shaped by the mate selection. Therefore, such high average energy input in AC2 is likely to be an indication that it is a breeding call. While low average energy input per unit time in AC1 is likely to be for a function with lower priority, such as territory call.

Interestingly, AC2 matches with the description of breeding call of *I. chiravasi* given by Gaitonde and Giri[10], for which they have assigned functions to this call as associated behaviour such as approach of female leading to amplexus and egg laying. Whereas they have mentioned that the calling males exhibit calls similar to AC1 with associated behaviour like vicinity of another male. However, they have not provided any analysis for the calls. Although we could not assign functions to calls AC1 and AC2 based on our field observations, we suggest that AC1 is a territorial call, whereas AC2 is a breeding call based on the energy expenditure and suggestions made by Gaitonde and Giri[10].

Call analysis for *Indirana* species provided by earlier workers is either qualitative[10] or with limited analysis[13–15], making it difficult to use them for compilations. Nevertheless, superficially, the spectral characteristics of the territory calls of various species of *Indirana* are similar, as also suggested by Kuramoto and Dubois[15], making territory calls of limited value for taxonomy and identification. However, the pattern of breeding calls and energy input may be different for different species. Further studies on the breeding calls of other species of *Indirana* could provide important insight into the ecology and evolution of species belonging to this endemic genus.

1. Dubois, A., *C. R. Acad. Sci.*, 1975, **281**, 1717–1720.
2. Micancin, J. P. and Mette, J. T., *Zootaxa*, 2009, **2076**, 1–36.
3. Penny, S. G. *et al.*, *Zookeys*, 2014, **435**, 111–132.
4. Acevedo, M. A. and Villanueva-Rivera, L. J., *Wildl. Soc. Bull.*, 2006, **34**, 211–214.
5. Funk, W. C., Caminer, M. and Ron, S. R., *Proc. R. Soc. London, Ser. B*, 2012, **279**, 1806–1814.
6. Modak, N., Dahanukar, N., Gosavi, N. and Padhye, A. D., *J. Threat. Taxa*, 2015, **7**, 7493–7509.
7. Modak, N., Padhye, A. D. and Dahanukar, N., *Zootaxa*, 2014, **3796**, 62–80.
8. Nair, A., Gopalan, S. V., George, S., Kumar, K. S., Teacher, A. G. F. and Merilä, J., *Anim. Conserv.*, 2012, **15**, 489–498.
9. Padhye, A. D., Modak, N. and Dahanukar, N., *J. Threat. Taxa*, 2014, **6**, 6293–6312.
10. Gaitonde, N. and Giri, V., *Curr. Sci.*, 2014, **107**, 109–112.
11. Bioacoustic Research Program, Raven Pro: Interactive Sound Analysis Software (Version 1.4), The Cornell Lab of Ornithology, Ithaca, New York, 2011, http://www.birds.cornell.edu/raven
12. Charif, R. A., Waack, A. M. and Strickman, L. M., *Raven Pro 1.4 User's Manual*, Cornell Lab of Ornithology, Ithaca, New York, 2010.
13. Kadadevaru, G. G., Kanamadi, R. D. and Schneider, H., *Amphibia–Reptilia*, 2000, **21**, 242–246.
14. Kuramoto, M. and Joshy, S. H., *Curr. Herpetol.*, 2001, **20**, 85–95.
15. Kuramoto, M. and Dubois, A., *Curr. Herpetol.*, 2009, **28**, 65–70.
16. Gerhardt, H. C. and Huber, F., *Acoustic Communication in Insects and Frogs: Common Problems and Diverse Solutions*, University of Chicago Press, Chicago, 2002.
17. Wells, K. D., In *The Ecology and Behavior of Amphibians* (ed. Wells, K. D.), University of Chicago Press, Chicago, 2007, pp. 268–337.
18. Wells, K. D. and Schwartz, J. J., In *Springer Handbook of Auditory Research* (eds Narins, P. M. and Feng, A. S.), Springer Verlag, New York, 2007, pp. 44–86.

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Ground foraging behaviour of Malayan giant squirrel (*Ratufa bicolor*)

Giant squirrels are considered an important component of forested ecosystems, and are advocated as indicators of forest health[1]. The Malayan giant squirrel (MGS; *Ratufa bicolor*), one of the four giant tree squirrels in the Oriental region (the other three being *R. affinis*, *R. indica* and *R. macroura*), is found in the Malayan region, North East India and Myanmar. It is listed as Near Threatened (NT) by IUCN, in Appendix II of CITES and Schedule II of Indian Wildlife (Protection) Act 1972. Some ecological information on the MGS exists from few studies[2,3].

