang	7.1	05° 20.055" N 100° 24.457"E	*Macaca fascicularis* and *Trachypithecus obscurus*
	Bukit Selambau Kedah	10.3	05° 39.509"N 100° 33.807"E	*Macaca fascicularis*
	Pondok Tanjung Perak	8.1	05° 02.101"N 100° 43.679"E	*Macaca fascicularis* and *Macaca nemestrina*

Table 2. Summary Statistics of the total Monkey Population of three species (*Macaca fascicularis*, *Macaca nemestrina* and *Trachypithecus obscurus*)

	Sites	Infant		Juvenile		Sub Adult		Adult	
		Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
Male	Botanical Garden, Penang	0.688±0.16	1.198	2.604±0.24	2.712	2.000±.021	2.213	2.917±0.32	4.972
	Cerok To,kun Penang	2.083±0.14	0.707	3.583±0.51	9.507	1.861±0.23	1.951	1.722±0.21	1.577
	Gunung Jerai Kedah	1.057±0.17	0.996	2.829±0.36	4.617	2.086±0.25	2.198	1.914±0.20	1.375
	Taiping Zoo, Perak	1.405±0.08	0.247	2.143±0.25	2.564	0.929±0.16	1.141	1.357±0.14	0.772
	Bukit Juru, Penang	1.512±0.86	0.306	2.219±0.35	5.126	1.439±0.17	1.252	1.805±0.15	0.961
	Bukit Selambau, Kedah	1.767±0.18	1.013	3.967±0.68	13.826	2.667±0.49	7.057	2.433±0.30	2.668
	Pondok Tanjung Perak	1.462±0.17	1.43	2.635±0.30	4.785	1.885±0.19	1.869	2.308±0.17	1.433
Female	Botanical Garden, Penang	0.688±0.16	1.198	4.292±0.29	3.998	3.292±0.28	3.828	3.208±0.40	7.53
	Cerok To,kun Penang	2.083±0.14	0.707	5.250±0.71	18.021	2.806±0.41	5.99	2.944±0.32	3.711
	Gunung Jerai Kedah	1.057±0.17	0.996	5.257±0.47	7.726	2.543±0.23	1.785	2.714±0.32	3.681
	Taiping Zoo, Perak	1.405±0.08	0.247	3.405±0.36	5.515	1.976±0.21	1.926	2.452±0.17	1.278
	Bukit Juru, Penang	1.512±0.86	0.306	3.537±0.39	6.255	1.780±0.24	2.276	3.268±0.32	4.201
	Bukit Selambau, Kedah	1.767±0.18	1.013	5.567±0.85	21.495	3.700±0.53	8.355	4.667±0.68	13.816
	Pondok Tanjung Perak	1.462±0.17	1.43	4.519±0.38	7.706	2.961±0.22	2.548	4.019±0.30	4.804

Table 3. F-statistic and mean separation for the Population of the three species under different weather Conditions.

Parameter	infant	Juvenile		Sub Adult		Adult		Mean of Total Frequency
		♂	♀	♂	♀	♂	♀	
F,statistic	6.50**	9.16**	4.53*	6.36**	3.45*	6.21**	3.04*	1.54
DF	2	2	2	2	2	2	2	2
Cloudy	1.3132[b]	3.0055[a]	4.7198[a]	1.6868[b]	2.6923[a]	1.9505[b]	3.0440[b]	18.412[a]
Sunshine	1.7143[a]	2.7922[a]	4.3247[a]	2.3377[a]	3.0909[a]	2.2597[ab]	3.6883[ab]	20.208[a]
Raining	0.9600[c]	1.1200[b]	3.0800[b]	1.0000[c]	1.6400[b]	2.5600[a]	4.1200[a]	14.480[b]

-*significant at p<0.05 and **significant at p<0.01,
-small letter superscript shows the different mean classifications.

Table 4. F-statistic and mean separation for the Population of the three species at Different Area.

Parameter	Infants	Juveniles		Sub-adults		Adults	
		♂	♀	♂	♀	♂	♀
F-statistic	12.47**	4.47**	6.19**	6.21**	8.21**	10.40**	5.91**
DF	6	6	6	6	6	6	6
Botanical Gardens	0.688[d]	2.604[bc]	4.292[ab]	2.000[bc]	3.292[ab]	2.917[a]	3.208[bc]
Cerok to,kun	2.083[a]	3.583[ab]	5.250[a]	1.861[bc]	2.806[bc]	1.722[d]	2.944[c]
Bukit Juru	1.512[b]	2.220[c]	3.537[b]	1.439[cd]	1.781[e]	1.805[cd]	3.268[bc]
Gunung Jerai	1.057[c]	2.829[bc]	5.257[a]	2.086[b]	2.543[cd]	1.914[bcd]	2.714[c]
Bukit Selambau	1.767[ab]	3.967[a]	5.567[a]	2.667[a]	3.700[a]	2.433[ab]	4.667[a]
Taiping Zoo	1.406[b]	2.143[c]	3.405[b]	0.929[d]	1.976[de]	1.357[d]	2.452[c]
Pondok Tanjung	1.462[b]	2.635[bc]	4.519[ab]	1.885[bc]	2.962[bc]	2.308[bc]	4.079[ab]

*significant at p<0.05 and **significant at p<0.01
-small letter superscript shows the different mean classifications.

Table 5. F-statistic and mean separation for the Population of the monkey by Species.

