An Evaluation of a Dairy Systems Study of the Effects of Contrasting Spring Grazing Managements on Pasture and Animal Performance

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Pastures and Crops Group
Institute of Natural Resources
College of Sciences
Massey University
Palmerston North
New Zealand

Gregory John Bishop-Hurley

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Abstract

Traditionally, the emphasis in dairying systems in New Zealand has been on maintaining pasture quality in late spring through increased grazing pressure and occasionally topping. Recent studies have reported an increase in summer and autumn herbage production by allowing some reproductive development during spring, followed by a period of hard grazing at the time of anthesis when seed heads are immature and still palatable (late control), through effects on tiller population and size. The objectives of this study were to (i) evaluate whether the benefits of late control can be measured within the management constraints of a self-contained spring calving dairy production system, (ii) investigate the conditions under which late control spring grazing management can be implemented, and (iii) investigate the options available for the use of additional feed over spring and summer assuming late control spring grazing management is effective.

A dairying systems study at No 4 Dairy Unit, Massey University was set up in which two 20-paddock perennial ryegrass/white clover dominant farmlets of 45 hectares were each stocked with 120 spring calving Friesian cows in October 1993 and run for three lactations until May 1996. With the exception of spring grazing management and spring supplement feeding the farmlets were balanced.

The first treatment, designated early control (EC), involved strict control of grazing throughout the spring and summer with average pasture cover targeted at approximately 2 000 kg DM ha^{-1} and a post-grazing residual of approximately 1 500 kg DM ha^{-1}. Pastures in the second treatment (late control - LC) were allowed to develop some reproductive growth through October and November for removal in December. Average pasture cover target was 2 700 kg DM ha^{-1}, with a post-grazing residual of approximately 2 000 kg DM ha^{-1} over spring. Average pasture cover was reduced to 2 000 kg DM ha^{-1} in December by grazing to lower residuals while at the same time removing paddocks from grazing for immediate conservation.

Bayesian smoothing provided an alternative to analysis of variance (ANOVA) for those variables where both treatments and/or all replicates were not measured at the same point in time, and for large data sets and produced mean values close to those that would be produced by conventional analysis methods without the need to group arbitrarily.

The development of a dynamic rising plate meter calibration equation which accounts for seasonal differences in pasture density allowed clearer definition of herbage mass estimates from rising plate meter measurements. Mass per unit height values showed a distinct seasonal pattern reflecting changes in the sward. The bulk density of pasture in the summer was found to be twice that in the winter.

Overall, there was no extended period of difference between early control and late control in either pasture production or animal production during the three years of the trial. However, large differences in animal performance would not be expected considering the marginal differences in pasture production achieved. While treatment differences in average pasture cover and pre- and post-grazing cover were achieved over late spring in all three years, the pasture cover differences required for the late control treatment were not achieved, and as a consequence the response in animal performance was smaller than the results of previous small-plot and paddock-scale experiments suggested.

The results of the trial showed good internal consistency between production components and good control of variability was achieved in this large systems trial, providing an objective basis for evaluation. A number of the variables (clover contents and tiller densities) measured during the trial suggest the potential for contrast in system performance between early control and late control. The ability of the system to buffer changes contributed to the difficulties in achieving treatment specifications. Systems research of this type needs to include tight specifications and control of pre- and post-grazing pasture cover in addition to average pasture cover. More flexibility in stocking rate or use of supplements may be needed to establish spring pasture cover contrasts in future studies.

A whole farm simulation model (UDDER) was used to investigate alternative management strategies for utilising grazed and conserved herbage, after modifications to achieve effective matching between predicted and measured levels of pasture production and animal performance. The level of milk production predicted by UDDER was not achieved in the field over three years using the same inputs, possibly due to the inability of the model to cope with the limitations of colder/wet winters and wetland dairy farming. The adjustments made to the parameters of UDDER were in general successful, allowing daily and annual milksolids production to be modelled. However, herbage intake was insensitive to higher spring pasture covers and resultant increase in allowance. For most of the year UDDER predicted the herbage intake of lactating cows to be at or near their potential.

Early control and late control base models were used to evaluate alternative management strategies for using the extra herbage accumulation generated under the late control management, including feeding conserved forage during summer to lactating cows or during winter to dry cows, stocking rate (2.6, 2.8 and 3.0 cows ha^{-1}) and the level of conservation (none versus increased).

The loss of quality associated with conservation meant that conserving and adding silage back into the system did not increase milksolids production or gross margin, particularly when UDDER predicted that no real feed shortage existed. However, in practice conserving herbage reduces the risk associated with poor growing years. The low stocking rate policy was the best for early control, although the stocking rate policy with 2.8 cows ha^{-1} and conserved supplements being fed back to lactating cows in summer was similar. The latter policy was the best for late control. At the high stocking rate the flexibility of the system was reduced. In general, milksolids production and gross margin were higher for late control than early control, provided the increase in herbage accumulation rate associated with lax spring grazing management (late control) was factored in.

Since a search of the literature failed to identify a model capable of predicting the response of pastures to late control spring grazing management, an attempt was made to develop a tiller-based model to allow the late control system to be investigated further. The model developed estimates equilibrium tiller density based on size or mass of ryegrass tillers at the environmental ceiling leaf area based on daily levels of photosynthetically active radiation. However, there was insufficient detailed sward data available to provide conclusive evidence for the validity of the tiller model.

Despite the lack of consistent treatment differences obtained from the trial and the difficulties experienced when modelling late control management altematives, this project has provided a comprehensive data set and considerable insight into the dairy production system. Late control spring grazing management can potentially increase the overall productivity of the seasonal dairying systems of New Zealand. In practical terms the main requirement is for a change in conservation management over the spring period, with no other direct costs involved. However, the timing limitations which are an inevitable consequence of rotational grazing systems restrict the opportunity to impose late control management with the rigorous timing that component research suggests may be necessary. During the course of this trial spring grazing management on dairy farms has tended towards that of late control management, with farmers operating grazing systems with higher average pasture covers through the spring with the aim of improving per hectare production through per cow performance.

