Studies on the nutritional requirements of adult red deer hinds during late pregnancy

G.W. Asher, R.C. Mulley, K.T. O'Neill, I.C. Scott

Abstract

There are considerable differences of opinion among deer farmers on appropriate nutritional management of hinds during the last trimester of pregnancy, ranging from virtual *ad libitum* feeding to highly restricted feeding leading up to calving. Such approaches reflect differing perceptions of the nutritional needs of the hinds/foetus for maximum calf survival, with emphasis on reducing incidences of dystocia while ensuring optimum birth weights.

We have initiated investigation of the influence of feed intake of hinds during late pregnancy on foetal growth, calf birth weight and subsequent hind lactation. In an initial study conducted over two seasons, hinds (n=36) with synchronised conceptions were maintained in individual pens for 70 days from Days 150 - 220 of pregnancy During this time they were each placed on one of three pellet-based nutritional regimens, (1) *ad libitum* (High), (2) 30% less (Medium) and (3) 50% less (Low), with restricted diets calculated retrospectively from the mean intakes of the High group in the previous week. Hinds were returned to pasture ~ 2 weeks prior to predicted calving date and maintained at the same level of feeding for the ensuing lactation period At weekly intervals from Day 150 until 12 weeks post-calving, the hinds were weighed, body condition scored (BCS) and lactation scored (0-5) Also, all hinds in the first year were CT scanned at the start of indoor confinement and again 10 weeks later All calves were tagged, weighed and sexed within 12 h of birth

The mean daily intake of the High groups increased progressively from ~1 8 kg DM to ~ 2.8 kg DM by Day 220 although there was considerably greater variation between hinds in Year 2 of the study Mean BCS was significantly higher for Highs by Day 220 and remained so throughout lactation. Interestingly, while foetal CT scans in Year 1 indicated significant retardation of foetal development in the Medium and Low groups after 10 weeks of restricted feeding, there were no subsequent effects on mean calf birth weight or survival (no calf mortalities occurred). However, there were significant effects of treatment on gestation length that may have compensated for retarded foetal growth. There was a 29-day and 11-day spread in gestation lengths for Years 1 and 2 respectively, with Highs having significantly shorter gestations than hinds on restricted feed.

Such variation in gestation length was an unexpected consequence of nutritional management of late-pregnant hinds, and has considerable significance to reproductive management of red deer

Introduction

The reproductive efficiency of adult red deer hinds under NZ pastoral conditions is far from optimum Despite 25 years of intensive management regimens, approximately 15 percent of hinds each year still fail to produce or raise calves Numerous studies to date indicate that the main cause of reproductive wastage is calf mortality (Asher & Adam 1985, Moore *et al* 1985, Wilson & Audigé 1998, Walker *et al* 1999; Beatson *et al* 1999)

In particular, perinatal calf losses due to starvation (i.e. mismothering), dystocia (difficult birth process) and stillbirth (non-viability syndrome) together account for >50% of all calf deaths. Rather than focus just on the proximate causes of such loss, we wondered if there may be predisposing factors related to management of hinds during pregnancy, in particular, nutrition during the last third of pregnancy.

There are considerable differences of opinion among deer farmers on the appropriate nutritional management of hinds during the last trimester of pregnancy, ranging from *ad libitum* feeding to highly restricted feeding leading up to calving. Such approaches reflect differing perceptions of the nutritional needs of the hind/foetus for maximum calf survival, with emphasis on reducing incidences of dystocia while ensuring optimum birth weights.

In the present study, the relationship between daily feed intake during the third trimester and conceptus development/dam fatness was examined. In doing so, we tested the following two hypotheses:

(1) Under-nutrition retards foetal growth and reduces hind energy reserves, leading to reduced birth weights, retarded mammary development and slower calf growth rates.

(2) Over-nutrition leads to excessive foetal development and hind fat accretion that inhibits normal parturition processes, resulting in increased incidences of calf mortality.

Materials and Methods

A total of 36 mature (>5 years old) hinds were used across two consecutive years (1998 and 1999). They were selected from larger groups of hinds that were treated with intravaginal CIDR devices and run with pure red deer stags, within the breeding season, to synchronise conceptions within respective years. Rectal ultrasonography was performed 45 days from CIDR device removal to assess the presence of an appropriately sized foetus. Pregnant hinds selected for the trial were assumed to have conceived 48 h after CIDR device removal. The conception dates were 16 April for 1998 (year 1) and 28 March for 1999 (year 2).

