The effect of prepubertal castration of red deer and wapiti-red deer crossbred stags on growth and carcass production.

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Abstract

This study investigated the effects of prepubertal castration of red deer and wapiti x red deer ("crossbred") stags on a yearling (< 12 months old) venison production system. From a pool of 140 red deer and 107 crossbred stags in March, 15 animals were allocated randomly to one of several groups for each genotype. Groups of each genotype were castrated surgically in April, May, June, July, August or September (4-9 months of age) and managed together with entire controls until 12 months of age. Live-weights were recorded fortnightly and scores for mud contamination on hides were recorded on five occasions. A total of 40 red deer and 39 crossbred stags, representing entire controls and stags castrated in April, June and August, underwent CT-Scanning in November (11 months of age) for carcass assessment. All animals in the trial were slaughtered in either mid November, early December or late January. Carcass weights and primal joint weights were recorded.

Entire stags exhibited a seasonal pattern of growth. However, crossbred stags suffered a notable growth check in June but exhibited greater live-weight gains in late spring to eventually surpass red deer for average live-weight. Castration in April and May was associated with higher daily live-weight gains within 2-4 weeks of castration, perhaps reflecting effects of chemical treatments for surgery. There were no significant differences in mean growth rates, within genotype, between entire and castrated groups, irrespective of date of castration, until October/November for red deer and November for crossbreds. By late November (11 months) the mean live-weights differed by 4-7 kg for red deer and 2-5 kg for crossbreds. The net effects of castration on the mean timing of attainment 93 kg live-weight was 14-23 days delay for red deer and 6-18 days delay for crossbreds for treatments between April and August, inclusive. September castration had a negligible effect for both genotypes. There were no significant effects of castration on carcass musculature, but a small effect on hind leg fatness. However, there were numerous significant breed effects on muscle distribution and fatness. Generally, crossbred stags showed an increase in the proportion of the carcass as hindquarter, but also a reduction in loin and overall fatness. There were no significant effects of castration on mean hide mud scores but there was a pronounced breed effect, with reduced mean scores for crossbreds. It was concluded that prepubertal castration resulted in relatively small effects on growth prior to puberty and it is possible to meet peak market supply dates with production systems that implement good nutrition and health management.

Keywords : red deer, *Cervus elaphus*, crossbreeding, castration, venison, carcass

1. Introduction

The New Zealand venison industry, based on pastoral farming of the European red deer (*Cervus elaphus* spp. *scoticus, hippelaphus*) and its crossbreds with North American wapiti (*C.e.* spp. *nelsoni*, *roosevelti*, *manitobensis*), supplies approximately 50% of the world's internationally traded product (Deer Industry New Zealand statistics 2007; I.Moffat *pers.comm*.). The industry has developed over the last 30 years from generalised feral game recovery through to the specialised production of young farm-reared animals to meet rigorous supply specifications for highly seasonal markets, mainly in Europe. Even the supply of farm-reared animals has shifted over the last 2 decades from 2-year-old to 1-year-old animals, recognising the need to maintain high venison quality standards and to capitalise on improved on-farm productivity for animal growth to reach earlier slaughter weights (approx 93 kg live-weight for a 50kg carcass). The peak venison schedule payout to producers is for the supply of 8-12 month old animals (principally stags) during the months of August – November, to enable supply of chilled venison into seasonal markets in Europe.

Castration has been practiced in livestock management systems for centuries as a means to control aggressive behaviours and alter favourably the quality attributes of meat from males (Field 1971; Seideman *et al* 1982). However, testicular androgens promote muscular development through increased nitrogen retention (Galbraith *et al* 1978; van Tienhoven 1983), and castration generally incurs a production penalty through reduced growth performance. The anabolic property of androgens, especially testosterone, influences the average daily live-weight gain of bulls to increase up to 19% compared with that of steers, with only a 3% higher average daily feed intake (Steen 1995). The differences in productivity between intact males and steers are mainly manifested after puberty in the entire cohort (Keane 1999).

While the inhibitory effects of prepubertal castration of male deer on pedicle and antler formation are well documented across a range of species (Goss, 1983), the effects on overall productivity, particularly carcass production, have not been extensively studied for cervids. Perhaps the most detailed investigations relate to farmed fallow deer (*Dama dama*), for which the main incentive for castration was to reduce aggressive behaviours prior to slaughter and extend the kill season beyond puberty (14-16 months of age) when such behaviours can lead to severe carcass damage (Asher 1986; Mulley 1989; Hogg *et al* 1990). As observed in other domesticated ruminants,

prepubertal castration of fallow deer reduced growth rate in an age-dependent manner. For example, Asher *et al* (1987) showed that the live-weight differential of bucks castrated at 5 months of age was 2%, 9%,11% and 18% less than entire bucks at 9, 12 , 22 and 35 months, respectively. However, Mulley (1989) and Hogg *et al* (1990) further demonstrated that while prepubertally castrated fallow bucks produced lighter carcasses than entires for given ages between 1 and 2 years, the proportional distribution of muscle differed between the sex classes. Castration favoured reduced muscling in the shoulder/neck region and increased muscling in the hind legs, relative to total carcass weight. The castrated bucks also tended to exhibit greater fatness at any given age, but were still regarded as "very lean" by 15 months of age. While it was argued that castration would penalize producers currently paid on total carcasses weight, a new payment system based on carcass conformation could compensate for lower carcass weights and provide an incentive for producers to supply castrated bucks at times of year when entire bucks are difficult to handle.

The effects of prepubertal castration on the growth and carcass yield of red deer stags have been shown to be similar to that of fallow deer (Blaxter *et al* 1974; Drew *et al* 1978; Tan and Fennessy 1981). Drew *et al* (1978) reported that at 16 and 27 months of age, prepubertally castrated red deer stags were 9% and 16% lighter, respectively, than entire stags. Similarly, Tan and Fennessy (1981) demonstrated that for prepubertally castrated stags slaughtered at 27 months of age, forequarter muscles were 7% lighter and hindquarter muscles were 7% heavier, than for entire stags. However, given that red deer venison supply systems have not been unduly disrupted by problems associated with entire male aggression, there has not been a strong incentive to consider castration as a behavioural management tool for this species. Consequently, the reduction in growth and carcass weight-for-age has been mooted as a strong disincentive to use prepubertal castration in red deer venison systems (Baxter *et al* 1974; Drew *et al* 1978). This recommendation was based on systems in which 90-120 kg stags were normally slaughtered between 15 and 27 months of age.