Dedicated to my wife, Sharon Bishop-Hurley

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Chapter One

Introduction, Objectives and Thesis Outline

1.1 Introduction

New Zealand's favourable climate allows dairy cows to be grazed almost exclusively on pasture throughout the year, although seasonality and year to year variation of pasture production have to be reconciled so that utilisation of herbage and animal performance can be optimised. Brookes & Holmes (1988) showed the diets of cows on seasonal supply dairy farms comprised 85% grazed pasture, 10% purchased feeds (silage, hay and other) and 5% farm grown feeds, which included hay, silage and *in-situ* crops. The systems that have evolved attempt to maximise production (milksolids) from pasture by maximising pasture growth and the utilisation of high quality herbage. Planning an efficient plant/animal system requires a good knowledge of the dynamics of pasture production and its distribution throughout the year (Judd *et al.* 1990). Animal production systems based on grassland areas depend upon the quality and efficient harvesting of the pasture produced. The primary factors determining milk output are stocking rate, cow quality, calving date, body condition or liveweight at calving, and level of feeding in early lactation (Bryant 1980a).

Traditionally, spring grazing management has tried to maintain sward quality through intensive grazing and temporarily removing paddocks from the rotation for conservation. Summer and autumn pasture quality and tiller density are maintained by relatively hard grazing throughout spring accompanied by conservation as required (L'Huillier 1987b, 1987c, 1988; Hoogendoorn *et al.* 1992). Defoliation management influences the amount of feed grown and the efficiency with which it is utilised. Grassland management aims to achieve an effective balance between the efficiency of the three main stages of animal production: herbage growth, herbage consumption and animal productivity

(Hodgson 1990). Growth and utilisation of herbage interact with one another to influence the eventual output of animal products.

Some farmers in New Zealand are at a point where current levels of utilisation are high and they have limited capacity to increase production without increased inputs and therefore cost. One way to make progress is to manipulate grazing management in such a way as to improve seasonal and annual pasture production. Recent studies have reported an increase in summer and autumn herbage production by allowing some reproductive development, followed by a period of control at the time of anthesis when seed heads are immature and still palatable (late control), through effects on tiller population and size (Matthew *et al.* 1989b; da Silva *et al.* 1993, 1994; Hernández Garay 1995). A series of small-plot and paddock-scale trials supported the hypothesis, suggesting late control could be achieved through grazing management, and animal performance could be enhanced as a consequence of sward conditions which lead to higher clover and total pasture growth rates in summer (da Silva *et al.* 1993, 1994). However, it remained to be seen whether the additional herbage produced could be converted into increased animal output or alternative management advantages within the management constraints of a closed production system.

1.2 Objectives

Consequently, the objectives of this study were to:

- Evaluate whether the benefits of late control can be measured on a whole farm basis within the management constraints of a self-contained spring calving dairy production system;
- Investigate the conditions under which late control spring grazing management can be implemented;

- Investigate the options available for the use of additional feed over spring and summer assuming late control spring grazing management is effective in producing additional feed.

1.3 Organisation of the thesis

The thesis is presented in seven chapters. Chapter Two provides a summary of late control grazing management and an overview of systems and systems research. Late control grazing management is reviewed in Chapter Two as a precursor to the experimental chapters. A large scale grazing systems trial conducted over three years on No 4 Dairy Unit at Massey University is described in Chapter Three. The development and use of a dynamic rising plate meter calibration equation which accounts for seasonal variation of pastures is presented in Chapter Four. Results, discussion and conclusion sections from the large scale grazing systems trial described in Chapter Three are presented in Chapter Five.

The use of a simulation model (UDDER) used to further investigate the application and results of the spring grazing management trial is presented in Chapter Six. Results, discussion and conclusion sections for the simulation modelling exercise are also presented in Chapter Six. Finally, a general overview of the results of this study and their practical implications for dairy farming systems in New Zealand is presented in Chapter Seven. Relevant data, a submitted paper (Appendix One) and the development of a preliminary ryegrass tiller-based model (Appendix Seven) are presented in the Appendices.

Chapter Two

Literature Review

2.1 Introduction

Traditionally, New Zealand's economy has relied on the agricultural sector for its export dollar. Land-based activities account for over half of New Zealand's export revenue (Table 2-1). New Zealand claims to be one of the most efficient countries in the world at growing and converting pasture through the grazing animal into milk, meat, fibre and by-products for human use. Distance from markets has imposed high freight costs on New Zealand's producers necessitating the production of high quality produce at relatively low cost to compete successfully with other producing countries. Currently, approximately 5% of global milk production is traded internationally in the form of dairy products, of which New Zealand accounts for about 22%, second only to the European Union.

Many of the production systems developed in New Zealand are relatively environmentally friendly and sustainable. Dairy production is based on the conversion of pasture into milk by grazing cows with the strategic addition of relatively small quantities of conserved and *in-situ* forage. Historically, few concentrates have been fed and until recently fertiliser inputs were limited to annual applications of superphosphate. New Zealand's temperate climate means that pasture production is seasonal throughout most of the country, with large differences in the quantity and quality of pasture produced in winter, spring, summer and autumn. Finely-tuned grazing systems have resulted from New Zealand's unique combination of climatic and economic conditions, which attempt to match pasture production with the feed requirements of animals (Holmes 1996).

Table 2-1 Value of pastoral-based exports as a percentage of total New Zealand exports for the year ended June 1997, valued at $21033.2 million.

