Body growth of captive eland *Taurotragus oryx* in Natal

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Post-natal growth in live mass and in body dimensions with age is described in a captive herd of eland *Taurotragus oryx*, using the von Bertalanffy growth equations. Asymptotic live mass of males (575 kg) was 45% higher than the value for females (316 kg). Asymptotic body dimensions were also higher in males, girth by 27%, height at withers by 13% and body length by 9%, these data illustrating the sexually dimorphic nature of growth in eland. In winter, body growth rates were significantly lower than in the summer, but these variations are not apparent from theoretical von Bertalanffy growth curves. A combination of linear measurements is described for the prediction of live mass.

S. Afr. J. Zool. 1981, 16: 183 – 189

Nageboortelike toename in lewende massa en liggaams-afmetings met toenemende ouderdom word vir 'n trop elande *Taurotragus oryx* in gevangenskap met behulp van die von Bertalanffy-groeivergelykings beskryf. Asimptotiese lewende massa van bulle (575 kg) was 45% hoër as dié van koeie (316 kg). Asimptotiese liggaamsafmetings was ook hoër in bulle, die omvang met 27%, hoogte by die skof met 13% en liggaamslengte met 9%. Hierdie gegewens illustreer die geslagsdimorfiese aard van groei in die eland. Die liggaams-groeitempo was betekenisvol laer in die winter as in die somer, maar hierdie variasies blyk nie uit die teoretiese von Bertalanffy-groeikurwes nie. 'n Kombinasie van lineêre afmetings vir die voorspelling van lewende massa word beskryf.

S.-Afr. Tydskr. Dierk. 1981, 16: 183 – 189

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The objectives of this paper are to analyse post-natal growth with age of a captive herd of common eland *Taurotragus oryx oryx* and to investigate the relationships between the growth parameters recorded. Current interest in the exploitation of game for meat production demands precise information on growth rates under specific conditions. In addition, growth studies can be used to compare the condition of different populations, to facilitate the field classification of a species, to enable population biomass to be estimated and to assist taxonomic studies (Howells & Hanks 1975). With the prospect of an expanding game industry, knowledge of age-specific and sex-specific live mass will facilitate the administration of correct, hence economical, drug dosages for the tranquilization or immobilization of animals and the treatment or prophylaxis of disease. Relationships between body mass and body dimensions can be used for live mass estimation (McCulloch & Talbot 1965; Hanks 1972; Howells & Hanks 1975).

The captive eland were stationed at Coleford Nature Reserve in the foothills of the Drakensberg Mountains in Natal (29°27′E, 29°58′S). The reserve of 1 278 ha lies within a zone of highland sourveld (Acocks 1953) and varies between 1 432 m and 1 676 m a.s.l. (Scotcher 1974). The eland were managed similarly to cattle in the same region, feeding on natural veld supplemented in winter by pastures, concentrates and hay (Jeffery 1978).

Materials and Methods
The study animals
Fifty-five live known-age eland were regularly weighed and measured in a four-point crush cattle weighbridge between March 1977 and March 1978 (Jeffery 1978). The eland were weighed and measured between 08h00 and 10h00 to reduce errors arising from diurnal variation in rumen-fill (Stainthorpe 1972). Ages of the eland were taken to the nearest month so that eland of similar ages could be lumped into appropriate monthly age-groups. The term 'age-group' is used rather than 'age-class' because chronological ages were used and not ages determined from the various age determination criteria available (Jeffery & Hanks 1981). The 39 females in the study group varied widely in age but only two out of the 16 males were older than 20 months. In order to increase the sample of males, the measurements of six adult males of known age from near-by reserves with similar environments to Coleford were included in this study (three

from Loteni Nature Reserve, two from Midmar Public Resort Nature Reserve and one from Vernon Crookes Nature Reserve).

Growth in live mass with age

Preweaning growth of calves (from birth to four months) was examined by carrying out linear regressions of growth in mass with age. Theoretical von Bertalanffy growth curves (von Bertalanffy 1938) were derived from values of mean live mass and standard error of the mean for each age group using the cubic growth equation of Beverton & Holt (1957):

$$m_t = M_\infty (1 - e^{-K(t - t_0)})^3 \text{ kg}$$

where:

m_t = mass at age t,
M_∞ = asymptotic mass,
K = a coefficient of catabolism,
t = age in months,
t_0 = theoretical age at which eland would have zero mass with the same growth pattern as that observed in later life.

The three coefficients (M_∞, K and t_0) were calculated from observed data with a computer (IBM 1130, University of Natal) using the program of Hanks (1972).

