Calculation of a Sustainable Quota Harvesting of Long-Tailed Macaque (*Macaca fascicularis* Raffles) in Their Natural Habitats

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Abstract**—**The global demand for long-tailed macaques for medical experimentation has continued to increase. Fulfillment of Indonesian export demands has been mostly from natural habitats, based on a harvesting quota. This quota has been determined according to the total catch for a given year, and *not* based on consideration of any demographic parameters or physical environmental factors with regard to the animal; hence threatening the sustainability of the various populations. It is therefore necessary to formulate a method for calculating a sustainable harvesting quota, based on population parameters in natural habitats. Considering the possibility of variations in habitat characteristics and population parameters, a time series observation of demographic and physical/biotic parameters, in various habitats, was performed on 13 groups of long-tailed macaques, distributed throughout the West Java, Lampung and Yogyakarta areas of Indonesia. These provinces were selected for comparison of the influence of human/tourism activities. Data on population parameters that was collected included data on life expectancy according to age class, numbers of individuals by sex and age class, and 'ratio of infants to reproductive females'. The estimation of population growth was based on a population dynamic growth model: the Leslie matrix. The harvesting quota was calculated as being the difference between the actual population size and the MVP (minimum viable population) for each sex and age class.

Observation indicated that there were variations within group size (24–106 individuals), gender (sex) ratio (1:1 to 1:1.3), life expectancy value (0.30 to 0.93), and 'ratio of infants to reproductive females' (0.23 to 1.56). Results of subsequent calculations showed that sustainable harvesting quotas for each studied group of long-tailed macaques, ranged from 29 to 110 individuals. An estimation model of the MVP for each age class was formulated as Log Y = 0.315 + 0.884 Log N_i (number of individual on i^{th} age class). This study also found that life expectancy for the juvenile age class was affected by the humidity under tree stands, and dietary plants' density at sapling, pole and tree stages (equation: Y=2.296 – 1.535 RH + 0.002 Kpcg – 0.002 Ktg – 0.001 Kphn, R2 = 89.6% with a significance value of 0.001). By contrast, for the sub-adult-adult age class, life expectancy was significantly affected by slope (equation: Y=0.377 = 0.012 Kml, R2 = 50.4%, with significance level of 0.007). The infant-to-reproductive-female ratio was affected by humidity under tree stands, and dietary plant density at sapling and pole stages (equation: Y = -1.432 + 2.172 RH – 0.004 Kpcg + 0.003 Ktg, R2 = 82.0% with significance level of 0.001). This research confirmed the importance of population parameters in determining the minimum viable population, and that MVP varied according to habitat characteristics (especially food availability). It would be difficult therefore, to formulate a general mathematical equation model for determining a harvesting quota for the species as a whole.

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Keywords**—**Harvesting, long-tailed macaque, population, quota.

I. Introduction

LONG-TAILED macaques (*Macaca fascicularis*) play a very important role in the fields of medical research and medicines [1] as they are often used as experimental animals, given their close relationship to humans genetically. The increasing global demand for them is in line with technological development and the product variations used by humans [2]. Macaques have been one of the commodity sources of foreign exchange earnings, and have supported the income of several companies associated with the use of the animal [1]. Indonesia is the third largest global exporter of long-tailed macaques, after Mauritius and the Philippines [3], supplying, for example, America and Britain, which are lucrative markets for long-tailed macaques.

Most of the fulfillment of Indonesian export demand comes from wild populations, based on a harvesting quota set by the Ministry for Environment and Forestry, as the Management Authority, on the recommendation of The Indonesian Institute of Sciences (LIPI), as the Scientific Authority. The current harvesting quota, which is based only on the actual number captured during a given year, is feared to threaten the wild populations. Improper policy on harvesting quotas could threaten the sustainability of long-tailed macaques [4]. It is thus necessary to formulate a method for calculating the sustainable harvesting quota, based on population demographic data in the natural habitat, for each sex and age class.