There has been unanimity about the obligate arboreal nature of giant squirrels (genus *Ratufa*) that occupy an ecological niche in the highest levels of primary rainforest. Moore[4] stressed the need of detailed observation and reporting of any ground foraging behaviour of Oriental giant squirrels. Of late, recent squirrel studies in the tropics report some incidents of giant squirrels coming down to the ground across their distributional range[5–13]. We describe here ground foraging of MGS in a tropical forest fragment of Brahmaputra valley, North East India (Figure 1), which is the western most distributional range of the species.

As part of a larger study (October 2012 through March 2015) on resource partitioning among sympatric arboreal squirrels in the tropical forests of Hollongapar Gibbon Sanctuary (HGS) (Figure 2), we observed five focal MGS from dawn to dusk. HGS (26°40′–26°45′N, 94°23′–94°23′E; area 20.98 km^2) is situated in Jorhat district, Assam. According to the classification scheme of Champion and Seth[14], the forest type in HGS is Assam Plains Alluvial Semi Evergreen Forests (1/2/2B/C), sparsely interspersed with wet evergreen forest patches dominated by *Dipterocarpus macrocarpus* in the upper canopy, while *Mesua ferrea* dominates the middle canopy.

We observed squirrels with equal effort in both dry (October–March) and wet (April–September) seasons. Observations were made using *ad libitum* and scan sampling methods[15] with 5 min interval. Whenever we found squirrels coming to the ground, we recorded the time, distance traversed and the following information.

(a) Distance of the squirrel from any nearest tree.
(b) Behaviour of the squirrel (foraging, alert, rest, play and chase). Alert behaviour, in the context of this study, is any sudden abrupt motionless body posture with raised head and emitting alarm vocalizations due to awareness of the presence of any threat.

MGS mostly foraged (98.9%) in the canopy and sub-canopy within source tree crowns ($n = 2340$ scans out of 2366 total scan observations). However, ground foraging was seen only during 11 occasions (1.1%) throughout the study period ($n = 26$ scans out of 2366 total scan observations). The mean distance travelled from the source tree (from which it descended) while on the ground was 7.7 m ± 6.5 SD ($n = 11$, range: 2–23 m). It was observed that MGS came down to the ground using the tree trunk and woody climbers more in the forest edge ($n = 9$) than in the interior ($n = 2$). The forest edge is the ecotone between forest and tea gardens, and forest and village. MGS also travelled more distance (8.3 m ± 7.1 SD, $n = 9$) in the forest edge than the interior (5.0 m ± 1.4 SD, $n = 2$). The mean time spent during each descent was 16.3 min ± 10.2 SD ($n = 11$). MGS spent more time on the ground in the morning (0600–0900 h, 21.1 min ± 8.1 SD, $n = 8$) than in the afternoon (1300–1500 h, 5.0 min ± 5.5 SD, $n = 3$). A notable change in behaviour was observed when MGS moved beyond 5 m from the source tree. Significant association of foraging behaviour was seen with the closeness from the source tree, while frequency of alertness was more when MGS crossed beyond 5 m distance from the source tree ($\chi^2 = 10.9$, $df = 1$, $P < 0.01$).

The tropical belt with significant topographic relief and forest cover serves as a global hotspot of diversity and endemism for arboreal squirrels, especially giant squirrels[1]. However, reports of ground foraging behaviour by arboreal giant squirrels are rare. This could be due to the paucity of squirrel research in the tropics in general and Asia in particular[1]. The ground foraging of giant squirrels was observed only 11 times during the present study. This suggests that such opportunistic foraging behaviour occurs infrequently. We observed that the ground-descending activity of MGS was related to feeding and foraging behaviour

Figure 1. Malayan giant squirrel foraging on the ground in Hollongapar Gibbon Sanctuary, Assam, India.