Growth in live mass with different seasons

Seasonal growth during the study period was divided into two phases, namely winter (14 April to 21 September) and summer (4 October to 22 March). Since the study group was a birth-pulse population (Jeffery 1979a), the growth patterns of separate generations were readily followed through each season. The following cohorts were identified at Coleford:

— calves
— calves-yearlings
— yearlings-subadults
— subadults (3 to 5 years of age)
— adults (over 5 years of age).

Mean monthly live mass values of each cohort were plotted against months of the study period. No attempt was made to fit theoretical growth curves to these data but the results of the calves-yearlings and yearlings-subadults were analysed to establish whether there were any significant differences between winter and summer growth rates.

Growth in body dimensions

The body dimensions recorded at Coleford were chest girth, height at withers (Ansell 1965) and length from withers to base of tail (Jeffery 1979b) as illustrated in Figure 1. Chest girth and length were measured with a steel tape measure and height was measured with a sliding scale. In order to reduce unnecessary variation in measurements, each eland was measured in the 'normal posture' (Underwood 1975) which is recommended as the standard measuring position by Jeffery (1979b). All measurements were taken in conjunction with live mass and were recorded to the nearest 1,0 cm. Theoretical von Bertalanffy growth curves were derived from observed
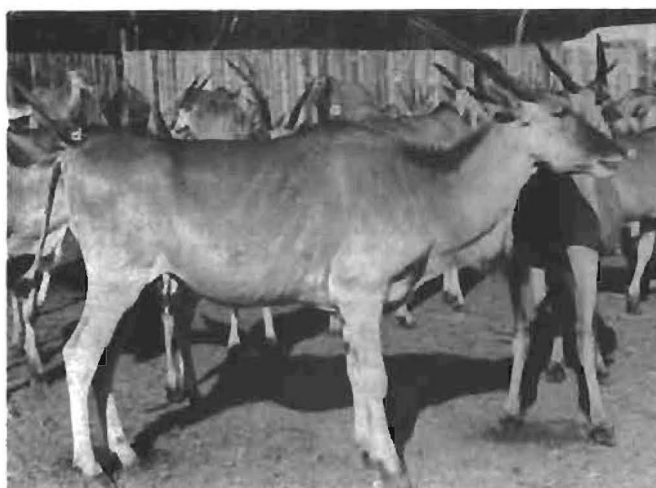

Figure 1 Eland cow in normal posture (Underwood 1975) showing the points for the measurements of girth (a-b-a), height at withers (a-c) and length from withers to base of tail (a-d).

data of girth, height and length as described for growth in live mass but using the non-cubic equation for growth in body dimensions:

$$l_t = L_\infty (1 - e^{-K(t - t_0)}) \text{ cm (Beverton & Holt 1957).}$$

Relationships between growth parameters

In order to establish practical and accurate methods of mass prediction for male and female eland, the relationships of each body dimension, or combination of the parameters, with live mass were determined.

Results and Discussion

Growth in live mass with age

The equations for preweaning growth in live mass with age are:

$y = 16,94x + 24,49$ kg ($n = 28$; $r = 0,92$; $P < 0,001$) for females
$y = 16,74x + 26,50$ kg ($n = 24$; $r = 0,94$; $P < 0,001$) for males

where y is live mass at age x in months. The preweaning growth rates of 16,94 kg month^{-1} and 16,74 kg month^{-1} were not significantly different ($P > 0,25$).

