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Liveweights, growth rates, and antler measurements of farmed red deer stags and their usefulness as predictors of performance

G. H. MOORE
R. P. LITTLEJOHN
G. M. COWIE
Invermay Agricultural Centre
Ministry of Agriculture and Fisheries
Private Bag, Mosgiel, New Zealand

Abstract Liveweights, growth rates, and velvet antler measurements were recorded for three cohorts of red deer (*Cervus elaphus* L.) stags ($n = 97$) from 3 months to 3 years of age and for one of these cohorts ($n = 36$) to 5 years of age to provide benchmark data. Regression relationships were investigated for liveweight and antler weight and between liveweight and antler weight, regressing measurements taken at older ages on younger ages. Variance in liveweights at 2-5 years of age was accounted for far more by 15-month liveweight than 3-month liveweight. Antler weight at 2 years of age accounted for more variance in antler weights at 3-5 years of age than any liveweight measurement. In the cohort recorded to 5 years of age, late summer liveweight increased linearly at 29 kg per year and antler weight increased linearly by 62 g for a 10 kg increase in late summer liveweight. Seven juvenile variables which are obtained by the age of 15 months were assessed for their ability to predict adult liveweight and velvet antler weight. These variables were liveweight at 3 months, liveweight when the pedicle was 2.5 cm, liveweight at 15 months, growth rate between 9 and 15 months, mean spike antler weight, and spike length. Liveweight at 15 months of age was found to be the best predictor of adult liveweight. Combining 15-month liveweight and spike antler weight provided the best juvenile predictor for later antler weight. Ranking of stags

Keywords red deer; *Cervus elaphus*; growth rate; liveweight; antler; velvet; performance predictors

INTRODUCTION

For efficient deer production it is important to know what liveweight, growth rate, and antler measurements are the most useful predictors of performance on which to select young stags for velvet antler production, venison production, or breeding. Also benchmark performance data are important for assessing herd improvement, management and potential yields of venison and antler by age for stags.

This paper aims to provide this information through a critical evaluation of performance data recorded for farmed red deer stags and to discuss its practical use for deer husbandry.

MATERIALS AND METHODS

Invermay Deer Farm

Over 400 red deer (*Cervus elaphus* L.), along with Wapiti and their hybrids, are run on Invermay's 74 ha deer farm which has been described by Moore et al. (1985). Liveweights and velvet antler weights of stags have been regularly recorded since 1975. Because red deer have been taken from the herd each year for other experimentation, the remainder of each cohort is not necessarily representative of the original group. Therefore the systematic statistical analysis for this study was carried out only on those cohorts born since 1974 where the mean weight of the removed male animals was not significantly different from that of the remaining subsequently at 3-weekly intervals during autumn. During winter (June - August) liveweights of the calves were recorded at 4 - 6-weekly intervals and then every 3 weeks in spring - summer. Adult stags were weighed after winter (early September) and in late summer (early February) before they became too aggressive to handle in large herds.

Medial pedicle height was recorded in young males at each weighing to estimate liveweight when pedicles were 2.5 cm high. Where pedicles were not c. 2.5 cm high at a weighing, liveweight for this measurement was interpolated, following Fennessy (1982).

Antler spikes were sawn off the yearling stags 2 cm above the pedicle once the antlers had cleaned. These were allowed to air-dry for several months before measurement. Spike length was measured along the outer side curve. Velvet antler was sawn off the older stags under local anaesthesia just above the coronet. Velvet antlers were removed when they had grown out above the trez tine and showed slight bulbing into the royal tines. At this stage the grooves between the developing royal tines were no deeper than 0.5 cm. A small proportion of antlers on 2-year-old stags did not bulb into royal tines and these were removed at a height similar to when bulbing was occurring in other 2-year-old stags. Velvet antlers were weighed to the nearest g and the circumference of the beam (a commercially desirable trait) was measured at the smallest diameter about half-way between the brow and trez tine.