Commodity	Percentage of total exports (free on board)
Dairy produce	19.4
Meat, including edible meat offal	13.0
Fibre, including hides and skins	8.2
Fruit and nuts	3.7
Fisheries	4.9
Forestry, including wood pulp and paper	11.1
Other agriculture	3.1
All other exports	36.6

Source: Statistics New Zealand

In this chapter, Section 2.2 provides a brief description of the New Zealand dairy industry followed by more specific information on the late control spring grazing strategy in Section 2.3. The final section (Section 2.4) briefly introduces systems and modelling concepts.

2.2 Dairy production in New Zealand

Nationally, the number of herds has been decreasing while total cows, average herd size, average effective area and cows per hectare have been steadily increasing over the last 15 to 20 years (LIC 1997). Relevant herd production statistics for 1996/97 are presented in Table 2-2.

Farm production statistics for 1996/97 are given in Table 2-3. Average milk fat and protein (milksolids) per farm have been increasing since 1988/89; production per cow has been improving for the last 45 years as the result of genetic gain and improvements in farm management (LIC 1997).

Table 2-2 Herd statistics for 1996/97.

District/Region	Total herds	Total cows	Farm average		
			Herd size	Eff. ha	Cows ha^{-1}
Manawatu	315	71 080	226	90	2.5
Wellington	695	161 513	232	95	2.5
North Island	12 804	2 517 098	197	81	2.5
South Island	1 937	547 425	283	119	2.4
New Zealand	14 741	3 064 523	208	86	2.5

Source: LIC 1997

The better seasonal dairy farms in the lower North Island of New Zealand achieved production of 350 kg MS per lactation and per hectare production of 880 kg MS per hectare over three seasons from 1990/91 (Crawford *et al.* 1995).

Table 2-3 Farm production statistics for 1996/97.

District/Region	Farm average			
	Litres	kg MS	kg MS ha^{-1}	kg MS cow^{-1}
Manawatu	784404	65 069	735	293
Wellington	802381	66 139	730	291
North Island	688 141	58 591	745	301
South Island	998 129	83 189	711	296
New Zealand	728 874	61 823	741	301

Source: LIC 1997

Over the last four years the median planned start of calving for mixed age cows in the Wellington region was 28 July, and the median national calving date was 20 August. Nationally, approximately 90% of cows are herd tested at least once a year, in the Wellington region approximately 83% of cows are tested. Herd test averages for 1996/97 are given in Table 2-4. Over the last 20 years milk volume has increased, while percent protein and fat have remained constant. Days-in-milk represents the number of days from the estimated start of lactation to the estimated end of lactation (LIC 1997).

Table 2-4 Herd test averages for 1996/97.

District/Region	Milk (litres)	Milkfat (%)	Milk protein (%)	Days-in-milk
Wellington	3754	4.72	3.64	224
South Island	4096	4.64	3.62	221
New Zealand	3641	4.78	6.66	223

Source: LIC 1997

The average dairy company total payout per kilogram of milk solids received by seasonal supply dairy farmers for 1993/94, 1994/95 and 1995/96 were $3.32, $3.40 and $3.99, respectively (LIC 1997).

2.3 Late control spring grazing management

2.3.1 Introduction

In New Zealand seasonal calving of cows is one strategy used on dairy farms in an attempt to match the requirements of the animal (demand) to pasture production (supply), the majority of cows calving between late July and early September to coincide with increasing pasture growth rates. The aim is for the lactating cow's requirement for dry matter and consequently energy (metabolisable energy - ME), to peak at the same time as pasture production, that is, by the end of September or early October (Holmes & Wilson 1987). The majority of the herbage consumed is removed by the cow from the pasture by grazing, although at times of deficit, stored forage, often in the form of hay, silage or an *in-situ* crop, may be fed. Feed deficits typically occur during summer due to drought or during late autumn or winter due to low temperatures. Cows are dried off in April or May to conserve feed for the dry cows through the winter and to save pasture for the following spring. The number of cows per hectare (stocking rate) is set so that the herd can be fully fed from pasture during spring, while allowing the surplus to be conserved for periods when pasture growth is less than cow requirements, for an average year. Pasture growth is restricted during winter by low temperatures and during summer by water deficit, and peaks during spring as temperatures increase and water is non-limiting (Holmes & Wilson 1987). As pasture becomes reproductive the objective of pasture management is to maintain pasture quality through intensive grazing and conservation, with the objective of interrupting ryegrass stem elongation at an early stage and preventing reproductive development.

However, hard grazing throughout spring may limit the intake of herbage by dairy cows, resulting in a loss of body condition that in turn may result in a shorter lactation length. There has been an increasing interest over recent years in improving the nutrition of dairy cows during spring to achieve greater milk production and longer lactation (Matthews 1995, 1997; Pinares & Holmes 1996). Nonetheless, to reduce the intensity of grazing has been considered undesirable because pasture quality declines and the use of large amounts of supplements is not considered economically feasible. Furthermore, an objective of pasture management during times when growth is high, and in particular when pasture growth rates exceed animal feed requirements, might be to position the pasture in the best possible situation for those periods when growth is restricted. That is, providing favourable conditions for pasture plants in spring may increase both their persistence and production through the rest of the year.

2.3.2 Evidence for late control

Traditionally, the emphasis in dairying systems has been on maintaining pasture quality in late spring through increased grazing pressure and sometimes topping. Usually, grazing pressure is increased by a combination of speeding up the round and dropping paddocks out of the round for later forage conservation (L'Huillier 1988). Pastures are not allowed to become rank during spring. Until recently, farmers have been reluctant to top paddocks, instead preferring to force the cows into removing the herbage. However, with renewed importance being placed on per cow production farmers are using mechanical control methods more frequently. Grazing management that allows cows to be fed better during the peak of lactation (October and November) is of considerable interest to dairy farmers, particularly if post-peak production does not suffer (Matthews *et al*. 1996).

