identified in the Kalpi section in the Yamuna Valley[2,5], and from other Indian and global sites[12,14].

The Ganga Plain exhibits megafans, linked to major Himalayan rivers, that accumulated few hundred metres thick sediments during 70–35 ka[1]. It is linked with high sediment supply and also high water discharge in the past. Deposition on the megafans also continued during latest Pleistocene, and there is a thick cover of Holocene sediments running several metres on the top. It has been argued that expansion and contraction of megafans are important in building the fluvial succession of Ganga Plain[1,15]. The western Ganga Plain exhibits evidence of relict Ganga–Yamuna Megafan (Ganga Megafan) which was active during middle late Pleistocene. The location of boreholes in the present study is on the distal part of this megafan (Figure 1). The proximal megafan deposits are exposed in cliff sections along Ganga river, and comprise coarser sediments than those of the present-day Ganga river. During its active phase, the Ganga Megafan had a predominantly anastomosing river system in proximal part and wide interfluves with few meandering channels in the distal part[16]. The active Ganga Megafan sedimentation in the proximal part continued until about 20 ka followed by deposition of a few-metre thick Holocene cover[6]. The rapid subsidence of Meerut–Bulandshahr region in late Pleistocene must be linked with the differential segment-wise movement in the subsurface Delhi–Haridwar ridge that underlies the Ganga Megafan.

It is reasonable to assume that in the distal part of the Ganga Megafan, the area of Meerut–Bulandshahr, predominantly fine-grained sediments were deposited accompanied by rapid syndepositional subsidence during 50–10 ka. The rate of deposition was exceptionally high during 40–30 ka (1 cm/a or more) and deposition took place mostly in small channels, ponds, flood plains and interfluve areas under moist climate.

1. Singh, I. B., *J. Palaeontol. Soc. India*, 1996, **41**, 99–137.
2. Singh, I. B., *Geol. Surv. India, Spec. Publ.*, 2001, **65**, xxxiii-I.
3. Singh, I. B., Rajagopalan, G., Agarwal, K. K., Srivastava, P., Sharma, M. and Sharma, S., *Curr. Sci.*, 1997, **73**, 1114–1117.
4. Singh, I. B., Srivastava, P., Sharma, S., Sharma, M., Singh, D. S., Rajagopalan, G. and Shukla, U. K., *Facies*, 1999, **40**, 197–210.
5. Singh, I. B., Sharma, S., Sharma, M., Srivastava, P. and Rajagopalan, G., *Curr. Sci.*, 1999, **76**, 1022–1026.
6. Srivastava, P., Shukla, U. K., Mishra, P., Sharma, M., Sharma, S., Singh, I. B. and Singhvi, A. K., *ibid*, 2000, **78**, 498–503.
7. Parkash B., Kumar, S., Someshwar Rao, M., Giri, S. C., Suresh Kumar, C., Gupta, S. and Srivastava, P., *ibid*, 2000, **79**, 438–449.
8. Pei-Yaan Chen, *Geol. Surv. Occas. Pap.*, 1977, **21**, 68.
9. Moore, D. M. and Raynolds, Sr. R. C., *X-ray Diffraction and the Identification and Analysis of Clay Minerals*, Oxford University Press, New York, 1997, p. 377.
10. Andrews, J. E., Singhvi, A. K., Kailath, A. J., Kuhn, R., Dennis, P. F., Tandon, S. K. and Dhir, R. P., *Quaternary Res.*, 1998, **50**, 240–251.
11. Rao, M. S., Bisaria, B. K. and Singhvi, A. K., *Curr. Sci.*, 1997, **72**, 663–669.
12. Nesbitt, H. W. and Young, G. M., *Geochim. Cosmochim. Acta*, 1984, **48**, 1523–1534.
13. Fedo, C. M., Nesbitt, H. W. and Young, G. M., *Geology*, 1995, **23**, 921–924.
14. Juyal, N., Raj, R., Maurya, D. M., Chamyal, L. S. and Singhvi, A. K., *J. Quaternary Sci.*, 2000, **15**, 501–508.
15. Ghosh, D. K. and Singh, I. B., Proceedings of the National Seminar on Recent Quaternary Studies in India, Dept. of Geology, M.S. University of Baroda, 1988, pp. 164–175.
16. Shukla, U. K., Singh, I. B., Sharma, M. and Sharma, S., *Sediment. Geol.*, 2001, **144**, 243–262.