Statistical analysis

Summary statistics were calculated for liveweight, growth rate, beam circumference, and antler weight for each available age of each cohort. Antler weight was calculated as the mean weight of left and right antlers, standardised to 55, 58, 61, and 64 days' growth at 2, 3, 4, and 5 years of age, respectively. Regression relationships were calculated for liveweights and antler measurements and between liveweights and antler weights, regressing measurements taken at older ages on younger ages. Differences in slope and intercept with cohort were assessed for measurements to 3 years of age and the 1978 cohort was analysed separately for measurements to 5 years of age.

The 1978 cohort from 2 to 5 years of age was analysed further by regressing liveweight on age and antler weight on liveweight for each stag (referred to as the individual fit, for which mean estimates are presented) and pooled over stags (referred to as the pooled fit).

Seven measurements which were obtained by the age of 15 months were assessed for their ability to predict later liveweights and antler weights. These were liveweight at 3 months (LWT3M), liveweight when the pedicle was 2.5 cm (LWTPED), liveweight at 15 months (LWT15M), growth rate between 9 and 15 months (GR9 - 15), mean spike weight (AWT1), and spike length (SPLN). The seventh (LWTSP) was obtained by adding LWT15M and AWT1 scaled by their standard deviations, to see if the combination of the two best velvet predictors improved their individual predictions:

$$\text{(1) LWTSP} = \text{LWT15M} + \text{AWT1} \times [\text{SD(LWT15M)}/\text{SD(AWT1)}]$$

where (from Table 1 and 2) SD(LWT15M) = 9, 8, 8, and SD(AWT1) = 0.068, 0.075, 0.056, for 1978, 1980, and 1982 data, respectively. A simple approximation is:

$$\text{LWTSP} = \text{LWT15M} + 130 \times \text{AWT1}.$$

The data were assessed in two groups; first, the 2- and 3-year-old measurements from all three cohorts and second, the 2- to 5-year-old measurements from the 1978 cohort. Cochran (1951) showed that the best criterion for selection was the linear regression of the adult variable on the juvenile variable, so for each adult variable and for each cohort, regressions on all of the juvenile variables were calculated and ranked by residual mean square. Liveweight and antler rankings were then ranked over age and then cohort. Correlation coefficients between all adult and juvenile variables were also calculated and meaned over age and cohort. These were found to be more useful in discriminating among predictors than any statistics derived from the regressions.

Statistical significance was assessed at the two-tailed 5% level.

RESULTS

Liveweight measurements

Table 1 shows liveweight and growth rate measurements for the three cohorts of stags. The calves at weaning (LWT3M) averaged 47 - 49 kg across years. During the 3 months post-weaning (GR3 - 6M), the 1978-born males had a low mean growth rate (18 g per day) compared to the other cohorts (119 and 161 g per day). Mean winter growth rates (GR6 - 9M) ranged from 60 to 102 g per day. Mean spring - summer growth rates (GR9 - 15M) ranged from 218 to 239 g per day resulting in a 15-month mean liveweight of 94 - 101 kg across the three cohorts. Stags gained a further 28 - 34 kg liveweight by 26 months of age, and 38 - 45 kg by 38 months of age. Although a few stags had small pedicles at weaning, mean pedicle size did not reach 2.5 cm until early spring when stags weighed 63 - 70 kg.

Table 1 Means (± standard errors) of liveweights (LWT), growth rates (GR), and estimated liveweight (LWTPED) and date (DATEPED) when pedicles were 2.5 cm high recorded in three cohorts of stags born in 1978, 1980, and 1982. Ages in months (M).

	Cohort (no. of stags)		
	1978 (36)	1980 (28)	1982 (33)
	Mean ± SE	Mean ± SE	Mean ± SE
LWT3M (kg)	49 ± 1.2	47 ± 0.8	49 ± 0.9
LWT6M	50 ± 1.2	57 ± 0.9	59 ± 0.9
LWT9M	62 ± 1.0	65 ± 1.1	66 ± 1.2
LWT15M	95 ± 1.5	94 ± 1.5	101 ± 1.4
LWT26M	123 ± 2.3	128 ± 2.8	131 ± 2.1
LWT38M	161 ± 3.2	173 ± 3.6	169 ± 3.3
LWT50M	183 ± 3.5	- -	- -
LWT62M	212 ± 3.3	- -	- -
GR3-6M (g per day)	18 ± 5.2	119 ± 6.8	161 ± 11.0
GR6-9M	102 ± 5.3	70 ± 4.3	60 ± 6.3
GR9-15M	239 ± 5.7	236 ± 5.1	218 ± 3.8
LWTPED (kg)	63 ± 0.5	66 ± 0.8	70 ± 0.9
DATEPED (days)	7 Oct ± 2.8	26 Sep ± 4.3	27 Sep ± 3.7

Table 2 Means (± standard errors) of antler measurements recorded at different ages in three cohorts of stags born in 1978, 1980, and 1982. Antler weight (AWT) for standardised growth period, circumference of antler beam (BEAM), and spike length (SPLN). Age in years.

