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Cover Page Footnote

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Exceptional size and form of Asian elephants in western Nepal

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Introduction

During a series of expeditions (1991-1999) to the Royal Bardia National Park in southwest Nepal (Fig. 1), we have been fortunate to study a very interesting population of wild elephants, in particular the very large bulls known as "Raja Gaj" ("King Elephant") and "Kansha" ("Younger") (Fig. 2) (Blashford-Snell and Lenska, 1996). Bardia comprises approximately 1,000 square kilometers (about 400 square miles) within the Terai zone, dominated by *Sal* forest but with a diversity of habitats including open grassy areas and riverside environments. Food for the elephants was plentiful. The elephants share the ecosystem with other ungulates (especially deer, wild boar and Indian one-horned rhino), carnivores (including tiger, leopard and jackal), monkeys (langur and macaque) and many smaller mammals and birds (Gurung and Singh, 1996). Before human disturbance, the Terai covered most of southern Nepal and adjacent northern India to the south of a range of hills known as the Siwaliks or Churias. The Siwaliks are famous for their rich fossil assemblages, including those of extinct elephantids (Osborn, 1942; Maglio, 1973).

Wild elephants in Nepal are now estimated at no more than 50-100 individuals (Sukumar and Santiapillai, 1996). These are known to migrate across the borders between India and Nepal, and the Bardia population, for example, has fluctuated greatly from only two individuals (Raja Gaj and Kansha) in the early 1990s, to over 40 in 1999. The erratic movements of the present elephant population can be seen as a disturbed remnant of former regular seasonal migrations across unbroken Terai (Lister, 1995). Today, animals seem principally to be moving between Bardia and Sukila Phanta Wildlife Reserve (White Grass Plains Reserve; cf. Byrne, 1990, p. 42), some 80 km to the west. Until 1995, Raja Gaj and