ACKNOWLEDGEMENTS. We thank the Central Ground Water Board (CGWB) for the samples, which were collected by B.K.S. while working with CGWB. Geochemical work was carried out at the Institute for Geology and Mineralogy, University of Erlangen-Nuremberg, Germany. We thank Prof. H. J. Tobschall for laboratory facilities, and the Alexander von Humboldt Foundation for financial support during the stay of I.B.S. in Erlangen. Dr M. Sharma helped with the clay mineral analysis.

Received 8 July 2002; revised accepted 7 October 2002

Discovery of the leaf deer *Muntiacus putaoensis* in Arunachal Pradesh: An addition to the large mammals of India

Aparajita Datta[†,#], Japang Pansa*, M. D. Madhusudan[#,‡] and Charudutt Mishra[#,,§]**

[†]Wildlife Conservation Society – India Programme, 403, Seebo Apartments, 26-2, Aga Abbas Ali Road, Bangalore 560 042, India
[#]Centre for Ecological Research and Conservation, Nature Conservation Foundation, 3076/5, 4th Cross Gokulam Park, Mysore 570 002, India
*Namdapha Tiger Reserve P.O. Miao, Changlang 792 122, India
[‡]National Institute of Advanced Studies, Indian Institute of Science Campus, Bangalore 560 012, India
**International Snow Leopard Trust, 4649, Sunnyside Avenue North, Suite 325, Seattle, Washington 98103, USA

Mammals, comprising over 4600 species, are considered among the best-known groups in the animal kingdom[1]. Among them, the distribution and natural history of large-bodied groups such as ungulates have been particularly well documented, with only ten new species of ungulates being described worldwide between 1930 and 1994 (out of 742 new mammals described during this period)[1]. However, in the last decade, surveys in Southeast Asia led to the description of four ungulate species new to science[2–6]. Amongst them is the leaf deer *Muntiacus putaoensis*, recently discovered in northern Myanmar[3,7]

[§]For correspondence. (e-mail: charu@ncf-india.org)

(see Figure 1). This is amongst the smallest known species of muntjacs (mean adult body mass 12 kg), at half the size of the Indian muntjac *M. muntjak* (22–29 kg)[7,8]. So far, the Indian muntjac is the only muntjac species known to occur in the Indian subcontinent. The discovery of the leaf deer in the hill forests of Myanmar led us to conjecture that the species should also occur in the adjoining hill forests of Arunachal Pradesh in northeast India (Figure 1), a region whose wildlife has remained poorly explored due to remoteness and difficult mountainous terrain. The possibility of occurrence of the species was first investigated in April 2002 during a study of hornbills and hunting patterns among tribal communities in eastern Arunachal[9], and in November 2002, we started a survey of large mammals that specifically aimed to establish the occurrence of leaf deer. The first phase of the survey has been completed, having covered the Jairampur Forest Division of Changlang District. In this communication, we report the presence of the leaf deer in India, from Changlang district, eastern Arunachal Pradesh. This perhaps represents the only addition so far to the ungulate fauna of the Indian subcontinent in the last century.

Arunachal Pradesh (26°28′–29°30′N and 91°30′–97°30′E) spans 83,743 km^2 in Eastern Himalaya, and still harbours large patches of tropical evergreen forests. The state has a relatively low human population density (*c.* 13 per km^2). Given its wide altitudinal range (100 to over 6000 m), and location at the confluence of the Palaearctic and Indo-Malayan biogeographical realms, Arunachal contains a diversity of habitats and species, making it a global biodiversity hot spot[10]. Greater detail on Arunachal is available in Datta[11].

The Jairampur Forest Division (307 km^2) lies to the west of the well-known Namdapha Tiger Reserve, and is interspersed with patches of unclassed state forests, cultivation and villages. The villagers belong to the *Tangsa* tribe, and are divided into numerous sub-tribes and clans. While some of them such as the *Tikhak* are predominantly Buddhist, others like the *Mossang* are Christians. Their main occupation is agriculture; both *jhum* (shifting cultivation) and settled wet rice cultivation. People regularly hunt wildlife for meat (see ref. 9 for a detailed account of hunting).