Current supply systems in NZ now reward producers supplying ≥93 kg stags between 8 and 12 months of age, when the effects of prepubertal castration on growth-for-age are likely to be less marked. As noted by Tan and Fennessy (1981), a valid evaluation of the effects of castration on red deer carcass production requires comparisons of animals slaughtered over a range of weights and ages (i.e. stages of the annual live-weight cycle). Furthermore, there has been no investigation of the effects of prepubertal castration on wapiti or wapiti-red deer crossbred stags.

The wallowing behaviour of red deer has recently been associated with issues of carcass contamination in DSP's. Mud-encrustion of hides has been identified as a major source of bacterial contamination during slaughter and processing. Such carcass contamination has been linked causally to clostridial 'blown-pack' spoilage of chilled venison product (Broda et.al., 2002). This has led to payment penalties to producers supplying dirty animals and, in severe cases in which animals presented for slaughter have been heavily coated in mud, rejection of the consignment for slaughter. Wallowing is a complex behavioural trait of red deer that is linked to their social environment, although it probably also confers various benefits such as thermoregulation and ectoparasite control (McDowell and Asher, 2006). A possible consequence of castration is an alteration in wallowing behaviour through changes in social behaviours; any reduction in pelage contamination would be seen as beneficial for venison production systems.

The present studied aimed to measure the effects of prepubertal castration of red deer and wapiti x red deer crossbred stags within a yearling (i.e. <14 months of age) venison production system. The objectives were to evaluate the effects of castration at various ages before puberty on:

(1) growth rate and time to attain 93 kg live weight (50 kg carcass weight),

(2) carcass yield and carcass primal joint yield,

(3) mud-caking of pelage (indicator of wallowing behaviour).

2. Materials and Methods

2.1. Animals and Management

The study was conducted on a commercial deer farm near Balclutha, Otago (46° 12' S, 169° 34" E), between March 2006 and January 2007, with young stags obtained from a breeding farm near Te Anau, Southland (45°30'S, 167°58'E). From a total pool of 140 red deer and 107 wapiti-red deer crossbred (i.e. 25-30% wapiti parentage) male weaners translocated to the finishing unit in March 2006 (i.e. 4 months of age), 15 animals were allocated randomly to each of seven groups for each genotype. Groups were checked for, and found to be, balanced for live-weight within genotype groupings (Table 1). Surplus animals were additionally allocated to Group 1 (red deer controls, N=47) and Group 2 (crossbred controls, N=17) without unbalancing the live-weight profile. During the course of the study, 24 individuals were eliminated from the data set due to clinical illness (ill thrift), death or misadventure. At an early stage of the study several animals showed clinical signs of foot abcess due

to *Fusobacterium necrophorum* (footrot), possibly exacerbated by recent transport from the breeding unit. Later in the trial, clinical cases of Johne's disease due to *Mycobacterum avium* subsp. *paratuberculosis* developed in 16 animals and they were euthanased. Overall, the losses were evenly distributed across the treatment groups and did not create any notable imbalances (Table 1).

While no data were available on animal birth dates, the crossbred weaners were estimated to be 2-3 weeks younger, on average, than the red deer weaners, due to the mating management system of the Te Anau breeding unit in the autumn of 2005. Crossbred weaners were sired by "chaser" crossbred bulls (50-60% wapiti parentage) over red deer hinds (i.e. the primary red deer sires were replaced with crossbred sire "chasers" after the primary mating period). In theory, the "chaser" sires inseminated those hinds failing to conceive to red deer stags at first oestrus and had returned to second oestrus 20-21 days later.

During the course of the study from March 2006, the stags were weighed fortnightly until slaughter in November-January (11-13 months of age). They received oral anthelmintic treatment prior to leaving the breeding unit, and subsequently received pour-on anthelmintic treatments monthly until August 2006 (8 months). Vaccination against yersiniosis and oral administration of copper oxide wire particles were done once when they arrived on the farm in March 2006.

This study was undertaken with the approval of the AgResearch Invermay Animal Ethics Committee, as required by New Zealand law under the Animal Welfare (Codes of Ethical Conduct) Act 1987.

2.2. Castration Technique

Castration was by surgical removal under general sedation and local anaesthesia. Animals were individually sedated by intravenous injection of 0.9 mg/kg xylazine, 0.06 mg/kg azaperone and 0.007 mg/kg fentanyl citrate (1.8 ml / 100 kg live-weight of Fentazin 5; Parnell Laboratories NZ Ltd, Auckland), to induce full recumbency. Local anaesthetic (10-15ml lignocaine hydrochloride 2%; Nopaine 2%, Phoenix Pharm Distributors Ltd, Auckland, NZ) was injected at the base of the scrotum. After 2-3 minutes from injection, the scrotum was incised, the testes exteriorized and, following clamping of the cords and vessels, the testes were pulled free. A subcutaneous injection of long-acting antibiotic solution (1ml/10 kg live-weight, Norocillin LA ; Norbrook NZ Ltd, Auckland, NZ) and an intramuscular injection of 0.5mg/kg meloxicam , a long-acting analgesic and anti-inflammatory, (2.5

ml/100 kg live-weight of Metacam 20; Boehringer Ingelheim NZ Ltd, Auckland) were delivered prior to reversal of general sedation by intravenous injection of 0.25 mg/kg yohimbine hydrochloride and 0.003 mg/kg naloxone hydrochloride (2.5 ml/100 kg live-weight of Contran H; Parnell Laboratories NZ Ltd, Auckland). Animals were held in a recovery pen for 1-3 hours prior to being returned to pasture with herd-mates.

2.3. Data Recording

On a fortnightly basis, the deer were yarded and individually weighed over electronic scales to the nearest 0.1 kg. The degree of mud-caking of pelage was performed on five occasions from July to November. Mud-caking was assessed by a 0-3 score of the relative amount of mud and "dags" (hanging masses of mud and hair) across the animal's pelage. Scores was 0 = clean, 1 = light mud caking (generally on the belly), 2 = moderate mud caking over body and some "dags", and 3 = generalized mud-encrusted dags over the entire body.

2.4. X-ray computed tomography (CT scan)

Body composition was measured in early November (11 months) using CT scanning (Jopson *et al* 1997) for 79 stags, representing 39 red deer and 40 crossbreds selected from groups 1 and 2 (n = 10+10), 3 and 4 (April castration, n = 10+10), 7 and 8 (June castration, n = 10+10), and 11 and 12 (August castration, n = 9+10). Scanned animals were selected on their 13 October live-weight to represent the weight range within each group up to 100 kg (absolute limit due to scanner aperture size). The deer were transported to the Invermay Agricultural Centre (45°51'S, 170°23'E) on the day prior to scanning on either; 7, 8, 14 or 15 November. They were fasted overnight prior to scanning and then individually anaesthetized with an intravenous injection of Fentazin 5 (1.8ml/100kg live-weight). They were then physically restrained on a purpose-built bed with the fore limbs strapped bent to the sides of the chest and hind limbs extended to allow the animal to pass through the scanner aperture. Cross-sectioned images were recorded on a Siemen Somatom AR.C X-ray CT scanner (Siemens Medical Systems, Erlangen, Germany) at 70 mm intervals along the length of the body, from distal to the proximal hind limb muscles through to the first cervical vertebra. Images were 450 mm in diameter and 5 mm in thickness. The image exposure time was three seconds, and the X-ray tube was set to 130 kV and 70 mA. Following scanning, anaesthesia was reversed with an intravenous

injection of Contran H (2.5 ml/100 kg live-weight) and the stags returned to their pens for a minimum of two hours before transporting back to the study site (Balclutha).

