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Morphometric Assessment of Rhesus Macaques (*Macaca mulatta*) from Bangladesh

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Abstract: The natural distribution of rhesus macaques (*Macaca mulatta*) extends from South to East Asia, with substantial morphological variation among populations from different geographic locations. In the following report we compare morphometric measurements from rhesus macaques from Bangladesh to measurements from free-ranging rhesus in Nepal and captive rhesus populations originating in China and India. Our data indicate that Bangladeshi rhesus are morphologically similar to populations in South Asia, particularly India, and distinct from rhesus macaques originating in China. Our results also indicate that relative to the South Asian population samples, the rhesus macaques originating from China are distinct morphometrically.

Key words: Macaques, Asia, morphology, growth, evolution, Bangladesh

Introduction

Rhesus monkeys are among the best studied of the nonhuman primates owing to their wide use as models for studying human physiology and disease. Their natural range extends from Afghanistan in the west to the eastern-most edge of China and south through central Thailand, and includes a variety of ecological niches. Rhesus macaques are among the handful of nonhuman primate species capable of thriving in human-altered environments, including densely populated urban areas. Research on Bangladeshi rhesus monkeys has provided data on their distribution, conservation status (Green 1978; Gittins and Akonda 1982; Khan and Ahsan 1986; Feeroz *et al*. 1995a; Feeroz 2001), ecology, behavior (Feeroz *et al.* 1995b; Taslima 2002; Sarker *et al.* 2005) and genetics (Feeroz *et al*. 2008). Feeroz *et al.* (1995a) described coat color variation in different local populations of rhesus macaques. To date, however, no morphological analysis of Bangladeshi macaques has been published. Morphometric analyses of other rhesus populations (see Smith *et al*. 1987; Smith and Scott 1989; Smith 1994; Clarke and O'Neil 1999; Hamada *et al*. 2005; Taylor and Schillaci 2008) provide a context for the present comparative intra-species study.

Methods

Between 2006 and 2008, 47 rhesus macaques (*Macaca mulatta*) from five sites in Bangladesh were trapped in conjunction with a large study on simian retroviruses in Asia (Jones-Engel *et al*. 2008) (Fig. 1). The sex and age-class distribution for the sample population is shown in Table 1. A number of morphological measurements were collected while the monkeys were under sedation (Table 2). Monkeys were placed in one of four age categories, based on their pattern of dental eruption and the occlusal wear of the adult third molars (Table 3). We compared these measurements to measurements taken on Nepalese macaques in 2005 (included in Table 1) and to previously published morphometric data from Indian and Chinese rhesus macaques (Hamada *et al*. 2005).

Univariate comparisons of adult morphometric variables were conducted using t-tests, and the nonparametric Mann-Whitney U-test. Growth patterns were assessed by plotting raw values by age category. A multivariate assessment of morphometric variation was achieved through principal components analysis of adult means, and through a cluster analysis of principal component scores.

Results

The results from our univariate comparison revealed significant differences between the Bangladesh adult female rhesus macaques and the adult female rhesus from Nepal in bizygomatic breadth and bifrontal breadth (Table 4). A significant difference in foot length between adult females from Bangladesh and India was detected, as was a difference in tail length between adult females from Bangladesh and adult females from China. The adult males from Nepal and China differed significantly from the adult males from Bangladesh in trunk and foot lengths. The Chinese adult males also differed significantly from the Bangladesh males in body mass.

Among the populations included in the analysis, the Bangladesh sample exhibited the lowest level of sexual dimorphism. The Bangladesh sample also showed the least variation in sexual dimorphism across traits. A similar condition was observed for the sample from India. The population samples from Nepal and China both exhibited a level of sexual dimorphism approximately 1.12 times greater than that observed for the Bangladesh sample.

Our evaluation of male and female growth for the Bangladesh sample revealed similar patterns of growth until age

Table 1. Maximum sample sizes for age- and sex-specific groupings for the free-ranging Bangladesh and Nepal sample populations.

	Bangladesh		Nepal	
Age category	♀	♂	♀	♂
Young juvenile	3	2	5	4
Juvenile	6	5	6	2
Older juvenile	10	1	1	0
Subadult	2	0	0	0
Adult	11	7	9	10
Total	**32**	**15**	**21**	**16**

Table 2. Morphometric variables used in the study.

Variable	Definition
Body weight	Weight in kilograms
Trunk length	Linear distance between the sternal notch and the superior margin of the pubic symphysis, measured with a flexible metal measuring tape
Foot length	Maximum length of the foot measured with spreading calipers
Tail length	Length measured from the craniodorsal margin of the first caudal vertebra to the tip of the tail
Bizygomatic breadth	Maximum breadth between the lateral margins of the zygomatic arches measured with spreading calipers
Bifrontal breadth	Maximum breadth between the lateral margins of the frontozygomatic suture measured with spreading calipers
Skull length	Maximum length between prosthion and inion measured with spreading calipers

Table 3. Age categories based on dental eruption patterns.