Parameter	Infants	Juveniles		Sub-adults		Adults		Total Frequency
		♂	♀	♂	♀	♂	♀	
F-statistic	2.900	5.820**	7.790**	21.800**	3.210*	31.53**	24.160**	19.230**
DF	2	2	2	2	2	2	2	2
Macaca fascicularis	1.521[a]	3.303[a]	4.951[a]	2.014[a]	2.852[a]	2.366[a]	3.859[a]	20.688[a]
Macaca nemestrina	1.438[a]	2.453[b]	4.250[ab]	1.953[a]	2.703[a]	1.813[b]	2.734b	17.344[b]
Trachypithecus obscures	1.115[b]	2.103[b]	3.769[b]	1.295[b]	2.449[a]	1.808[b]	2.795[b]	15.333[b]

*significant at p<0.05 and **significant at p<0.01
-small letter superscript shows the different mean classifications.

Table 6. Summary of the probability distribution function for the Total frequency of the Monkey.

s/N	Distribution	Kolmogorov		Anderson	
		Statistic	Rank	Statistic	Rank
1	Uniform	0.15336	1	81.01	4
2	Geometric	0.2843	3	33.258	1
3	Logarithmic	0.47896	5	103.45	5
4	Neg. Binomial	0.30171	4	43.63	2
5	Poisson	0.20152	2	79.959	3

DISCUSSION

The goal of this study was to evaluate monkeys population in selected protected and non-protected areas of Peninsular, Malaysia. The predominance frequencies of monkeys in Bukit Selambau showed in this study contradict the results of Panchanathan (2005) who concluded that Proboscis monkeys were not observed in villages and agricultural land. Similarly, an evaluation of the species of Sambar and Muntjak habitats using geostatistical modeling established that Rhesus monkey showed great affinity towards large distances from human settlements and high tree densities surround by low shrubs (Kushwaha, 2004). In another study, Cawthon (2005) observed that Rhesus macaques are exceptionally adapted to coexisting with humans and thrive near human settlements, in both urban and agricultural areas. Rhesus macaques can be said to be adaptive to living close to human as long as human are not posing any threat to them like it has been noted in India. However, they would definitely prefer the former when they are poached upon for safety of their dare life too. Two reasons adducible to this predominance include i) Controlled Cropping - Unpublished reports said that in controlled cropping of the monkey in recent year by the Malaysia's Department of Wildlife and National Parks almost 250,000 monkeys were killed (Schweitzer, 2014: Sha *etal.*, 2009) and ii) Malaysia wildlife protection Act 1974 which listed *Macaca fascicularis* as a protected animal that cannot be killed and captured without permission from the Department of Malaysia Wildlife and National Parks (Zain, *et al*, 2011, Sha, *et., al*, 2008). The latter reason can enhance migration of monkey during controlled harvesting as earlier stated while the former would ensure their security with humans.

In addition, monkeys colonies consisted of a few individuals among which differences were noticed in the structures with respect to weather conditions. The average group size of 12.3 individuals per colony has been reported in some areas of India (Chetry *et al.* 2003). Whereas, the higher number of individuals in groups mentioned by Chetry and co-authors (2003) coincided with our corresponding mean higher numbers of monkeys colony. In a study, conducted by González-Martínez (2004) perceived that the Rhesus macaque consisted various numbers of individuals per colony in a specified study site; i) the size of Sierra Bermeja Rhesus population derived from research colonies during observation was 65-85 individuals and ii) the Rhesus population in mountainous regions were found as 40-45 individuals per colony. Such observations concluded that the monkeys numbers in a specified colony was not fixed, which were parallel to our observations. Such findings might be dependent on factors like the rate of recruitments in a population etc. (Maestripieri and Hoffman, 2012).

Another goal of present study was to assess the monkeys population structure in term of species component. The dominance species observed was *Macaca fascicularis* which posses the capabilities to adopt any environmental and weathers conditions. Which further have significant impact on the birth ratios, immigrations, deaths and emigrations of the mentioned species. Moreover the BIDE (Birth, Immigration, Death and Emigration) have been described as four major determinants of population structure (Fedigan, *et.al.*, 1983). The predominance nature of *Macaca fascicularis* justified by Crocket and Wilson, (1980) is in line with our findings, they claimed that the species were usually most abundant in swampy habitat which have been visualised in most part of their study area. In the last, the highest RRI values in our study presented by *Macaca nemestrina* suggested that RRI is not a function of frequency, where the most populous species of the day might not be the most populous species of tomorrow. It would, therefore, be worthwhile to carry out adequate inventory to ascertain the population structure before controlled cropping and avoid population mismanagement.

It can be concluded that the implementation of GLM (Generalized Linear Model) for such kind of studies and the likelihood further applications could easily be employed in any type of quasi research. In present study, it have been observed that the monkeys colony size as well as the rate of recruitment in preliminary population census will be essential before regular population control measures, should be taken. It is worth recommending that periodic controlled harvesting of monkey would be essential to avoid imminent population explosion, evident in the rate of recruitment index and consequently avoid the nuisance of the animal. Further it is suggested that socio-economic characteristics survey of the living people around study areas should be carried out.

Acknowledgements: The authors wish to acknowledge the support provided by the School of Biological Sciences, Universiti Sains Malaysia for providing the field work transportation facilities. The University Grant Scheme (RU-PRGS, USM) provided by the University Sains Malaysia is equally acknowledged. We are grateful for the Commonwealth Scholarship and Fellowship Plan provided by the Ministry of Higher Education Malaysia to Karimullah and the TWAS-USM PostDoctoral Fellowship provided to Dauda T.O. and Hafiz NidaUllah.

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