CT images were analysed using a semi-automated procedure. Images were transferred to a PC and the CT images rescaled to a 256 grey scale set to maximise the contrast between lean and fat tissue covering the range from -256 to +255 Hounsfield units. The non-carcass visceral components were manually traced and deleted, and then the area of muscle, fat and bone calculated in each image. Images were then divided into one of three primal cut regions, namely the hind-leg, loin and shoulder. The hind-leg was defined as all images caudal of the cranial tip of the ilium. The shoulder was defined as all images cranial of the caudal tip of the scapula. The loin region was all the remaining images, and represented the approximate region between thoracic vertebra 7 and lumbar vertebra 6.

All tissue not associated with each of the three primal cuts was deleted from the image. For the hind-leg, this required removal of the *Obliquus abdominis internus* and other abdominal muscles and any associated skin and fat. For the loin the truncation line was defined as the tangent to the outer edge of the *Longissimus dorsi* and perpendicular to outer edge of the carcass. The shoulder cut was defined as a square-cut shoulder so the brisket, ribs and neck were removed from the cut. The areas of muscle, fat and bone was measured from these process images.

Tissue areas from each scan were numerically integrated to estimate volume for that depot (Gundersen *et al.*, 1988). Volumes were then corrected for differences in tissue density to give an estimate of tissue weight based on the relationship between Hounsfield units and density (Fullerton, 1980).

2.5. Carcass Evaluation from Slaughter

All stags were slaughtered at a commercial deer slaughter premise (DSP) on either 17 November (n=49). 7 December (n=73) or 30 January (n=103). Animals were selected in batches as they attained a suitable slaughter weight of ≥93 kg. They were weighed and then transported to the DSP on the day prior to slaughter and held in fasted lairage overnight. Following slaughter, the carcasses were held in chilled storage (4°C) for a minimum of 24 hours prior to carcass dissection. Carcass weights (CW) were obtained immediately following slaughter/dressing (Hot CW, hereafter termed HCW) and immediately before carcass dissection (Cold CW, hereafter termed CCW).

Carcasses were broken down into primal joints, of which hind legs (including pelvic bone) and square-cut shoulders (x 2) were weighed on electronic scales to 0.01 kg. Loin muscles were also weighed but due to inconsistency in cutting technique between slaughter groups, these data were discarded.

2.6. Statistical Analyses

Live-weight at each sample, and growth rate between samples, was analysed by least squares, fitting breed, treatment and their interaction. Slaughter data were analysed using a similar model, with additional terms for kill day and its interaction with breed, with and without an adjustment for cold carcass weight. CT scan data were analysed by analysis of variance, fitting breed, treatment and their interaction, with a covariate adjustment for cold carcass weight. Dag score was analysed in the same way as live-weight.

3. Results

3.1. Growth performance

3.1.1. Controls

The relative growth performance of the two genotypes represented in the study differed in several respects (Figure 1). The crossbred stags, despite being 25-30% wapiti parentage, were lighter at the start of the study in March, probably as a result of their later birth dates. They also exhibited live-weight losses between May and July, while the red deer stags showed small incremental increases in weight over this period. This resulted in a significant mean live-weight difference of about 5 kg in June ($P<0.005$) which favoured the red deer. However, subsequent growth rates were greater for the crossbred animals, resulting in a 3 kg advantage to this genotype by the end of November ($P>0.005$). Both genotypes exhibited a seasonal pattern of live-weight change, with greatest daily live-weight change occurring in spring

3.1.2. Castration effects

The effects of castration were considered in relation to acute responses (i.e. within 4-6 weeks of surgery) and chronic responses (i.e. effects on growth performance up to 11-12 months of age). The acute responses to castration are presented in Figure 2. On all occasions when castration was

performed there were no indications of live-weight loss within 2-4 weeks of treatment. However, for castration treatments in April and May there was, paradoxically, significantly increased mean live-weight gains following castration relative to the controls ($P< 0.05$). For red deer stags castrated in April, this was observed as a mean live-weight gain of 165 g/day over the 4-week period following treatment compared with 68 (SED 26.7) g/day for the red deer controls over this same period. Similarly, for the May treatment the live-weight gains of red deer stags were 104 g/day vs. 69 (SED 30.2) g/day, respectively. For crossbred stags the treatment vs. control growth rate differences were 109 vs. 74 (SED 31.6) g/day and 30 vs. -48 (SED 35.8) g/day for April and May castration, respectively ($P< 0.05$). At all other treatment times there were no significant differences in mean growth rates between castrated and control groups. The reasons for the short-term growth advantage of stags castrated in April and May are unknown but may relate to the administration of a number of drugs at the time of surgery.

Mean live-weight profile between March and November are presented in Figure 3. For each of the genotypes, the growth characteristics of the control and castrated stags were similar until October. Thereafter, significant growth rate differences occurred, principally between control and castrated stags. For red deer, the mean daily live-weight gain through October/November was 188 g/day for the controls but the means ranged from 80 to 200 (median SED 33.7) g/day for the castration groups. For crossbred deer, the mean growth rates were 241 g/day for the controls but ranged from130 to 215 (median SED 38.8) g/day for the castration groups. Of the castration groups, the latest treatment in September was associated with the greatest live-weight gains through October/November for both genotypes. However, there were no other notable associations between time of castration and mean growth rate during this period.

Excluding the live-weight data for the September castration treatment group, which did not differ from control group ($P>0.05$), the net effect of castration treatments by November was a reduction in mean live-weight relative to controls of between 4-7 (median SED 2.1) kg for red deer and 2-5 (median SED 2.5) kg for crossbred deer. Interpolation of the date at which each animal in the trial attained a live-weight of 93 kg allowed an analysis of the additional time required for castrated stags to reach a target slaughter weight relative to controls (Table 2). For red deer stags, castration between April and August resulted in mean delays of 14 to 23 (median SED 8.3) days, but for crossbred stags

castrated over this period the mean delays were 6 to 18 (median SED 9.5) days. September castration had minimal effect on the date of slaughter weight attainment for both genotypes.