		Cohort (no. of stags)		
		1978 (36)	1980 (28)	1982 (33)
	Days growth	Mean ± SE	Mean ± SE	Mean ± SE
AWT1 (kg)		0.144 ± 0.0113	0.172 ± 0.0142	0.161 ± 0.0097
AWT2 (kg)	55	0.505 ± 0.0158	0.555 ± 0.0248	0.477 ± 0.0139
AWT3	58	0.801 ± 0.0253	0.895 ± 0.0359	0.728 ± 0.0218
AWT4	61	0.964 ± 0.0260	- -	- -
AWT5	64	1.162 ± 0.0337	- -	- -
BEAM2 (cm)		- -	12.0 ± 0.21	11.7 ± 0.23
BEAM3		12.7 ± 0.17	13.0 ± 0.25	13.2 ± 0.19
BEAM4		13.6 ± 0.22	- -	- -
BEAM5		14.1 ± 0.23	- -	- -
SPLN (cm)		35.2 ± 1.45	37.8 ± 1.42	39.2 ± 1.76

Antler measurements

Table 2 shows the mean and standard error of antler weight and antler beam circumference over age and of spike length. Mean antler weight and beam circumference increased with age. The 1978-born cohort doubled antler weight from 2 to 5 years of age.

Liveweight relationships

Table 3 shows the regression slopes for later on earlier liveweights to 3 years of age, adjusted for variation in intercept among the three cohorts of stags. An additional 1 kg at 3 months of age corresponds to an increase in liveweight of 0.9 kg at 15 months, 1.1 kg at 26 months, and 1.4 kg at 38 months of age. Liveweight at 15 months was a better predictor of older liveweight than was 3-month liveweight.

Table 4 gives liveweight relationships for the 1978-born cohort. In this cohort there was a decline in the additional liveweight gain by heavier animals after 50 months of age.

Liveweight at 15 months accounted for considerably more of the variance in older liveweight than 3-month liveweight. Liveweight at 26 months accounted for about 7-15% more of the variance of later liveweight than 15-month liveweight.

Table 3 Regression slopes (standard errors) (upper triangle) for stag liveweights (LWT) to 38 months of age on liveweights at younger ages. R^2(adj)% values (lower triangle). Common slope over years.

Regression slope (SE) R^2(adj)%	LWT3M	LWT15M	LWT26M	LWT38M
LWT3M	-	0.883 (0.115)	1.130 (0.212)	1.434 (0.316)
LWT15M	44.1	-	1.462 (0.079)	1.909 (0.133)
LWT26M	25.3	79.1	-	1.246 (0.061)
LWT38M	21.2	71.1	83.0	-

Table 4 Regression slopes (standard errors) (upper triangle) for stag liveweights (LWT) to 62 months of age on liveweights at younger ages. R^2(adj)% (lower triangle). 1978-born cohort.

Regression slope (SE) R^2(adj)%	LWT3M	LWT15M	LWT26M	LWT38M	LWT50M	LWT62M
LWT3M	-	1.009 (0.121)	1.324 (0.241)	1.771 (0.343)	2.025 (0.344)	1.896 (0.329)
LWT15M	66.7	-	1.417 (0.116)	1.837 (0.189)	1.920 (0.253)	1.880 (0.185)
LWT26M	46.2	80.9	-	1.278 (0.082)	1.388 (0.129)	1.252 (0.100)
LWT38M	43.1	72.7	87.4	-	1.009 (0.090)	0.923 (0.071)
LWT50M	51.2	63.9	78.1	79.6	-	0.856 (0.070)
LWT62M	48.7	74.5	81.7	82.7	82.3	-