This study has as its objective the formulation of a calculation method for deriving a sustainable harvesting quota, i.e. the total number of long-tailed macaques allowed to be captured from natural populations for each sex and age class.

II. Research Methodology

A. Research Location and Period

Please Fieldwork was conducted in the Provinces of Lampung (Bukit Banten and Tirtosari urban forests), Yogyakarta (Paliyan Wildlife Sanctuary-WS and Kaliurang Tourism Forest-TF), and West Java (Gunung Walat Education Forest-GWEF and Pananjung Pangandaran Strict Nature Reserve/ Nature Recreation Park-SNR/NRP). The study was carried out over a period of seven months (February - August 2014). Tools and instruments used in the study were: (1) map of the research sites, (2) tape measurement, (3) GPS receiver,

(4) hand counter, (5) rope, (6) camera, (7) tally sheets, (8) compass, (9) identification books of plant species, (10) writing equipment, and (11) software: SPSS 16.0 and Powersim 2.0.

B. Data Collection Method

1. Demographic Parameters

Data on demographic parameters of long-tailed macaque populations were collected using a concentration count method, based on preliminary information obtained either from field workers or the surrounding community. Observations were made twice daily, *i.e.* in the morning (6:00 to 8:00 am) and afternoon (4:00 to 6:00 pm), each with five replications. Data recorded during the observations included: number of individuals in each group, and number of individuals by sex and age class (infants, juvenile, sub-adults, and adults).

2. Habitat Factors

Data collection in respect of habitat factors at the study sites included: altitude, slope, humidity, temperature, and density of dietary plants. Data on altitude, slope, humidity and temperature were gathered at the plots where the macaques groups were observed, whereas data on dietary plants were gathered from the macaques' home ranges.

Dietary plants were identified through vegetation analysis performed at observation plots measuring 20 x 20 m that were staked out around fodder trees, which had been marked as the starting points for the vegetation analysis. For each feeding plant point location, five observation plots were established. Each feeding plant formed the starting point for making the first observation plot, followed by four other plots on every corner, *i.e*., north, south, west, and east Identification of dietary plants was done according to the information given by the community and field observations.

C. Data Analysis

1. Minimum Viable Population (MVP)

Calculation of MVP and population growth (N_{t+1}) for each group of long-tailed macaques was performed using the Leslie Matrix, where only the females were taken into account; data on the males were derived from the sex ratio. The matrix in question is as follows:

$$M \times N_t = N_{t+1}$$

$$\mathbf{M} = \begin{vmatrix} \delta_0 & 0 & Fx_m & Fx_d \\ P_1 & \delta_1 & 0 & 0 \\ 0 & P_2 & \delta_2 & 0 \\ 0 & 0 & P_2 & \delta_3 \end{vmatrix} \qquad Nt = \begin{vmatrix} N_{0,t} \\ N_{1,t} \\ N_{2,t} \\ N_{3,t} \end{vmatrix}$$

where, Fxm: fecundity in the sub-adultest age class; Fxd: fecundity in adult age class; Xd: adult age class; δ0: proportion of infant age class; P1: infant life expectancy; δ1: proportion of juvenile age class; P2: juvenile life expectancy; δ2: proportion of sub-adult age class; P2: sub-adult life expectancy; δ3: proportion of adult age class.

The Minimum Viable Population (MVP), which is the smallest population size that will ensure the population's survival in the long term [5] was calculated using the algebraic equation of two equations, namely B=D and N_t. The value at the intersection of the two equations is the MVP value. The formula used was:

$$F_{xm}.\ X_m + F_{xd}.\ X_d - m_b.\ X_b + m_a.\ X_a + m_m.\ X_m + \delta_{md}.X_d = Nt - F_{xm}.$$
$$X_m + F_{xd}.\ X_d + \delta_b.\ X_b) + (P_{xb}.\ X_b + \delta_a.\ X_a) + (P_{xa}.\ X_a + \delta_m.\ X_m) + (P_{xm}.\ X_m + \delta_d.\ X_d)$$