3.2. Carcass characteristics

Carcass parameters for entire controls and castrated stags are presented in Table 3 (CT Scan data of 79 stags in early-mid November) and Table 4 (slaughter data of all stags between late November and late January). For CT Scan data all carcass component weights were covariate adjusted to a standard carcass weight of 46.6 kg to allow for the wide variance in live-weight at the time of scanning. The only castration treatment effects observed relative to control were for fasted live-weight (1-2 kg lighter), dressing % (0.5-1.5 % less) and hind leg fat (0.15-0.02 kg heavier) ($P< 0.05$). By contrast, there were highly significant genotype effects for a range of fat, hind leg and loin parameters ($P< 0.01$). On average , red deer carcasses contained about 0.8 -1.0 % more fat per unit of lean tissue, and had 1.0 – 1.2 % lighter hind legs and 0.9 – 1.3 % heavier loins relative to total carcass weight than did crossbred deer carcasses. The overall mean dressing percent ranged from 54.8% to 56.7%, with no significant breed difference ($P> 0.05$).

Primal carcass data obtained from actual carcasses (Table 4) aligns well with that from CT Scan images (Table 3). The mean CCW dressing percentages ranged from 56.4% to 57.6%, with no treatment or breed effects ($P> 0.05$). There was a small (< 0.5 kg) but significant castration treatment effect on absolute CCW ($P< 0.05$) but no other such effects were observed for any other parameter. By contrast, as with CT Scan data there were significant genotype effects for carcass weight and primal hind leg weight. There was also a significant genotype effect on primal shoulder weight ($P< 0.05$) that had not been observed with CT Scan data but it should be noted that there were some notable differences in primal shoulder weight, and its ratio to carcass weight, between the two data sets. The CT Scan images appeared to provide an overestimate of actual primal shoulder weight.

For both CT Scan data and actual carcass data there were no significant genotype x treatment effects ($P>0.05$).

3.3. Pelage 'dag' scores

'Dag' scores were recorded in winter/early spring, between July and September (approximately 6-9 months of age). There were no significant effects of castration treatments on pelage 'muddiness'

(P>0.05). However, there was a highly significant effect of genotype (P<0.01; Figure 4), with red deer stags exhibiting greater mean ‘dag’ scores than the crossbred stags in the period from June to August.

4. Discussion

Testicular androgens exert anabolic effects on musculature, resulting in more rapid live-weight gains and larger muscling for males than for females and leading to pronounced sexual dimorphism in mature body size across a wide range of mammalian species. For cervids, this effect is initiated within the foetus such that birth weights are generally 5-10% heavier for males than females. However, the principle expression of such anabolic effects occurs well after birth and generally increases as the testes become more active in androgen secretion approaching puberty. The results of the present study, in which groups of stags were castrated at either 4, 5, 6, 7, 8 or 9 months of age (April-September, inclusive), demonstrated that the subsequent effects on growth rate were small (2-8% by November) across all groups. Interestingly, there were no apparent differences in daily live-weight gains between castrated and control stags over the period from April (autumn) to September (early spring). For crossbred stags, this was also the case during October (mid spring). Subsequent growth rates over October and November for red deer stags, and over November for crossbred stags were significantly greater for the entire controls, accounting for the entire magnitude of live-weight differential by late November. The September red deer castration group was a notable exception, with October and November growth rates comparable with the red deer controls. The observed differential in growth rate between castrated and entire crossbred stags, which occurred later in spring, resulted in relatively smaller live-weight differentials by November for this genotype (0-6%). These results indicate a delayed effect of September castration on growth retardation and a genotype effect in which the crossbreds appear to be later to show the anti-anabolic effects of castration. This later effect maybe indicative of the generally accepted concept that wapiti are a slower maturing genotype, although this has not been conclusively demonstrated for the male.

The overall result of prepubertal castration under the management system of the study farm was a delay in the mean date of attainment of a target slaughter weight (93 kg) of 2-3 weeks for red deer and 1-2 weeks for crossbreds. In effect, the ability to supply stags during peak market demand (August-November) with a prepubertal castration system is possible with management systems that optimises growth potential. In this respect, the study farm encountered a number of animal

performance issues that may have comprised optimal growth of all stags in the study. First of these were serious health issues related to early foot disease (*Fusiobacterium necrophorum* infection) and chronic infection with Johne's Disease (*Mycobacterium paratubericulosis*) leading to ill-thrift in a high proportion of animals. Secondly, the crossbred cohort was apparently disadvantaged by later birth dates and ill-thrift in early winter (possibly linked to parasitism). Despite these issues, the majority of animals in the study, including entires and castrates, attained target slaughter weight by late December (the final slaughter group was killed in late January due to lack of available slaughter space at the DSP earlier in the season). It should be noted in particular that if the apparent under-performance of the crossbred stags were to be addressed, the opportunities for utilising a prepubertal castration system with minimal penalty in terms of optimal supply dates is considerably greater than for red deer. A realistic target of 10% improvement in growth rates of the crossbred stags would realise an average date of attainment of slaughter weight by 4-6 weeks with very little difference between entires and castrates.

One consideration not investigated in the present study is the potential of holding castrated stags until 15-17 months of age to supply high quality venison animals during the period when entires enter their first rut. In theory, while entires will lose weight and body condition through rutting (as well as gaining some unpleasant behaviours and body odours), castrated stags would, at the very least, maintain body condition and not exhibit other sexual characteristics that may adversely affect venison quality. At present, the venison schedule does not favour supply of stags over the March-May period, and market commitments over this period are generally satisfied with cull females.

On the basis of previous studies on prepubertal castration of deer, it was anticipated that castration may alter the relative distribution of muscle mass within the carcass. In particular, castrate red deer and fallow deer aged between 17 and 27 months exhibit reduced relative muscle mass (i.e. as a percentage of total carcass weight) in the neck/shoulder region and increased relative muscle mass in the hindquarter region. Although absolute carcass weights-for-age have been shown to be reduced in these older castrated males, it has been argued that this may be partially offset by increased relative mass of the (high-value) primal regions (Mulley 1989; Hogg *et al.* 1990). In the present study, there were no significant effects of prepubertal castration on any musculature, and only a minor effect on increased fatness within the hind leg. This indicates that the previously described effects are instigated by the process of puberty, in which high levels of testosterone induce neck and

shoulder muscle hypertrophy. Although this effect is partly reversible in deer as they enter their sexually quiescent phase in the following spring (Field *et al.* 1985), there is clearly a permanent effect carried though.