Hinds were maintained at pasture until Day 130 of pregnancy. During the last three weeks at pasture they were offered increasing amounts of concentrate supplementation to facilitate acceptance of feed and ruminal adaption to diet change. On Day 130 the hinds were placed in individual pens on total concentrate ration, which was provided ad libitum for the first 3 weeks of confinement. Thereafter, until turnout on pasture 70 days later (Day 220), each hind received daily an allocated amount of a grain-based pelletised ration ("Invermay Formula", Harraway and Sons Ltd, Dunedin, NZ) containing 11 MJME/kg DM and 16% crude protein. In addition to pellets, 5% by weight of daily offer was chaffed lucerne hay to maintain an adequate intake of rumen roughage.

Each hind was allocated to one of 3 feeding levels (n=6 hinds per level per year). The "High" group remained on *ad libitum* offer throughout the trial. In year one, the "Medium" group were offered a daily ration estimated to be ~30% less than the *ad libitum* intake of the "High" group averaged over the previous week. Similarly, the "Low" group received ~50% of the daily feed intake of the "High" group. In effect, the "Medium" and "Low" groups received a stepwise increase in offer during the study to maintain approximate relativity with the "High" group (Figure 1). In year two, feeding levels of the "Medium" and "Low" groups were matched exactly with those of the previous year based on gestational age (i.e. given a 3-week disparity in conception dates between years).

At weekly intervals from one week before indoor penning until 12 weeks after calving at pasture, the hinds were yarded to record liveweight, body condition score (BCS) and lactation score (LS). BCS was based on a standardised 5-point ranking, whereby very low scores represent emaciation and very high scores represent obesity. For ethical reasons, contingencies were established to "rescue" hinds attaining a BCS of ≤1.5 by re-introducing an *ad libitum* offer (necessary on one occasion in year one). LS was based on a 5-point ranking of palpable mammary development (Asher *et al* 1994), representing the range from no palpable tissue (0) to full mammary and teat extension (5). Both BCS and LS were assessed by the same observer throughout the course of the study.

Once returned to pasture on Day 220 of gestation, the hinds were monitored closely at least twice daily until calving was complete. Calves were tagged within 12h of birth and data recorded included birth date, birth weight, sex and dam. Calves remained with their dams for 12 weeks, during which time they were weighed weekly. Contingencies for assessment of calf mortalities were established but were not needed as all calves survived.

In year one, body composition was measured in the live hinds using x-ray computed tomography (CT scan) on two occasions, once at the start of feed regimens (Day 150 of pregnancy) and again 60 days later Hinds were scanned using a Seimens Somatom ARC CT scanner following procedures described by Jopson *et al* (1997) Hinds were anaesthetised (0.02 ml kg^{-1} liveweight i v Fentazin; Parnell Laboratories, Auckland) and physically restrained on a purpose-built bed. Cross-sectional images were recorded at 70 mm intervals along the body Additional CT images were recorded through the uterus (35 mm intervals) CT images were analysed using a semi-automated procedure, with images transferred to a PC and rescaled to a 256 grey scale to maximise the contrast between lean and fat tissue Images were manually "dissected" into carcass, non-carcass (viscera), uterus and foetal components, and then the program "AutoCAT" (Jopson *et al* 1995) automatically segmented the various components into lean, fat and bone Tissue areas for each depot were numerically integrated to estimate tissue volume, which was then corrected in density between depots to estimate tissue weight

Data were analysed by ANOVA, fitting treatment, year and their interaction. This included data measured over time, for which selected intervals were defined in two ways for calculating summary statistics, such as growth rates or differences Firstly, during pregnancy data were synchronized between years relative to date of conception, and secondly, from a month before parturition data were synchronized between hinds relative to date of parturition

Results

The data from 4 hinds in year one were completely removed from the final analysis due to various ineligibility factors, including a death from MCF, a late-term abortion (probably due to anaesthetics delivered for CT scanning), hind rescue (low BCS) and one case of misdiagnosed conception date (detected at the first CT scan). The overall analysis involved the complete data set for 32 hinds and their calves (all surviving to 12 weeks of age)

The weekly means of daily dry matter (DM) intake for the three treatment groups in both years are presented in Figure 1 Hinds on *ad libitum* offer exhibited a progressive increase in daily DM intake from about 1.6 - 1 8 kg around Day 150 to 2 6 - 2 8 kg around Day 220 However, a change in feed batch around Day 195 in year two was associated with a transient depression in DM intake over a period of ~1 week There was no variance in mean daily intake of the "Medium" and "Low" group as no daily feed residues remained (they licked their troughs clean!)

