CHAPTER-I
INTRODUCTION

1.1 Introduction

In the 18th century, Carl Linnaeus developed a system of classification for living organisms ('Systema Naturaea') and named order "primate" for monkey, apes and human that shares the similar characteristics [1]. The oldest fossil of non-human primate was an arboreal primate and reported from China, which was 55 million years old from early Eocene period [2]. Taxonomically, order primate is diverse group in mammals and can be categorized into the lineage of old world monkey and new world monkey, whereas, apes (Hominoidea) are classified as a sister taxon of old world monkey group (Cercopithecidae). Old world monkey (Cercopithecidae) has two sub-families namely; Cercopithecinae and Colobinae that covers the highest number of primates (159 species in 23 genera) than any other family of primates [3]. Most of the Cercopithecidae species has distribution in Africa and Asia from low altitude tropical habitat to high-altitude temperate habitat. New world monkey has 5 (five) families namely: Callitrichidae, Cebidae, Aotidae, Pitheciidae and Atelidae and distributed mostly in the region of central and south America.

The name "macaque" has origin of Portuguese word "macaco (a)" and west African Fiot word (ma)kaku, which mean monkey [4]. Macaque species belongs to the old world monkey in the family of Cercopithecidae from the genus Macaca. A total of 22 species (including 2 new species) are well recognized from the genus Macaca that distributed in southeast Asia, Africa and single population in Europe [5–8]. Among the non-human primate species, macaque species has greater ecological adaptation and that might result in distribution in wide geographical area of 5 ×106 km^2 [6]. Stevens et. al. [9] reported that the divergent between old world monkey (Cercopithecoid) and apes (hominoids) has been occurred during the Oligocene period. The earliest known fossil of macaque was reported from North Africa and Europe (dated around 5.5 million years) [10]. However, radiation of macaque towards the Asia has been considered as very recent (within last 5 million years) [10,11]. The taxonomy of macaque has been extensively carried out based on genital structure, morphometry and colour variation [5,6,12–14]. Further, molecular genetic study has been given priority in review of macaque taxonomic classification and evolutionary study [4,13,15]. Recently, molecular basis of identification has given important in description of new primate species [16,17]. The molecular basis of taxonomic classification in macaque species were coincide with Fooden [5] taxonomic classification [11,13]. Fooden [5] classified four group of macaque species based on tail

length variation and glans penis namely: *fascicularis* group, *silenus-sylvanus* group, *sinica* group and *arctoides* group. Toque macaque (*M. sinica*), Bonnet macaque (*M. radiata*), Assam macaque (*M. assamenesis*) and Pere David's stump tail macaque *(M. thibetana*) are included in *sinica* group of species. In *sinica* group of species, length of glans penis was reported <30 mm, penis sub-acute and sagittate in dorsal view. The tail length of sinica group of species was found inversely correlated with body size i.e., small bodied size of species has long tail and large bodied has short tail [5,6]. The small bodied size and longest tail of *sinica* group species has distribution in low latitude and altitude of southern India (*M. radiata*) and Sri Lanka (*M. sinica*). The large bodied with shorter tail of *M. assamensis* are occupied northeast India and Southeast Asia and the heaviest and shortest tail of *M. thibetana* occupied higher altitude region of China. The sub-species description in *sinica* group of species was found based on morphological variation [14,18,19]. The sub-species explanation in *sinica* group macaque species has given emphasised on tail length variation and morphometric characterization [20,21]. Eastern Assamese macaque (*Macaca assamensis assamensis*) and western Assamese macaque (*Macaca assamensis pelops*) are the two sub-species of Assamese macaque (*M. assamensis*) that differ in tail length [14,20]. Subsequently, shorter tail *M. a. assamensis* was reported from higher altitude area and longer tail of western Assamese macaque from low altitude area (*M. a. pelops*) [22]. Weinstein et.al. [23] reported that morphometry in species of genus macaca were significantly influence by climate and altitude i.e., higher altitude species has shorter limb than low altitude. Clarke et al. [24] reported the body size of *Macaca mulatta* subjected to change under the influence of climatic variation. Similarly, the high altitude Assamese macaque (*M. assamensis*) population of Nepal are considered as a variant of *Macaca assamensis* due its darker coat colour and morphological variation from the low altitude population [25]. Among the macaque species, relative tail length was found to vary according to variation in latitude and altitude; Crab eating macaque (*M. fascicularis*) relative tail length (RTL) decrease with increases of latitude [26]. Pigtail macaques (*Macaca nemestrina*) exhibit opposite latitudinal gradients of increasing size [27], *Macaca fascicularis fascicularis* exhibit no difference in body size according to the latitude [28]. However, genus macaca species have found shorter limb with increasing altitude [23]. Similarly, *Macaca munzala* has been described from the high altitude area based on relative shorter tail than geographically closer *M. assamensis* [7]. The interspecific pelage colour variation in primates was support by Gloger's rule [29]. However, the influence of