Antler and liveweight relationships

Table 5 gives the regression slopes with standard errors and adjusted R^2% for antler weights regressed on liveweights and earlier antler weights, correcting for and averaging differences in intercept between cohorts. Significantly positive slopes indicate that an increase in liveweight at 3 or 15 months corresponded to an increase in antler weight at all ages. Stags which were 10 kg heavier at 15 months produced 68 g more velvet antler at 2 years and 91 g more at 3 years of age. Stags with 100 g heavier spike antlers produced 67 g more velvet antler at 2 years and 78 g at 3 years. Liveweight was a poor predictor of spike antler weight (AWT1). Liveweight at 15 months was a moderate predictor of antler weight at 2 and 3 years of age. The slopes of antler weight at 2 and 3 years of age on end of winter liveweights (LWTW) were steeper than for the end of summer liveweights (LWTS) and more of the variability in antler weight at 3 years of age was accounted for by LWTW than LWTS. Spike antler weight (AWT1) was moderately good for predicting antler weight at 2 years and the latter was a far better predictor of

Table 5 Regression slopes (standard errors) and R^2(adj)% for antler weights to 3 years of age (AWT) on liveweights and antler weights at various ages. Common slope across years, antler weights in g, liveweights in kg.

Regression slope (SE) R^2(adj)%	AWT1	AWT2	AWT3
LWT3M	2.88 (1.12) 6.4	7.63 (1.65) 28.2	9.23 (2.53) 22.5
LWT15M	2.47 (0.77) 10.1	6.76 (1.08) 38.3	9.10 (1.61) 34.6
LWTW[a]	-	5.53 (1.07) 31.7	5.79 (1.15) 30.8
LWTS[a]	-	3.44 (0.69) 30.6	2.85 (0.78) 22.3
AWT1	-	0.674 (0.150) 27.6	0.775 (0.228) 21.7
AWT2	-	-	1.076 (0.099) 62.3

[a] End of winter (LWTW) and late summer (LWTS) liveweights for season antler grown.

Table 6 Regression slopes (standard errors) and R^2(adj)%, for antler weight to 5 years of age (AWT) on liveweights and antler weights at various ages. 1978-born cohort, antler weights in g, liveweights in kg.

Regression slope (SE) R^2(adj)%	AWT1	AWT2	AWT3	AWT4	AWT5
LWT3M	3.60	5.95	9.46	5.91	4.64
	(1.37)	(2.02)	(3.21)	(3.49)	(4.71)
	14.8	18.4	18.5	5.2	0.0
LWT15M	2.85	4.82	9.60	6.73	6.79
	(1.10)	(1.60)	(2.36)	(2.72)	(3.64)
	14.0	18.8	30.7	12.8	6.6
LWTW[a]	-	5.22	6.37	4.71	4.94
		(1.58)	(1.65)	(1.90)	(2.33)
	-	22.1	28.5	12.8	9.1
LWTS[a]	-	2.16	3.12	1.82	2.60
		(1.08)	(1.23)	(1.29)	(1.70)
	-	7.9	13.3	3.0	3.7
AWT1	-	0.930	0.998	0.909	0.951
		(0.200)	(0.372)	(0.390)	(0.519)
	-	37.0	15.0	11.2	6.3
AWT2	-	-	1.231	1.155	1.481
			(0.176)	(0.200)	(0.261)
	-	-	57.9	48.0	47.1
AWT3	-	-	-	0.812	0.960
				(0.107)	(0.157)
	-	-	-	61.6	51.0
AWT4	-	-	-	-	1.040
					(0.132)
	-	-	-	-	63.6

[a] End of winter (LWTW) and late summer (LWTS) liveweights for season antler grown.

Table 7 Parameter estimates (with standard errors) for linear regressions of late summer liveweight (LWTS) on age and of antler weight (AWT) on LWTS. Individual fits meaned and pooled fit, 1978-born cohort from 2 to 5 years of age. Age in years, liveweight in kg, antler weight in g.