Intensive field studies of spring grazing management at Massey University between 1985 and 1992 demonstrated that manipulation of reproductive growth can result in large differences in herbage production (total dry matter, green leaf and clover accumulation), sward quality and composition in perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) dominant pastures (Korte 1981, 1982, 1986; Korte *et al*. 1982, 1984, 1985; Butler 1986; Korte & Harris 1987; L'Huillier 1987a, 1987b, 1987c; Matthew *et al*. 1989b; Xia *et al*. 1990; Matthew 1992; da Silva *et al*. 1993, 1994; da Silva 1994; Hemández Garay 1995). A number of studies have reported an increase in summer and autumn herbage production by allowing a brief period of reproductive development, followed by a period of control at the time of anthesis, through effects on tiller population and size (Korte 1982; Korte *et al*. 1984; Matthew *et al*. 1989b; Xia *et al*. 1990; Matthew 1992; da Silva *et al*. 1993, 1994; da Silva 1994; Hernández Garay 1995), with flow-on production benefits for grazing animals (da Silva 1994). The benefits of increased pasture allowance on animal performance have been well demonstrated (Thomson *et al*. 1984; Bryant & L'Huillier 1986; Hoogendoorn *et al*. 1988, 1992; McCallum *et al*. 1991).

Late control management involves lax grazing in early spring, allowing reproductive growth to take place, then switching to hard grazing in late spring/early summer, to decapitate and kill the majority of flowering tillers. Grazing management as described would enhance herbage accumulation in spring due to reproductive development and in summer/autumn due to enhanced ryegrass tillering activity and white clover performance.

However, a year long farmlet study at Ruakura found that a loss of pasture production and consequently animal production were incurred during the control phase, offsetting the gains made later in the season from a denser and more clover dominant-controlled sward (L'Huillier 1987a).

It has been generally accepted that reproductive growth limits tillering through shading and apical dominance and that removing seedheads will enhance tillering. However, Korte (1986) and L'Huillier (1987b) identified a seasonal peak of tillering for Nui perennial ryegrass in November/December. The majority of daughter tillers appearing at this time arose from the basal intemodes (often below ground) of flowering stems and the appearance of these daughter tillers coincided with a high death rate of older tillers so that 50-60% of tillers in the sward in mid December were from recently formed daughter tillers arising from the basal intemodes of flowering stems (Matthew *et al.* 1989a). Furthermore, Matthew *et al.* (1989b) suggested that substrate supply from tillers whose development had been interrupted at early flowering (anthesis) promotes tiller bud initiation at the base of those flowering tillers.

Monitoring grazed swards in detail under hard, lax, hard-lax and lax-hard management from spring to autumn revealed that tiller appearance rate was highest in December for lax-hard (Xia *et al.* 1990), followed by high leaf appearance rates through January. Matthew *et al.* (1989b) showed herbage production to be highest for the lax-hard treatment in April. Late control (LC) management (lax-hard) gave rise to pasture accumulation rates up to 10 kg DM ha^{-1} day^{-1} higher from December through to April.

A hypothesis was developed which suggested that allowing for a brief period of reproductive growth before controlling seedheads encouraged daughter tillers by making substrate available for their development. Under the hypothesis proposed, the optimal time for 'controlling' reproductive growth is somewhat later and the defoliation height greater than has been recommended in the past. The requirement is for a grazing regime which maximizes pasture accumulation rates by allowing seedheads to develop and then quickly moves into a control phase while they are immature and still palatable. The result should be a flush of daughter tillers and higher summer pasture production and hence sustained higher animal production. Persistence of the pasture should also be improved through increased tiller numbers.

da Silva (1994) demonstrated the high turnover of tillers over the late spring-early summer of swards comprised mainly of perennial ryegrass plants, with only 25% of tillers tagged in October present four months later in February. This tiller replacement process plays an important role in determining tiller populations in summer and autumn (Korte *et al.* 1982, 1984, 1985; Korte 1986; Matthew 1991; Thom 1991). The formation of tillers from reproductive tillers is an effective way of enhancing tiller replacement and likely to improve the perennation and persistency of perennial ryegrass swards (Matthew *et al.* 1993).

Several workers have reported lax defoliation in spring results in increased clover stolon size and density (Grant & Barthram 1991; Barthram & Grant 1993; da Silva 1994), although these differences were negated by April (da Silva 1994). Following the common winter grazing management stolon densities were lower than those observed in autumn, attributable to the burial of stolons over winter (Hay *et al.* 1987).

The advantages of LC grazing management were subsequently tested using paddock scale experiments under both sheep and dairy cattle grazing as reported by Hernández Garay (1995) and da Silva (1994), respectively. Hernández Garay (1995) concluded that allowing some early seedhead development (lax spring grazing management) followed by hard grazing at the time of anthesis increased herbage production during spring, summer and autumn. In spring the increase in production was attributed to higher tiller weights, and over summer and autumn to higher tiller population density and leaf growth per tiller. Furthermore, enhanced tillering was accompanied by increased leaf elongation in ryegrass and leaf expansion in white clover leaves. The duration of lax grazing was important in determining the pasture production response, herbage production increasing with the duration of lax grazing. To achieve the maximum increase in the herbage produced, lax grazing should start in early September.

da Silva (1994) reported on three paddock-scale experiments investigating whether pasture production is enhanced by late control grazing management using dairy cows. In addition, the defoliation height used when controlling the pastures was investigated. These trials were conducted at No 4 Dairy Unit, Massey University on five paddocks each split into three grazing treatments during October 1990 to April 1991 and October 1991 to April 1992. In the first experiment pastures were controlled with a mower prior to grazing. The second trial investigated the timing of control and whether the height of defoliation when controlling pastures in the spring should be higher than has been recommended in the past, pastures being controlled at either 30-50 mm or 80-100 mm sward height. Results from the first trial supported the hypothesis that pasture production is enhanced by 'late control' grazing management with pasture production being increased by 24% on average. In the second trial the results were more variable, with only the late lax treatment producing more pasture than conventionally controlled swards (15.5%). While the response in the 1990/91 trial was attributed primarily to an increase in the yield of ryegrass, in the 1991/92 trial it was attributable to an increase in the yields of both ryegrass and white clover.