The equations and theoretical von Bertalanffy growth curves describing growth in live mass of male and female eland are shown in Figure 2. Asymptotic live mass of males (575 kg) was 45% higher than the value for females (316 kg). The higher coefficient of catabolism of females suggests that they attained their asymptotic live mass earlier than males. Ages at which the eland reached their computer-derived asymptotes are biologically meaningless since the growth equations predict continuous growth *ad infinitum* without a senescent phase when growth becomes insufficient for body maintenance prior to death (Sinclair 1969). Since the standard errors of specific means in some cases extended above the computer-derived asymptotes before they were theoretically reached, it was decided to consider ages at attainment of asymptotes as being the corrected ages at 2,5% less than the computer-derived asymptotes. Using this criterion males and females reached their asymptotes at 99 months and 73 months respectively. These data
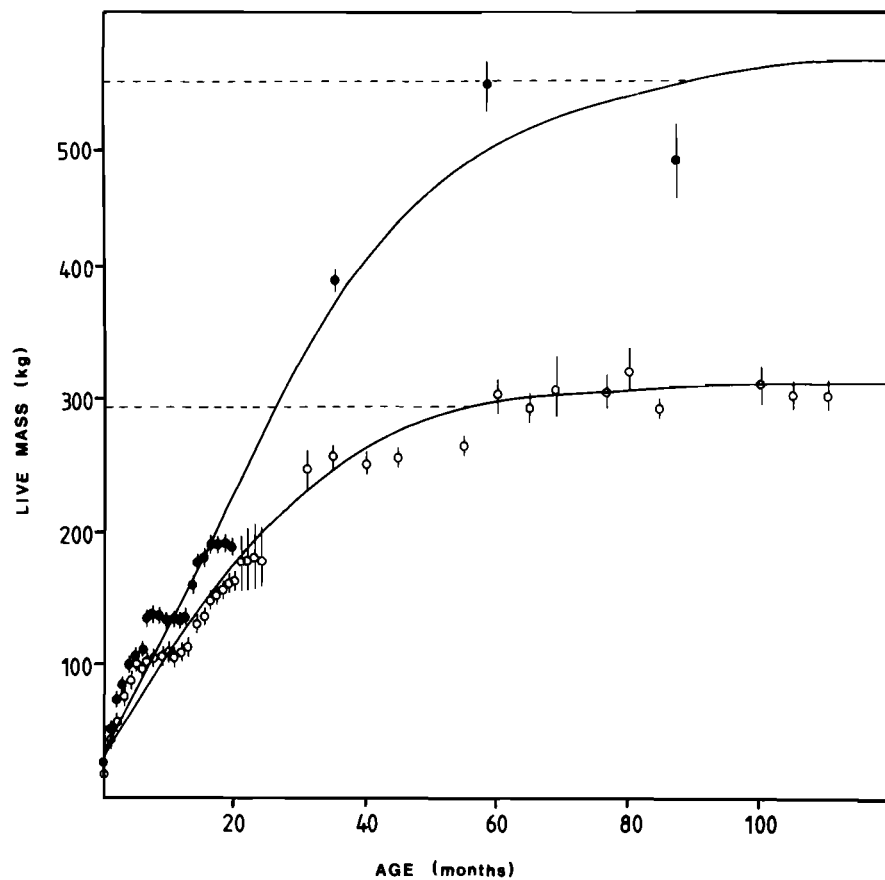
Figure 2 Theoretical von Bertalanffy growth in live mass curves for eland at Coleford Nature Reserve. Open circles denote mean live mass at age of females and closed circles mean live mass at age of males. Vertical lines denote one standard error either side of the mean. Dashed lines are live mass values of 2,5% less than the computer-derived asymptotes (see text). For females: $m_t = 315,9 (1-e^{-0,057(t + 11,23)})^3$ kg. For males: $m_t = 574,8 (1-e^{-0,043(t + 11,41)})^3$ kg.

clearly illustrate the sexually dimorphic nature of growth in live mass of eland and support the statement of Lightfoot (1977) that male eland continue to gain in live mass up to a greater age than do females. Attwell (1977) used this method to compare the growth of male and female blue wildebeest *Connochaetes taurinus*.

Growth in live mass with different seasons

Figure 3 depicts the patterns of growth of eland at Coleford during the study period. These patterns demonstrate that the theoretical von Bertalanffy growth curves are purely ideal representations of growth in live mass. In practice, it appears that rates of growth varied in a regular manner apparently related to season.

Table 1 shows that the seasonal variations in growth rates of calves-yearlings and yearlings-subadults were similar and that winter growth rates were significantly lower than summer growth rates. The data indicated that the plane of nutrition of the non-adult eland was barely sufficient for maintenance during winter. The decline in quality and availability of forage during winter was responsible for a concurrent depression of condition of eland at Coleford (Jeffery 1978) and this resulted in the winter depressions of growth rates. The effect was probably aggravated by the severe cold of the Highveld winter and the higher requirement of metabolic energy for maintenance of body temperature (Taylor & Lyman

Table 1 A comparison between the winter and summer growth rates of calf-yearling and yearling-subadult eland at Coleford Nature Reserve

	Winter growth ± 95% c.l. kg month⁻¹	Summer growth ± 95% c.l. kg month⁻¹	Significance of difference between winter and summer growth rates
Female calves-yearlings (n = 10)	1,22 ± 0,06 (n = 120)	9,46 ± 0,12 (n = 80)	P < 0,001
Male calves-yearlings (n = 4)	-0,58 ± 0,07 (n = 40)	10,68 ± 0,09 (n = 28)	P < 0,001
Female yearlings-subadults (n = 2)	1,53 ± 0,06 (n = 20)	11,29 ± 0,11 (n = 14)	P < 0,001

1967). Since weaning at a time when poor quality forage or harsh environments are encountered may subject calves to nutritional stress, the weaning of spring-born calves in autumn may be another factor influencing the subsequent reductions in their growth rates during winter.