	Intercept	Slope	R^2(adj)%
LWTS-age			
Individual fit	63.2 (2.56)	29.2 (0.49)	96.6
Pooled fit	63.0 (5.32)	29.3 (1.39)	76.3
AWT-LWTS			
Individual fit	−394 (43)	7.36 (0.31)	95.5
Pooled fit	−207 (66)	6.24 (0.38)	66.5

3-year antler weight than any liveweight measurement.

Table 6 corresponds to Table 5 for the cohort born in 1978 through to 5 years of age. Where comparable, these relationships did not differ significantly from the grouped relationships. The steepest slope for antler weight on liveweight was at 3 years. There was a relative decline in additional velvet production by higher producing animals at 4 years of age, comparable to that which was noted for liveweight. Antler weight at 2 years accounted for more of the variance in later antler weights than any liveweight measurement. Liveweight at 15 months was a poor predictor of antler weight after 3 years of age as were LWTW and LWTS. Antler weight at 2 years was a good predictor of antler weight through to 5 years.

Longitudinal analysis of late summer liveweights and antler weights

Table 7 presents the mean individual and pooled parameter estimates for the regressions of liveweight on age and of antler weight on liveweight for the 1978 cohort from ages 2 to 5 years. Liveweight increased linearly at 29 kg per year. Mean antler weight increased linearly by 62 g for a 10 kg increase in liveweight (Fig. 1), with corresponding individual increases varying between 47 and 114 g and averaging 74 g. There was no evidence of non-linearity in this relationship.

Predictor variables

The performance of the seven juvenile variables as indices for selecting adult liveweight and antler weight is given in Table 8 for 2- and 3-year-old data for the three cohorts and in Table 9 for 2 - 5-year-old data from the 1978 cohort. In both instances, results derived from the regressions were generally consistent with those derived from correlation coefficients, and were consistent over age. There

Table 8 Ranks from regressions and correlations of juvenile predictor variables with adult liveweights, and velvet antler weights, averaged over cohorts and ages.

	Predictor variables						
	LWT3M	LWT15M	GR9-15	LWTPED	AWT1	SPLN	LWTSP
Ranks from regressions							
Liveweight	5	1	3	4	6	7	2
Antler weight	4	2	5	7	3	6	1
Correlations							
Liveweight	0.398	0.858	0.628	0.520	0.298	0.172	0.714
Antler weight	0.386	0.534	0.349	0.209	0.388	0.293	0.571

Table 9 Ranks from regressions and correlations of juvenile predictor variables with adult liveweights, and mean velvet antler weights, 1978 cohort.

	Predictor variables						
	LWT3M	LWT15M	GR9-15	LWTPED	AWT1	SPLN	LWTSP
Ranks from regressions							
Liveweight	2	1	3	4	6	7	5
Antler weight	4	2	7	6	3	5	1
Correlations							
Liveweight	0.720	0.841	0.701	0.672	0.132	0.146	0.595
Antler weight	0.337	0.430	0.228	0.239	0.416	0.367	0.512

was some variation between cohorts, which is apparent from comparing Tables 8 and 9.

The best predictor for adult liveweight was LWT15M, followed by LWTSP over cohorts, and by LWT3M for the 1978 cohort. LWTSP was best for predicting antler weight, with mean correlation of 0.571 over cohorts, compared to 0.534 for LWT15M, which was next best. If these criteria had been used to cull each cohort by 50%, LWTSP would have resulted in an overall mean improvement in antler weight of 9.0% and in liveweight of 6.0%, compared to 6.9% and 7.8%, respectively, for LWT15M.

Antler measurements (AWT1, SPLN) were much poorer predictors of liveweight than liveweight measurements were of antler weight. Of the predictors evaluated at 15 months of age, LWT15M was always better than GR9-15, LWTSP was always better than AWT1, and SPLN was always poor. LWT3M was a satisfactory predictor of liveweight, except for the 1982-born cohort.