Based on the results of the first two experiments, a feed budgeting exercise was then undertaken to investigate the feasibility of late control spring grazing management (da Silva 1994). The results showed that relaxing grazing pressure over spring by manipulating grazing management would not interfere with the feeding levels of cows, since herbage accumulation rates where usually higher than feed requirements. Simple manipulation of the timing and proportions of the farm to be set aside for conservation allowed higher post-grazing residuals and the targeted extra 500-600 kg DM ha^{-1} of extra pasture to accumulate without causing a restriction on the feed intake of cows. Furthermore, since animals would be offered a higher daily herbage allowance and pre-grazing herbage mass, enhanced levels of herbage intake could be expected. The simulations showed that conserved feed would be in excess of animal requirements and could be used to raise the feeding levels of cows at different times of the year. However, since milk production was an input into the model used it was not possible to obtain milk yield responses from the additional herbage produced. It was concluded that setting the sward conditions for late control did not constitute a problem in normal spring years, but further information was necessary on how to best achieve effective control of reproductive growth without excessive reduction in herbage allowance for cows, and how effectively the extra summer-autumn growth could be converted into extra milk production.

A third dairy paddock trial was conducted to study the methods of obtaining late control in practice and to measure the effect of the control measures on animal performance (da Silva 1994). By manipulating spring grazing management an early control treatment (2 000 kg DM ha^{-1} average pasture cover) and late control treatment (2 700 kg DM ha^{-1} average pasture cover) were established by 01 December. Late control areas were controlled by either lactating cows on a fast rotation or by increasing stocking rate on the grazed area, as would be the case with removing paddocks for conservation.

The results of this final trial, conducted during 1992/93, showed that while control could be achieved through grazing it was more successful when associated with an increase in the stocking rate. Late control increased pasture growth rates (20%) in the spring period and over mid summer, and the production response was seen in both ryegrass and white clover (25% and 35%, respectively). Production per cow was 5% higher on late control treatments than on early control for the period from December to March, although there were no differences in live weight and condition score over the summer and autumn. The results suggest that late control could be achieved through grazing management, and animal performance will be enhanced as a consequence of sward conditions which lead to higher total pasture and clover accumulation rates. However, it remains to be seen whether the additional herbage produced can be realised in terms of increased output or alternative management advantages within the management constraints of a closed production system. That is, can the benefits of late control spring grazing management be measured on the whole farm basis of a self-contained production system.

Researchers (Matthew 1991; Hernández Garay 1995; da Silva 1994) investigating the LC strategy were concerned by the development of patchiness in pastures. Patchiness has been associated with variability in tiller population dynamics and clover content with consequences for pasture quality, herbage utilisation, intake and the feasibility of controlling reproductive growth and converting the extra feed produced into milk. However, the development of patchiness in pastures may be attributable to an excess of pasture (Ring *et al.* 1985) rather than solely to heterogeneous patterns of defoliation.

In 1995/96 Padilla (1997) investigated the effects of the LC strategy on patchiness in No 4 Dairy Unit pastures. In this experiment three paddocks per treatment were sampled intensively to investigate the consequences of heterogeneity in pasture production and utilisation over December and January. It was concluded that patchiness on LC paddocks before the control phase in December did not adversely affect herbage utilisation. Short patches on both EC and LC had lower utilisation than tall patches. Topping proved to be an effective method of controlling tall patches, improving the structure of the sward and ensuring that herbage quality is maintained in those areas. In general, it was found that LC increased accumulation rate and leafiness compared to EC but did not affect the clover content of LC pastures. While LC tall patches increased tillering and tiller weights, EC short patches produced more white clover. Morphological differences between short and tall patches were evident within the treatments, with tall LC patches having higher ryegrass content due to increased tillering and tiller weights. In short LC patches ryegrass tiller numbers were increased, although their weight decreased. Early control tall patches had more other grasses and stem compared to trimmed tall patches in LC. The higher utilisation of tall patches on either treatment indicated that higher pasture covers may increase herbage intakes despite patchiness.

This experiment highlighted the fact that some areas within both EC and LC experience the benefits highlighted previously of lax spring grazing management. Padilla (1997) suggested that the rotation length of LC pastures should be increased before controlling reproductive growth in late spring, to allow a greater proportion of the sward to achieve a higher herbage mass. Grazing followed by topping of pastures gave high herbage intakes and effective pasture control. Patchiness will have no long term effects provided it is controlled before pasture quality declines. For LC management, this means controlling reproductive growth prior to anthesis. Increasing the rotation length in summer following LC management may further benefit ryegrass tillering.

There is also interest in late control among farmers interested in increasing the herbage intake of cows during spring without sacrificing pasture quality into summer, thereby raising feeding levels and enhancing milk production of dairy cows (Matthews *et al*. 1996). Lax spring grazing management would favour individual cow productive and reproductive performance in the first half of lactation by increasing feeding levels, and in the second half of lactation by increasing herbage accumulation rates and the white clover content of pastures, providing seedheads are not allowed to become over mature. Creating the sward conditions (reproductive growth) necessary for executing late control without sacrificing animal performance during spring requires grazing pressure to be relaxed to give higher post-grazing residuals or the intake of the animals may be restricted (da Silva 1994). This may result in less of the forage grown being available to the animals for consumption in early spring, limiting the feed intake of cows in early lactation. Later in the season (mid spring), as the accumulation rates of pastures exceed the intake of herbage by the cows and pastures are allowed to become reproductive under lax grazing management, the nutritive value of the herbage on-offer may decrease. A reduction in the quality of the herbage offered could reduce current and future milk production.