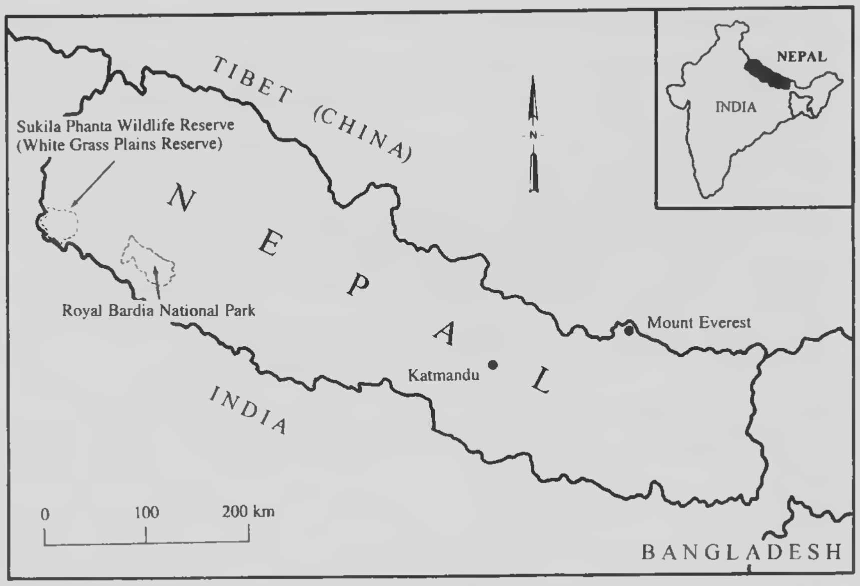
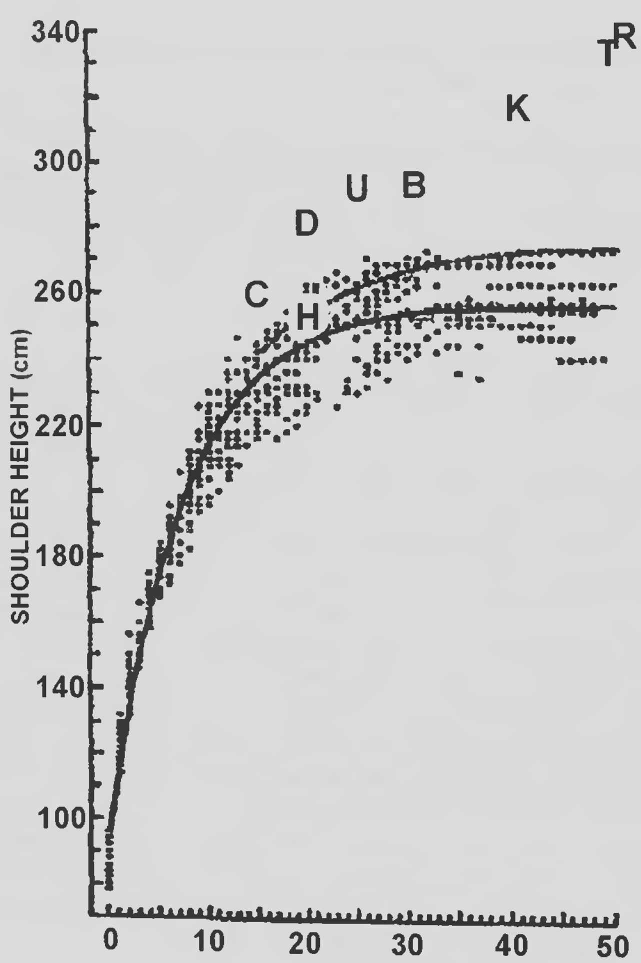
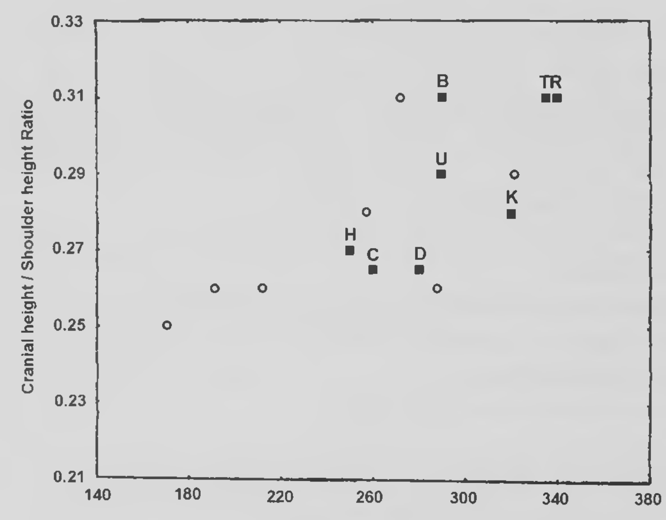


Figure 1. A map of Nepal and surrounding countries, showing the Royal Bardia National Park (home of Raja Gaj and Kansha) and Sukila Phanta Reserve (White Grass Plains Reserve), the former home of Tula Hatti [artwork by Jann S. Grimes].

Figure 2. Raja Gaj with secretion of temporin staining the side of his face. With an estimated shoulder height of 343 centimeters (11 feet 3 inches), Raja Gaj is one of the largest, possibly the largest, Asian elephants ever to have lived [photo credit: John Blashford-Snell].