The most notable feature of the carcass data (both CT Scan and actual slaughter data) was the observation of a significant genotype difference in musculature. This was not entirely unexpected but has not been previously quantified. The crossbred stags, with 20-30% Wapiti parentage, exhibited a higher proportion of hind leg to carcass weight and a lower proportion of loin (saddle) to carcass weight, and lower overall levels of carcass fatness. Such effects far outweighed any putative castration effects at 11-13 months of age. The data highlight a paucity of information on genotype or sire effects on carcass conformation, data that is potentially useful to exporters/processors as well as establishing benchmark phenotypes for genetic selection for improved carcass performance.

This study has also demonstrated that there was no effect of castration on “dag scores”. This indicates that the behaviours, such as wallowing, that lead to the formation of mud-encrusted “dags” and general pelage muddiness, are also not affected by castration within the first year of the animal’s life. However, there was clearly a marked breed effect, with crossbred stags exhibiting significantly lower “dag scores”. This is in general agreement with common knowledge that wapiti tend not to wallow as frequently and fervently as red deer. This is clearly a factor in favour of crossbred systems designed to supply slaughter animals in late winter/early spring when pelage contamination is most prevalent and can lead to venison contamination during carcass processing.

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Table 1: Allocation of stags to treatment groups (i.e. final sample sizes after losses).

Group	Genotype*	N	Treatment	Initial means (s.d.) live weight (4 months)
1	Red	47	Controls	58.1 (3.8)
2	Crossbred	17	Controls	55.8 (4.9)
3	Red	14	Castration : Apr	57.9 (2.7)
4	Crossbred	14	Castration : Apr	57.1 (5.3)
5	Red	13	Castration : May	58.0 (2.6)
6	Crossbred	14	Castration : May	54.5 (4.3)
7	Red	13	Castration : Jun	57.6 (2.7)
8	Crossbred	11	Castration : Jun	55.6 (4.8)
9	Red	13	Castration : Jul	57.5 (2.5)
10	Crossbred	13	Castration : Jul	57.0 (6.6)
11	Red	13	Castration : Aug	58.9 (3.3)
12	Crossbred	15	Castration : Aug	55.9 (3.9)
13	Red	14	Castration : Sept	59.6 (4.7)
14	Crossbred	14	Castration : Sept	55.5 (4.4)

* "Red": sired by red deer stags over red deer hinds.
"Crossbred: sired by crossbred stags (50-60% Wapiti parentage) over red deer hinds (i.e. 25-30% Wapiti parentage)

Table 2: Predictions from the regression model of the mean dates for individual stags within each group to attain a target slaughter weight of 93kg.

	Red deer				Wapiti x red deer			
	Day of year	Calendar date	Difference from genotype controls	SE	Day of year	Calendar date	Difference from genotype controls	SE
Controls	253.7	11 Sept	-	3.86	243.6	1 Sept	-	6.41
April castration	276.0	3 Oct	22.3	7.06	249.8	7 Sept	6.2	7.06
May castration	267.9	25 Sept	14.2	7.33	253.8	11 Sept	10.2	7.06
June castration	277.1	4 Oct	23.4	7.33	262.2	19 Sept	18.6	7.97
July castration	269.7	27 Sept	16.0	7.33	252.2	9 Sept	8.6	7.33
August castration	271.0	28 Sept	17.3	7.33	253.8	11 Sept	10.2	6.82
September castration	249.9	7 Sept	-3.8	7.06	248.9	6 Sept	5.3	7.06
Overall (by genotype)	264.2	21 Sept	-	2.38	250.5	8 Sept	-	2.78

Table 3: Mean total carcass weight and other carcass parameters covariate adjusted to a standard total carcass weight of 46.6 kg, calculated from CT-Scan images of entire (control) and castrated stags April, June & August groups only) of two genotypes.

	Red deer				Wapiti x red deer						
	Entire	Castrate			Entire	Castrate					
	Control	Apr	Jun	Aug	Control	Apr	Jun	Aug	SED	Genotype	Treatment
Total carcass weight (kg)	46.7	46.0	45.0	46.9	47.4	46.2	47.8	46.7	1.38	ns	ns
Fasted liveweight (kg)	83.5	84.8	82.9	82.8	85.2	85.0	82.3	83.6	0.94	ns	**
Dressing (%)	55.8	55.0	56.2	56.2	54.7	54.8	56.7	55.8	0.62	ns	**
Carcass bone to lean (%)	19.2	19.7	19.1	19.9	20.0	20.0	19.6	19.8	0.64	ns	ns
Carcass fat to lean (%)	4.0	4.8	4.5	4.9	3.9	4.2	4.1	3.9	0.32	***	ns
Primal bone to lean (%)	17.0	17.3	16.9	18.2	17.8	17.9	17.9	17.6	0.77	ns	ns
Primal fat to lean (%)	2.7	3.2	3.0	3.5	2.6	2.8	2.7	2.7	0.24	***	ns
Hind leg fat (kg)	0.44	0.57	0.49	0.59	0.44	0.47	0.46	0.46	0.046	**	*
Hind leg lean (kg)	15.60	15.65	15.63	15.67	16.15	15.97	15.98	16.20	0.293	**	ns
Hind leg bone (kg)	2.34	2.49	2.42	2.29	2.51	2.63	2.59	2.46	0.115	**	ns
Total hind leg (kg)	18.38	18.71	18.54	18.55	19.10	19.07	19.04	19.12	0.311	***	ns
Primal hind leg fat (kg)	0.38	0.47	0.41	0.50	0.36	0.39	0.39	0.39	0.038	**	*
Primal hind leg lean (kg)	15.25	15.19	15.28	15.21	15.66	15.54	15.58	15.77	0.240	***	ns
Primal hind leg bone (kg)	2.33	2.48	2.41	2.28	2.50	2.62	2.58	2.45	0.115	**	ns
Total primal hind leg (kg)	17.96	18.14	18.10	17.99	18.53	18.55	18.54	18.61	0.254	***	ns
Hind leg as % of carcass	39.5	40.2	39.8	39.8	41.0	41.0	40.8	41.0	0.66	***	ns
Primal hind leg as % of carcass	38.6	39.0	38.8	38.6	39.8	39.9	39.8	39.9	0.54	***	ns
Loin fat (kg)	0.38	0.44	0.42	0.41	0.34	0.35	0.40	0.32	0.041	**	ns
Loin lean (kg)	7.29	6.99	7.14	7.08	6.56	6.67	6.92	6.62	0.330	**	ns
Loin bone (kg)	1.47	1.52	1.49	1.49	1.38	1.38	1.41	1.38	0.081	**	ns
Total loin (kg)	9.13	8.95	9.04	8.98	8.29	8.40	8.73	8.33	0.408	**	ns
Primal loin fat (kg)	0.09	0.10	0.10	0.11	0.08	0.09	0.10	0.08	0.011	*	ns
Primal loin lean (kg)	3.97	3.81	3.91	3.82	3.47	3.63	3.78	3.64	0.189	*	ns
Primal loin bone (kg)	0.73	0.77	0.74	0.77	0.68	0.71	0.74	0.72	0.050	ns	ns
Total primal loin (kg)	4.79	4.68	4.76	4.70	4.23	4.43	4.62	4.44	0.226	**	ns
Loin as % of carcass	19.6	19.2	19.4	19.2	17.8	18.0	18.7	17.9	0.86	**	ns
Primal loin as % of carcass	10.3	10.0	10.2	10.1	9.1	9.5	9.9	9.6	0.47	**	ns
Shoulder fat (kg)	0.68	0.79	0.78	0.83	0.67	0.76	0.67	0.69	0.058	**	ns
Shoulder lean (kg)	14.97	14.76	14.94	14.59	14.93	14.87	14.77	14.86	0.289	ns	ns
Shoulder bone (kg)	3.42	3.36	3.29	3.63	3.60	3.49	3.37	3.59	0.169	ns	ns
Total shoulder (kg)	19.07	18.92	19.01	19.05	19.20	19.12	18.81	19.14	0.323	ns	ns
Primal shoulder fat (kg)	0.29	0.32	0.32	0.37	0.29	0.30	0.27	0.28	0.029	*	ns
Primal shoulder lean (kg)	8.71	8.68	8.74	8.62	8.57	8.63	8.69	8.68	0.185	ns	ns
Primal shoulder bone (kg)	1.65	1.53	1.57	1.95	1.72	1.63	1.67	1.73	0.128	ns	ns
Primal shoulder (kg)	10.64	10.53	10.62	10.94	10.58	10.56	10.63	10.70	0.166	ns	ns
Shoulder as % of carcass	41.0	40.6	40.8	40.9	41.2	41.1	40.5	41.1	0.69	ns	ns
Primal shoulder as % of carcass	22.9	22.6	22.8	23.5	22.7	22.7	22.8	23.0	0.35	ns	ns