Implementation of a late control grazing strategy on a farm basis would have to rely on efficient control of reproductive stems in order to capitalise on potential benefits, and that would imply some degree of re-thinking of the conventional role of forage conservation practices and conserved feed use in New Zealand (da Silva 1994). At the time when control is required pastures are usually accumulating herbage faster than the cows are eating it, making it relatively difficult to remove seedheads from reproductive swards using only well-fed grazing animals. Finally, assuming that late control management could be achieved and the increase in summer/autumn pasture production was obtained, the question remains, what is the best management strategy for ensuring the extra herbage is eaten and converted into additional milk?

2.4 Agricultural systems research

2.4.1 Introduction

Over the last century agriculturalists have developed New Zealand's grazing systems to the point where much of the slack that existed in these systems has been exploited (Townsley 1973). During the early years advances were made through the application of fertilisers, correction of trace element deficiencies, increasing stocking rates, farm subdivision, and improved grazing techniques (McCall 1984). Since the path to increased production has increasingly depended on subtle interactions as opposed to single-factor constraints, a greater level of understanding is required on the part of the farmer in order to apply new information efficiently to the system (McCall 1984).

Farming systems research is a broad term which involves on-farm research, the socioeconomic environment and transmission of information. These activities are interdisciplinary, farmer and system oriented, in order to achieve good identification and adoption of the technology. Farming systems are characterised by the fact that people are attempting to control biological systems in an uncertain environment to achieve goals which are often economic in nature. Interactions between seasonal climate variations, farming intensity and farm improvement are critical in assessing and comparing production systems, and should not be excluded from research.

2.4.2 Systems

Biological systems, of which agricultural systems are an example, are made up of interacting chemical and physical processes. Living systems are composed of numerous subsystems and components and have unique characteristics and behaviour, while contributing to the overall form and function of the entire system (Jones & Luyten 1998). Many components interact simultaneously and these interactions may be nonlinear or chaotic. When attempting to understand or predict system behaviour these interactions and non-linearities must be taken into account. More often than not our understanding of these interactions is incomplete and guided by empirical evidence of overall system behaviour rather than empirical data on processes that lead to overall system behaviour (Jones & Luyten 1998). Jones & Luyten (1998) make the point that these complexities have meant that classical mathematical methods used to study nonliving physical and chemical systems have been inadequate for living systems and that computer simulation has proved to be a powerful tool in the basic and applied biological sciences. Simulation of biological processes and their interactions can provide considerable insight into the behaviour of living systems and into ways of managing these systems to achieve specific goals. The general acceptance and rapid growth of personal computers, largely due to improved price/performance, has made it possible for simulation to become an integral part of biological research.

A large number of different entities can be regarded as systems, although not everything is a system (Spedding 1988). There have been a number of attempts to define a system over the last 20-30 years. Simply put, a system may be defined as a group of interrelated components that interact for a common purpose and react as a whole to external and internal stimuli. Rountree (1977) defined a system as a functional or conceptual unit at a given level of organisation, made up of interacting components. Murthy *et al.* (1990) simply defined a system as a collection of one or more related objects and an object as a physical entity with special characteristics or attributes. Objects may be either non-interacting or interacting and their attributes can be described in terms of parameters and variables. Dillon (1976) gave the following properties to the components of a system:

- each affects the properties of the system as a whole;
- each depends for its own properties and its effect on the whole system;
- each depends on the properties of some other components of the system.

Spedding (1988) proposed that 'A system is a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks.'

More recently Jones & Luyten (1998) defined a system as a collection of components and their interrelationships that have been grouped together for the purpose of studying some part of the real world. Furthermore, the selection of the components to include in a system depends on the objectives of the study and represents our simplified view of reality. Subsystems are described in terms of entities and their properties are termed attributes. Any process, either internal or external, which causes changes in the system over time is called an activity. The initiation, alteration or conclusion of an activity is called an event. State of the system is used to mean a description of all the entities, attributes and activities as they exist at one point in time. The evolution of the system is studied by following the changes in the state of the system.

The behaviour of a complete system is different from the sum of its parts (Doyle 1990) and the interactions and interrelationships between system components over time are a primary determinant of its behaviour (Bywater 1990). Therefore, the isolated study of system components does not provide an understanding of the complete system (Dent & Blackie 1979). To put it another way the systems view is a holistic one, which implies that an isolated study of parts of the system will not be adequate to understand the complete system. That is, the systems approach recognises the indivisibility of the whole system (Dillion 1976).

Central to systems concepts is the hierarchy of systems, which allows one system to be a subsystem of the other. At one level of aggregation we may be concerned with the atom and, at the other end of the scale, with social interactions (van Dyne & Abramsky 1975). That is, biological systems are hierarchically organised and can be studied at a number of levels (Jones & Luyten 1998). Scientists, engineers and economists are performing modelling and simulation analysis at different hierarchical levels.

Spedding (1975) points out that the application of systems concepts relies on recognising the purposes for which a system is to be studied. This becomes important when attempting to define the boundaries of the system being studied and providing a basis for balancing the need for detail against generality (Rountree 1977). That is, ensuring that all relevant subsystems are included, yet making sure unnecessary subsystems are excluded. It is essential to realise in advance the boundaries of the system because it is impractical to take all factors into account when analysing a system. However, it is important to include all factors that are likely to significantly impact on the behaviour of the variables of interest. A system's boundary is a contrived component designed to assist the understanding of the system's function; in reality no such boundary exists in any system (Dent & Blackie 1979). In practice, problems still exist as to which components to include and which to exclude. Rountree (1977) suggested that a boundary be viewed as a band rather than a rigid cutoff line and within the band the effect factors have on the system diminishes.