	Age Category	Approximate age range[1]	Definition
1	Young juvenile	0.43 to 1.32 years	Complete eruption of deciduous dentition observed without eruption of any adult first molars
2	Juvenile	1.32 to 3.15 years	Eruption of any of the adult first or second incisors without eruption of the adult second molars
3	Older juvenile	3.15 to 4.04 years	Eruption of the adult second molars and premolars without eruption of the adult canines
3.5	Subadult	4.04 to 6.40 years	Eruption of canines without complete eruption of the third molars.
4	Adult	>6.40 years	Complete eruption of adult third molars

[1] based on dental eruption schedule presented in Smith *et al.* (1994).

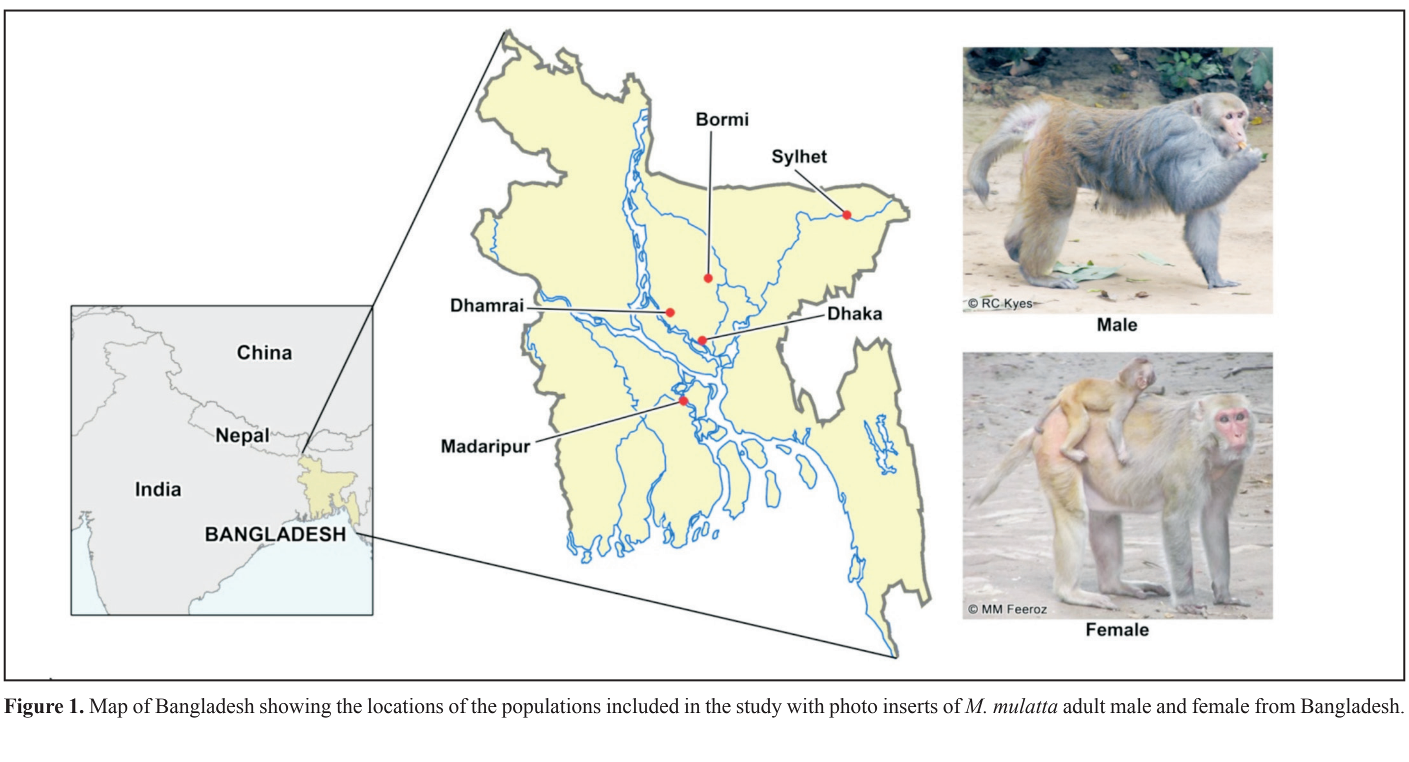

Figure 1. Map of Bangladesh showing the locations of the populations included in the study with photo inserts of *M. mulatta* adult male and female from Bangladesh.

category 3 (approximately 3 to 4 years of age), at which time females exhibit slower rates of size increases (Fig. 2). A comparison of the growth patterns of the Bangladesh and Nepal samples revealed similar patterns with some minor differences apparent for both males and females (Fig. 3). Small sample sizes for some age categories, however, limit interpretation of small pattern differences.