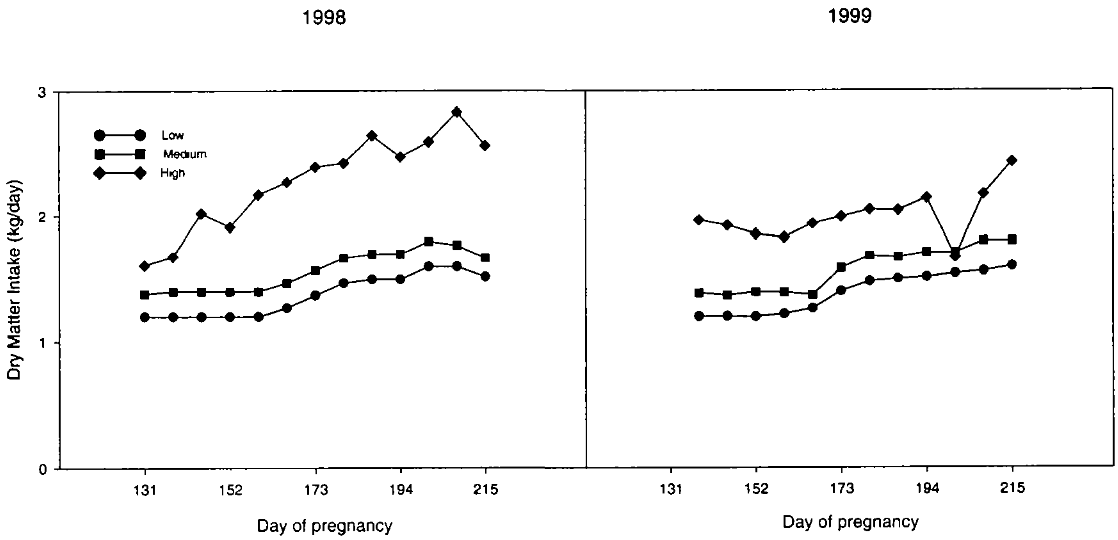

Figure 1: *Profiles of weekly means of daily dry matter (DM) intake of High, Medium and Low hinds in year one (1998) and year two (1999). (Profiles represent the indoor confinement period only.)*

Mean hind liveweights (Figure 2) increased during late pregnancy in all treatment groups Hinds in the "High" group attained higher mean liveweights immediately pre-calving (P<0.05), although this was more obvious in year one than year two. Post-calving mean liveweights were not significantly different between treatments (P>0 05) Mean BCS (Figure 3) showed marked differentiation towards the end of pregnancy, especially in year one (P<0.05). This persisted throughout the lactation period in year one but not in year two. Interestingly, mean BCS for the three treatment groups generally declined in parallel over lactation in year one, but merged and increased over lactation in year two, reflecting a large difference between years in climatic/pasture conditions over summer/autumn.