climatic variation based on altitude has been given less emphasized in colour variation study in primates [25,30,31].

Arunachal macaque or Tawang macaque (*Macaca munzala*) has been described based on the relative short tail and morphological characteristics by Sinha et al. [7]. Earlier, the species was first reported from high altitude area of Tawng district (2000 m above mean sea level-2700 m amsl) as potential new species from sub-tropical broad-leaved habitat by Mishra et. al. [32]. Later, the holotype and paratype of *M. munzala* was described from photograph that recorded in Zemithang, Tawang district of Arunachal Pradesh and subsequently recognized as new species [7]. The species was recognized as a *sinica* group of species based on the penile morphology as per Fooden [21]. *M. munzala* was distinguish from other *sinica* group of species based on relative short tail and external morphology [7]. The craniodental size and structure in *M. munzala* are reported near proximate to geographically closer *M. assamensis* and *M. thibetana* [33]. Chakraborty et.al. [16] molecular genetic analysis of *M. munzala* was found close phylogenetic affinities of the species with allopatric *Macaca radiata* and geographically closer *M. assamensis* and *M. thibetana*. The time of origin of *M. munzala* was estimated *c*. 0.48 mya and suggested possible male introgression from ancestral *M. assamensis–M. thibetana* stock into an ancestral *M. munzala* stock [16]. *M. munzala* was distinguish from closely related Assamese macaque (*M. a. pelops* and *M. a. assamensis*) in their extremely dark coat, dark brown facial skin, stocky tail, facial mark on the temples and forehead [7]. Further, chin and cheek whisker of *M. a. assamensis* was reported to absent in *M. munzala*.

Macaca munzala is categorized as an "Endangered species" by International Union for Conservation of Nature and reported a decreasing trend of population size (IUCN, 2018) [34]. There are only few study available regarding population distribution, habitat structure, behaviour pattern and conservation issues of *M. munzala* [35,36]. The known distribution range of the species is western Arunachal Pradesh (Tawang and West Kameng district), whereas, Tawang district was reported to have highest population of the species [38]. Chakraborty et al. [16] study confirm macaque population of Upper Subansiri and West Siang district of Arunachal Pradesh were *M. munzala*. *M. munzala* was reported as a highest altitudinal dwelling primate in India with an altitudinal distribution of 2000 m amsl-3500 m asml [7,36]. Based on habitat continuity, *M. munzala* distribution was also predicted to bordering country of Arunachal Pradesh by Kumar et al. [36]. Subsequently, the lowest distribution of the species was recorded in Bhutan at 1000 m amsl [37]. *M.*

munzala are reported form sub-tropical broad-leaved forest, degraded broad leaved, degraded open scrub, abies forest, dense oak forest and riverine forest [36]. The highest population of *Macaca munzala* was reported from the human-modified landscape that indicated species is tolerance to human presence [36]. However, the detail explanation of phytosociology of habitat and their status are unknown. Hunting for bush-meat was reported as a major threat of the species in its distribution range [35,36,38]. Moreover, though Arunachal Pradesh is an integral part of eastern Himalaya biodiversity hotspot but region is poorly explored due to its difficult mountainous landscape [38,39]. Thus, predictive distribution modelling based on environmental variable has greater potential in identification suitable habitat of the species in the state. Recently, distribution modelling has been found extensively used in primate distribution study in eastern Himalaya region [40–42].