The results from the multivariate analysis suggest that the Chinese macaques are distinctive when all variables are considered simultaneously. A plot of the first two principal components that explain over 89% of the total variation revealed separation of males and females along the first principal component, and separation of the Chinese male and female samples from the South Asian samples along the second principal component (Fig. 4). All positive eigenvector loadings for the first principal component indicate that it describes size variation, while subsequent components describe variation in shape (Table 5). A plot of second and third principal components describing over 92% of the shape variation again shows that the Chinese samples are distinct (Fig. 5). The eigenvector directions and magnitudes mapped onto the bivariate plot of shape components indicates the second component is defined by variation in tail length relative to body mass and foot length. The Nepal and Indian samples are separated along the third principal component which is defined primarily by variation in bizygomatic breadth and trunk length.

A UPGMA cluster analysis of the second and third principal components describing shape variation grouped the samples from India and Bangladesh together. The Nepal samples joined the India and Bangladesh grouping to form a larger cluster to the exclusion of the Chinese samples (Fig. 6). Two primary groups are therefore apparent: one South Asian and one East Asian.

Discussion

To date there has been no systematic characterization of the morphology of rhesus macaques from Bangladesh. The results of our study suggest that the rhesus macaques from Bangladesh are more similar morphometrically to rhesus macaques from South Asia, particularly India. The rhesus macaques of Chinese origin are distinct. Short tail length seems to be the primary trait distinguishing the Chinese rhesus from the South Asian samples. Fooden (2000) indicated that tail length in *M. mulatta* does vary slightly with latitude (also see Fooden and Albrecht 1999), consistent with Allen's rule (Allen 1877). More interesting, perhaps, is Fooden's observation of a strong negative correlation between tail length and longitude. The Chinese rhesus in the present study exhibited the shortest tails.

The female macaques from Bangladesh exhibited a mean body weight (7.73 kg, SD = 1.43) generally comparable to the other populations in the study, but much larger than the species average reported by Fooden (2000) (5.34 kg, SD = 1.34). A similar condition was observed for male body weight. In our study, the male rhesus macaques exhibited the lowest mean body weight estimate (8.66 kg, SD = 2.66) among the geographic populations. This estimate, however was greater than Fooden's (2000) reported mean male body weight for the species (7.70 kg, SD = 2.33). The reason for this difference is not immediately apparent but may be a product of provisioning or access to human food sources (e.g., crops or garbage) for our Bangladesh and Nepal populations.

A comparison of male and female growth patterns for the Bangladesh sample revealed divergent trajectories after age category 3 (approximately 3 to 4 years of age), eventually leading to observed dimorphism in adult dimensions. This sexual dimorphism is more pronounced for cranial traits than for body weight and trunk length. Interestingly, the overall level of sexual

Table 4. Comparison of adult body size variables among populations of *M. mulatta*. Shaded values differ significantly (α = 0.05) from those observed for the population sample from Bangladesh.

	Bangladesh			Nepal			India			China		
	Mean	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**
Female												
Body mass	7.73	1.43	10	6.9	1.26	5	7.90	1.90	17	7.80	1.40	36
Trunk length	35.57	2.20	10	36.10	2.44	8	34.23	2.83	16	35.63	2.14	36
Foot length	15.45	0.71	10	15.02	0.61	5	14.71	0.89	13	15.99	0.80	24
Tail length	23.09	2.37	10	21.98	2.18	8	22.09	1.80	16	18.86	1.58	14
Bizygomatic br.	81.45	5.47	11	76.19	5.88	8	82.90	5.20	13	84.20	3.80	23
Bifrontal br.	69.27	2.83	11	66.33	2.16	9						
Skull length	114.0	4.49	10									
Male												
Body mass	8.66	2.66	7	9.76	1.47	9	9.80	2.50	6	12.10	1.80	15
Trunk length	37.11	2.49	7	40.06	1.80	8	37.25	3.75	6	39.62	2.56	15
Foot length	16.41	1.42	7	18.01	0.92	9	16.17	1.22	5	17.77	1.15	10
Tail length	25.71	4.18	7	26.33	1.97	8	24.96	0.99	6	21.77	3.26	9
Bizygomatic breadth	91.00	8.41	7	90.20	7.14	8	96.80	10.50	5	96.60	4.30	11
Bifrontal breadth	74.67	4.72	6	74.19	2.90	8						
Skull length	123.43	8.34	7									

Note: Formal comparisons between the Bangladesh samples and those from India and China were made using a t-test based on published estimates of means and standard deviations, while comparisons made between the samples from Bangladesh and Nepal were made using a Mann-Whitney U-test based on the raw data dimorphism in the Bangladesh sample is low relative to the other population samples. The observed differences in sexual dimorphism invites speculation that there may be variation within the species in the magnitude of male-male competition for mates.

