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Age and sex determination of gaur *Bos gaurus* (Bovidae)

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Abstract

One reason why the gaur *Bos gaurus* is a poorly understood species is because there are no reliable data to age and sex individuals. We studied captive gaur for two years in Mysore Zoo, India and Omaha Zoo, USA, and determined age-specific differences in morphological features and physical growth, by measuring shoulder height, of male and female gaur. We fitted von Bertalanffy growth functions to the shoulder height data and found maximum shoulder heights of 175 cm and 147 cm for males and females, respectively. This study ascertained for the first time that the greater the amount of white on the horns of a gaur, the older it is, and that the sexes can be distinguished based on horn shape and size differences. We found that gaur aged 15 months and below can be classified into three age classes, but are difficult to sex. The sex of gaur aged 15–36 months is best determined by a study of their horns. Adult gaur, greater than three years, are easy to sex, but are difficult to classify into single-year age classes and are reliably classified only into two age classes for females and three for males.

Keywords: Bovini; demography; dimorphism; field identification; horns; von Bertalanffy.

Introduction

In spite of its lofty status as Asia's largest bovid species, its Vulnerable (VU) Red List status (IUCN 2010) and the imminent danger of its extirpation from much of its Southeast Asian range (Duckworth and Hedges 1998), the gaur *Bos gaurus* Smith, 1827 is surprisingly a poorly studied species.

To better understand gaur population biology and demography, there remains a need for a reliable method on how to age and sex free-ranging gaur. Schaller's (1967) seminal study of gaur, although giving little detail as to how, established different age-size classes for gaur: three for males, two for females, and three for calves. Schaller acknowledged, however, that this was a 'crude and relative age scale' and suggested that 'an accurate aging technique based, perhaps, on horn length and shape, as was used for the American bison by McHugh, would be more desirable'.

There are other Bovini tribe species, such as the American bison *Bison bison* Linnaeus, 1758, African buffalo *Syncercus caffer* Sparrman, 1779, and European buffalo *Bison bonasus* Linnaeus, 1758, which are well-studied. This is largely because for over 50 years McHugh (1958) and Fuller (1959) have provided reliable techniques to age and sex American bison, for over 30 years Grimsdell (1973) and Sinclair (1977) have provided similar information for African buffalo, and Krasinska and Krasinski (2007) is the definitive reference for European buffalo. What is common and highlighted by all these studies is that it is possible to age and sex individuals of Bovini species based on the characteristics of their horns. In fact, both McHugh's (1958) and Sinclair's (1977) studies, important works in the study of American bison and African buffalo, respectively, illustrate and use only differences in the horns to classify the individuals they studied.

Using a two-year study of India's largest captive gaur population housed in Mysore Zoo, Mysore (Ahrestani 2009), we present detailed age-specific differences in morphological characteristics (with an emphasis on the shape, size and color of the horns) that can be used to age and sex free-ranging gaur. An important component of this information is the shoulder height data that we present in this paper, which is the first quantitative illustration of the difference in the growth, and the high degree of dimorphism, between male and female gaur.

Materials and methods

Captive populations with individuals of known age provide the ideal setting to study age-specific morphological growth patterns of a species. We studied India's largest captive gaur population housed in Mysore Zoo, Mysore, from November 2005 to August 2007, and the world's largest captive gaur population housed at Henry Doorly Zoo, Omaha, NE, USA, in July 2006.

We compiled data and recorded (with photographs) the morphological characteristics of 28 different individuals of known age, 16 females (aged 2 weeks to 16 years) and 12 males (aged 3 weeks to 11 years), during the study period in Mysore Zoo. We ascertained age-specific differences in body and horn color and the growth of distinguishing features such as dewlap and dorsal ridge in males. We established the differences in length, size, and shape of the horns using relative measurements from individuals of known age in the photographs.

Table 1 Morphological characteristics of different age classes of male and female gaur (*Bos gaurus*).