where, Fxm: fecundity in sub-adult age class; Fxd: fecundity for adult age class; Xd: total number of adults with a maximum fecundity of 12 years; mb: mortality for infant age class; Xb: Jum total number of infants; ma: mortality for juvenile age class; Xa: total number of juvenile; mm: mortality for sub-adult age class; δmd: mortality proportion for adult age class; δb: proportion of infants age class; Pxb: infant life expectancy; δa: proportion of juvenile age class; Pxa: juvenile life expectancy; δm : proportion of sub-adult age class; Pxm: Sub-adult life expectancy; δd: proportion of adult age class.

2. Harvesting Quota

The harvesting quota value was calculated for each age class and sex. The equation used was:

$$\mathbf{Q_{ij} = Nt_{ij} - MVP_{ij}}$$

where, Qi= harvesting quota for ith age class for j sex; Ntij = total individuals in ith age class for j sex at year tth; MVPij= minimum viable population for ith age class for j sex.

III. Results and Discussion

A. Demographic Parameters at Each Study Site

1. Size of Macaque Group at Each Observation Site

Results of the observation of the 13 groups of the long-tailed macaque populations across the regions, plus comparison with the results from previous years, are presented in Table IV. These results showed that the size of the groups in Gunung Walat Education Forest (GWEF) and Pangandaran SNR/NRP tended to increase; whereas the population of one group found in Paliyan WS fell by nearly half, from its size in 2010.

The largest group size of long-tailed macaques observed was found in Paliyan WS, which comprised 106 individuals. The reason for this could be the close proximity of the WS to the local communities' plantations of cassava, peanuts and coconuts, providing additional dietary plants for the macaques. Reference [6] shows that long-tailed macaques have a high degree of adaptation to the environment, including adaptations involving extended range or feeding regimes. Thus, long-tailed macaques have a greater ability to survive than other species with more specific types of food requirement.

The adaptability to food availability was also indicated by the increasing number of long-tailed female macaques which conceived during the peak fruiting season of fodder trees [7]. Although long-tailed macaques were considered to be frugivorous, in reality, they could consume various types of food other than fruits; these other foods were collected from both inside and outside the macaques' natural habitats, such as both inside and outside of tourism areas. Reference [8] shows that the ability to adapt to various forms of foods, could be a stress-reducing factor, so that its increased the macaque's foraging ability (ability to find food).

2. Life Expectancy, and The 'Ratio Of Infants and Juvenile to Reproductive Females'

In accordance with the Leslie Matrix, life expectancy (p_x) and the ratio of the 'number of infants and juvenile to reproductive females' (r) were two demographic parameters that were analyzed. The results of the calculations for these parameters are presented in Table I.

The results shown in Table I indicated that the macaque groups inhabiting North Pasir Putih, Plot 141 and Gunung Banten showed the highest life expectancy in the 'juvenile to sub-adult' age class. The highest life expectancy in the 'sub-adult to adult' age class was shown by the groups in Plot 141 and Tirtosari. Reference [9] shows that high life expectancy is very likely when habitat environmental conditions support the development of wild populations.

The highest ratio of the number of infants and juvenile to reproductive females was shown by the populations found in Plot 139 Paliyan WS. Natality can provide an indication of the condition of a wild population through an increase in the number of individuals and group size [10]. The lowest ratio of the number of infants and juvenile to reproductive females was shown by the populations found in Plot 141 Paliyan WS. This was supported by the fact that when compared with observations made in 2010, the population size for Plot 141 showed a declining trend. Although life expectancy for the macaques was high, the number of infants and reproductive females tended to decrease.

3. Habitat Parameters and Environmental Conditions

Results of measurements for microclimate under the stands, density of dietary plants, slope of habitats, and altitude above sea level are given in Table V.