In conclusion, the results of our comparative morphometric study of the rhesus macaques from Bangladesh indicates this population is broadly similar to other South Asian populations, but differs, like other South Asian populations, from the rhesus macaques of Chinese origin.

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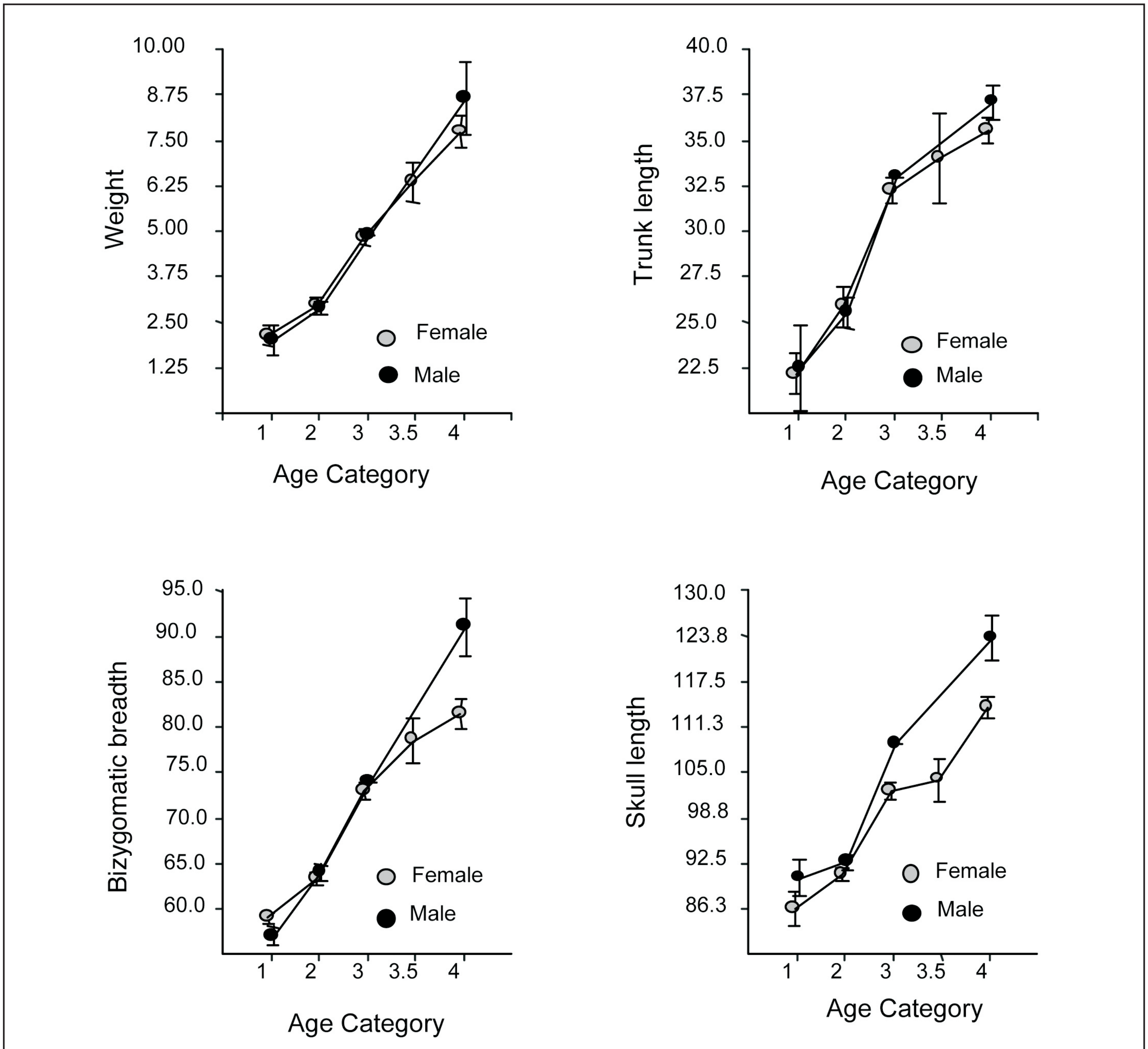

Figure 2. Bivariate plots describing sex-specific growth trajectories.

Table 5. Sexual size dimorphism scores for adult *Macaca mulatta*[1].

	Bangladesh	Nepal	India	China
Body mass	1.120	1.414	1.241	1.551
Trunk length	1.043	1.110	1.088	1.112
Foot length	1.062	1.199	1.099	1.111
Tail length	1.113	1.198	1.129	1.154
Bizygomatic breadth	1.117	1.184	1.168	1.147
Mean	1.091	1.221	1.145	1.215
Median	1.113	1.198	1.129	1.147
Range	0.077	0.304	0.153	0.440

[1] Sexual dimorphism scores calculated as the male mean/female mean

Table 6. Eigenvector loadings and eigenvalues from the principal components analysis of adult means.