Gaur	Morphological characteristics	
Calves	Females and males	
0–2 months	Easily distinguishable by light orange-brown body coat and absence of 'white stockings'. At birth gaur stand ∼70 cm at the shoulder and grow ∼15 cm in height and 50% in body mass in the first two months. A white throat patch is visible for the first 2–3 weeks, horns appear only as bumps on the head, and the insides of legs above the knees are white	
3–5 months	Not much bigger than the previous age class, but color of coat has changed to brown and 'white stockings' become visible. Shoulder height at five months is ∼100 cm. Horns are visible, completely black and are ∼10–15 cm long. Horns of males are longer than those of females, but it is not possible to discern between the sexes based on horn length. The presence of the scrotum is the only morphological difference between the sexes, but is difficult to detect in free-ranging gaur of this age	
6–15 months	Both females and males grow equally and significantly in this age class and reach two-thirds adult female shoulder height. Horns of males in this age class are longer, but do not differ in shape from those of females. Besides the scrotum, which is difficult to observe in free-ranging gaur of this age class too, no other visible morphological difference can be used to distinguish between the sexes	
	Females	**Males**
Juveniles		
15–24 months The sexes are similar in height and size, but are distinguishable by horn shape and size	Size: 90% of height at shoulder and 80% of body size of adult females Horns: Reach 15–25 cm in length, remain completely black, curve less away from the head, making the horns less apart from each other, and their ends point inwards	Horns: Begin to whiten from the base up, are 25–30% white by the age of two years, ∼30 cm in length, and curve spreading away from the head to taper into sharp ends pointing upwards
2–3 years Males are bigger than females, but sexes are best differentiated based on horn differences	Size: By the age of three years they are 90–95% as tall at the shoulder and 80–90% as big as adult females Horns: Develop significantly in length and thickness, are 20–30% white, and have a semi-circular shape with ends pointing towards each other	Size: By the age of three years, males begin to exceed the size of adult females Horns: 50–60% white with ends that still point upwards. They are significantly longer, thicker, and wider apart than those of females of the same age and males of the previous age class
Adults		
>3 years It is easy to differentiate between the two sexes	Size and color: Not much growth in height, but they continue to increase in size until the age of 5–6 years. Females remain dark brown and do not turn black Horns: Continue to become thicker, longer, and to curve more inwards and closer to each other with increasing age. If the amount of white on a female's horns exceeds 80% it would be safe to assume that the female is older than 10 years	3–5 years Size and color: Bigger in size; dorsal ridge begins to become prominent. The anterior of the back and flanks begins to blacken Horns: Are 60–70% white by the age of five, and are less pointed at the ends. Horns thicken and begin to curve inwards at the ends, an important distinguishing feature from previous age class >5 years Size and color: Beyond the age of five, males can be called 'black bulls'. With advancing age bulls continue to increase in height and mass, their coats continue to blacken, their dorsal ridge continues to grow in height, thickness and prominence, and their dewlaps continue to become bigger Horns: Males with horns that are over 85% white, worn at the ends, and heavily corrugated closer to the head, can be to be considered older than 8 years old

Measurements of shoulder height are precise, whereas those of horns are best estimates.

We supplemented the morphological data with quantitative data of the growth in shoulder height of gaur. We measured the shoulder height (height on the dorsal ridge aligned vertically with foreleg) of different aged gaur by (a) directly measuring individuals photographed against scales painted within their zoo enclosures, and (b) indirectly measuring the relative heights of gaur photographed alongside individuals that had been measured against scales. We collected a total of 51 measurements (25 for females and 26 for males), 37 of which were from Mysore Zoo and 14 were from Henry Doorly Zoo. The measurements were either the most reliable one, or the mean of two to four, of an individual at a particular age. This yielded data of females at 18 distinct ages (between 2 weeks and 17 years) and of males at 17 distinct ages (between 2 weeks and 10 years).

The von Bertalanffy function (von Bertalanffy 1938) was fitted to the shoulder height data of both sexes. This function has been used to fit physical growth data of other large herbivore species including elephants, both Asian *Elephas maximus* and African *Loxodonta africanus* (Hanks 1972, Sukumar et al. 1988), and African buffalo (Sinclair 1977). The von Bertalanffy function is expressed as: $L_t = L_\infty\{1-\exp[-K(t-t_0)]\}$, where L_t=shoulder height at age t (years), L_∞=asymptotic shoulder height, K=growth rate, and t_0= theoretical age at which the animal would have zero height. These parameters were determined by minimizing the sum of squared deviations from the data using the Nelder-Mead method in the 'optim' function in the R statistical programming environment (R Development Core Team 2008).

Finally, using the shoulder height measurements and the relative differences in head and horn measurements between different aged gaur we developed sketches illustrating the pattern in growth of male and female gaur from 2 weeks to 10 years of age.

Results

Our observations provide the most detailed and comprehensive data on the visual morphological differences between male and female gaur. The changes in the visible morphology of male and female gaur as they age, that can be used to identify gaur by age and sex, are listed in Table 1 and illustrated in Figure 1. Schaller (1967) was correct to classify adult gaur into broad age-classes; we found that it is not possible to age gaur into single-year age-classes beyond the age of three years based only on visual morphological features. The new and important result that emerged from this study was that horn characteristics differences make it possible to differentiate between the sexes of gaur above the age of 15 months. Gaur above the age of three years are even easier to sex (Table 1).