Annual rainfall in the region is high (between 1700 and 5500 mm). The area has tropical evergreen and subtropical forests dominated by two dipterocarps, *Shorea assamica* and *Dipterocarpus macrocarpus*. Together with the adjoining Namdapha National Park, the area harbours a diversity of mammalian fauna, including the elephant (*Elephas maximus*), and ungulates such as gaur (*Bos gau-*

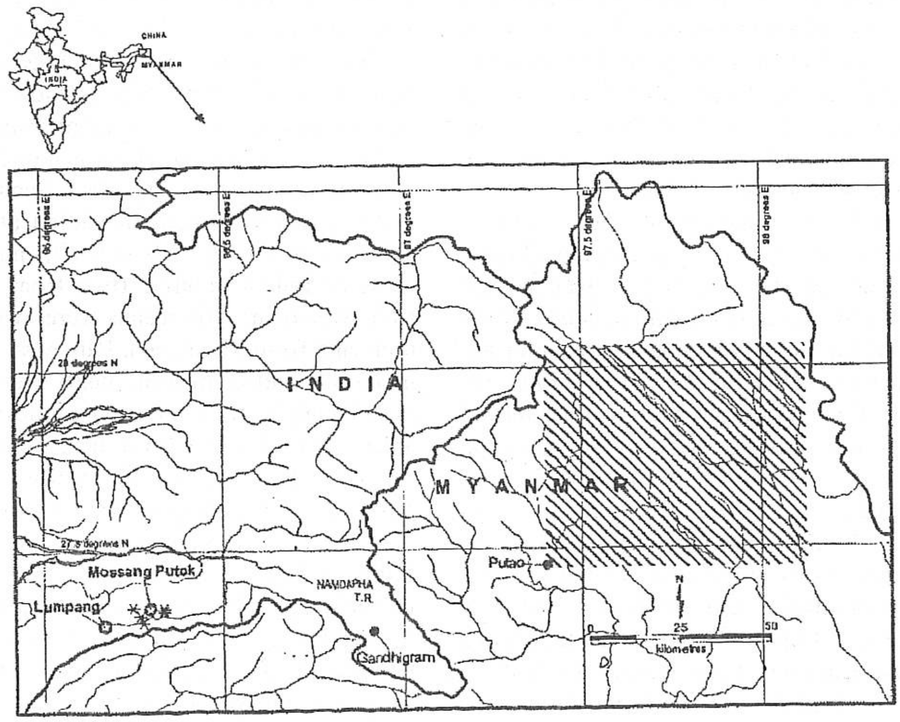

Figure 1. Global distribution of the leaf deer *Muntiacus putaoensis*. Prior to this study, the species was known only from northern Myanmar. Hatched region represents the limits of leaf deer range in Myanmar based on information in Rabinowitz and Khaing[12] and Rabinowitz *et al.*[7]. The Latin name of the species owes its origin to the town of Putao in Myanmar, a recognizable reference point in the region where it was first discovered. Our survey sites in Changlang District, eastern Arunachal Pradesh are marked with asterisks. We found one skull each in the villages of Lumpang and Mossang Putok that was presumably of the leaf deer.

rus), sambar (*Cervus unicolor*), hog deer (*Axis porcinus*) Indian muntjac, wild pig (*Sus scrofa*), goral (*Nemorhaedus goral*), and serow (*N. sumatraensis*). Large carnivores include tiger (*Panthera tigris*), leopard (*P. pardus*), clouded leopard (*Neofelis nebulosa*), and wild dog (*Cuon alpinus*).