Variable	PC1	PC2	PC3	PC4	PC5
Weight	0.480	-0.330	0.266	-0.681	0.355
Foot	0.490	-0.121	-0.442	0.512	0.537
Trunk	0.488	0.007	-0.519	-0.211	-0.669
Tail	0.279	0.931	0.113	-0.124	0.166
Bizygomatic	0.461	-0.099	0.673	0.463	-0.332
Eigenvalue	3.663	0.816	0.426	0.073	0.022
% of variation	73.258	16.322	8.516	1.489	0.431
Cumulative %	73.23	89.55	98.07	99.56	100

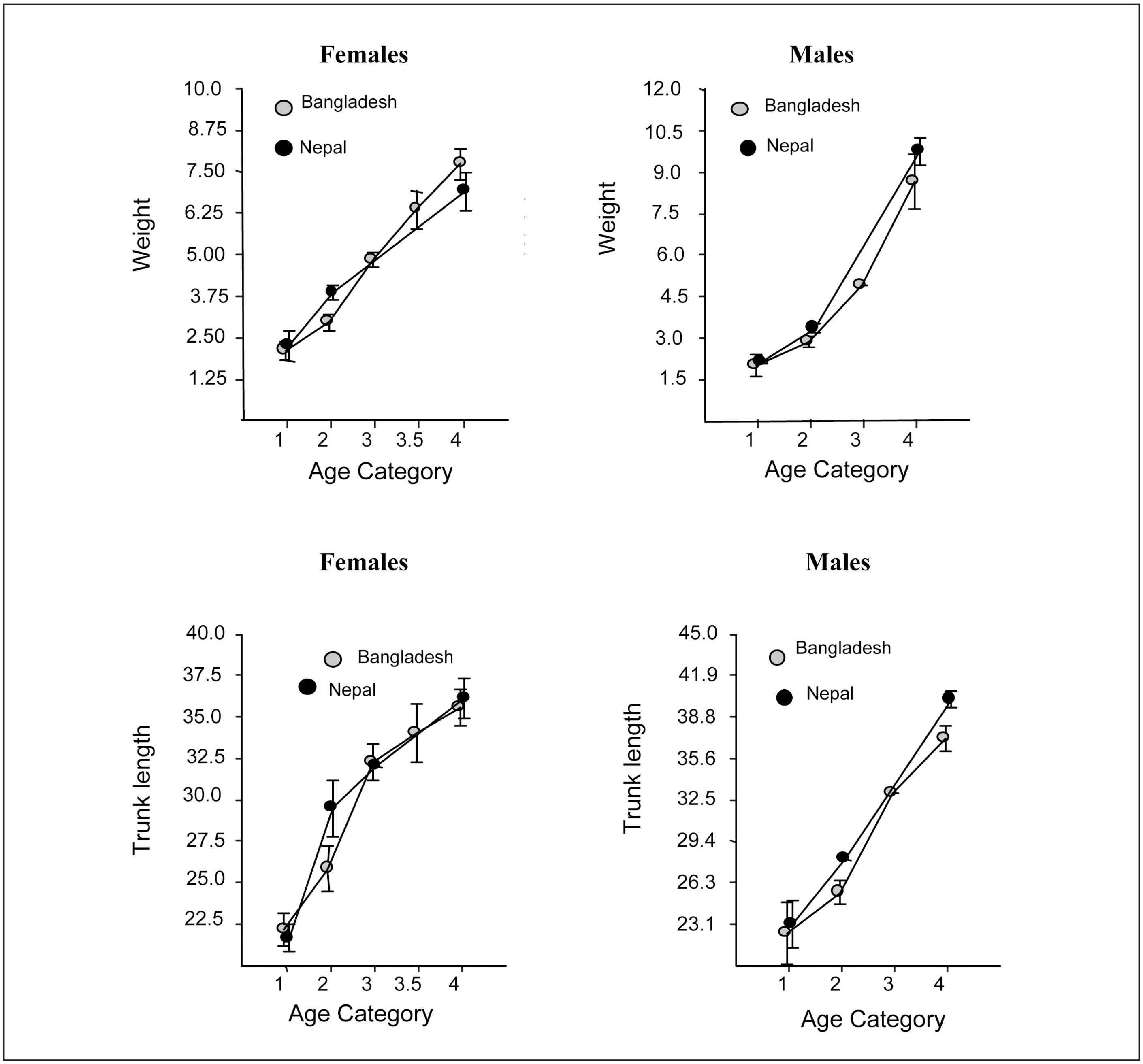

Figure 3. Bivariate plots describing growth trajectories for the Bangladesh and Nepal samples.