Growth in body size is similar in the sexes until the age of 15 months, after which growth rates in males is greater than in females (Figures 1 and 2). Although females appear to attain 90–95% of their maximum shoulder height by three

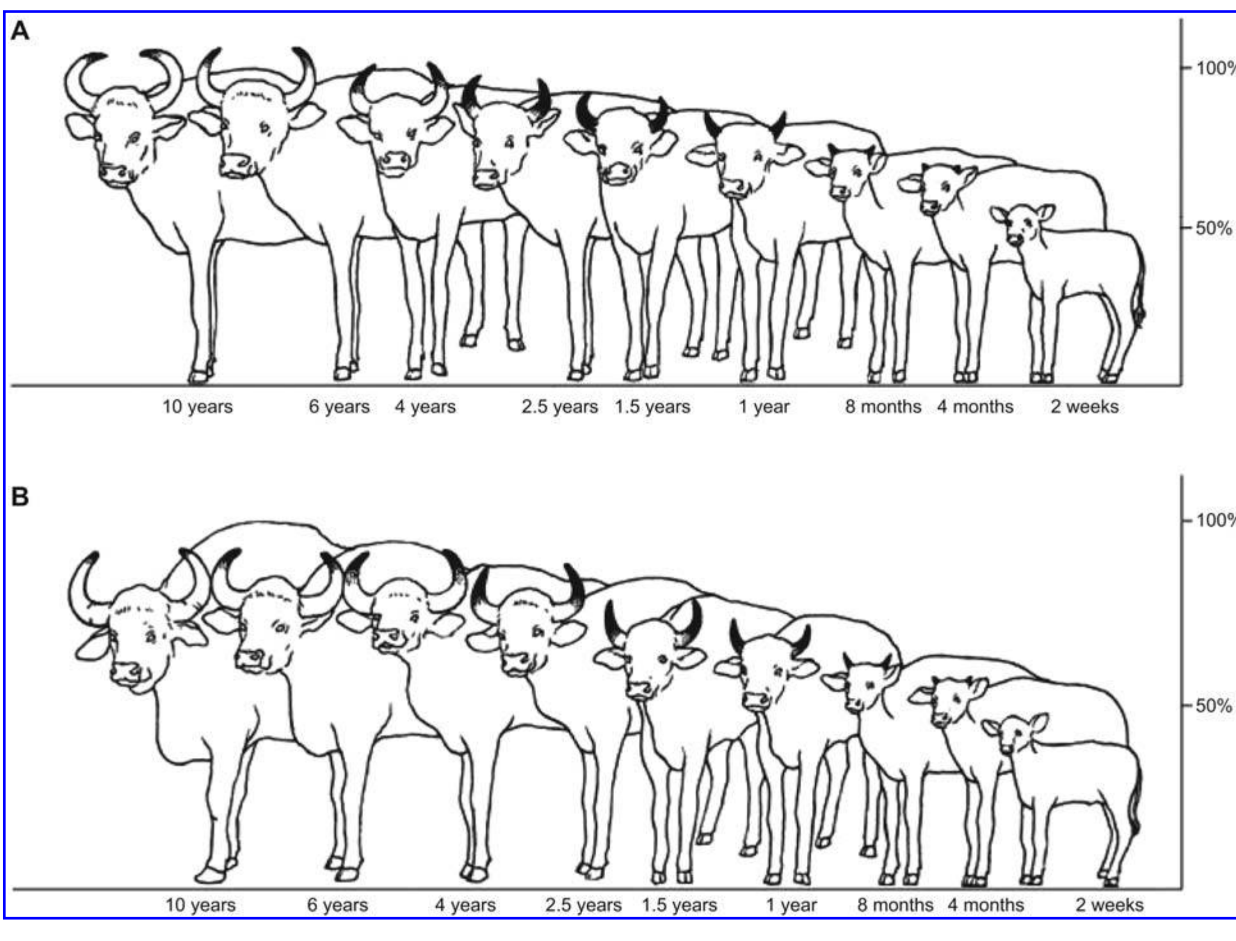

Figure 1 Age-specific relative growth of (A) female and (B) male gaur *Bos gaurus*. 100%, shoulder height of a 10-year-old.