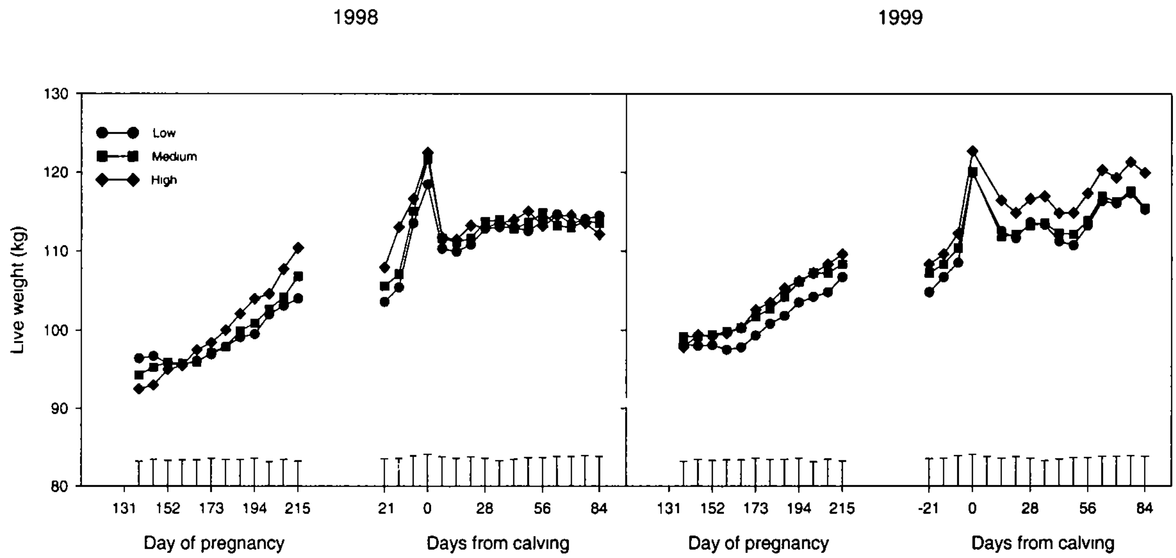

Figure 2: *Profiles of weekly means (and SED) of hind liveweight normalised around (1) Day of pregnancy and (2) Days from calving, for High, Medium and Low hinds in year one (1998) and year two (1999)*

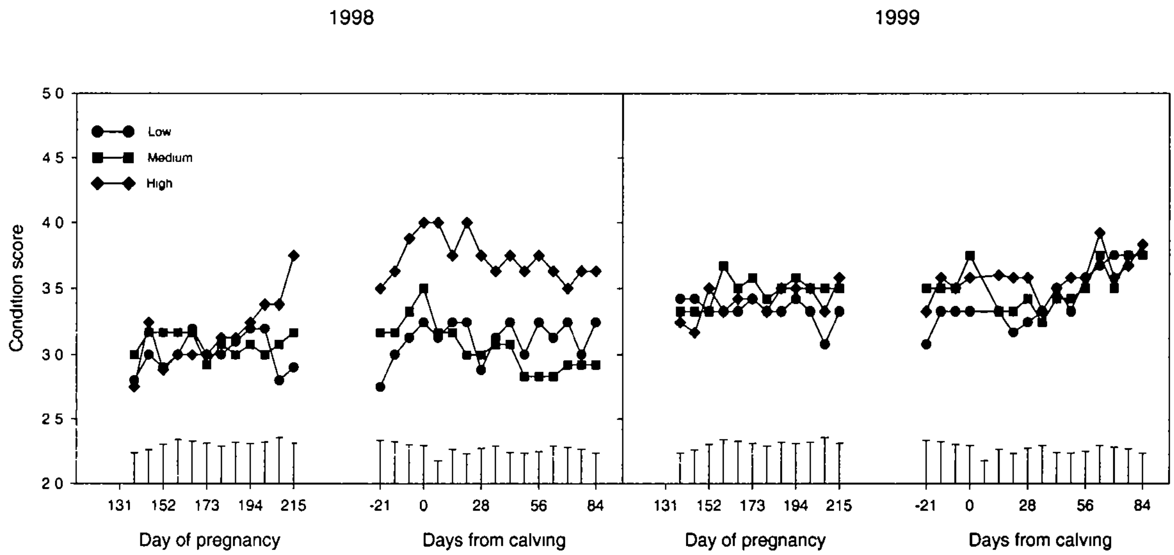

Figure 3: *Profiles of weekly means (and SED) of hind BCS of High, Medium and Low hinds in year one (1998) and year two (1999).*

Mean lactation scores (Figure 4) likewise differentiated between treatment groups towards the onset of calving (P<0.05). Again, this was more obvious in year one, with the "Low" group having a significantly lower mean score three weeks before actual calving date (i.e. 1.5 vs 2.6 for "Low" vs "High"). However, there were no detectable differences between treatment groups post-calving (>0.05)