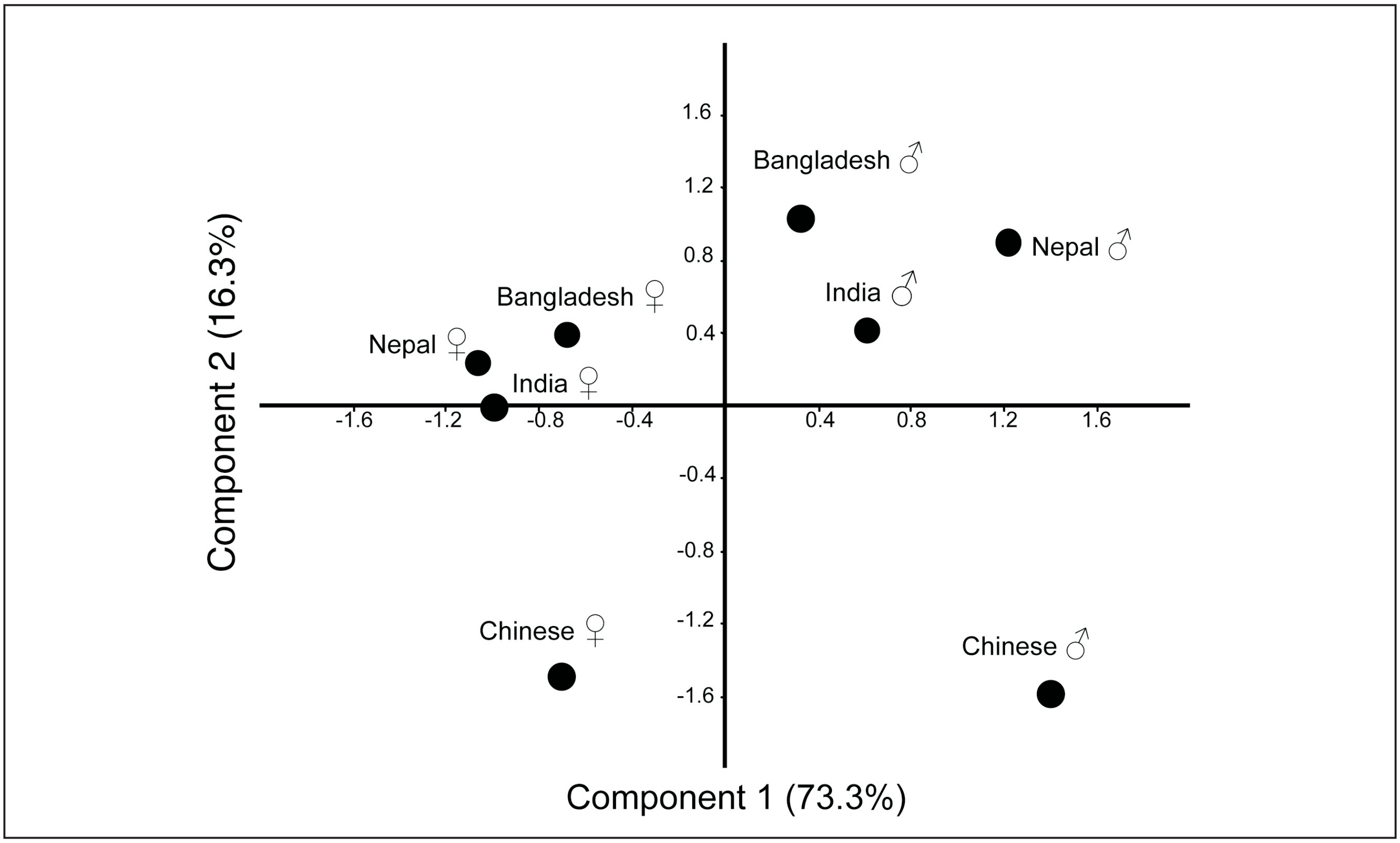

Figure 4. Plot of scores for the first two principal components extracted from a matrix of means for five morphometric variables.