Organisational levels outside the boundary of the system form the environment and while providing inputs into the system are usually left unchanged by the operation of the system (McCall 1984). The environment of a system includes everything except the components of the system. Jones & Luyten (1998) suggest that a system boundary is an abstraction of the limits of the system components, separating them from the environment and, while the boundary may be physical, it is better to think of it in terms of cause and effect. Finally, the environment may affect the system in a number of ways, but the system does not affect the environment (Murthy *et al.* 1990; Jones & Luyten 1998). Therefore, the environment does not need to be modelled.

Historically, the majority of agricultural research has been targeted at the farm level and concerned with the solution of specific problems or the identification and evaluation of opportunities for improving production (McCall 1984). Therefore, the boundaries of the system can be relatively easily defined. While experiments to study components of the system in more detail may be performed on scaled versions of the whole production system (farmlet studies for example), researchers usually draw boundaries that lie within those of the farm. This ensures that any changes made to a very specific component (part) do not impact to the detriment of the whole system through interaction with other components (Morley & Spedding 1968).

Research into agricultural systems can be classified as systems analysis and systems synthesis (Wright 1973; Dent & Blackie 1979). Systems analysis involves getting an understanding of the relationships between system components to understand the mechanisms underlying observed system behaviour. Systems synthesis involves formulating improved systems based on hypotheses about system behaviour, derived from knowledge of the components gained during system analysis, or the design of new systems. Extending the boundary of the system to include other components is one way of designing new systems. For example, introducing forage cropping to dairy systems (McCall 1984). Dent & Blackie (1979) suggest that the analysis and synthesis phases of systems research are carried out together rather than distinct in time.

Bywater (1990) classified systems approaches as being either formal or informal. Formal approaches are defined as those that employ techniques which explicitly quantify the effects of dynamic interactions within the system being analysed. The response of the system is endogenously determined by its previous mathematical formulation with a formal approach. Informal approaches are those which, while aware of dynamic interactions within systems, attempt to accommodate them primarily through descriptive or intuitive means rather than by rigorous quantification. They do not explicitly quantify the dynamics of the systems they represent, only its expected outcome. While informal systems approaches may or may not utilise computers, formal systems approaches are likely to involve models solved by computers. Traditional farm management techniques such as budgeting are applications of informal systems thinking, requiring the practical experience and knowledge of the individual using them. Informal approaches are dependent on the assignment, by the user, of expected responses, through assumptions and estimates, by the system to changes in its inputs. The use of systems trials or farmlet studies are another example of the informal approach, because in themselves they do not quantify the dynamic interactions characteristic of agricultural production systems (Bywater 1990).

Bywater (1990) suggests that the methodology of systems trials is not well developed. The tendency for new technical problems or environmental constraints to arise, and thereby diminish previous gains, both reinforces the need for a systems view and at the same time highlights our current limitations in applying such a view. However, as gains become harder to achieve through the application of existing knowledge and intuition, a better understanding of systems level interaction will become increasingly necessary (Bywater 1990).

2.4.3 Models

We all observe the world that surrounds us and formulate how we believe it functions in terms of physical, social and economic relationships (Loewer 1998). Modelling can be defined as the act of formulating a model, a mental construction process used to make sense out of phenomena that are made explicit to others through the use of one or more of the following: symbolic languages, narrative, pictures, mathematical equations, charts, diagrams, scaled replicas and games. In their simplest form models are representations of the real world (Murthy *et al.* 1990), simplified for some purpose, including only those features required and excluding those not essential for the intended purpose (Spedding 1988). Rothemberg (1989) defined a model as an abstraction of reality to allow us to deal with the world in a simplified manner, avoiding the complexity, danger, and irreversibility of reality. Definitions are also provided by Thomley & France (1984) whom define mathematical models as 'an equation or set of equations (and algorithms) used to represent the behaviour of a system'. While Sinclair and Seligman (1996) and Dent & Blackie (1979) suggest that a model is a collection of hypotheses about the behaviour of a system. In the context of the current study, Spedding (1988) defines a model as a simplified abstraction of the real world used to capture the principal interactions and behaviours of the systems under study, and to be capable of experimental manipulation to project sequences of changes in the determinants of system behaviour. Most models are the result of the scientist-researchers's desire to express his or her understanding of system interactions (Barrett & Nearing 1998) and the desire to solve real world problems (Murthy *et al.* 1990).

Dillon & Anderson (1990) noted, quite correctly, that there are almost as many schemes for classifying models as there are modellers. Dent & Anderson (1971) and Dent & Blackie (1979) classified models as either iconic, analogue or symbolic. In this classification scheme iconic models are scaled representations (usually smaller) of the real system with all relevant properties, for example, the farmlet in agronomic research. Analogue models are based on the use of one property for another. Examples include the lines of a graph which represents the variation in some quantities when other quantities are changed. Mechanically mowing pasture as a substitute for grazing is another. In symbolic models, properties are represented by symbols and they are the most abstract and the easiest to manipulate (Shannon 1975).

Recently, Loewer (1998) proposed the following classification scheme; mental models, physical models and mathematical models. The latter are further subdivided into statistical models, mechanistic models and simulation models. This scheme differs slightly from that described above in both structure and the naming conventions used, for example, iconic models are referred to as physical models in this scheme. Mental models are composed of images and words and are used to communicate our understanding to others. When we observe something that cannot be explained by an existing model we reformulate the model adding the new information (learning). Physical models, which are formed from mental models, are a system or object made to scale. A model aeroplane is a simple example as is a grazing trial, since they both attempt to represent scaled-down systems. Mathematical models are mental models expressed in mathematical form quantifying the system in question. Statistical models include regression models which use experimental observations to mathematically relate one or more input parameters with an associated output. Mechanistic models are based on a mathematical form that is believed to best represent the relationship between one or more input parameters and an associated output. Input terms are often conceptual rather than physical. Simulation models usually use computers for computational purposes and are often referred to as computer models. Computer models are collections of mathematical logical expressions that relate inputs to outputs and may include both statistical and mechanistic expressions. Optimisation models, such as linear programming (LP), are sometimes called static simulations, while models that predict relational changes that occur over time are called dynamic simulations. According to Loewer (1998), dynamic simulations offer the greatest potential for describing the complex relationships associated with grazing trials.