Two of us (A.D. and J.P.) visited the villages and surveyed the forests in Jairampur. A total of 116 km was walked along forest trails (mostly between villages; 30 km with hunters in hill forests they identified as leaf deer habitat) to obtain direct and indirect evidences of the leaf deer. In April 2002, during the study on hornbills, we had visited four villages, and in November 2002, we surveyed an additional eight villages (*c.* 1000 people in the 12 villages). We interviewed hunters and village elders about the occurrence of leaf deer, Indian muntjac and other large mammals. In most villages, hunters display skulls and sometimes, skins of animals in their houses. We examined such trophies in 53 of the nearly 120 houses. We also tried to ascertain from the hunters, the approximate date and location where specific trophy-animals were hunted.

Trail walks did not yield any direct sightings of the Indian muntjac or the leaf deer in this heavily hunted area, but alarm-calls of the Indian muntjac were heard thrice. It is amongst the most commonly hunted animals; we counted a total of 89 Indian muntjac skulls.

The presence of leaf deer was reported by residents of all but one village. All others recognized the leaf deer as being distinct from the Indian muntjac, and being much smaller in size. Indeed, the local tribes had different names for the two species. Amongst the *Tangsa*, the *Mossang* sub-tribe call the leaf deer *Ling-pun* and the Indian muntjac *Khi-ji*, while the *Tikhak* sub-tribe call them *Lang-wu* and *Ko-koi* respectively. We spoke to some hunters of the *Lisu* tribe from Gandhigram (Figure 1), who also reported the presence of leaf deer in their area. The *Lisu* name for the Indian muntjac is *che*, while for the leaf deer it is *Lugi-che* (which is similar in meaning to the Myanmarese name for the animal, *Phet-gyi*, denoting a deer small enough to be wrapped in a leaf of *Phrynium* sp. This in fact is the origin of the common name of the species[12]). Among the 53 *Tangsa* families visited, nine reported having killed the leaf deer, and another three having seen it, though only two had retained the skulls. Leaf deer skulls are usually discarded since they are small (much smaller than the Indian muntjac), and make unimpressive trophies. Another distinguishing characteristic of the leaf deer is the greater similarity in size and appearance of adult males and females, including an equally pronounced development of canines in females[7], which has not been reported in any other muntjac species.

We took standardized morphometric measurements following Rabinowitz *et al.*[7] on skulls of two Indian muntjacs (an adult male, a subadult female). We also obtained and measured two distinctively smaller skulls which the hunters identified as belonging to the leaf deer (Figure 2). The first was of a subadult male, collected from Lumpang village (96°10′9″E, 27°17′45″N; Figure 1). The skull was partially damaged, lacking the mandible and all the teeth. It had short, unbranched antlers and short, thin pedicles. Hunters reported that the animal was killed about seven years ago in the nearby Pangsu Reserve Forest at an elevation of *c.* 950 m. The second skull, from an adult female, was collected from Mossang Putok village (96°17′38″E, 27°20′37″N). It was killed 1–2 years ago in an area north of the village between 900 and 1100 m, bordering the Namdapha Tiger Reserve. This skull lacked the mandible, but the rest of it was intact, with all teeth, including the canines. The hunter recollected encountering an adult male and a female together, and having killed the female, which was reportedly pregnant. In addition to recovering a foetus from the carcass, the hunter found leaves and fruits in its stomach. The dentition on the small skull, consisting of fully erupted teeth, established that it was of an adult animal, thereby precluding the possibility of it being a subadult Indian muntjac (that would have incompletely erupted teeth[13]; Figure 2). The canines were unusually long relative to the skull size, and the preorbital fossa was larger compared to that of the Indian muntjac (pers. obsv., Rabinowitz *et al.*[7]).

Morphometric measurements of these four skulls (and antlers in males) are shown in Table 1, together with those of known specimens of leaf deer and Indian muntjac from Myanmar. Similarity between the putative leaf deer skulls which we found, and the known leaf deer skulls from Myanmar, is evident from Table 1 and Figure 2. We further compared measurements from the intact skull of the putative leaf deer female with those from eight known specimens of adult leaf deer (five females and three males from Myanmar[7]), and three known specimens of Indian muntjac (two from Arunachal and one from Myanmar; only means were available for the measurements from Myanmar). Pair-wise Euclidean distances in morphometric measurements were computed among the 12 samples to generate a similarity matrix. Input variables included all ten skull measurements in Table 1. The matrix of Euclidean distances was plotted as a dendrogram using an average-linkage clustering algorithm. We expected that the known specimens of the leaf deer and Indian muntjac would form two clusters, with the putative leaf deer skull from Arunachal positioning with the former cluster. All known specimens of the two respective species did separate at the first branching (from left to right in Figure 3) itself, except for the single subadult Indian muntjac (IMSA in Figure 3) that positioned along with the leaf deer. This sample, however, separated from all the leaf deer at the second level of branching, thus yielding three distinct clusters – Indian muntjac, leaf deer and subadult Indian muntjac. This unique placement of the subadult Indian muntjac skull is perhaps due to its