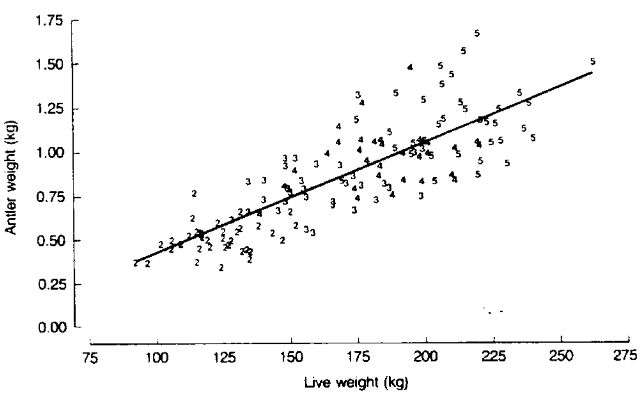

Fig. 1 Data from the 1978-born cohort coded by age in years and regression of antler weight on liveweight for pooled data.

DISCUSSION

The liveweight, growth rate, and velvet antler yield data presented provide a benchmark for performance under good farming conditions. As the groups used for analysis are representative of their cohort at weaning, variability of characters is a fair measure of what occurs before culling. The means are likely to be lower and the variability higher than those for commercial deer where young stags are heavily culled.

The analysis of liveweight changes shows 44% of the variance in 15-month liveweight was accounted for by 3-month liveweight. Hence, ranking weaner males on 3-month liveweight could be used to select young stags which will be heavier at 15 months of age. Older liveweight was more strongly related to 15-month liveweight than 3-month liveweight, with 79% of the variance in 26-month liveweight accounted for by 15-month liveweight compared to 25% by 3-month liveweight. More variation occurred in individual gain between 3 and 15 months than from 15 to 26 months of age.

The decline in the additional liveweight gained by heavier stags after 50 months of age (Table 4) suggests they mature earlier than lighter stags. The finding that liveweights from 2 to 5 years of age increased linearly at 29 kg per year (Table 7) is surprising. Both these results are based on only one cohort and to establish their generality, further research is required on more cohorts of stags to older ages.

Antler weight at 2 and 3 years of age is positively related to both liveweight at 15 months and liveweights for season of antler growth. However, as antler weight at 2 years in the present study accounts for more of the variance in later antler weight than any liveweight this should be used in selecting 2-year-old stags for velvet antler production.

The relationship between antler weight and body weight in red deer has been examined by Huxley (1931) who showed that there was a logarithmic relationship between antler weight and body weight. However, in our study there was no evidence of non-linearity in the relationship between velvet antler weight and liveweight but our data set is limited to stags aged up to 5 years. Schroder (1983), studying antler and body (carcass) weight allometry in 1700 German red deer, found that antlers continued to increase in weight after bodyweight had reached an asymptote at 7 - 8 years of age. Her analysis of the data revealed a two-phase antler-body weight growth pattern. Growth rate of antlers versus bodyweight was higher in mature stags ($\geqslant 5$ years of age) than young stags. If this occurs in farmed stags, then it has important implications for the efficiency of velvet antler production as returns would improve as mature stags became older.

In sika deer which are conspecific with red deer, Zhou & Wu (1985) found a strong relationship between velvet antler yield and both age and liveweight. There was a positive relationship between antler weight and liveweight with regression coefficients of 11.4 and 26.4 g/kg for two- and three-branch antlers respectively. Three-branch sika antlers are more similar to the three- or four-branch velvet antlers of red deer analysed (Table 5) with regression coefficients of 5.5 and 5.8 g/kg in relation to end of winter weights and 3.4 and 2.9 g/kg to late summer weights of 2- and 3-year-old red deer stags respectively. Zhou & Wu (1979) reported that the heritability of velvet antler weight (in sika deer) was 0.35 with a repeatability of 0.79. Thus it is likely that improvements in velvet antler production from farmed red deer stags can be achieved by selecting sires on velvet production corrected for age and liveweight.

In the farming of red deer, stags are either slaughtered at 1 - 2 years of age for venison or kept to older ages for production of antler in velvet. Conventionally, the earliest predictor adopted for culling stags on potential for velvet antler production has been velvet antler production at 2 years of age. Our study supports the use of this predictor. With greater culling of stags as yearlings, an earlier predictor for potential velvet antler production is desirable. The finding that combining 15-month liveweight and spike antler weight (Equation 1) is the best juvenile predictor for total velvet antler production, could be used for selection/culling of stags at 15 months of age for velvet antler production.

Our results are derived from three cohorts of stags under common management. More research is required to establish the generality of the results, particularly for heavily selected herds.

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