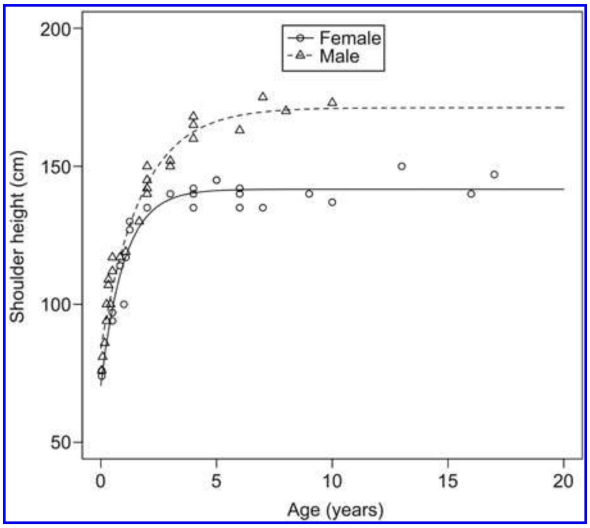

Figure 2 Growth of male and female gaur *Bos gaurus* measured at shoulder height. The shoulder height data (51 measurements) were fitted by plotting von Bertalanffy (1938) growth functions for both sexes: for females, L_t=142{1-exp[-0.19(t+0.69)]} and for males, L_t=171{1-exp[-0.57(t+1.18)]}. Note: The 51 measurements included females at 18 different ages and males at 17 different ages, derived from 12 females and 10 males at Mysore Zoo, Mysore, India, and eight females and six males at Henry Doorly Zoo, Omaha, NE, USA. Multiple individuals in Mysore Zoo were measured at multiple ages.

years (Figure 2), they continue to grow in body mass and probably attain their maximum body size by the age of six years. Males continue to grow for a greater number of years than females, attain their maximum shoulder height at 8–10 years (Figure 2), and probably attain maximum body size by 10–12 years. Maximum shoulder height was found to be 175 cm for males and 147 cm for females.

The von Bertalanffy function that best fits the shoulder height data of female gaur is: L_t=142{1-exp[-0.19(t+0.69)]}, and that which best fits the shoulder height data of male gaur is: L_t=171{1-exp[-0.57(t+1.18)]}.

Discussion and conclusion

This study is the first to quantify the difference in growth and capture the high degree of size dimorphism between male and female gaur. We now know that one reason for the high degree of dimorphism in gaur is because females complete most of their growth by the age of six years whereas males continue to grow past the age of 10 years.

The novel findings of this study were related to the age-specific similarities and differences in the shape, size, and color of horns between the sexes: the amount of white on gaur horns is a function of age in both sexes; it is possible to sex gaur older than 15 months based only on horn characteristics; and, horn characteristics are often all one can use to determine the sex of juvenile (15–36 months) gaur, an age-class when there is little difference in body size between the sexes and distinguishing features such as the dorsal ridge and dewlap of males have yet to develop and the scrotum in males is difficult to detect. Understanding the differences in horn characteristics by age and sex is also important for field researchers because often only the heads of gaur are seen above the forest undergrowth.

Differences in horns characteristics cannot be used, however, to determine the sex of gaur (calves) <15 months old. Although difficult to detect in free-ranging gaur, confirming the presence/absence of a scrotum remains the only way to sex gaur calves. Determining the sex of gaur >36 months (adults) is normally not a problem. This is not only because of the differences in horn characteristics, but also because of distinct differences in body size, color, and prominent features such as the elevated dorsal ridge and dewlap found only in males. It is difficult, however, to classify adults of either sex into single-year age-classes based only on visible morphological traits, and the best one can do is to classify both sexes into broad age-classes.

If gaur can be immobilized, one potential alternative to what we propose in this paper would be to determine the age of gaur by studying their dentition, similar to what Fuller (1959), Grimsdell (1973), and Ancrenaz and Delhomme (1997) have shown is possible with American bison, African buffalo, and Arabian oryx *Oryx leucoryx* Pallas, 1777, respectively. To our knowledge there have been only two studies (Conry 1989, Pasha et al. 2001) that have immobilized gaur in the past, neither of which provided information on dentition.

The differences in growth patterns and shape characteristics between male and female gaur horns are similar to those of other Bovini species, particularly the American bison (McHugh 1958) and the European bison (Krasinska and Krasinski 2007). Similar to gaur, the horns of males in both bison species are longer, thicker, and curve away more from the head (which sets them further apart) than the horns of females. However, the white-to-black color ratio on a gaur's horns that provides an estimate of its age is a feature that is not common to the bison species. Our observations made of the gaur population in Omaha Zoo, which included individuals from Southeast Asia as well as India, confirmed that our findings should apply to sex and age gaur throughout its distribution range.

In conclusion, although it is possible to classify free-ranging gaur below the age of three years into four age classes, it is not easy to determine their sex. The opposite is true for adult gaur: although it is easy to determine the sex of free-ranging adult gaur, it is possible to reliably classify gaur above the age of three years into only two age classes for females and three for males. The findings of this paper are helpful to age and sex free-ranging gaur and are therefore useful to further research the population biology and conservation of the vulnerable and poorly studied gaur.

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