ns = not significant; * P<0.05; ** P <0.01; *** P<0.001

Table 4: Mean carcass parameters obtained following slaughter of all individuals within the study between November and January (11-13 months of age).

	Red deer							Wapiti x red deer									
	Entire	Castrate						Entire	Castrate								
	Control	Apr	May	Jun	Jul	Aug	Sept	Control	Apr	May	Jun	Jul	Aug	Sept	SED	Genotyp	Treatment
Liveweight (kg)	99.6	97.1	98.4	97.1	97.5	98.0	98.1	101.8	101.7	98.9	99.4	101.3	99.7	99.5	1.69	*	ns
HCW[1] (kg)	57.1	55.6	57.0	55.2	56.4	57.0	56.7	58.5	58.6	57.0	57.4	58.7	57.6	57.7	1.02	**	ns
CCW[2] (kg)	56.6	55.0	56.4	54.7	55.8	56.7	56.3	57.7	57.8	56.5	56.9	58.0	57.0	57.2	1.02	*	**
HCW dressing %	57.3	57.3	57.9	56.9	57.8	58.2	57.8	57.5	57.6	57.6	57.6	58.0	57.8	58.0	0.49	ns	ns
Adj.[3] HCW dressing	**57.3**	**57.5**	**58.0**	**57.2**	**58.0**	**58.1**	**57.8**	**57.3**	**57.5**	**57.7**	**57.7**	**57.9**	**57.8**	**58.0**	**0.47**	**ns**	**ns**
CCW dressing %	56.8	56.7	57.4	56.4	57.3	57.5	57.2	56.9	57.2	57.2	57.2	57.6	57.3	57.5	0.49	ns	ns
Adj.[3] CCW dressing	**56.8**	**57.0**	**57.4**	**56.7**	**57.4**	**57.5**	**57.5**	**56.7**	**57.0**	**57.3**	**57.2**	**57.4**	**57.2**	**57.5**	**0.47**	**ns**	**ns**
Primal hind leg (kg)	21.7	21.2	21.6	21.2	21.6	22.0	21.6	22.5	22.5	22.0	22.4	22.6	22.3	22.4	0.41	***	ns
Adj.[3] primal hind leg (kg)	**21.8**	**21.8**	**21.7**	**22.0**	**21.9**	**22.0**	**21.8**	**22.1**	**22.1**	**22.1**	**22.3**	**22.1**	**22.2**	**22.3**	**0.16**	*******	**ns**
Primal hind leg as % of CWT	38.4	38.6	38.3	38.8	38.6	38.8	38.5	39.0	38.9	38.9	39.3	39.9	39.2	39.2	0.30	***	ns
Primal shoulder (kg)	15.0	14.6	15.0	14.6	14.9	15.0	15.0	15.4	15.5	15.2	15.0	15.3	15.1	15.2	0.31	***	ns
Adj.[3] primal shoulder (kg)	**15.0**	**15.0**	**15.1**	**15.1**	**15.1**	**15.0**	**15.1**	**15.2**	**15.3**	**15.2**	**14.9**	**15.0**	**15.0**	**15.1**	**0.18**	******	**ns**
Primal shoulder as % of CWT	26.5	26.6	26.7	26.6	26.7	26.5	25.7	26.7	26.9	26.9	26.3	26.4	26.5	26.6	0.31	**	ns

[1] Hot carcass weight; [2] Cold carcass weight; [3] Adjusted by co-variance to a standard CCW of 56.8kg
ns = not significant; * P<0.05; ** P <0.01; *** P<0.001