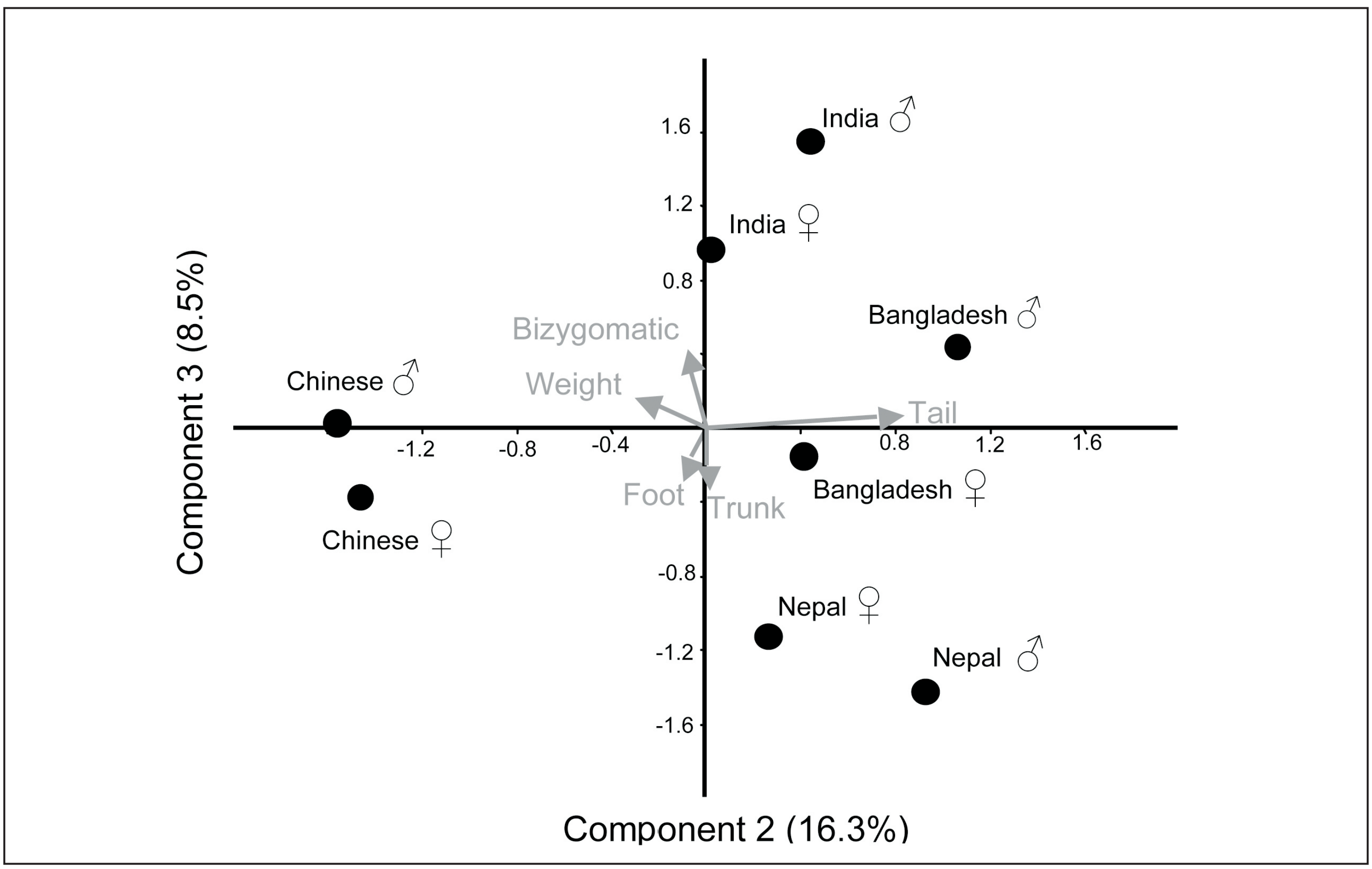

Figure 5. Plot of scores for the second and third principal components extracted from a matrix of means for five morphometric variables. Gray arrows mark the direction and magnitude of eigenvector loadings.

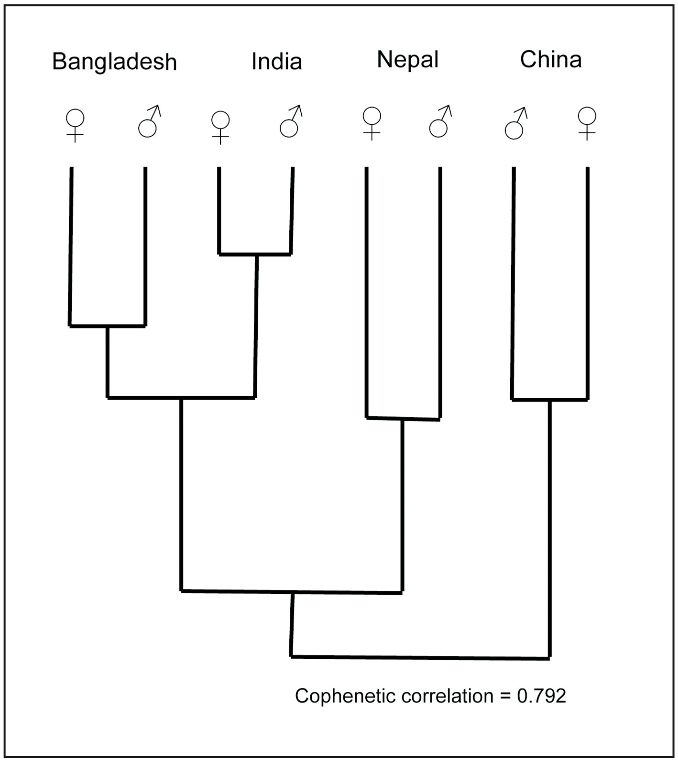

Figure 6. Dendrogram from UPGMA cluster analysis of the second and third principal components describing shape.