The knowledge on ecological aspect of the Arunachal macaque (*M. munzala*) is very limited. A few study on time activity pattern, feeding and ranging behaviour of the species are known from degraded habitat [43,44]. Kumar et al. [43] have studied foraging ecology and time-activity budget of *M. munzala* for two months (July-August). The study reported that foraging was the highest time spent activity of *M. munzala* and the species was largely frugivorous in diet. Moreover, diet of *M. munzala* was suggested seasonal [43]. Home range of *M munzala* was reported smallest among the macaque species that inhabited in similar type of environment. Mendiratta et al. [44] have studied ecology of the species in winter (December-February) and Spring season (March-May). The study reported that *M. munzala* spent highest time in feeding during the winter season than spring season, whereas, time spent on movement was reported highest in spring season. Thermoregulatory cost and availability of food resource has been explained as a major factor that influence in variation of time activity pattern of the species. The diet of *M. munzala* was reported to comprises of plant material and animal matter. Further, the percentage contribution of food plant material was reported to varied based on seasonal availability [44]. Although, *M. munzala* feed on number of food plants but major contribution was reported from limited food plant species [43,44]. *M. munzala* has been adopted raiding behaviour, but influence of raiding behaviour in time spent activity is yet to be studied [43]. Primate adopt different feeding strategies to fulfil the feeding requirement and it varied according to the structure of habitat [45–48]. The response of habitat degradation in primate species was studied based on plasticity in feeding and

adjustment in behavioural activity [49]. But, criteria for selection of food plant in response to changing habitat is yet to be established. To understand this phenomenon, an investigation is required to understand the temporal and spatial alternations in habitat characteristics in terms of availability and nutritional basis of food plant. Recently, nutritional basis of food plant selection has been given significance importance in diet selection study of primates [50]. Meanwhile, knowledge on nutritional basis of food plant selection in *M. munzala* is yet to be study.

Primate vocalization has been extensively studied in terms of animal communication and evolution of speech [51–54]. Further, cognitive science has given significance importance in study of social basis of communication and learning evolution in primates [55–57]. The study on primate vocalization found that vocal repertoire has significance signal that convey particular empathy of primates [54,58–60]. Moreover, different referential vocalization has been found in primates, which are acoustically differ with one another [61–63]. Alarm call is one of the widely studied vocalization in primates that associated with predatory threat. It has been reported that many of primate use different type of alarm call for different predatory threat [54,64–66]. Functional structure of vocalization of primate has been characterized based on frequency and formant distribution of sound using computer base software [67,68]. The vocalization of primate has been used in species variation studies in terms of geographical distribution [8,69]. So far, no study has been carried out in vocalization behaviour of *M. munzala* but, there are some circumstantially report of alarm vocalization of the species and it was suggested as a species specific [70].

A very limited ecological and behavioural knowledge are available for Arunachal macaque *Macaca munzala*. Therefore, a long term systematic study is essential to generate a detail scientific knowledge on this newly discovered species. To broaden the ecological knowledge and behavioural understanding of *Macaca munzala*, the objective of the present study has emphasised on population distribution, phytosociology of habitat, altitudinal influence in morphometric variation and behavioural pattern of *Macaca munzala*. The objectives of the present study are as follows,

1. Ecological niche modelling and population distribution of *Macaca munzala*

2. Habitat structure, status and conservation of *Macaca munzala* in protected and non-protected habitat

3. Behavioural ecology of *Macaca munzala*

3.1. Activity and feeding pattern of *Macaca munzala* in heterogeneous habitats of western Arunachal Pradesh, India

3.2. Home range and habitat use pattern of *Macaca munzala*

3.3. Nutritional ecology of *Macaca munzala*

3.4. Acoustic analysis of "alarm call" of *Macaca munzala*

4. Comparative morphometric analysis of *Macaca munzala* and *Macaca assamensis*

1.2 References

[1] Linnaeus, C. *Systema Naturae*. Holmiae, Impensis Direct, 1758.