The observed microclimatic conditions under the stands included the average daily temperature and air humidity. Habitats with the lowest average daily temperatures were found in GWEF TVRI station, GWEF watershed, Nirmolo and Tlogo Muncar. By contrast, Plot 141 and Plot 139 in Paliyan WS, and Tirtosari, showed the highest average daily temperatures. As for air humidity, the highest value was shown in the Rear Camp area of GWEF, with 85%, and the lowest was in Gunung Banten, with 65.33%.

Reference [11] shows that the long-tailed macaque is a species that is widely dispersed and inhabits a variety of habitat types. The various habitats that formed the study sites were: plantation (GWEF), coastal and lowland forest (Pangandaran SNR/NRP), karst forest (Paliyan WS), montane forest (Kaliurang TF), and the urban forest areas of Bandar Lampung City. Such habitat distribution suggests that the long-tailed macaque is a species with a high degree of adaptability to the conditions of their habitats [7]-[12], and an ability to proliferate in such habitats.

TABLE I
LIFE EXPECTANCY AND THE RATIO OF 'NUMBER OF INFANTS AND JUVENILE TO REPRODUCTIVE FEMALE MACAQUES'

No.	Group name	Life expectancy (px) Juvenile - Sub-adult	Life expectancy (px) Sub-adult-Adult	Ratio of infants per reproductive female (r)
1.	GWEF TVRI station	0.509	0.446	0.647
2.	GWEF rear camp	0.276	0.542	0.967
3.	GWEF watershed	0.300	0.231	1.200
4.	North Pasir Putih	0.945	0.545	0.344
5.	South Pasir Putih	0.686	0.764	0.350
6.	Rengganis Cave	0.303	0.720	0.813
7.	Kalenhaur	0.369	0.625	0.725
8.	Plot 141	0.933	0.952	0.231
9.	South of Plot 139	0.302	0.688	1.559
10.	Nirmolo	0.376	0.885	0.567
11.	Tlogo Muncar	0.565	0.833	0.405
12.	Gunung Banten	0.933	0.595	0.240
13.	Tirtosari	0.400	0.909	0.550

The topography of the various habitat types observed, ranged from flat to hilly areas. Flat topographies were found in parts of the GWEF observations sites and in Pangandaran SNR/NRP, with slopes ranging from 5^0-15^0. Hilly topographies, on the other hand, were found in several observations sites within GWEF, Kalenhaur in Pangandaran SNR/NRP, Paliyan WS, Kaliurang TF, and the urban forest areas in Bandar Lampung City. Slopes in the various hilly areas ranged from 20^0-40^0.

The highest densities of dietary plant at seedling stage were found in South Pasir Putih (SPP) area, with a density of 3505 individuals/ha, and Rengganis Cave area, with 2145 individuals/ha. This was due to the presence of many bayur (*Pterospermum javanicum*) seedlings in SPP, which is the natural dietary plant for macaques. Bayur is a fast growing species during seedling stage, although not all seedlings tend to survive past the seedling stage. The lowest density value for dietary plants at seedling stage was found in the watershed area of GWEF, with a value of 160 individuals/ha.

The highest densities of dietary plants at sapling stage were found in Kalenhaur, Plot 141, and Tlogo Muncar, each with a value of 245 individuals/ha; the lowest density value was found in Plot 139. The highest density of dietary plants at pole stage was found in Plot 139, with a density value of 245 individuals/ha, whereas the lowest densities were found in GWEF TVRI station and watershed, each with a density value of 55 individuals/ha.

The long-tailed macaques' area in GWEF has long been dominated by trees planted since 1951 [13], resulting in few natural dietary plants at pole stage. The highest density of dietary plants at tree stage was found in GWEF watershed, with a value of 435 individuals/ha, whereas the lowest density value was found in Plot 139, with 70 individuals/ha.