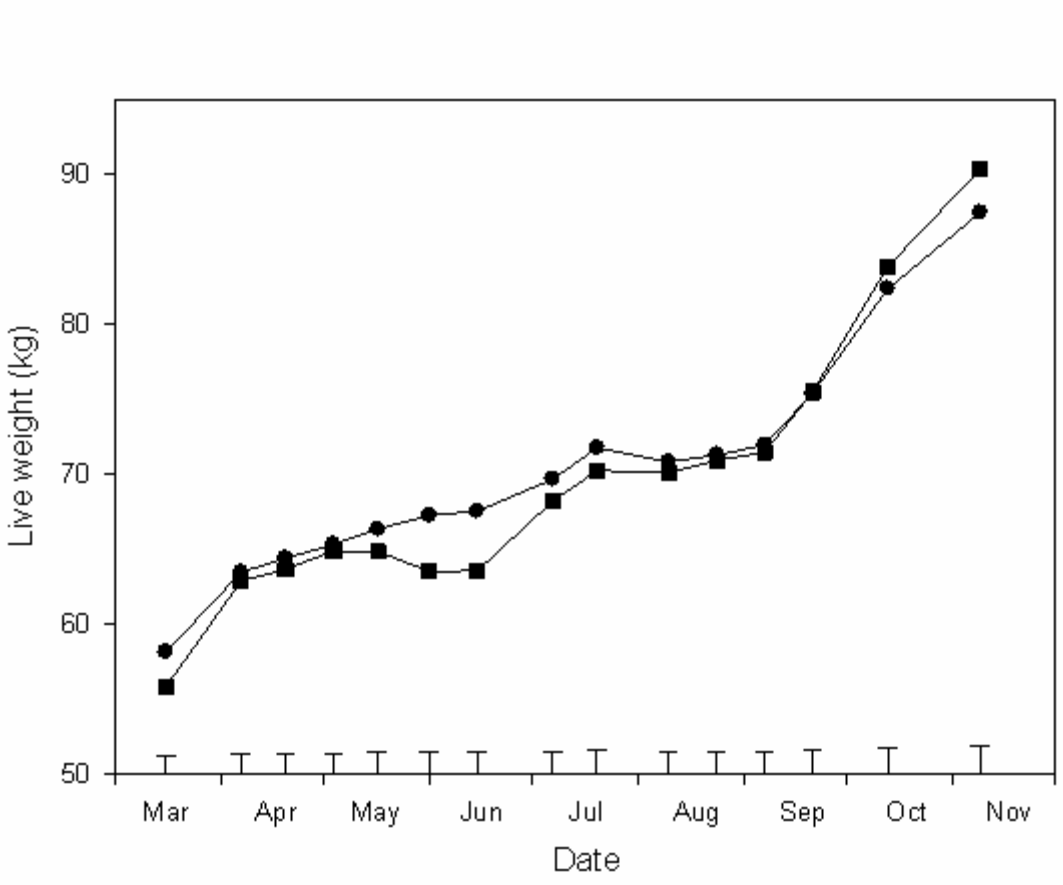

Figure 1: Profile of mean liveweights (with SED) of control red deer (●) and crossbred (■) stags from 4-12 months of age.

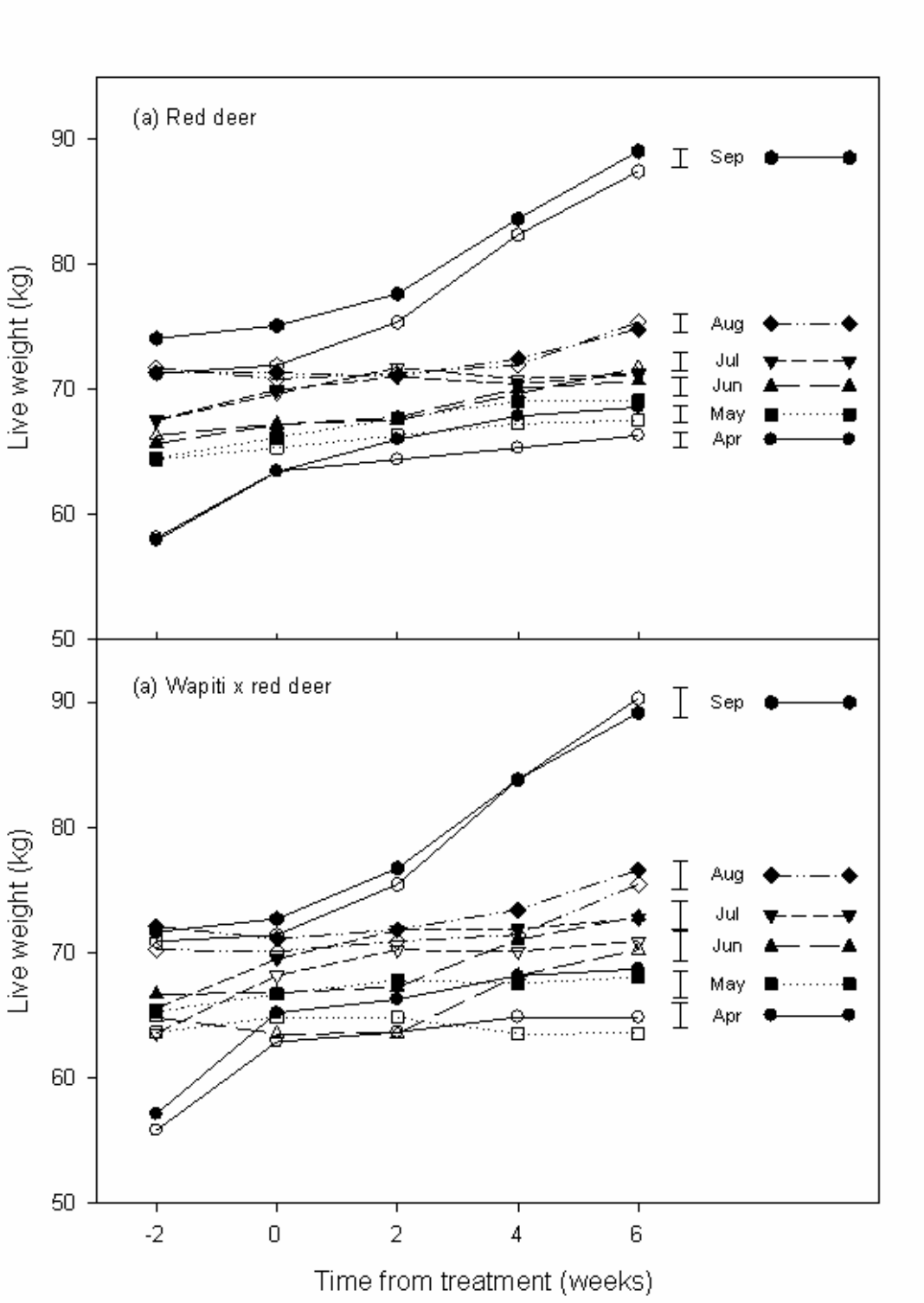

Figure 2: Mean liveweights of red deer (a) and crossbred (b) stags normalized around day of castration (-2 weeks to +6 weeks) relative to the controls stags (open symbols). (The median SED between each treatment group and the control group is shown).