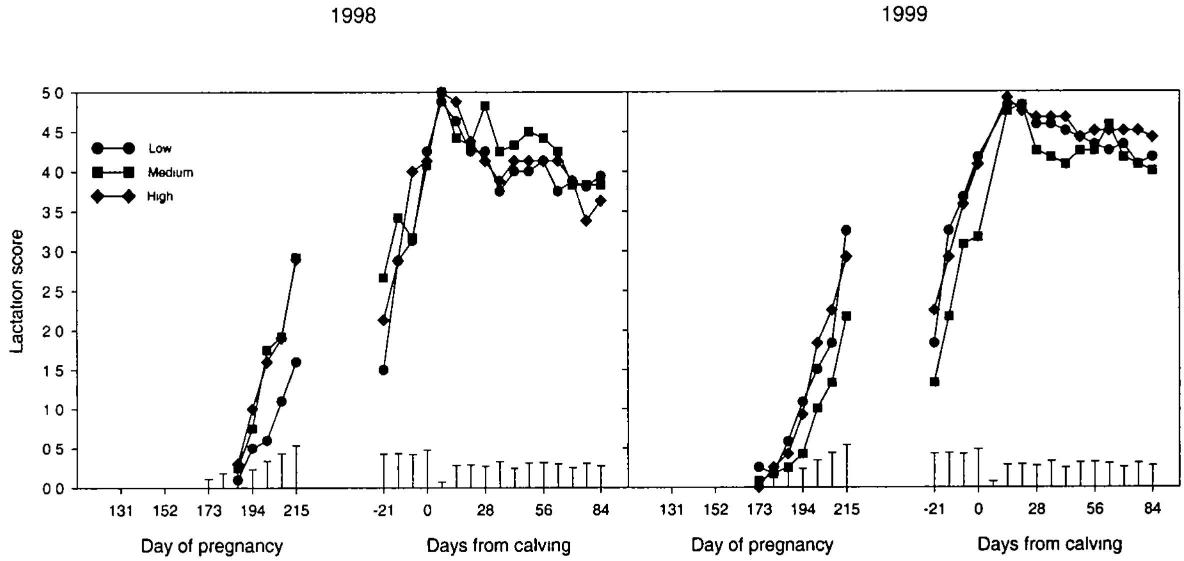

Figure 4 *Profiles of weekly means (and SED) of hind lactation scores of High, Medium and Low hinds in year one (1998) and year two (1999).*

CT scan measurements of year one hinds 10 weeks after the start of indoor feeding regimens indicate a significant effect of treatment on hind fatness (P<0.01) and total lean tissue (P<0.05) but not bone or gut components (P>0.1)

Table 1: **Adjusted means of CT scan measurements (kg) for hinds in year one (1998) 60 days after the start of composition of feed regimens (adjusted by covariance for initial scan data).**

	Low	Medium	High	SED	Significance
Total body fat	3.89	3.79	8.30	1.10	**
Total body lean	43.84	45.23	46.54	1.00	*
Total bone	7.50	7.64	7.07	0.32	ns
NFVC+	10.60	11.64	10.83	0.51	ns

+Non-fat visceral components (gut)
* p < 0.05, ** p < 0.01

All calves born in the study survived to weaning at 12 weeks of age. No calving difficulties were experienced. CT scan results of the conceptus (i.e. uterus + fluids + foetus) in year one showed a significant effect of treatment on foetal growth, with adjusted mean weights of the total conceptus and of the foetus exhibiting a linear trend across treatments (Table 2)

However, despite the difference in foetal growth in year 1, calf birth weights in both year one (Table 2)and year two (not shown) were not significantly different between treatments (P> 01)

Table 2: Adjusted means of pregnancy/foetus weights in year one (1998) at about Day 210 of pregnancy (adjusted by covariance for initial scan data and foetal sex) and sex-adjusted mean birth weights.

	Low	Medium	High	SED	Significance
Conceptus weight	13 49	14 14	14 55	1 2	*
Foetus weight	6 78	7 05	7.70	0.73	*
Birth weight	9 2	9 5	8 4	0.70	ns

* p < 0 05

Although all hinds within year groups conceived at the same time, calving dates in both years showed considerable variance, reflecting considerable variation in gestation length (Table 3). There was a statistically significant effect of treatment on gestation length in both years, with the "High" group exhibiting significantly shorter gestations than the "Low" Group.

Table 3: Mean gestation lengths (days) in year one (1998) and year two (1999) (adjusted for calf sex).

	Low	Medium	High	SED	Spread
Year one (1998)	239 3	234.7	231 1	2.10	28 days
Year two (1999)	236 1	237 0	233 8	2 10	11 days

While the means differed by 8 days in year one and 3 5 days in year two, the actual spread of calving dates was 28 and 11 days, respectively The difference between years was not significant (P>0 1).