One adult male gained in live mass during summer leading up to the rutting peak in January (Jeffery 1979a). Both adult males declined in live mass from the end of January. These reductions may have been precipitated by the high level of sexual activity and declining plane of nutrition in January and February.
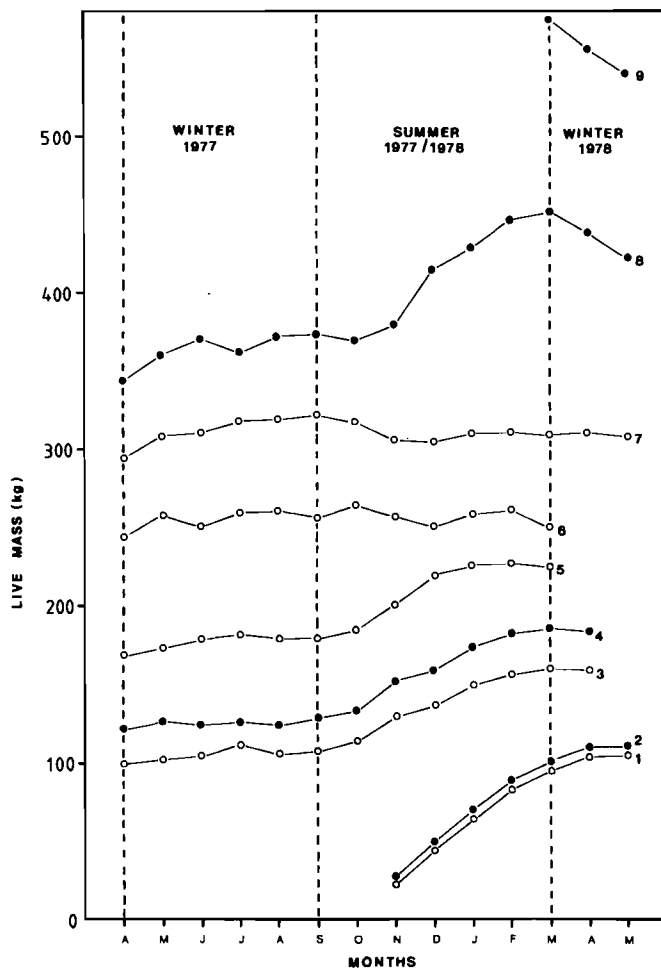
Figure 3 Seasonal growth of eland at Coleford Nature Reserve. Open circles denote mean monthly live mass values of females and closed circles mean monthly live mass values of males. The numbers refer to the following cohorts: 1: female calves ($n = 9$), 2: male calves ($n = 7$), 3: female calves-yearlings ($n = 10$), 4: male calves-yearlings ($n = 4$), 5: female yearlings-subadults ($n = 2$), 6: female subadults ($n = 3$), 7: female adults ($n = 10$), 8: male adult ($n = 1$), 9: male adult ($n = 1$).

Figure 4 Theoretical von Bertalanffy growth in girth curves for eland at Coleford Nature Reserve. Open circles denote mean values of girth at age of females and closed circles mean girth at age of males. Vertical lines denote one standard error either side of the mean. Dashed lines are girth values of 2,5% less than the computer-derived asymptotes. For females: $l_t = 166,45 (1 - e^{-0,047(t + 14,85)})$ cm. For males: $l_t = 229,52 (1 - e^{-0,036(t + 9,75)})$ cm.

In contrast to non-adults and adult males, adult females gained in live mass during winter as a result of pregnancies. The sudden decrease in live mass values in spring coincided with the calving peak and any subsequent increments of live mass were possibly limited by lactation. Gross seasonal changes in live mass of adult females were thus a manifestation of the breeding cycle which concealed the effect of variations in condition. This phenomenon requires further investigation.