[2] Ni, X., Gebo, D. L., Dagosto, M., Meng, J., Tafforeau, P., Flynn, J. J. and Beard, K. C. The oldest known primate skeleton and early haplorhine evolution. *Nature*, 498: 60–64, 2013.

[3] Lambert, J. E. Handbook of the Mammals of the World :3. Primates. *Journal of Mammalogy*, 95: 906–907, 2014.

[4] Roos, C. and Zinner, D. Diversity and evolutionary history of macaques with special focus on *Macaca mulatta* and *Macaca fascicularis*. *The Nonhuman Primate in Nonclinical Drug Development and Safety Assessment* 3–16, 2015.

[5] Fooden, J. Provisional classification and key to living species of macaques (Primates: Macaca). *Folia Primatologica* 25: 225–236, 1976.

[6] Fa, J.E. The genus *Macaca*: a review of taxonomy and evolution. *Mammal Review*, 19: 45–81, 1989.

[7] Sinha, A., Datta, A., Madhusudan, M. D. and Mishra, C. *Macaca munzala*: A new species from western Arunachal Pradesh, northeastern India. *International Journal of Primatology*, 26: 977–989, 2005.

[8] Li, C., Zhao, C. and Fan, P. F. White-cheeked macaque (*Macaca leucogenys*): A new macaque species from Medog, southeastern Tibet. *American Journal of Primatology*, 77: 753–766, 2015.

[9] Stevens, N. J., Seiffert, E. R., O'Connor, P. M., Roberts, E. M., Schmitz, M. D., Krause, C., Gorscak, E., Ngasala, S., Hieronymus, T. L. and Temu, J. Palaeontological evidence for an Oligocene divergence between old World monkeys and apes. *Nature*, 497: 611–614, 2013

[10] Eric Delson, Ian Tatersall, John A. Van Couvering, A. S. B. *Encyclopedia of Human Evolution and Prehistory*. Garland Publishing, Inc., Taylor & Francis Group New York & London, 2 edition, 2000.

[11] Li, J., Han, K., Xing, J., Kim, H. S., Rogers, J., Ryder, O. A., Disotell, T., Yue, B. and Batzer, M. A. Phylogeny of the macaques (Cercopithecidae: Macaca) based on Alu elements. *Gene*, 448: 242–249, 2009.

[12] Osman Hill, W. C. and Bernstein, I. S. On the morphology, behaviour and systematic status of the Assam macaque (*Macaca assamensis* McClelland, 1839).

Primates, 10: 1–17, 1969.

[13] Morales, J. C. and Melnick, D. J. Phylogenetic relationships of the macaques (Cercopithecidae: Macaca), as revealed by high resolution restriction site mapping of mitochondrial ribosomal genes. *Journal of Human Evolution*, 34: 1–23, 1998.

[14] Brandon-Jones, D., Eudey, A. A., Geissmann, T., Groves, C. P., Melnick, D. J., Morales, J. C., Shekelle, M. and Stewart, C. B. Asian primate classification. *International Journal of Primatology*, 25: 97–164, 2004.

[15] Abegg, C. and Thierry, B. Macaque evcolution and dispersal in insular south-east Asia. *Biological Journal of the Linnean Society*, 75: 555–576, 2002.

[16] Chakraborty, D., Ramakrishnan, U., Panor, J., Mishra, C. and Sinha, A. Phylogenetic relationships and morphometric affinities of the Arunachal macaque *Macaca munzala*, a newly described primate from Arunachal Pradesh, northeastern India. *Molecular Phylogenetics and Evolution*, 44: 838–849, 2007.

[17] Fan, P., Liu, Y., Zhang, Z., Zhao, C., Li, C., Liu, W., Liu, Z. and Li, M. Phylogenetic position of the white-cheeked macaque (*Macaca leucogenys*), a newly described primate from southeastern Tibet. *Molecular Phylogenetics and Evolution*, 107: 80–89, 2017.

