A method of calculating anterior horn mass in South African rhinoceroses

D.J. Pienaar*
Centre of Wildlife Research, University of Pretoria, Pretoria, 0002 Republic of South Africa

A.J. Hall-Martin
National Parks Board, P.O. Box 7400, Roggebaai, 8012 Republic of South Africa

Received 12 October 1992; accepted 24 May 1993

The density of white rhinoceros *Ceratotherium simum simum* and black rhinoceros *Diceros bicornis minor* horn was ascertained using the mass and volume of 43 anterior and posterior horns. The horn density was then used to derive a method of calculating the anterior horn mass accurately without having to weigh the horn. It is thus possible to calculate the anterior horn mass of a live rhinoceros. The relationship between some horn measurements and horn mass were also examined using curvilinear regression. The correlations describing the relationship between horn mass and anterior horn basal circumference for males and females separately were found to be the highest.

Die digtheid van witrenosterhoring *Ceratotherium simum simum* en swartrenosterhoring *Diceros bicornis minor* is bepaal deur gebruik te maak van die massa en volume van 43 anterior- en posteriorhorings. Deur die horingdigtheid te gebruik is 'n metode ontwikkel waarmee die massa van 'n anteriorhoring akkuraat bepaal kan word. Dit is dus moontlik om die massa van 'n anteriorhoring op 'n lewendige renoster te bepaal. Die verwantskap tussen sekere horingmates en horingmassa is ondersoek deur lynkurwe regressie te gebruik. Die beste korrelasie is verkry tussen horingmassa en anteriorhoring basis omtrek vir manlike en vroulike diere apart.

Keywords: Black rhinoceros, field technique, horn measurement, white rhinoceros

* To whom correspondence should be addressed at: Private Bag X402, Skukuza, 1350 Republic of South Africa

Introduction

The microscopic morphology of rhinoceros horn has been described (Ryder 1962; Earland, Blakely & Stell 1962; Lynch, Robinson & Anderson 1973). These authors report that rhinoceros horn is composed of closely packed filamentous units. Horn growth rate has been described by Pienaar, Hall-Martin & Hitchins (1991) and the regenerating potential by Bigalke (1945) and Klös (1969). The antipyretic effects of rhinoceros horn are documented by But, Lung & Tam (1990) and But, Tam & Lung (1991).

Rhinoceros horn is a valuable and scarce commodity and rhinoceroses have been hunted to the verge of extinction in Africa over the past 20 years (Cumming & Du Toit 1989; Hillman-Smith 1990). An attempt to stop the decline of Africa's rhinoceros population by a total ban on trade in rhinoceros products, through listing the species in Appendix 1 of CITES, has failed (Western 1989; 1990). The alternative of sustained yield and use is of importance and therefore needs to be examined. In this context, data on horn mass and density are necessary.

This study attempts to ascertain the density of rhinoceros horn and to establish if there is a difference in density between the anterior and posterior horns. The density of black rhinoceros *Diceros bicornis minor* and white rhinoceros *Ceratotherium simum simum* horns are also compared to determine if species-related variation in this variable exists.

The relationship of rhinoceros horn density, volume, and mass is also investigated. The density of a substance is the unit mass per volume, usually kg m^{-3} or g ml^{-1}. Thus if the density and the volume of a substance are known, mass can be determined by multiplying density by volume. If the volume of a rhinoceros horn can be calculated mathematically, and the density is known, the mass of the horn can be ascertained without having to weigh it. It would thus be possible to ascertain the mass of a horn on a live animal.

Methods

Samples of white rhinoceros and black rhinoceros anterior (n = 30) and posterior horns (n = 13) were weighed on an electronic balance to determine the mass of each horn in grams.

A metal cylinder with a radius of 135 mm and a height of 870 mm was used to measure the volume of each horn. A thin glass tube was fitted on the side of the cylinder and connected to the bottom of the cylinder (Figure 1) which was then filled with water. An adjustable O-ring was fitted to the glass tube to mark the water level accurately. The O-ring was adjusted so that the water meniscus in the glass tube just touched it. A rhinoceros horn was then submerged in the cylinder causing the water level to rise. Water was then drained from the cylinder through a tap at the bottom until the water meniscus in the glass tube had dropped to the O-ring mark. The volume of the drained water was determined using a measuring cylinder.

Horn density was calculated in g cm^{-3} using the individual mass and volume of each horn. The Mann-Whitney U-test was used to test for species-related differences in horn densities between white rhinoceroses (n = 28) and black rhinoceroses (n = 14). The same test was used to ascertain any difference in anterior and posterior horn densities.