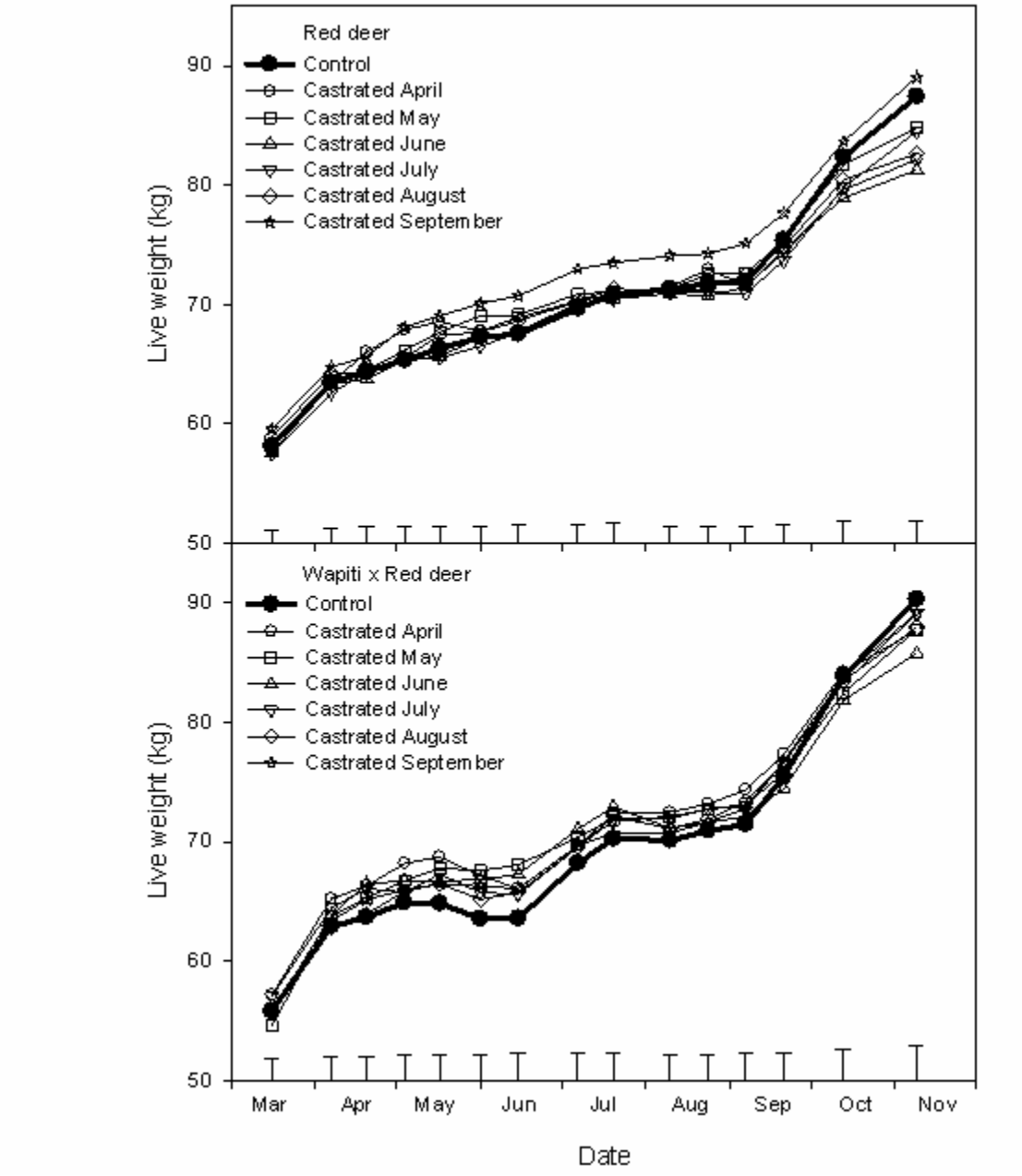

Figure 3: Profile of mean liveweights of red deer (a) and crossbred (b) stags between 4-12 months of age. The SED between any treatment and the controls is shown.

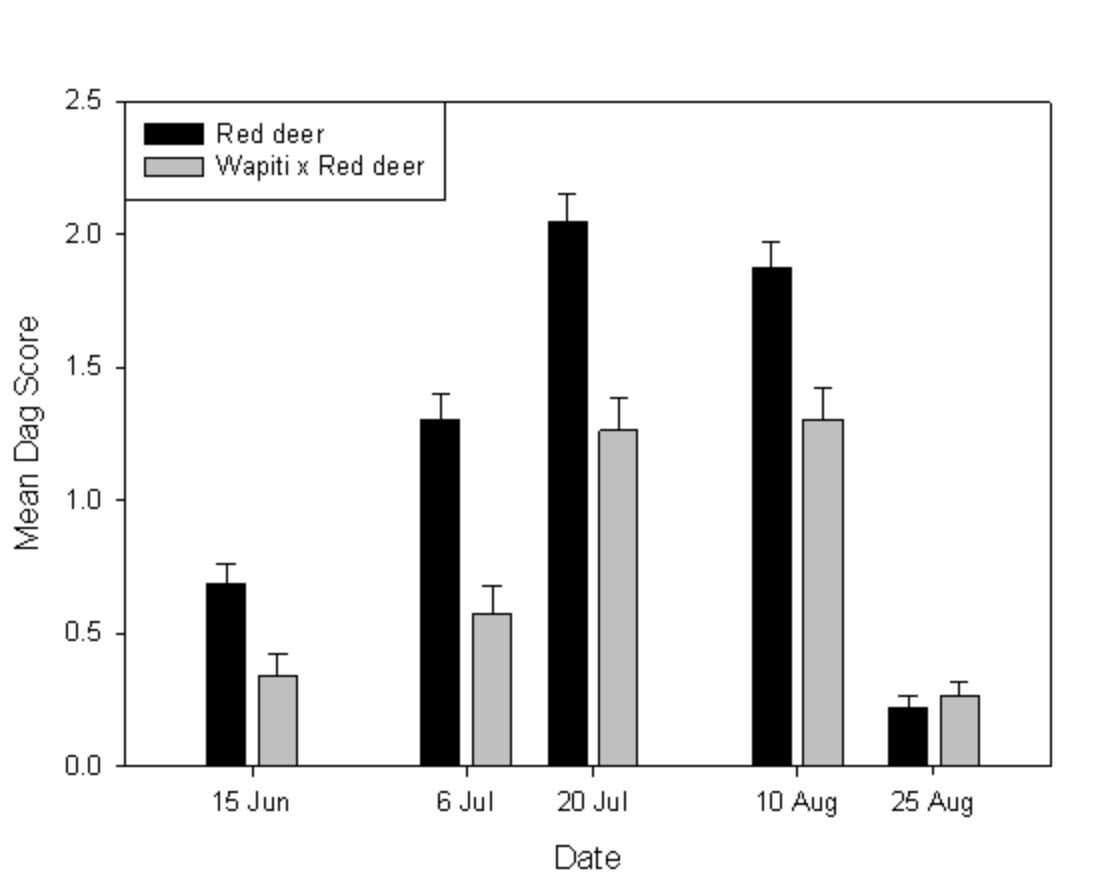

Figure 4: Mean (+SEM) "dag" scores for red deer and crossbred stags between June and August (late winter/early spring). All treatments have been combined.