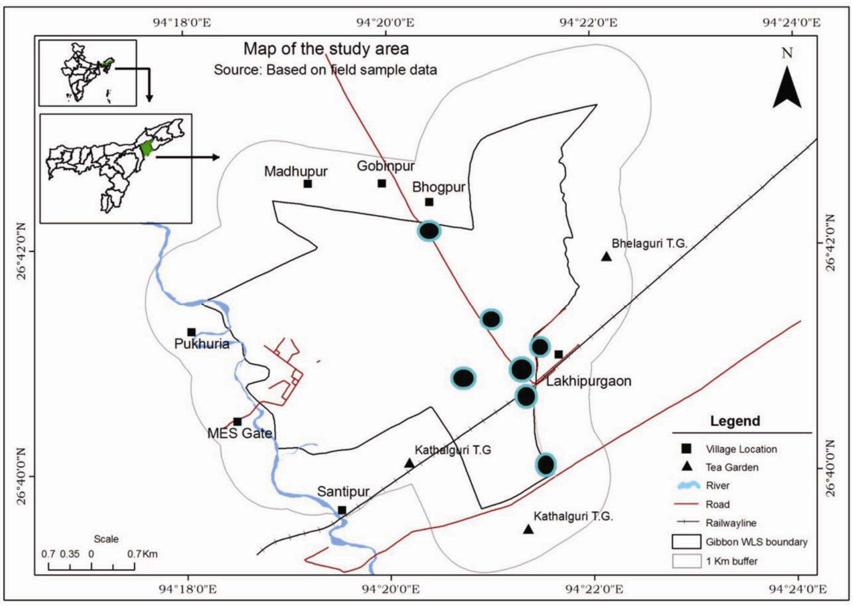

Figure 2. The location and study area of Hollongapar Gibbon Sanctuary. Black dots indicate areas where the giant squirrel descended to the ground.

on fallen fruit clusters of *Mesua ferrea* (flesh juicy part ingested, while seed discarded) and termite hills (top soft part), which may be due to their ability to exploit a wider variety of food in periods of fruit scarcity. There are reports of giant squirrels consuming soil[5,8,9] after feeding on seeds rich in secondary metabolites such as *Olea dioica* to neutralize the effect of the metabolites from a seasonal cloud forest of the Western Ghats[6], as well as termites[10,11] and fallen fruit clusters of *Zizyphus mauritiana* from South India[5]. Diets of giant squirrels can shift to bark and leaves during fruit scarcity, but they prefer fruits, especially seeds, when they are available[5]. Food is usually consumed within the source tree crown itself[3], as in the case of *R. affinis* and *R. color*[4]. Nevertheless, such sporadic incidents throw light upon behavioural plasticity and the ability of the giant squirrels to expand the spectrum of food items as well as foraging height depending upon the resource availability.

MGS could concentrate on foraging near the source tree, as it was safer for them to access it when in danger. Therefore, more frequency in alertness was seen when they were far from the source tree. Most of the observations were recorded in the forest edges. This might be due to different microclimatic condition at the forest edges. A recent study on arboreal squirrels shows variation in their normal diurnal activity pattern with changes in environmental variables[16]. The observations of ground foraging behaviour of MGS were recorded in an area which also supports a healthy population of six other primate species (including three sympatric macaque species) with overlapping home ranges and showed no aggressive interspecific interactions among them. This supports the findings of Sushma and Singh[17], that predation of giant squirrel by macaque species may be a sporadic event[17]. Giant squirrels of the genus *Ratufa* have been reported to jump 3.5 m ± 0.1 SE within canopy cover, but failed to jump >5 m distance in fragmented habitats[18]. Forest fragmentation increases edge effects and isolation, and thus decreases the ability of arboreal animals to move widely without coming down to the ground.

1. Koprowski, J. L. and Nandini, R., *Curr. Sci.*, 2008, **95**, 851–857.
2. Mackinnon, K. S., *Malay. Nat. J.*, 1978, **30**, 593–608.
3. Payne, J. B., Ph D dissertation, University of Cambridge, UK, 1979.
4. Moore, J. C., *Syst. Zool.*, 1960, **9**, 1–17.
5. Borges, R. M., In *Mammals of South Asia* (*Volume 2*) (eds Johnsingh, A. J. T. and Manjrekar, N.), Universities Press, Hyderabad, 2015, pp. 483–500.
6. Somanathan, H., Mali, S. and Borges, R. M., *Ecoscience*, 2007, **14**(2), 165–169.
7. Hutton, A. F., *J. Bombay Nat. Hist. Soc.*, 1949, **48**, 681–695.
8. Borges, R. M., Ph D dissertation, University of Miami, Florida, 1989.
9. Datta, A., Dissertation. Saurashtra University, Rajkot, 1993.
10. Krishnan, M., *J. Bombay Nat. Hist. Soc.*, 1975, **81**, 180–181.
11. Thorington Jr, R. W. and Cifelli, R. L., In *Conservation in Developing Countries: Problems and Prospects* (eds Daniel, J. C. and Serrao, J. S.), Oxford University Press, Mumbai, 1990, pp. 212–219.
12. Meijaard, E. and Sheil, D., *Ecol. Res.*, 2008, **23**, 21–34.
13. Ramachandran, K. K., KFRI Research Report 55, 1988.
14. Champion, H. G. and Seth, S. K., *A Revised Survey of the Forest Types of India*, Government of India Press, New Delhi, 1968.
15. Altmann, J., *Behaviour*, 1974, **49**, 227–266.
16. Williams, C. T. *et al.*, *J. Mammal.*, 2014, **95**, 1230–1239.
17. Sushma, H. S. and Singh, M., *Curr. Sci.*, 2008, **95**, 1535–1536.
18. Kumbhar, A., Pradhan, A. and Patwardhan, G., *J. Environ. Res. Technol.*, 2012, **2**(4), 366–368.

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