Thirty anterior horns were measured in mm along the anterior and posterior surfaces from the base to the tip using a steel tape. The basal circumference of each anterior horn

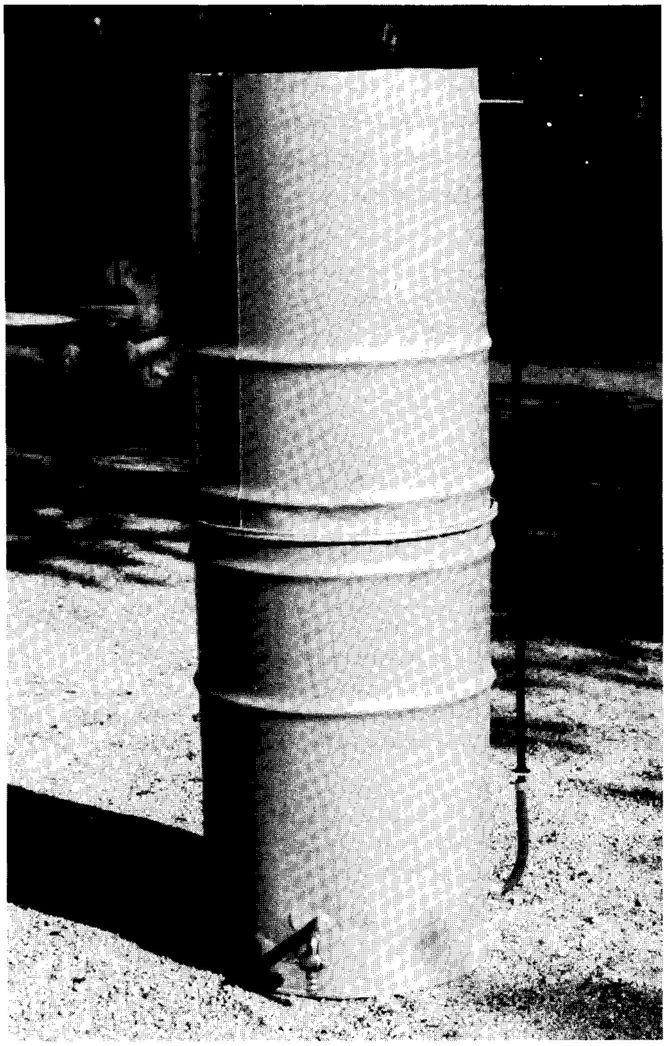

Figure 1 Metal cylinder used to measure rhinoceros horn volume.

was also measured (Figure 2). The volume of each anterior horn was then calculated using the following formula:

Volume of a cone = $\frac{1}{3} \pi r^2 h$

$r = (0{,}31831 \times \text{horn circumference})/2$

$h = \sqrt{[(a + p)/2]^2 - r^2}$

a = horn length along anterior surface in mm
p = horn length along posterior surface in mm
The formula for 'h' is derived from Pythagoras' rule

Calculated volumes were tested for functional relationships with the measured volumes using regression analysis and Pearson correlation analysis in the SAS package (SAS Institute Inc. 1987). Only anterior horns were used in this test because the shape of the posterior horn restricts the use of a simple mathematical formula.

The mass of each anterior horn was also calculated using both individual and mean horn density, and the calculated volume.

Calculated mass = density (g ml^{-1}) $\times$ volume (ml)

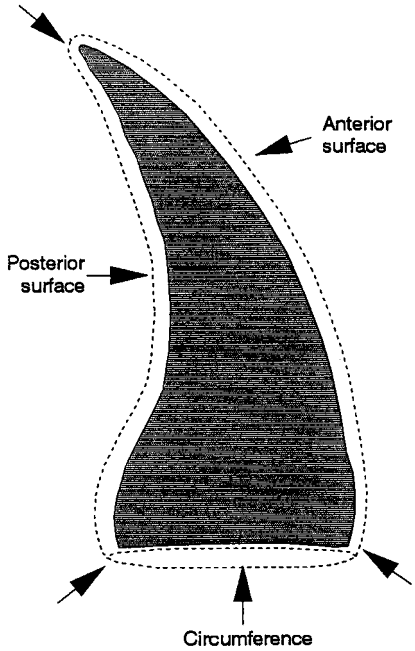

Figure 2 Diagram of a rhinoceros anterior horn to indicate where the measurements were taken.