[18] Jiang, X. and Wang, Y. Taxonomy and distribution of Tibetan macaques. *Zoological Research*, 17: 361–369, 1996.

[19] Fooden, J. and Aimi, M. Systematic review of Japanese macaques, *Macaca fuscata* (Gray, 1870). *Fieldiana Zoology*, new series, no.104. *Primates*, 47: 184–185, 2005.

[20] Fooden, J.. Taxonomy and evolution of the sinica group of macaques*: 2.* Species and subspecies accounts of the Indian Bonnet macaque, *Macaca radiata*. *Field Museum of Natural History*, 9, 1981.

[21] Fooden, J. Taxonomy and evolution of the sinica group of macaques: 3. Species and subspecies accounts of *Macaca assamensis*. *Fieldiana Zoology*, new series, 10: 1–52, 1982.

[22] Biswas, J., Borah, D. K., Das, A., Das, J., Bhattacharjee, P. C., Mohnot, S. M. and Horwich, R. H. The enigmatic Arunachal macaque: Its biogeography, biology and taxonomy in Northeastern India. *American Journal of Primatology*, 73: 458–473, 2011.

[23] Weinstein, K. J. Climatic and Altitudinal Influences on Variation in *Macaca* Limb Morphology. *Anatomy Research International*, 2011: 1–18, 2011.

[24] Clarke, M. R. and O'Neil, J. A. S. Morphometric comparison of Chinese-origin

and Indian-derived rhesus monkeys (*Macaca mulatta*). *American Journal of Primatology*, 47: 335–346, 1999.

[25] Molur, S., Brandon-Jones, D., Dittus, W., Eudey, A., Kumar, A., Singh, M., Feeroz, M. M., Chalise, M., Priya, P. and Walker, S. Status of South Asian Primates: Conservation Assessment and Management Plan (C.A.M.P.) workshop report, www.zooreach.org/downloads/ZOO_CAMP_PHVA_reports, 2003.

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

[27] Albrecht, G. H. Latitudinal, taxonomic, sexual, and insular determinants of size variation in pigtail macaques, *Macaca nemestrina*. *International Journal of Primatology*, 1: 141–152, 1980.

[28] Hamada, Y., Suryobroto, B., Goto, S. and Malaivijitnond, S. Morphological and body color variation in Thai *Macaca fascicularis fascicularis* north and south of the Isthmus of Kra. *International Journal of Primatology*, 29: 1271–1294, 2008.

[29] Kamilar, J. M. and Bradley, B. J. Interspecific variation in primate coat colour supports Gloger's rule. *Journal of Biogeography*, 38: 2270–2277, 2011.

[30] Bradley, B. J. and Mundy, N. I. The primate palette: The evolution of primate coloration. *Evolutionary Anthropology*, 17: 97–111, 2008.

[31] Wangchuk, T., Inouye, D. W. and Hare, M. P. A new subspecies of golden langur (*Trachypithecus geei*) from Bhutan. *Folia Primatologica*, 74: 104–108, 2003.

[32] Mishra, C., Datta, A. Madhusudan, M. D. The high altitude wildlife of Western Arunachal Pradesh. Nature Conservation Foundation, International Snow Leopard Trust, and Wildlife Conservation Society (India Program), Mysore, India. Technical report no. 8, www.ncf-india.org/publication/210, 2004.

[33] Mishra, C. and Sinha, A. A voucher specimen for *Macaca munzala*: Interspecific affinities, evolution, and conservation of a newly discovered primate. *International Journal of Primatology*, 29: 743–756, 2008.

[34] Kumar, A., Sinha, A. & Kumar, S. 2008. Retrived on 15 Dec. 2018 from https://www.iucnredlist.org, 2018.