Growth in body dimensions

The equations and theoretical von Bertalanffy growth curves describing growth in girth, height and length of the eland at Coleford are given in Figures 4, 5 and 6. Asymptotic girth of males (230 cm) was 27% higher than that of females (186 cm). Girth is not considered to be a purely skeletal measurement and is more closely related to growth in live mass than the skeletal measurements of height and length used in this study. The asymptotic height at withers of males (157 cm) was 13% higher than that of females (137 cm). The asymptotic length from withers to base of tail of males (115 cm) was 9% higher than the corresponding asymptote of females (105 cm).
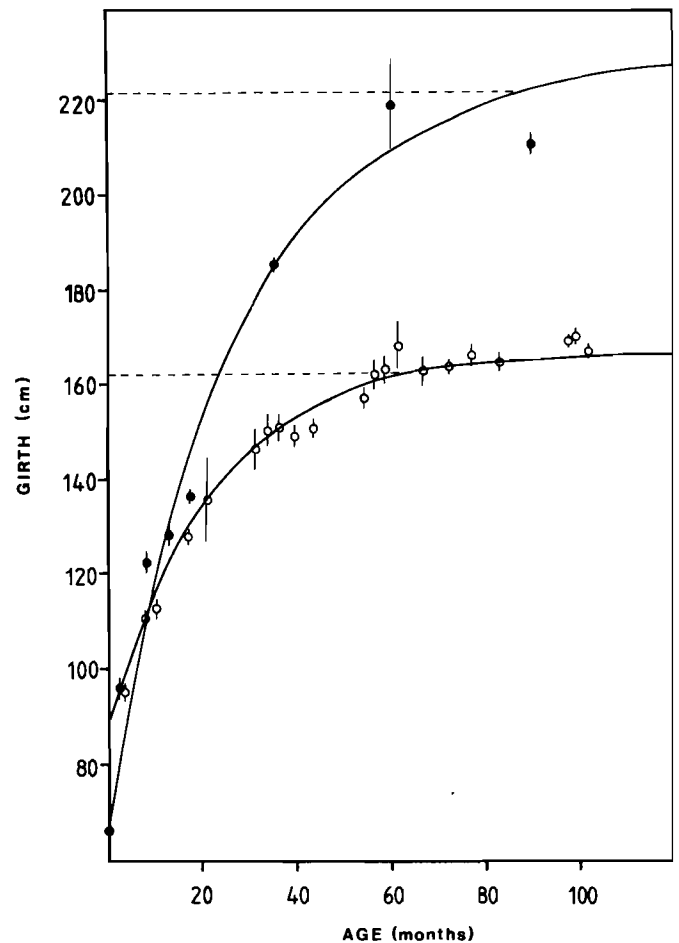
These results establish that male eland not only reach higher live mass values than females but also attain larger body dimensions. Further, corrected ages at which males reached their asymptotes of height and length (54 months and 57 months) indicate that they attained these skeletal asymptotes before females (at corresponding corrected ages of 69 months and 77 months). This shows that the increases in live mass of males between 4,5 and 8 years did not occur with any commensurate increases in skeletal size.

Relationships between growth parameters

The relationships of girth, height at withers and length from withers to base of tail with live mass were allometric (Table 2). Girth showed the highest correlations with live mass and the relationships for males and females were similar (Figures 7 and 8).

Linear relationships are more useful for predictive purposes and Howells & Hanks (1975) found that length × girth^2 had a high linear correlation with mass of impala *Aepyceros melampus*. Similar isometric relationships were found in this study between height at withers × girth^2 and live mass and between length from withers to
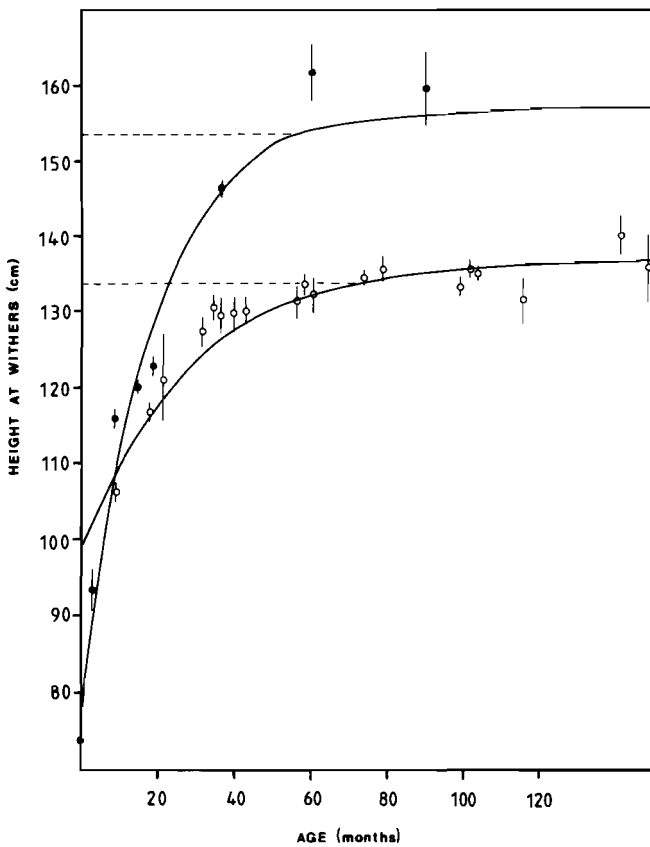
Figure 6 Theoretical von Bertalanffy growth in length from withers to base of tail curves for eland at Coleford Nature Reserve. Open circles denote mean values of length at age of females and closed circles mean length at age of males. Vertical lines denote one standard error either side of the mean. Dashed lines are length values of 2,5% less than the computer-derived asymptotes. For females: $l_t = 104,88 (1 - e^{-0,038(t + 20,15)})$ cm. For males: $l_t = 115,42 (1 - e^{-0,057(t + 8,07)})$ cm.