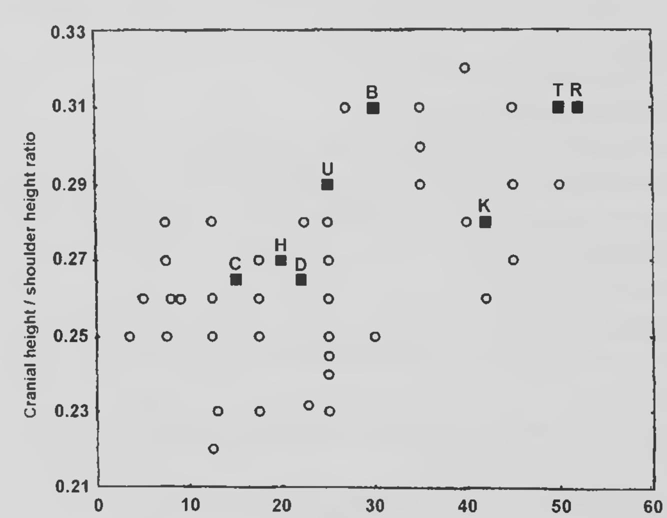


Figure 3 [above left]. Shoulder-height in an age-controlled population of male elephants from south-west India (after Sukumar *et al.* 1988). The lower curve is a standard growth curve (von Bertalanffy equation) fitted to data on domestic animals; the upper curve represents a likely best-fit for wild animals in the same area (Sukumar *et al.* 1988). Added are eight elephants from Nepal: B=Bahadur Gaj, C=Beli Chor, D=Deep Gaj, H=Bhim, K=Kansha, R=Raja Gaj, T=Tula Hatti, U=Tul Gaj.

Figure 4 [above right]. The ratio of cranial height to shoulder height, plotted against age for male Asian elephants. Circles, elephants from southwest India; squares, elephants from Nepal (see Fig. 3 for key).

Figure 5 [bottom right]. The ratio of cranial height to shoulder height, plotted against shoulder height for male Asian elephants. The positive correlation signifies positive allometric growth. Circles, elephants from southwest India; squares, elephants from Nepal (see Fig. 3 for key).

Kansha were always seen in each other's company, but with the arrival of other bulls in the park, more complex, shifting alliances between the bulls have been observed. We currently have detailed data on eight adult males, and observations on herds totaling around 35 females and young. Another very large bull, studied at Sukila Phanta by Byrne (1990), was "Tula Hatti" ("Great Elephant"). He was, unfortunately, killed in 1995 after stepping on a mine intended for wild boar.

Methods

Wild elephants were observed in the field from the backs of domestic elephants. Aging the wild bulls is based on a combination of factors (Sukumar, 1994 and personal communication), including skin folding and depigmentation, temporal and buccal "sinking", and tusk girth. Shoulder height was excluded as an aging criterion, to avoid circularity in the analysis of age/height relationships. Where an age range was estimated in the field (e.g., 5-10 years), the mean was used for plotting (e.g., 7.5 years). All age estimates should therefore be regarded as correct $\pm$ 3 years.

To estimate the height of an elephant, it is conventional in Asia to take the circumference of the forefoot and multiply it by two, or the front-to-back diameter and multiply it by six. Sukumar *et al.* (1988), using a sample of 111 Asian elephants, confirmed the validity of this approach. They fitted a regression line[1] with formula h = 2.03C, where h is the shoulder height and C is the circumference of the forefoot. Western *et al.* (1983), working with African elephants, determined the formula h = (f - 3.008)/0.158, where f is the forefoot length in cm. Clearly, however, there is variation in the foot size to height ratio among elephants, so an error term must attach to any height estimate. Sukumar *et al.* (1988) noted that while the mean ratio in his sample was 2.03, it ranged in individual animals from 1.74 to 2.18. Realistic confidence intervals on shoulder height are generally $\pm$ 10 cm. Heights of the Nepalese elephants were determined by measuring forefoot impressions on the ground.

Note that the Indian data on which Sukumar *et al.* (1988) demonstrated the viability of the determination of height from foot dimensions are the same as that used here to compare the heights of Nepalese and southern Indian elephants. Thus, we have confidence in the comparison between the Nepalese and Indian height data, even though the latter were obtained by direct measurement, the former from foot dimensions.

An attempt has also been made to quantify the relative cranial height of the elephants. The Nepalese animals were photographed in lateral view, the photographer (on the back of a domestic elephant) approximately at the level of the target animal's head. Apparent shoulder height was measured on the photographic print, as well as apparent cranial height from the eye to the cranial vertex. The ratio of cranial to shoulder height could then be calculated. For each animal, independent estimates were made from 2-4 different photographs (which never differed by more than 0.2 ratio points), and the mean plotted. Measurements of Tula Hatti have been taken from photographs provided by P. Byrne.