B. Harvesting Quota

1. Minimum Viable Population (MVP)

Results of calculations, as shown in Table II, indicated that the lowest MVP was that of Group 5, located within South Pasir Putih (Pangandaran NRA), and having only 29 individuals, composed of: ten juvenile, four sub-adult males, four sub-adult females, four adult males and seven adult females. The highest MVP was that of Group 9, found in Plot 139, with 110 individuals, composed of 62 juvenile, 14 sub-adult males, 18 sub-adult females, ten adult males, and six adult females. The values of the minimum sustainable population of the 13 groups of long-tailed macaques varied with an average of 62 individuals, consisting of 27 juvenile; 7 sub-adult males and 20 sub-adult females; 7 adult males and 12 adult females. Some primates have minimum values which vary between 50 and 100,000 individuals, depending on the total area. For long-tailed macaques, the minimum or smallest area was found to be 23 km^2, with a population density of 33.5 individuals/km^2. For the genus Macaca, a higher level of resistance due to the former's ability to survive in various environmental conditions; even within disturbed environments when compared to other primates.

The MVP obtained for long-tailed macaques in this research was the average obtained from a variety of group sizes with a similar ratio of 'infants and juvenile to reproductive females', and life expectancy. The average value of life expectancy for the 'juvenile to sub-adult' age class was 0.89, and for the 'sub-adult to adult' age class was 0.92. The average fecundity was 1, and the ratio of 'infants and juveile per reproductive female' was found to be 0.66. Comparison of the MVP size of each group, with the average value of the MVP per group, is presented in Fig. 1.

2. Harvesting Quota Value

Based on the size of the MVP (Table II), and the size of the populations observed (Table IV), it could be stated that none of the groups found in the selected provinces, *i.e*., Bandar Lampung (Gunung Banten, Tirtosari), Yogyakarta (Paliyan WS and Kaliurang TF) and West Java (GWEF and Pangandaran SNR/NRP), had reached their MVP at the time of data collection, meaning that no group should be harvested. Further harvesting quota values were obtained using simulation results for population growth, processed using Powersim 2.0

These results suggested that the MVP for each group would be reached in year one, except for two groups: the Gunung Banten group, where it would be reached in year three; and the Tirtosari group, where harvesting could begin from year four. Harvesting quota values were calculated for each age class and sex; (an example of a simulation up to year two, is presented in Table III). This was done to avoid the possible exploitation of particular sex and age classes that would threaten the groups' sustainability.

The results showed that the highest harvesting quota for the infant age class was that calculated for Plot 139 being 13 individuals, whereas the lowest was for GWEF Rear Camp, where no harvest was possible. For the sub-adult age class, the harvesting quota was found to be the highest for GWEF Rear Camp. The highest harvesting quotas for the adult age class were those for Plot 141 and Plot 139 (Table VI).

TABLE II
MVP FOR EACH MACAQUE GROUP

Group	Sex Ratio	MVP	J	Sub-adult		Adult	
				M	F	M	F
1	1:2	64	26	5	14	9	10
2	1:2	67	33	6	10	7	11
3	1:3	47	27	3	9	2	6
4	1:2	52	15	11	4	5	17
5	1:2	29	10	4	4	4	7
6	1:2	34	15	5	7	2	6
7	1:2	73	32	6	20	8	7
8	1:2	70	25	7	12	11	15
9	1:2	110	62	14	18	10	6
10	1:2	53	26	9	4	6	18
11	1:2	63	18	11	4	5	15
12	1:3	55	21	5	9	4	16
13	1:2	92	35	4	12	16	25
Average		62	27	7	20	7	12

Note: J-juvenile; M-male; F-female

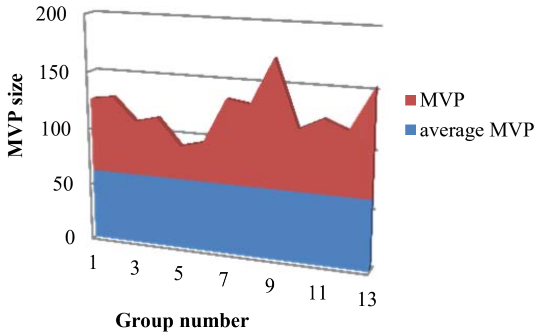

Fig. 1 Value of MVP for each group compared to average MVP of each group

TABLE III
EXAMPLE OF POPULATION GROWTH SIMULATION FOR EACH MACAQUE GROUP DURING YEAR ONE AND YEAR TWO

Group	MVP	N1	N2	Group	MVP	N1	N2
1	64	67	81	8	70	33	42
2	67	65	81	9	110	129	144
3	47	57	55	10	53	53	36
4	52	52	65	11	63	65	78
5	29	29	35	12	55	58	71
6	34	35	43	13	92	68	77
7	73	71	61				