Anterior horn masses calculated from both individual and mean horn density were tested for functional relationships with the measured mass using regression analysis and Pearson correlation analysis in the SAS package (SAS Institute Inc. 1987). The null hypothesis, that there was no functional relationship between measured volume and mass, was rejected if $P \leq 0{,}05$. Linear regression was used to compare calculated and actual volumes and masses.

The relationhip between anterior horn basal circumference and mass, and between anterior horn length and mass was examined also using regression analysis. The null hypothesis, that there was no functional relationship between basal circumference and mass, and between horn length and mass, was rejected if $P \leq 0{,}05$. Power curves were used to compare horn measurements and mass as they presented the best fit to the data.

Results

To test the precision of the measuring cylinder, a series of 10 measurements on the same horn was conducted. The mean volume was 3 244 ± 1 ml with a range of 9 ml and the method was therefore considered adequate for accurate volume determination.

Mean rhinoceros horn density was 1,261 ± 0,024 g cm^{-3} (n = 43). No difference was found between the densities of black rhinoceros (n = 14) and white rhinoceros (n = 28) horns (P = 0,1888) nor between the densities of anterior (n = 30) and posterior (n = 13) horns (P = 0,093).

The density of a 150-mm section of anterior horn tip and that of a 100-mm section of anterior horn base were measured as 1,283 g cm^{-3} and 1,247 g cm^{-3}, respectively.

Only the anterior horns (n = 30) were used to study the relationship between horn density, volume and mass. Significant linear relationships were obtained between the calculated horn volumes and the measured horn volumes (r^2 =

0,96; P = 0,0001; n = 30) (Figure 3) and between the calculated and measured horn mass (r^2 = 0,95; P = 0,0001; n = 30) (Figure 4).

The relationships between anterior horn length and mass, and between anterior horn basal circumference and mass were examined separately for males and females and also jointly for the entire sample (Figures 5 – 10). Although significant correlations were obtained in every case, those describing the relationship between horn mass and anterior horn basal circumference for males and females separately were found to be the highest.

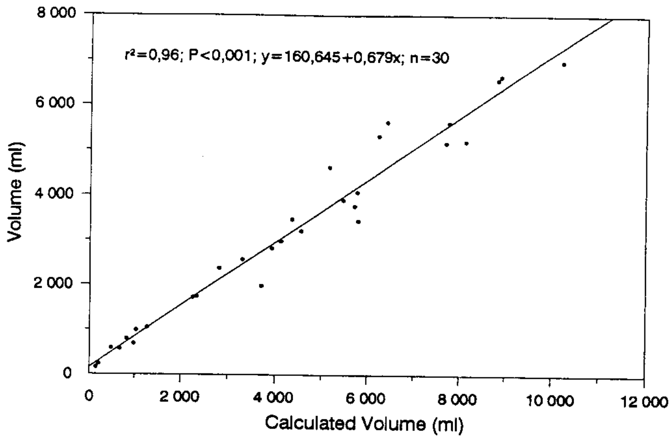

Figure 3 The relationship between the measured rhinoceros anterior horn volume, and the volume calculated for each horn (r^2 = 0,98; P = 0,0001; n = 30).

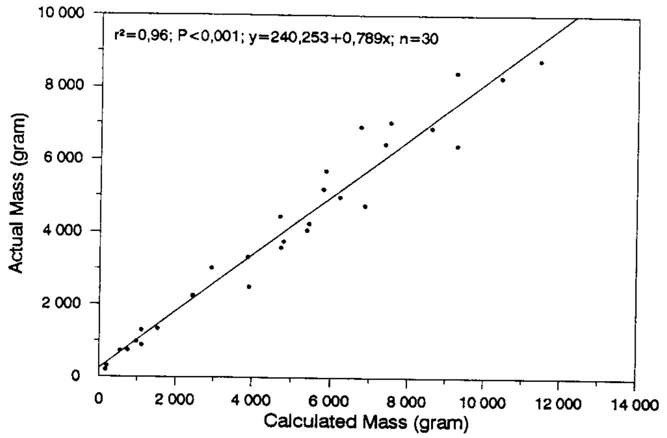

Figure 4 The relationship between measured rhinoceros anterior horn mass and the mass calculated for each horn using the mean horn density and the calculated volume of each horn (r^2 = 0,98; P = 0,001; n = 30).