The Indian sample used for comparison is all from a restricted area (Nagarahole and Mudumalai, Karnataka State, southwest India). The Indian data were collected in exactly the same way as in Nepal: animals were aged by appearance in the field, photographed in lateral view, and measurements taken from photographic prints. Most data points are from our 1998 expedition to Nagarahole. A few are from photographs of now-deceased old bulls from Nagarahole, kindly provided by Colonel J. Wakefield. The remainder are photographs from Mudumalai kindly provided by Dr. R. Sukumar. Absolute shoulder heights are restricted to the latter sample (data from R. Sukumar).

Results

Our expeditions (January – March) were always in the dry season, but the elephants seemed generally to be well-nourished and in excellent health. The twin frontal forehead protuberances, characteristic of Asian elephant, appear exceptionally well developed, especially in the older bulls, and the frontal region itself is high, giving the animals a very high-domed appearance. Raja Gaj and Kansha carry large, thick tusks measuring 1 to 1.3 m (3.3 to 4.3 ft) long from the lip to the tip. Raja Gaj had broken his right tusk at least half-way along in 1995, but this had regrown to full length by 1999, a growth rate of approximately 15 cm (6 inches) per year. Raja Gaj and Kansha also seem to have lost much of their hair, apparently lacking eyelashes, head hair and the tail tuft, although the latter may result partly from loss of the tip of the tail itself. Raja Gaj and Tula Hatti are estimated at 50 years, Kansha at 40 years, while other adult bulls range from 15 to 30 years (Fig. 3).

The diameter of Raja Gaj's footprint was measured on numerous occasions, and the clearest forefoot prints always measured between 56 and 58 cm (about 22 and 23 inches), most commonly 57 cm (about 22.5 inches). For Kansha, diameters ranged between 52 and 54 cm (about 20 and 21 inches). Taking mean diameters as 57 and 53 cm (22.5 and 21 inches), respectively, and multiplying by six gives shoulder heights of 343 cm (11 ft, 3 inches) and 320 cm (10 ft, 6 inches) for the two animals. Using Western's (1983) independently derived method, the heights are 341 cm (11 ft, 2 inches) and 316 cm (10 ft 4 inches), respectively. The large bull of Sukila Phanta, Tula Hatti, was estimated in life to have been 335 cm (11 feet) tall at the shoulder (Byrne, 1990), and was measured as 343 cm (11 ft, 3 inches) after death (Byrne, personal communication). The latter figure may have been slightly enhanced by stretching when laid out, but clearly Tula Hatti was of comparable size to Raja Gaj.

The large size of the Nepalese elephants is graphically illustrated in Fig. 3, where the calculated shoulder heights of Kansha, Raja Gaj and Tula Hatti, plus five younger bulls from Bardia are plotted against estimated age, in comparison with a sample of 119 male elephants from southern India (Sukumar *et al.* 1988). Although Raja Gaj and Kansha attracted attention because of their size, the other Bardia bulls were observed opportunistically: there is no reason to think they have an unusually high age-specific size for the population. Their consistent position above the Indian sample (Fig. 3) indicates a very high mean size of the Nepalese population. Fig. 3 also suggests that the great adult size of the Nepalese animals is due to a prolonged growth period after 25 years, the age at which growth slows down in other populations. Growth trajectories of individual animals should be examined to test this.

Figure 4 shows the ratio of cranial height to shoulder height, plotted against age. There is a clear positive correlation in the Indian sample ($r=0.482$, $n=51$, $p<0.001$), indicating that the cranium is relatively higher in older animals. The Bardia animals fall within the Indian sample, all individuals (except Kansha) toward the upper edge of the scatter. The giant bull of Sukila Phanta, Tula Hatti, also possessed a very high frontal region and

[1] A regression line is a standard statistical term indicating the best fit datum for predicting one variable (in this case shoulder height) from another (in this case footprint diameter).

raised cranial domes (Byrne, 1990, pp. 200-201). These results may suggest a generally higher cranium at a given age in the Nepalese animals, although equaled by extreme animals elsewhere. However, in view of their larger body size at given age, the higher cranium may simply be a size effect. In Fig. 5, a positive allometric relationship of cranium height to shoulder height is clear, i.e., larger animals have relatively higher crania (Nepalese plus Indian pooled, $r = 0.724$, $n=15$, $p< 0.01$). Moreover, although the Indian sample is insufficient, there is no evidence of a difference in position of the two samples. The very high cranial domes of the Nepalese elephants can therefore be explained by the exceptional body size of the animals.