Figure 5 Theoretical von Bertalanffy growth in height at withers curves for eland at Coleford Nature Reserve. Open circles denote mean values of height at age of females and closed circles mean height at age of males. Vertical lines denote one standard error either side of the mean. Dashed lines are height values of 2,5% less than the computer-derived asymptotes. For females: $l_t = 136,85 (1 - e^{-0,035(t + 36,65)})$ cm. For males: $l_t = 157,39 (1 - e^{-0,056(t + 11,98)})$ cm.
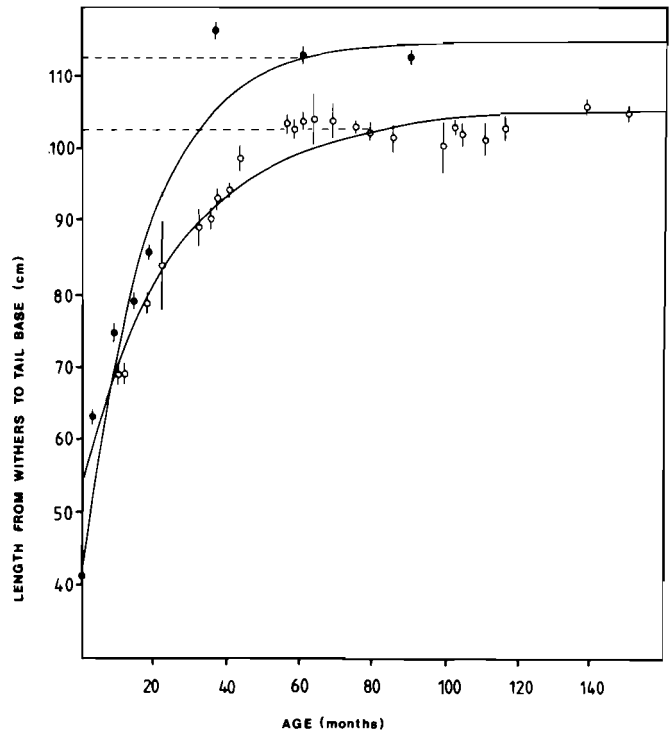
Table 2 Equations for the relationships between body dimensions and live mass of eland at Coleford Nature Reserve, where x = body dimension and y = live mass (kg)

Body dimensions	Females ($n = 63$)	Males ($n = 27$)
Girth (G) cm	$y = 0,0009x^{2,52}$ ($r = 0,992$)	$y = 0,0010x^{2,46}$ ($r = 0,992$)
Length (L) cm	$y = 0,0021x^{2,55}$ ($r = 0,974$)	$y = 0,0004x^{2,96}$ ($r = 0,989$)
Height (H) cm	$y = 2,959 \times 10^{-6}x^{3,75}$ ($r = 0,959$)	$y = 2,703 \times 10^{-6}x^{3,76}$ ($r = 0,988$)
LG^2 m^3	$y = 95,98x + 26,81$ ($r = 0,988$)	$y = 95,92x + 27,59$ ($r = 0,994$)
HG^2 m^3	$y = 79,35x + 4,70$ ($r = 0,987$)	$y = 70,61x + 19,27$ ($r = 0,991$)

base of tail × girth^2 and live mass (Table 2). The latter relationship has the marginally higher correlation coefficients for both sexes which have almost identical predictive equations (Figures 9 and 10).

Comparative performance in growth

In the absence of other statistical analyses of eland growth, it was necessary to use the original data recorded
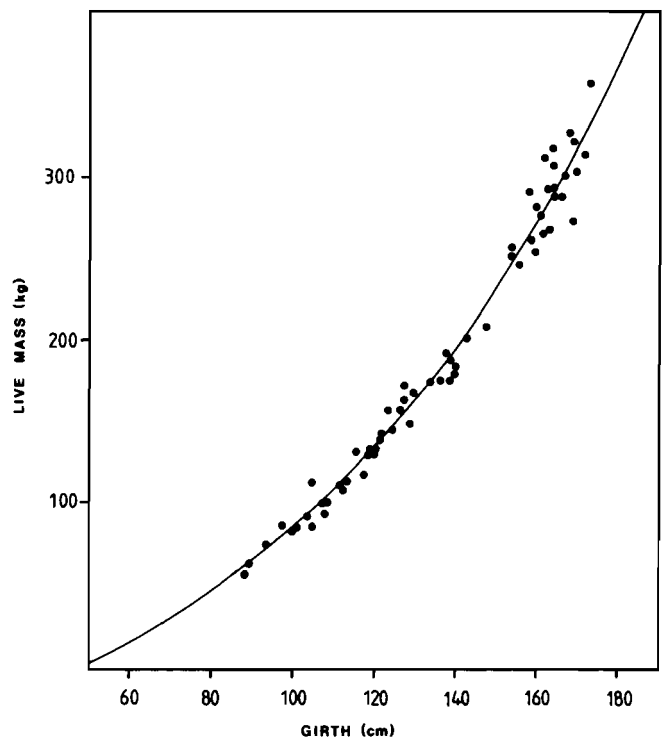