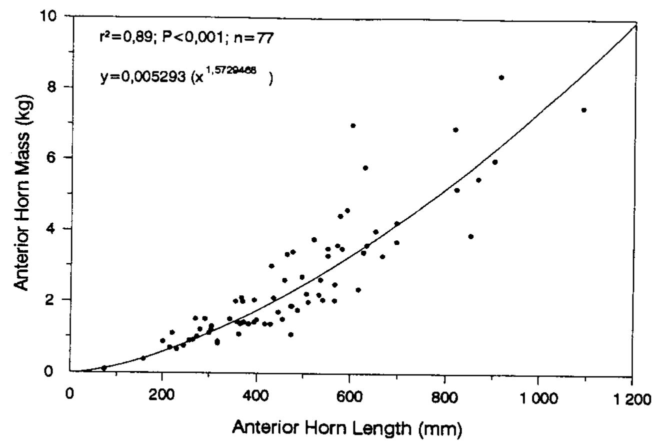

Figure 5 The relationship between anterior horn length and horn mass for female rhinoceroses (r^2 = 0,89; P = 0,0001; n = 77).

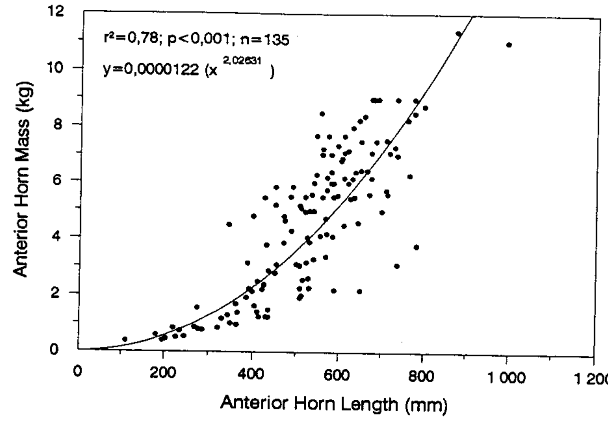

Figure 6 The relationship between anterior horn length and horn mass for male rhinoceroses (r^2 = 0,78; P = 0,0001; n = 135).

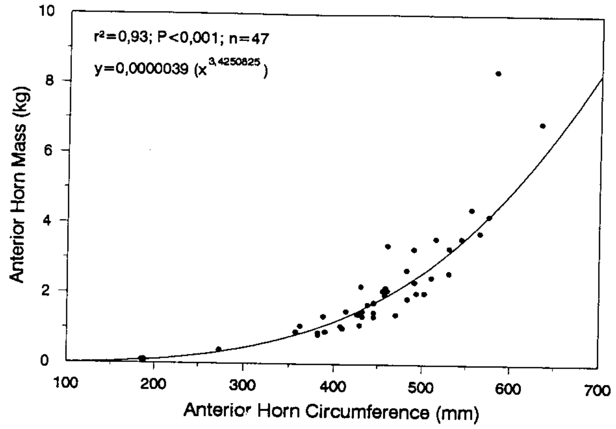

Figure 7 The relationship between anterior horn circumference and horn mass for female rhinoceroses (r^2 = 0,93; P = 0,0001; n = 84).

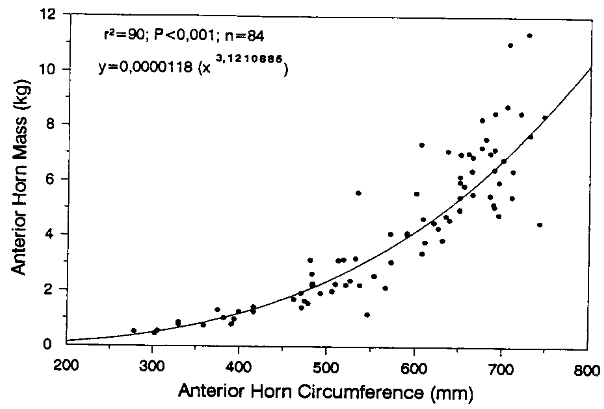

Figure 8 The relationship between anterior horn circumference and horn mass for male rhinoceroses (r^2 = 0,90; P = 0,0001; n = 84).

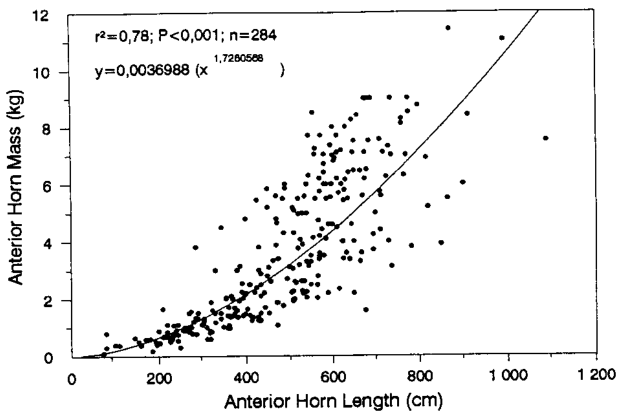

Figure 9 The relationship between anterior horn length and horn mass for male and female rhinoceroses (r^2 = 0,78; P = 0,0001; n = 284).