[35] Sinha, A., Kumar, R. S., Gama, N., Madhusudan, M. D. and Mishra, C. Distribution and conservation status of the Arunachal Macaque, *Macaca munzala*, in Western Arunachal Pradesh, Northeastern India. *Primate Conservation*, 145–148, 2006.

[36] Kumar, R. S., Gama, N., Raghunath, R., Sinha, A. and Mishra, C. In search of the munzala: distribution and conservation status of the newly-discovered Arunachal

macaque *Macaca munzala*. *Oryx*, 42: 360–366, 2008.

[37] Choudhury, A. Primates of Bhutan and observations of hybrid langurs. *Primate Conservation*, 23: 65–73, 2008.

[38] Mishra, C., Madhusudan, M. D. and Datta, A. Mammals of the high altitudes of western Arunachal Pradesh, eastern Himalaya: An assessment of threats and conservation needs. *Oryx*, 40: 29–35, 2006.

[39] Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. Biodiversity hotspots for conservation priorities. *Nature*, 403: 853–858, 2000.

[40] Sarma, K., Kumar, A., Krishna, M., Medhi, M. and Tripathi, O. P. Predicting suitable habitats for the vulnerable Eastern Hoolock Gibbon, *Hoolock leuconedys*, in India using the MaxEnt model. *Folia Primatologica*, 86: 387–397, 2015.

[41] Suwal, M. K., Huettmann, F., Regmi, G. R. and Vetaas, O. R. Parapatric subspecies of *Macaca assamensis* show a marginal overlap in their predicted potential distribution: Some elaborations for modern conservation management. *Ecology and Evolution* 1–16, 2018.

[42] Regmi, G. R., Huettmann, F., Suwal, M. K., Nijman, V., Nekaris, K. A. I., Kandel, K., Sharma, N. and Coudrat, C. First open access ensemble climate envelope predictions of Assamese macaque *Macaca assamensis* in Asia : a new role model and assessment of endangered species. 36: 149–160, 2018.

[43] Kumar, R., Mishra, C. and Sinha, A. Foraging ecology and time-activity budget of the Arunachal macaque *Macaca munzala* - A preliminary study. *Current Science*, 93: 532–539, 2007.

[44] Mendiratta, U., Kumar, A., Mishra, C. and Sinha, A. Winter ecology of the Arunachal macaque *Macaca munzala* in Pangchen Valley, western Arunachal Pradesh, northeastern India. *American Journal of Primatology*, 71: 939–947, 2009.

[45] Pruetz, J. D. and Isbell, L. A. Correlation of food distribution and patch size with agonistic interactions in female vervets (*Chiorocebus aethiops*) and Patas monkey (*Erythrocebus patas*) living in simple habitats. *Behavioral Ecology and Sociobiology* 49: 38–47, 2000.

[46] Cullen, L., Bodmer, R. E. and Valladares Pádua, C. Effects of hunting in habitat fragments of the Atlantic forests, Brazil. *Biological Conservation*, 95: 49–56, 2000.

[47] Isabirye-Basuta, G. M. and Lwanga, J. S. Primate populations and their interactions with changing habitats. *International Journal of Primatology*, 29: 35–48, 2008.

[48] Agetsuma, N. Effects of habitat differences on feeding behaviors of Japanese

Monkeys: Comparison Between Yakushima and Kinkazan. *Primates*, 39: 275–289, 1998.

[49] Schwitzer, C., Glatt, L., Nekaris, K. A. I. and Ganzhorn, J. U. Responses of animals to habitat alteration: An overview focussing on primates. *Endangered Species Research*, 14: 31–38, 2011.

[50] Chapman, C. A., Chapman, L. J., Rode, K. D., Hauck, E. M. and McDowell, L. R. Variation in the nutritional value of primate foods: Among trees, time periods, and areas. *International Journal of Primatology*, 24: 317–333, 2003.

[51] Riede, T., Bronson, E., Hatzikirou, H. and Zuberbühler, K. Vocal production mechanisms in a non-human primate: Morphological data and a model. *Journal of Human Evolution*, 48: 85–96, 2005.