Figure 7 The relationship between girth and live mass of female eland at Coleford Nature Reserve. Solid line is fitted curve, and the equation is: $y = 0,0009x^{2,52}$ ($r = 0,991$).
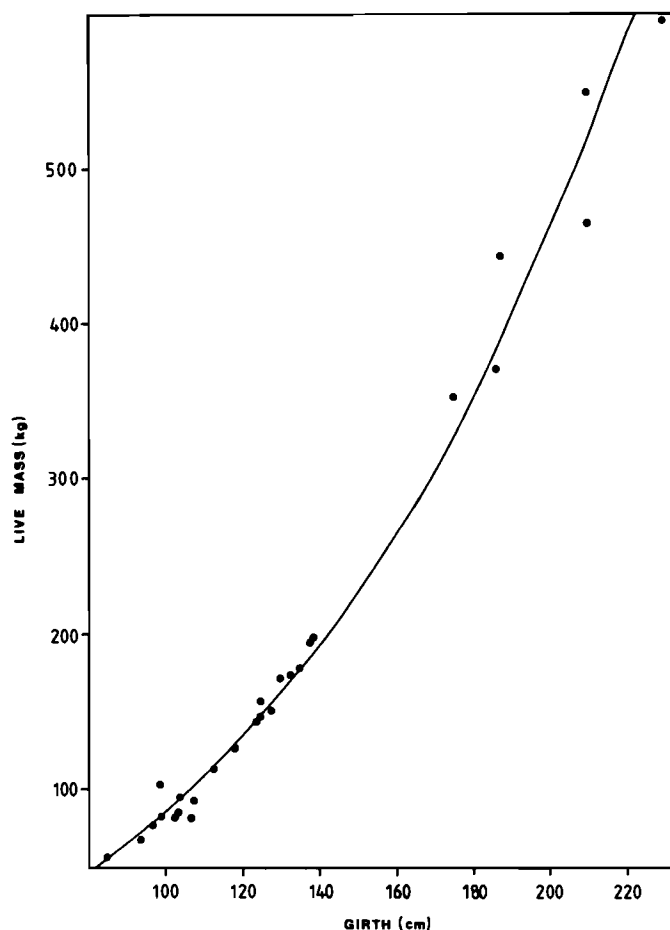
Figure 8 The relationship between girth and live mass of male eland at Coleford Nature Reserve. Solid line is fitted curve, and the equation is: $y = 0,0010x^{2,46}$ ($r = 0,992$).
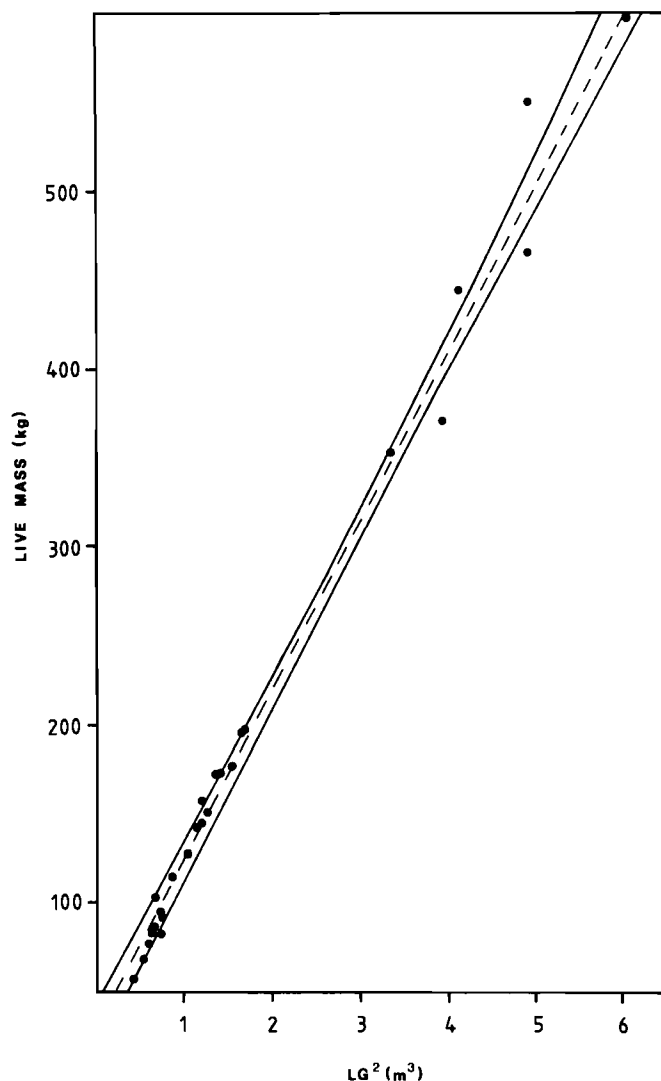

Figure 9 The relationship between length from withers to base of tail × girth^2 (LG)^2 and live mass of female eland at Coleford Nature Reserve. Dashed line is fitted and solid lines are 95% confidence limits, and the equation is: $y = 95,98x + 26,81$ ($r = 0,988$).