Due to the spread in calving dates experienced in both years, calf liveweights on given dates varied greatly. However, adjustment to a common age (e.g 12 weeks) removed the differences between treatments within each year (Table 4) However, there was a highly significant year effect on calf liveweight and growth rate (P<0 05), with calves in year 2 being considerably heavier at 12 weeks than in year one

Table 4: Mean calf liveweights at 12 weeks of age in year one (1998) and year two (1999) (adjusted for calf sex).

	Low	Medium	High	SED**
Year one (1998)	37.0	39 1	36 9	2.54
Year two (1999)	48 0	46 0	44 1	2 54

** Significant year effect

Discussion

This study represents one of the first attempts to investigate the interaction between nutrition and reproduction using a reductionist approach (as opposed to multi-factoral holistic approaches) In this case, we have looked at the effect of level of nutrition during a specific phase of pregnancy on foetal/calf development The third trimester of pregnancy in red deer (i e Days 150 - 230 of gestation) represents a crucial phase in conceptus development, whereby >70% of conceptus mass accumulation occurs One could argue, therefore, it is the period when foetal growth is most likely to induce a significant metabolic drain on the hind or, conversely, when inclement extrinsic factors (e.g. nutritional stress) may perturb foetal development

Under NZ pastoral farming practices, late pregnancy in red deer hinds coincides with the spring pasture flush in many regions, a period normally associated with an abundance of high quality feed. This is perhaps at variance with the northern boreal environments in which this species has evolved a summer calving pattern. Thus we observe a potential maladaption to the NZ environment, whereby the potential for inappropriate nutrition of the pregnant hind exists. For a number of years, some NZ deer farmers have often argued that "over-feeding" of red deer hinds in late pregnancy leads to excessive hind fatness and/or over-development of the foetus that ultimately leads to high incidences of dystocia. To combat this perceived situation, highly restricted hind feeding practices have been commonly employed during spring/early summer in some regions of the country. Other farmers have argued that luxury nutrition to hinds during late pregnancy is beneficial to calving success by optimising birth weights (i.e. avoiding non-viability syndromes resulting from low birth weights) and promoting an optimum lactation response after parturition.

Thus, we observe a dichotomy in opinion and practice, the consequences of which still remain unresolved.

If there is one over-riding theme emerging from the present study, it is this: *pregnancy in red deer is very robust. There are strong intrinsic mechanisms to compensate for environmental extremes.* The case in point is that while the imposition of extremes in nutrition to hinds clearly impacted on foetal/conceptus development, birth weight (and survival) of calves was ultimately unaffected. However, gestation length varied enormously, with hinds on the low plane of nutrition exhibiting significantly longer pregnancies than those or the high plane of nutrition. Therefore, it appears that the ability to adjust gestation length is a mechanism for compensating for differing growth trajectories of the foetus and thus, maintain calf viability through control of birth weights.

Such putative compensatory mechanisms have not been demonstrated for sheep and cattle (if anything, some studies suggest that nutritionally deprived ewes may actually have shortened pregnancies; presumably to the detriment of lamb survival) (Wallace *et al.*, 1999, Robinson *et al.*, 1999). However, there are indications from the literature that some wild ungulate species (including some cervids) exhibit variable gestation lengths to compensate for seasonal vagaries in food supply during pregnancy (Racey, 1981).

The implications of such variability in gestation length on deer farming practice in NZ need to be considered further. The variability observed within a single group of hinds in the present study represents a range of nutritional conditions imposed within that group. In reality, hinds within a single group are unlikely to face such variation in extremes and, therefore, unlikely to exhibit such variation in gestation length. Nevertheless, some farmers may be compromising calving date within the herd by applying extreme nutritional management practices across the entire herd. Given that the current "push" within the industry is for early calving (i.e. October/November vs November/December) to better align pasture with lactational needs, the imposition of severe nutritional regimens during late pregnancy may negate earlier management aimed at establishing the earliest possible conception dates. Clearly, this is a new area of consideration when planning optimum calving seasons within a district.