TABLE IV
RESULTS OF CALCULATION OF LONG-TAILED MACAQUES IN SEVERAL STUDY SITES

Location	Group Number	Group Name	Population 2012[1]					Population 2014				
			J	SA	MA	FA	Total	J	SA	MA	FA	Total
Walat	1	TVRI	9	6	6	9	**30**	22	14	7	8	**51**
	2	Rear Camp	7	5	4	7	**23**	29	10	5	8	**52**
	3	Watershed	12	5	2	12	**31**	24	9	1	4	**38**
Location	**Group Number**	**Group Name**	**Population 2009[2]**					**Population 2014**				
			J	**Y**	**MA**	**FA**	**Total**	**J**	**Y**	**MA**	**FA**	**Total**
Pangandaran SNR/NRP	4	NPP (North Pasir Putih)	4	21	9	10	**44**	11	13	3	14	**41**
	5	SPP (South Pasir Putih)	2	5	8	4	**19**	7	6	3	8	**24**
	6	KH (kalenhaur)	2	7	4	3	**16**	13	6	3	6	**28**
	7	Rengganis Cave (RC)	2	11	6	7	**26**	29	11	5	14	**59**
Location	**Group Number**	**Group Name**	**Population 2010[3]**					**Population 2014**				
			J	**Y**	**MA**	**FA**	**Total**	**J**	**Y**	**MA**	**FA**	**Total**
Paliyan WS	8	Plot 141	24	25	3	5	**57**	6	7	5	11	**29**
	9	South of Plot 139	30	24	3	11	**68**	53	20	9	24	**106**
Location	**Group Number**	**Group Name**	**Population 2010[4]**					**Population 2014**				
			J	**Y**	**MA**	**FA**	**Total**	**J**	**Y**	**MA**	**FA**	**Total**
Kaliurang Tourism Forest	10	Tlogo Muncar	14	14	3	5	**36**	17	12	6	18	**53**
	11	Nirmolo	10	5	2	3	**20**	17	8	7	10	**42**
Location	**Group Number**	**Group Name**	**Population 2010[5]**					**Population 2014**				
			J	**Y**	**MA**	**FA**	**Total**	**J**	**Y**	**MA**	**FA**	**Total**
Bandar Lampung City	12	Gunung Banten	15	4	8	4	**9**	40	12	5	9	**4**
	13	Tirtosari	10	5	10	14	**23**	62	22	4	7	**11**

Note: J-juvenile (include infants); SA – sub-adult; MA – male adult; FA – female adult; [1] [13]; [2] [18]; [3] [19]; [4] [20].

Based on calculations up to year 10, the harvesting quotas for each age class and sex, showed an increase of an average 25% annually. This calculation was based on the population growth data, assuming the absence of early harvesting. With the increasing number for group size, the harvesting quota also increased, making it possible for the group to be in a sustainable state. Harvesting was also one strategy for maintaining a balance in nature. Reference [14] shows that populations that are rarely harvested do not tend to experience a population increase; hence harvesting could actually increase population growth.