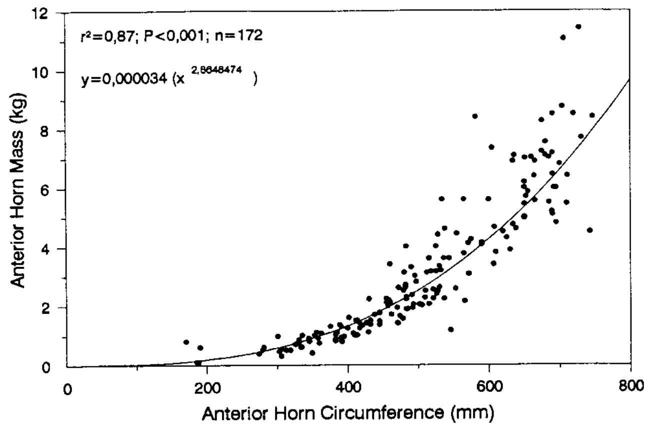

Figure 10 The relationship between anterior horn circumference and horn mass for male and female rhinoceroses (r^2 = 0,87; P = 0,0001; n = 172).

Discussion

The density of a white rhinoceros horn was found to be greater at the tip than at the horn base. Bigalke (1945) described a black rhinoceros horn as consisting of an inner core and an outer sheath of fibres although Lynch *et al.* (1973) found no evidence of this. Ryder (1962) mentions that horn fraying seems to take place more readily at the base and attributed this to a lack of interfilamentous substance.

All the horns examined had a distinctive dark centre with paler outer filaments, this being consistent with Bigalke's 1945 description of a inner core and an outer sheath of fibres. A section of a white rhinoceros anterior horn was cut and examined under a dissecting microscope. A dark interfilamentous substance appears to be responsible for the dark coloured centre whereas this was not present between the pale outer fibres. At the horn tip all the pale outer filaments have been rubbed off, leaving the dark inner section as the functional horn tip. The fact that the horn tip was found to be denser than the horn base indicates that the dark centre is denser than the pale outer fibres. It is interesting to note that Chinese herbalists regard the tip as the most potent part of a horn (Martin 1980).

The significant correlation between the calculated mass and the actual horn mass indicates that the actual horn mass can be predicted accurately by calculating the horn mass using the formula for volume and the mean horn density. The calculated mass is then transformed to derive the actual mass (Figure 4):

Actual mass = 240,253 + (0,789 × calculated mass)

As the relationship between anterior horn mass and anterior horn basal circumference is significant, a meaningful estimate of anterior horn mass can also be made by using the following formulae where the sex of the animal is known (Figures 7 & 8):

For males: Anterior horn mass = 0,0000118 × anterior horn circumference^{3,1210885}

For females: Anterior horn mass = 0,0000039 × anterior horn circumference^{3,4250825}

Conclusions

The mean density of rhinoceros horn is 1,26131 g cm^{-3}. The volume of a rhinoceros anterior horn can be ascertained by using horn measurements and a mathematical formula as the correlation between actual volume and calculated volume is high. Using the calculated volume and the mean horn density the calculated mass of a rhinoceros horn can be ascertained. The actual mass of the horn can be determined by applying a correction factor to the calculated mass. In this way the anterior horn mass on a live rhinoceros can be predicted. The correlations describing the relationship between horn mass and anterior horn basal circumference for males and females separately were found to be the highest. This method may prove useful in gathering data from immobilized animals such as rhinoceroses immobilized by sportsmen as an alternative to trophy hunting (Matthews 1991). It will also provide a measure of horn regrowth of rhinoceroses dehorned for security purposes (Lindeque 1990) or as part of rhinoceros ranching operations.

Acknowledgements

We are grateful to the National Parks Board of Trustees for allowing us to carry out this study. We thank the University of Pretoria, the FRD and the National Parks Board for financial support and our colleagues in the Kruger National Park for assisting with the weighing and measuring of the horns. We thank I. Thrash who assisted with the statistical analysis of the data. Our sincere thanks also to Professors J. du P. Bothma and G.K. Theron of the Centre for Wildlife Research, University of Pretoria, D. Barratt and Drs H. Biggs and C. Knox for valuable criticism of this manuscript. The data in this paper form part of an M.Sc. study conducted on the white rhinoceros by the senior author.

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