Discussion

The current published maximum height for Asian elephants is 343 cm, or 11 feet, 3 inches (Pillai, 1941; cf. Shoshani and Eisenberg, 1982). Thus, Raja Gaj is one of the largest Asian elephants that has ever lived, and very likely the largest now living. Our observations indicate that this is not restricted to one individual but that the population as a whole has high age-specific body size, probably as a result of prolonged adult growth.

The cause of the large size of the Nepalese population is unknown. It may have a genetic basis, or be (at least in part) an ecophenotypic effect of favorable feeding conditions. It is interesting to note that the largest Asian elephant ever owned by the Zoological Society of London — "Jung Pershad", who lived at Regent's Park from 1876 to 1897 — also came from Nepal (C. Keeling, personal communication).

The function of the high cranial domes of the Asian elephant is likely to be, at least in part, intimidatory. In the threat posture or when preparing to charge, the ears are moved laterally, maximizing facial area from the front. In the African elephant (*Loxodonta africana*), the very large ears create a huge area. In *Elephas maximus*, the smaller ears are compensated for by the much higher cranial domes than in *L. africana*. It is also possible that the cranial domes form part of the animals' sexual display, consistent with the finding that their average size seems to increase at around 30 years of age (Fig. 4), approximately the age after which successful bulls are most sexually active.

Popular reports that Raja Gaj resembles a mammoth are exaggerated: despite the large size, high cranium and sloping back of Raja Gaj, other elements of his morphology are quite unlike that of *Mammuthus*, for example, the double, as opposed to single, cranial dome. Suggestions by Coe and others (cited in Shuker 1993, pp. 255-256), that the heads of the elephants at Bardia resemble those of the extinct proboscidean *Stegodon*, are equally unfounded. *Stegodon*, in fact, has an exceptionally low forehead, quite the opposite to *E. maximus*. Although not relicts of a prehistoric era, the exceptionally large body size of the Nepalese population marks them out and has given them, by a process of relative growth, striking cranial morphology.

An intriguing comparison can be made with the type skull of the extinct Pliocene elephant *Elephas hysudricus*, a species known from Siwalik rocks and regarded as a likely ancestor for *E. maximus* (Maglio, 1973). This specimen, conserved in the Natural History Museum, London, was figured by Osborn (1942, cf. pp. 1320, 1349) and has been examined by the present authors. It has exceptionally high cranial domes, overhanging at the front, giving the reconstructed head an appearance very similar to that of Raja Gaj and Kansha (Lister, 1995). The size and form of the molar teeth indicate a large animal of at least 50 years of age, which may partly explain its similar cranial morphology to its likely modern descendants in Bardia.

Concluding Remarks

Byrne (1990, pp. 238-240) writes that Tula Hatti was declared a national treasure or a national monument in Nepal, a status similar to that given to the legendary African elephant, "Ahmed" of Marsabit, Kenya (Marnham, 1979), and to "Raja", the Maligawa tusker from Sri Lanka (Cannon and Davis, 1995). With Tula Hatti's death, this mantle has now passed to Raja Gaj. The purpose of such a designation is to protect these magnificent elephants and use them as symbols for conservation. It is hoped that this report, with its indication of exceptional size and morphology, will help to further the cause of preservation of this endangered population.

Acknowledgments

For their assistance in the field, we thank Pradeep Rana, Ram Din and other naturalists at Royal Bardia National Park, as well as volunteers on successive expeditions of the Scientific Exploration Society to Bardia and to Nagarahole. Iain and Oria Douglas-Hamilton and Derek Bromall are acknowledged for providing independent measurements of the forefoot diameter of Raja Gaj. Dr. R. Sukumar, Colonel J. Wakefield, and P. Byrne kindly provided photographs and data on elephants, and Sukumar helped with age estimates for the Nepalese animals. Thanks to Hezy Shoshani for his editorial help and suggesting additional references.

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