[52] Science, C., Dictionary, O. E., Iii, S. and Iv, S. A Primate Dictionary ? Decoding the function and meaning of another Species ' Vocalizations. 24: 445–475, 2000.

[53] Fitch, W. T., De Boer, B., Mathur, N. and Ghazanfar, A. A. Monkey vocal tracts are speech-ready. *Science Advances*, 2: 2016.

[54] Seyfarth, R. M., Cheney, D. L. and Marler, P. Vervet monkey alarm calls: Semantic communication in a free-ranging primate. *Animal Behaviour*, 28: 1070–1094, 1980.

[55] Lemasson, A., Ouattara, K., Petit, E. J. and Zuberbühler, K. Social learning of vocal structure in a nonhuman primate? *BMC Evolutionary Biology*, 11: 2011.

[56] Green, S. Dialects in Japanese Monkeys: Vocal learning and cultural transmission of local-specific vocal behavior? *Zeitschrift für Tierpsychologie*, 38: 304–314, 1975.

[57] Lameira, A. R., Hardus, M. E. and Wich, S. A. Orangutan (Pongo spp.) whistling and implications for the emergence of an open-ended call repertoire: A replication and extension. *The Journal of the Acoustical Society of America*, 2013. doi:10.1121/1.4817929

[58] Levine, S., Wiener, S. G., Coe, C. L., Bayart, F. E. S., Levine, S., Wiener, S. G., Coe, C. L., Bayart, F. E. S. and Hayashi, K. T. Primate vocalization : A psychobiological approach. *Child development*, 58: 1408–1419, 1987.

[59] Parr, L. A., Waller, B. M. and Fugate, J. Emotional communication in primates: Implications for neurobiology. *Current Opinion in Neurobiology*, 15: 716–720, 2005.

[60] Masataka, N. Psycholinguistic analyses of alarm calls of Japanese monkeys

(*Macaca fuscata fuscata*). *American Journal of Primatology*, 5: 111–125, 1983.

[61] Cäsar, C., Byrne, R. W., Hoppitt, W., Young, R. J. and Zuberbühler, K. Evidence for semantic communication in Titi monkey alarm calls. *Animal Behaviour*, 84: 405–411, 2012.

[62] Rendall, D., Seyfarth, R. M., Cheney, D. L. and Owren, M. J. The meaning and function of grunt variants in baboons. *Animal Behaviour*, 57: 583–592, 1999.

[63] Crockford, C. and Boesch, C. Context-specific calls in wild chimpanzees, *Pan troglodytes* verus: analysis of barks. *Animal Behaviour*, 66: 115–125, 2003.

[64] Cäsar, C., Byrne, R., Young, R. J., Zuberbühler, K., Ecology, S. B., May, N., Casar, C., Byrne, R. and Young, R. J. The alarm call system of wild black-fronted Titi monkeys, *Callicebus nigrifrons*. *Behavioral Ecology and Sociobiology*, 66: 653–667, 2012.

[65] Seyfarth, R. and Cheney, D. The assessment by vervet monkeys of their own and another species' alarm calls. *Animal Behaviour*, 40: 754–764, 1990.

[66] Coss, R. G., McCowan, B. and Ramakrishnan, U. Threat-related acoustical differences in alarm calls by wild bonnet macaques (*Macaca radiata*) elicited by python and leopard models. *Ethology*, 113: 352–367, 2007.

[67] Lieberman, P. on the Acoustic Analysis of Primate Vocalizations. *Behavior Research Methods and Instrumentation*, 1: 169–174, 1968.

[68] Gamba, M. and Giacoma, C. Key issues in the study of primate acoustic signals, an update. *Journal of Anthropological Sciences*, 88: 215–220, 2005.

[69] Burton, J. A. and Nietsch, A. Geographical Variation in Duet Songs of Sulawesi Tarsiers: Evidence for new cryptic species in south and southeast Sulawesi. *International Journal of Primatology*, 31: 1123–1146, 2010.

[70] Choudhury, A. Pere David's macaque discovered in India. *The Rhino Foundation* 2: 7, 1998.