3. Effect of Environmental Factors on Demographic Parameters

The demographic parameters that were analyzed were life expectancy and 'ratio of infants and juvenile to reproductive females'. Models of the relationship between environmental factors and long-tailed macaque demographic parameters, obtained at 5% significance level, are as follows:

1. $Y_{(\text{life expectancy juvenile-sub-adult})} = 2.296 - 1.535$ RH + 0.002 Kpcg – 0.002 Ktg – 0.001 Kphn (R^2 = 89.6% with significance of 0.001);
2. $Y_{(\text{life expectancy sub-adult-adult})} = 0.377 + 0.012$ KML(R^2 = 50.4% with significance of 0.007); and
3. $Y_{(\text{ratio number of infants to reproductive females})} = -1.432 + 2.172$ RH – 0.004 Kpcg + 0.003 Ktg(R^2 = 82% with significance of 0.001).

Results of ANOVA analysis of the demographic parameters (life expectancy and 'ratio of infants and juvenile to reproductive females') with several environmental variables, showed that life expectancy of the juvenile to sub-adult age class was influenced by humidity under stands, and density of dietary plants at sapling, pole and tree stages. These results were different from the life expectancy for the sub-adult to adult age class, where the most influential environmental factor was the degree of slope. The ratio of the 'number of infants and juvenile to reproductive females' was affected by humidity under the stands, and dietary plant density at sapling and pole stages.

The life expectancy of 'infants and juvenile to sub-adult' was affected by air humidity and dietary plant density at sapling, pole and tree stages. During infancy, long-tailed macaques required a good environment in which to grow, and this should be supported by the conditions of the group itself. From the equation, it was known that the relationship between air humidity and life expectancy was negative, suggesting that an increase in humidity by as much as 1% would decrease the life expectancy of the 'juvenile to sub-adult age' class by 1.535, assuming other independent variables have fixed values. During the infant age class, macaques would require more food than other age classes, since infants were in an important stage of development.

As against this, life expectancy for the sub-adult to adult age class, based on the equation model, was influenced only by the slope of the terrain. Locations with extreme slopes would certainly have affected the pattern of development of the sub-adult macaques. The sub-adult age class involves a transition to adulthood, and thus sub-adult macaques tend to explore more of their environment, to search for food, or expand their daily ranges while trying not to enter into the territory of another macaque group. Therefore, flat environmental conditions would increase the life expectancy of sub-adult macaques compared to habitats with extreme slopes, regardless of the fact that long-tailed macaques showed a high degree of adaptability to the environment [7]-[12].

Air humidity under the stands proved to be one environmental variable that equally impacted life expectancy and the 'ratio of number of infants and juvenile to reproductive females'. Temperatures and seasonal precipitation levels at a habitat would affect the availability of dietary plants for primates, which in turn would affect the breeding season; although reproductive ability was also influenced by age of parents, group composition, group social status, nutrition, body weight, external factors, and stress level [15]. Primates are a group of animals with continuous potential for sexual activity [16]. Long-tailed macaques in tropical regions do not have particular seasons for mating, so the sexual activity of these animals could take place every day during the year [17]. However, sexual activity that took place throughout the year was not necessarily an indication of successful breeding for long-tailed macaques. There were other external factors that affected the observed demographic parameter variables.

4. MVP Estimation Model Based on Actual Population Number

The size of the MVP was related to the condition of the actual population. This was observed in the relationship between the values of the MVP and the actual population, in the formulation of the equation. Based on linear regression analysis, it was known that this relationship was very significant, as represented by the quadratic equation, MVP = 0.315 + 0.884 N_0 (R^2 = 72.4% with significance value of 0.001).