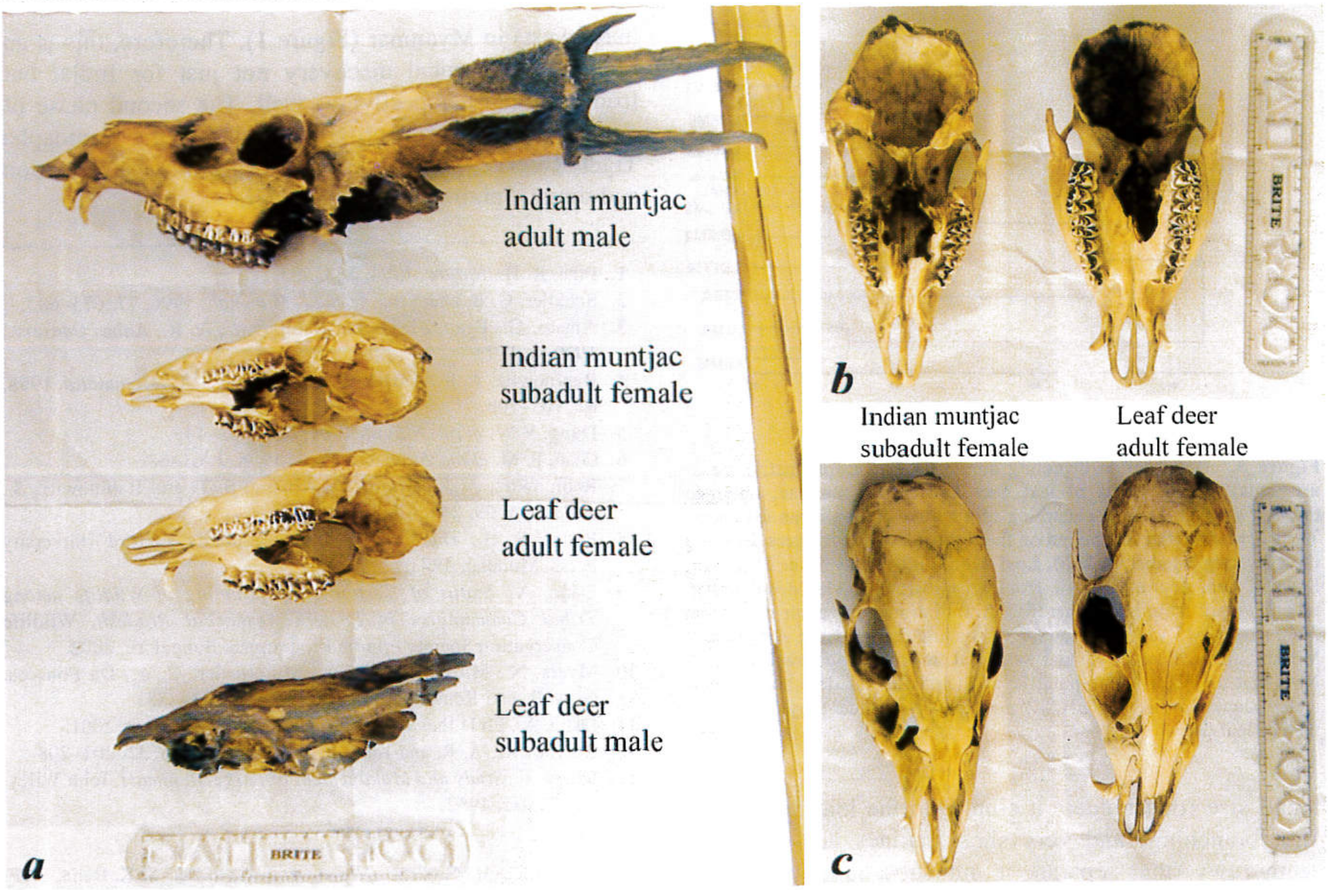

Figure 2. *a*, Skulls of leaf deer *Muntiacus putaoensis* and Indian muntjac *M. muntjak*. Adult leaf deer skull is much smaller in size and comparable with subadult Indian muntjac. Note the long canines of the leaf deer adult female. *b* and *c*, Ventral and dorsal view of the skull of Indian muntjac subadult female (left) and leaf deer adult female (right). The subadult Indian muntjac has incompletely erupted cheek teeth.

Table 1. Morphometric measurements from skulls of leaf deer *Muntiacus putaoensis* and the Indian muntjac *M. muntjac* from Myanmar (Rabinowitz *et al.*[7]) and Arunachal Pradesh

Measurement (all in mm)	Putative leaf deer subadult male from Arunachal	Putative leaf deer adult female from Arunachal	Known leaf deer adults from Myanmar (means)	Known Indian muntjac subadult female from Arunachal	Known Indian muntjac adult male from Arunachal	Known Indian muntjac adults from Myanmar (means)
Skull measurement						
Greatest length of skull	142*	162	175	163	218	212
Zygomatic breadth	67	75	73	67	95	87
Greatest width of braincase	54	53	47	52	62	58
Inter-orbital breadth	24	22	33	30	49	46
Length of frontal suture	Not available	70	71	60	79	83
Nasal length	Not available	43	47	45	62	60
Nasal width	Not available	16	16	21	29	25
Maxillary teeth row length	Not available	R: 84; L: 85	86	R: 41; L: 43	R: 108; L: 103	103
Canine length	Not available	R: 19*; L: 24	24	R: 7; L: 3	R: 31; L: 28	36
Palatal width between the third molar	Not available	32	33	32	39	40
Antler measurement						