Conversely, we cannot ignore the possible negative consequences of luxury nutrition to pregnant hinds. While all hinds in the present study calved with relative ease, and no incidences of dystocia were encountered (despite some animals having BCS of 4.5 - 5.0 around calving time), these hinds represent a highly select group of high performing animals that may not be representative of the wider population. The instigation of luxury feeding practices to further advance calving dates may well comprise the calving ability of many hinds.

In reality, most farmers do, and will, opt for a balance between these extremes. For example, rather than set strict intake levels for hinds in late pregnancy, a more appropriate approach may be to budget feed according to changing BCS or liveweight profiles of hinds.

The present study has also highlighted, in a less direct way, the importance of level of nutrition during lactation on hind BCS and calf growth. By chance alone, the study was conducted over two contrasting summers, one dry (1998) and one wet (1999). This contrast was reflected in the quality of feed the farm staff were able to supply to the lactating hinds In year one, poorer nutritional conditions over lactation resulted in lower calf growth rates and a progressive loss of hind BCS It could be further argued that the earlier differences in BCS induced by the artificial nutritional regimen in late pregnancy persisted through lactation, although this was not reflected in lactation score and calf growth. In year two, not only were calf growth rates considerably improved over year one, the hinds were also able to improve in BCS and the relativity between the poor treatment groups all but disappeared These considerations suggest that good nutritional conditions over summer may, to a certain extent, compensate for a "bad" start to calving brought about by sub-optimal nutrition during pregnancy However, summer conditions are highly unpredictable and certainly cannot be factored into management during the pregnancy period

While the present study investigated the interaction of nutrition and pregnancy in adult red deer hinds, a note of caution should be sounded when attempting to extrapolate the results to other groups of deer. For example, first calving hinds (rising two-year-olds) are still exhibiting a degree of somatic growth superimposed on foetal growth requirements. The relationship between nutrition and pregnancy may differ considerably in these animals Also, hinds carrying Wapiti hybrid foetuses may respond differently to nutrition These are both areas of ongoing research

References

Asher, G W , Veldhuizen, F A , Morrow, C J and Duganzich, D M (1994) Effects of exogenous melatonin on prolactin secretion, lactogenesis and reproductive seasonality of adult female red deer (*Cervus elaphus*) *Journal of Reproduction and Fertility* 100: 11-19

Asher, G W and Adam, J L (1985) Reproduction of farmed red and fallow deer in northern New Zealand *In: Biology of Deer Production, The Royal Society of New Zealand,* Bulletin 22. 217-224

Beatson, N S., Campbell, A.C., Judson, H G , Pfeiffer, D U and Wilson, P.R. (1999) Deer Master report to the NZ Deer Industry February 1999 *Proceedings of a Deer Course for Veterinarians, Deer Branch NZVA Course No 16* 91-108

Jopson, N B., Kolstad, K E S and Vangen, O (1995) Computed Tomography as an accurate and cost effective alternative to carcass dissection *Proceedings of the Australian Association of Animal Breeding and Genetics* 11 635 638

Jopson, N B , Thompson, J M and Fennessy, P F (1997) Tissue mobilisation rates in male fallow deer (*Dama dama*) as determined by Computed Tomography. the effects of natural and enforced food restriction. *Animal Science* 65 311-320

Moore, G H. (1985) Management-mating, calving, lactation, weaning *Proceedings of a Deer Course for Veterinarians, NZVA Deer Branch, Course No 2* 155-172

Racey, P A (1981) Environmental factors affecting gestation in mammals *In Cook, B and Gilmore, D P editors, Environmental factors in mammal reproduction* Macmillan, London 199-213.

Robinson, J J , Sinclair, K D and McEvoy, T G (1999) Nutritional effects on foetal growth. *Animal Science* 68 315-331

Walker, I , Fraser, R , Mason, A and Wilson, P (1999) Richmond Wrightson Deer Performance Project - Interim Reproduction Results *Proceedings of a Deer Course for Veterinarians, Deer Branch NZVA Course No 16* 85-90.

Wallace, J.M , Bourke, D A and Aitken, R P (1999) Nutrition and fetal growth paradoxical effects in the overnourished adolescent sheep *Journal of Reproduction and Fertility Supplement* 54 385-399

Wilson, P R and Audigé, L J-M (1998) Deer reproductive performance, risk factors, and management decisions *Proceedings of a Deer Course for Veterinarians, NZVA Deer Branch Course No 15* 13-30