Literature Cited

Allen, J. A. 1877. The influence of physical conditions in the genesis of species. *Radical Rev.* 1: 108–140.

Clarke, M. R. and J. A. S. O'Neil. 1999. Morphometric comparison of Chinese-origin and Indian-derived rhesus monkeys (*Macaca mulatta*). *Am. J. Primatol*. 47: 335–346.

Feeroz, M. M. 2001. Species diversity and population density of nonhuman primates in north-east and south-east of Bangladesh. *Ecoprint* 8: 53–57.

Feeroz, M. M., M. A. Islam and M. M. Kabir. 1995a. Status, distribution and conservation of primates of Bangladesh. *Kyoto Univ*. *Overseas Res. Rep. Studies on Asian Nonhuman Primates* 9: 73–82.

Feeroz, M. M., M. A. Islam, S. Begum and M. M. Kabir. 1995b. Observations on the breeding activities of rhesus macaques (*Macaca mulatta*) of the Dhaka Zoo. *Bangladesh J. Life Sci*. 7(1–2): 7–14.

Feeroz, M. M., Md. Kamrul Hasan, Y. Hamada and Y. Kawamoto. 2008. STR polymorphism of mtDNA D-loop in rhesus macaques of Bangladesh. *Primates* 49:69–72.

Fooden, J. 1997. Tail length variation in *Macaca fascicularis* and *M. mulatta*. *Primates* 38: 221–231.

Fooden, J. 2000. Systematic review of the rhesus macaque, *Macaca mulatta* (Zimmermann, 1780). *Fieldiana Zoology* 96: 1–180.

Fooden, J. and G. H. Albrecht. 1999. Tail-length evolution in *fascicularis*-group macaques (Cercopithecidae: *Macaca*). *Int. J. Primatol*. 20: 431–440.

Gittins, S. P. and A. W. Akonda. 1982. What survives in Bangladesh? *Oryx* 16: 275–281.

Green, K. M. 1978. Primates of Bangladesh: a preliminary survey of population and habitat. *Biol. Conserv.* 13: 141–160.

Hamada, Y., T. Watanabe, K. Chatani, K., S. Hayakawa and M. Iwamoto. 2005. Morphometrical comparison between Indian- and Chinese-derived rhesus macaques (*Macaca mulatta*). *Anthropol. Sci.*113: 183–188.

Jones-Engel, L., C. C. May, G. A. Engel, K. A. Steinkraus, M. A. Schillaci, A. Fuentes, A. Rompis, M. K. Chalise, N. Aggimarangsee, M. M. Feeroz, R. Grant, J. S. Allan, A. Putra, I. N. Wandia, R. Watanabe; L. Kuller, S. Thonsawat, R. Chaiwarith, R. C. Kyes and M. L. Linial. 2008. Diverse contexts of zoonotic transmission of simian foamy viruses in Asia. *Emerg. Infect. Dis*. 14: 1200–1208.

Khan, M. A. R. and A. W. Ahsan. 1981. The Population Status of the Nonhuman Primates of Bangladesh. Report, University Grants Commission, Dhaka, Bangladesh.

Sarker, G. C., M. M. Kabir, M. M. Feeroz and M. K. Hasan. 2005. Substrate and height use of rhesus macaque (*Macaca mulatta*) at Gazipur of Bangladesh. *Bangladesh J. Life Sci.* 17(1): 83–92.

Smith, D. G. and L. M. Scott. 1989. Heterosis associated with regional crossbreeding between captive groups of rhesus macaques. *Am. J. Primatol.* 19: 255–260.

Smith, B. H., T. L. Crummett and K. L. Brandt. 1994. Ages of eruption of primate teeth: a compendium for aging individuals and comparing life histories. *Yearb. Phys. Anthropol*. 37: 177–231.

Smith, D. G., F. W. Lorey, J. Suzuki and M. Abe. 1987. Effect of outbreeding on weight and growth rate of captive infant rhesus macaques. *Zoo Biol*. 6: 201–212.

Taslima, S. 2002. Ecology and Behavior of Rhesus Macaques in Charmugria. MSc thesis, Jahangirnagar University, Savar, Dhaka, Bangladesh.

Taylor, N.D. and M. A. Schillaci. 2008. Heterochrony in hybrid macaques. *Zool. Studies* 47: 713–719.

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