Beam length	R: 21; L: 20	Not applicable	R: 32; L: 33	Not applicable	R: 106; L: 105	R: 95; L: 95
Pedicel length	R: 30; L: 31	Not applicable	R:30; L: 30	Not applicable	R: 86; L: 85	R: 62; L: 64
Greatest width of antlers	60	Not applicable	56	Not applicable	133	140
Gap between antler tips	60	Not applicable	47	Not applicable	93	97
Main beam circumference	R: 27; L: 27	Not applicable	23	Not applicable	R: 85; L: 79	73
Burr circumference	R: 41; L: 41	Not applicable	38	Not applicable	R:134; L: 132	94
Pedicel circumference at midlength	R: 29; L: 30	Not applicable	27	Not applicable	R:62; L:50	54

Measurement techniques and definitions follow Rabinowitz *et al.*[7] *, Incomplete measurements where the part was broken; R and L, Measurement from the right and left sides respectively.

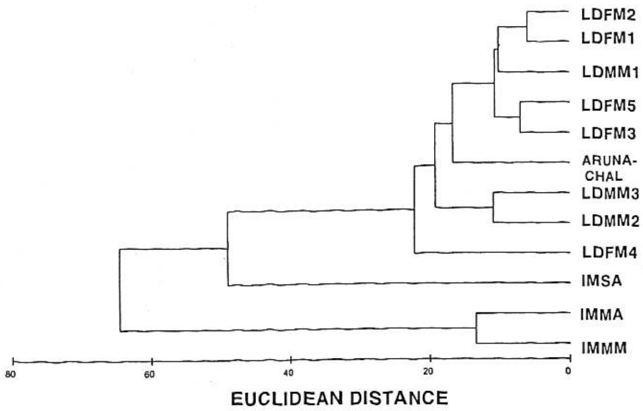

Figure 3. Dendrogram depicting similarity (in morphometric measurements) among skulls of leaf deer and Indian muntjac, obtained through average-linkage clustering of a matrix of Euclidean distances. The sample identity is labelled on the right side, with integers denoting the specimen number (LDFM, Leaf deer adult female from Myanmar; LDMM, Leaf deer adult male from Myanmar; IMMM, 'Mean' Indian muntjac adult from Myanmar; IMMA, Indian muntjac adult male from Arunachal; IMSA, Indian muntjac subadult female from Arunachal). Measurements from Myanmar were taken from Rabinowitz *et al.*[7]. Note that the skull of the putative adult female leaf deer that we collected (labelled ARUNACHAL) positions alongside those of Myanmarese leaf deer.