Figure 10 The relationship between length from withers to base of tail × girth^2 (LG)^2 and live mass of male eland at Coleford Nature Reserve. Dashed line is fitted and solid lines are 95% confidence limits, and the equation is: $y = 95,92x + 27,59$ ($r = 0,994$).
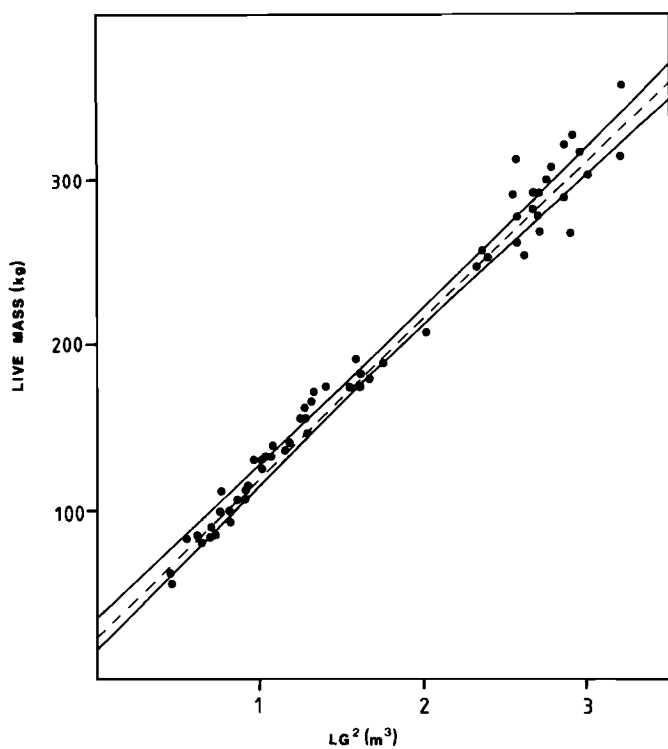
from captive Livingstone's eland *Taurotragus oryx livingstonei* from the Zimbabwe bushveld (Posselt 1963) for a comparison of growth. The combined results are summarized in Table 3 and show that growth of the captive Highveld population *T.o. oryx* was inferior to that of the captive bushveld population *T.o. livingstonei*.

Lewis (1974) suggested that the management of domesticated eland could limit their productivity and Hillman (1974) and Lightfoot & Posselt (1977) attributed the success of wild eland to their nomadic behaviour and low population densities. Thus the performances in growth of both captive populations may not be indicative of their genetic potentials. For this reason it is not known whether the differences between the growth of the two subspecies are phenotypic or genotypic.

It has been demonstrated in Russia that the growth performances of domesticated eland may be improved by selective breeding and supplementary feeding (Treus & Kravchenko 1968). However, Skinner (1972) concluded that eland cannot compete with cattle within the confines of traditional agriculture and suggested that the adaptions of eland to hot, semi-arid environments (Taylor &

Table 3 A comparison between growth in live mass of captive high-veld eland (*Taurotragus oryx oryx*) and captive bushveld eland (*Taurotragus oryx livingstonei*)

	T.o. oryx (this study)	*T.o. livingstonei* (Posselt 1963)	Significance of difference between populations
Live mass at birth (kg)			
males:	26,8 (*n* = 6)	36,3 (*n* = 3)	*P* < 0,01
females:	24,7 (*n* = 9)	28,6 (*n* = 4)	*P* > 0,01
Preweaning growth rate (kg month^{-1})			
males:	16,7 (*n* = 24)	26,9 (*n* = 10)	*P* < 0,001
females:	16,9 (*n* = 28)	19,9 (*n* = 12)	*P* > 0,05
Asymptotic live mass (kg)			
males:	575[a]	726 (*n* = 1)	(21%)[b]
females:	316[a]	405[a]	(22%)[b]
Corrected age at asymptote (months)			
males:	99	–	–
females:	73	59	(20%)[b]

[a]Theoretical von Bertalanffy asymptotes
[b]% difference for asymptotic live mass and corrected age at asymptote.

Lyman 1967) be best exploited in such marginal habitat for cattle.

The present study provides objective data on the growth of the common eland under specified conditions of management. The practical methods for the mass estimation of eland provided are suitable for the study of wild eland in the field.

Acknowledgements

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