TABLE V
HABITAT PARAMETERS AND ENVIRONMENTAL CONDITIONS IN ALL STUDY SITES

No.	Group Name	Microclimate conditions		Altitude (m asl)	Slope (^{0})	Dietary plants density			
		Air temperature (^{0}C)	Relative humidity (%)			seedling	sapling	pole	tree
1.	GWEF TVRI station	21.50	82.33	709	21	170	95	55	230
2.	GWEF rear camp	23.25	85.00	624	15	255	120	150	295
3.	GWEF watershed	22.88	82.67	602	7	160	125	115	435
4.	North Pasir Putih	26.50	76.00	37	12	800	240	95	220
5.	South Pasir Putih	26.50	77.33	76	5	3505	235	305	145
6.	Rengganis Cave	26.75	79.00	30	28	2145	95	100	320
7.	Kalenhaur	26.38	76.00	93	28	535	245	120	265
8.	Plot 141	27.50	68.67	274	40	380	245	200	120
9.	South of Plot 139	27.50	71.00	196	38	375	55	245	70
10.	Nirmolo	21.00	80.00	1040	23	705	240	160	400
11	Tlogo Muncar	22.75	84.33	920	40	325	245	135	145
12.	Gunung Banten	27.75	65.33	146	23	290	130	70	85
13.	Tirtosari	28.00	70.67	125	28	340	90	120	180

TABLE VI
THE HARVESTING QUOTA OF LONG-TAILED MACAQUES FOR EACH SEX AND AGE CLASS DURING YEAR TWO

Group	Infants+Juvenile	sub-adult		Adult		Group	Infants+Juvenile	sub-adult		adult	
		Male	Female	Male	Female			Male	Female	Male	Female
		GWEF TVRI group						**Paliyan WS Plot 141**			
Total	28	6	25	8	7	Total	34	9	15	18	13
MVP	26	5	14	9	10	MVP	25	7	12	11	15
Quota	2	1	11	0	0	Quota	9	2	3	7	0
		Rear camp						**Plot 139**			
Total	33	13	27	4	4	Total	75	27	19	14	9
MVP	33	6	10	7	11	MVP	62	14	18	10	6
Quota	0	7	17	0	0	Quota	13	13	1	4	3
		DAS						**Kaliurang TF, Tlogo Muncar**			
Total	30	5	13	3	4	Total	29	14	6	7	20
MVP	27	3	9	2	6	MVP	26	9	4	6	18
Quota	3	2	4	1	0	Quota	3	5	2	1	2
		Pangandaran NRP North Pasir Putih						**Kaliurang TF Nirmolo**			
Total	20	13	12	8	12	Total	20	6	9	9	17
MVP	15	11	4	5	17	MVP	18	11	4	5	15
Quota	5	2	8	3	0	Quota	2	0	5	4	2
		South Pasir Putih						**Bandar Lampung City, Bukit Banten**			
Total	12	5	8	4	6	Total	30	8	14	4	15
MVP	10	4	4	4	7	MVP	21	5	9	4	16
Quota	2	1	4	0	0	Quota	3	2	1	0	0
		Pangandaran SNR Kalenhaur						**Bandar Lampung City Tirtosari**			
Total	20	6	9	3	5	Total	40	6	11	22	25
MVP	15	5	7	2	6	MVP	35	4	12	16	25
Quota	5	1	2	1	0	Quota	5	2	0	6	0
		Rengganis cave									
Total	38	9	19	6	12						
MVP	32	6	20	8	7						
Quota	6	3	0	0	5						

IV. Conclusion and Recommendation

At the 5% significance level, the results of ANOVA analysis of the demographic parameters (life expectancy and the ratio of 'the number of infants to reproductive females'), with multiple environmental parameters, indicated that the life expectancy for the juvenile-sub-adult age class was affected by humidity under the stands, and density of dietary plants at sapling, pole and tree stages. The life expectancy of the sub-adult-adult age class, by contrast, was affected by the slope of the habitat. The ratio of the 'number of infants to reproductive females' was influenced by humidity and dietary plant density at sapling and pole stages.

The sustainable harvesting quotas for each group of long-tailed macaques ranged from 6 to 34 individuals. The largest component of these harvesting quotas was found to be the sub-adult age class, with number of individuals varying between one and 17.

MVP for each age class and sex can be estimated based on the calculations of the number of individuals in a group according to age class and sex, using the equation of $Y = 0.315 + 0.884 N_0$.

For said equation to be applied in a variety of different habitat types and conditions, it is required that this research be extended, in terms of duration and habitat variability, to obtain spatio-temporal variations in life expectancy and ratio of the 'number of infants and juvenile to reproductive females'.

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