small size (that renders it similar to the leaf deer in the first branching) and very short canines and maxillary teeth rows (that separate it out subsequently). Importantly, the putative leaf deer skull from Arunachal (ARUNACHAL in Figure 3) clusters closely with known leaf deer skulls from Myanmar, suggesting that it is indeed a leaf deer and not an Indian muntjac.

We infer that the different criteria employed in this study – (i) knowledge of tribal hunters, (ii) skulls collected and (iii) results of morphometric analyses – together provide conclusive evidence for the occurrence of leaf deer in India. This study has revealed the presence of the leaf deer in areas that are 120–130 km west of its hitherto known distributional range (Figure 1). In fact, this western range extension means a twofold increase in the total east-west range of the leaf deer, which, prior to this survey, was known to occur only in a stretch of *c.* 70 km (east–west) in Myanmar (Figure 1). Therefore, this is an important biological discovery not just for India, but from a global perspective as well. The second phase of our survey is now in progress, covering the Namdapha Tiger Reserve, where we hope to get more information and direct sightings of the leaf deer.

1. Pine, R. H., *Nature*, 1994, **368**, 593.
2. Schaller, G. B. and Vrba, E. S., *J. Mammal.*, 1996, **77**, 675–683.
3. Amato, G., Egan, M. G. and Rabinowitz, A. R., *Anim. Conserv.*, 1999, **2**, 1–7.
4. Rabinowitz, A. R., Amato, G. and Khaing, S. T., *Mammalia*, 1998, **62**, 105–108.
5. Dung, V. V. *et al.*, *Nature*, 1993, **363**, 443–445.
6. Giao, P. M. *et al.*, *Anim. Conserv.*, 1998, **1**, 61–68.
7. Rabinowitz, A. R., Myint, T., Khaing, S. T. and Rabinowitz, S., *J. Zool.*, 1999, **249**, 427–435.
8. Prater, S. H., *The Book of Indian Animals*, Oxford University Press, Mumbai, 1971.
9. Datta, A., *Status of Hornbills and Hunting of Wildlife among Tribal Communities in Eastern Arunachal Pradesh*, Wildlife Conservation Society – India Programme, Bangalore, 2002.
10. Myers, N., Mittermeier, R. A., Mittermeier, C. A., Da Fonseca, G. A. B. and Kent, J., *Nature*, 2000, **403**, 853–858.
11. Datta, A., Ph D thesis, Saurashtra University, Rajkot, 2001.
12. Rabinowitz, A. R. and Khaing, S. T., *Oryx*, 1998, **32**, 201–208.
13. Riney, T., *Study and Management of Large Mammals*, John Wiley, Chichester, 1982.

ACKNOWLEDGEMENTS. We are grateful to Shri S. K. Raha, CCF-Wildlife Arunachal Pradesh, for granting permission to conduct this study, and for his support and encouragement to our programmes. We thank the headmen, hunters and other residents of surveyed villages for support and hospitality. We also thank the office and field-staff of Jairampur Forest Division and Namdapha Tiger Reserve for their help. The survey was made possible by a grant to A.D. from the Wildlife Conservation Society (WCS), NY (science and exploration), and was implemented under the joint science and conservation programme of WCS-India and the Nature Conservation Foundation. Dr Alan Rabinowitz and U. Saw Tun Khaing are thanked for their invaluable help. Shri Samba Kumar, Ms Kathleen Conforti and Shri Phaniraj greatly facilitated project administration. Comments by Dr N. V. Joshi greatly helped to improve the manuscript. We also acknowledge the continued support and encouragement from Dr K. Ullas Karanth.

Received 30 November 2002; revised accepted 21 December 2002