Chapter Three

Dairy Systems Grazing Trial Methodology

3.1 Introduction

A large scale comparison of two contrasting spring grazing managements was established at No 4 Dairy Unit, Massey University. Management contrasts were early control (EC), in which pastures were closely controlled throughout the spring and summer with average pasture cover kept at approximately 2 000 kg DM ha^{-1}, and late control (LC), in which average pasture cover was increased to 2 700 kg DM ha^{-1} through October and November allowing some reproductive growth before returning average pasture cover to 2 000 kg DM ha^{-1} in December. The trial ran over three lactations, from 01 August 1993 to 01 May 1996. The aim was to measure the effects of contrasting spring grazing management on pasture and animal production within the constraints of a closed production system. This chapter reports on the experimental site and design of the trial and the measurement procedures used.

3.2 Experimental site

This section provides a brief outline of No 4 Dairy Unit. The management practices described below represent the management practices carried out on No 4 Dairy Unit prior to the start of the spring grazing management trial.

3.2.1 Physical resources

No 4 Dairy Unit is situated 5 km south of Palmerston North on State Highway 54 ($40^0$23'S $175^0$37'E) at an altitude of 40 metres above sea level. The prevailing wind arrives from the west and the average annual rainfall is approximately 1 000 mm. Weather conditions for the trial site were assumed to be similar to those of the Crown Research Institute (CRI) meteorological station, approximately 2 km northwest. Monthly average air and soil (10 cm depth) temperatures, rainfall, pan evaporation and wind run (monthly means) are presented in Table A3-1 of Appendix Three. Fifty year mean values are presented in Table A3-2 of Appendix Three.

The farm is located on the Tokomaru terrace (high terrace) and the Ohakea terrace (intermediate terrace) with a remnant Tokomaru terrace intruding across the Ohakea terrace in the southern corner (Figure 3-1). Streams dissect both the Tokomaru and Ohakea terraces. The Tokomaru and Ohakea terraces are composed of Tokomaru (predominantly Tokomaru Silt Loam) and Ohakea (predominantly Ohakea Silt Loam) soil series, respectively. Tokomaru Silt Loams are poorly drained, compact clay loams with compact subsoils. They have poor natural drainage with a tendency to dry out in summer and moderate to low natural fertility (15 ppm Olsen-P and 0.25 meq Exch-K 100g $soil^{-1}$). The Ohakea Silt Loam is a moderate clay alluvial overlaying gravel and stones approximately one metre from the surface. This soil is imperfectly drained and dries out in summer. A large proportion of the property has been tile and mole drained with mole drains at two metre intervals crossed by 100 or 150 mm tile drains.

No 4 Dairy Unit is subdivided into 78 paddocks by 2,3 or 4 wire electric fences and a 50-mm ring main supplies water to a trough in each paddock. All paddocks and the 36-bail turn-style rotary cowshed, which is located on the west side of the property, are accessible by an internal compacted race system (Figure 3-1). The capacity of the yards is 550 cows. A sawdust loafing pad and a concrete feed pad make winter management simpler by helping to reduce winter pugging damage. The sawdust loafing pad measures 55 m x 30 m and can accommodate 250 cows while the feed pad measures 55 m x 5 m and can feed 170 cows. Other buildings and improvements on No 4 Dairy Unit include calf rearing sheds, haybarns with 5 000 conventional bale capacity, and a 500 tonne silage pit. Machinery and equipment owned are typical for the farm type. Figure 3-1 shows the general layout of the property.

3.2.2 Pasture composition

Twenty years ago a large proportion of the property was in older pasture consisting of ryegrass, browntop, crested dogstail and sweet vemal with limited clover. Each year an area of five to ten hectares is planted in a summer forage crop before being re-sown into pasture. At the start of the trial pastures were on average six years old and comprised a mixture of perennial ryegrass (*Lolium perenne* L. cv. 'Ellett') and white clover (*Trifolium repens* L. cv. 'Grasslands Pitau') and red clover (*Trifolium pratense* L. cv. 'Grasslands Pawera'). Pasture composition varied according to the age of the pasture with the dominant species being perennial ryegrass and white clover. Pasture weeds include ragwort, thistles, buttercup, docks and some gorse.

3.2.3 General management

The aim is to feed all stock on pasture in early lactation with any excess pasture being harvested as silage to be used in either winter or late autumn/early spring. A forage crop, usually maize or tumips, is grown for use in February-March as green feed/silage or green feed and comprises the farm's pasture renovation programme. Cows are dried off based on feed supply and cow condition. Calving begins in early August with late calving cows being induced so that calving is normally completed by the end of September. The condition score target at the start of calving is 5.5. Replacements are raised on-farm until 01st May and then grazed off-farm as Rising One Year Olds for 12 months. The stocking rate of the farm is 2.67 cows ha^{-1} (490 cows on 183.3 ha).

The annual maintenance fertiliser policy adopted on the farm has generated a moderate to high (25 ppm Olsen-P and 0.37 meq exchangeable K 100g soil^{-1}) soil nutrient status. Annually the farm receives two tonnes of lime and 350 kg of 30% long-life superphosphate (0.7.15.5) or 350 kg of a 15% long-life superphosphate (0.9.8.7) per hectare. In addition, on average 90 kg N ha^{-1} is applied as urea in 30 kg N ha^{-1} side dressings after grazing during spring.

3.3 Experimental treatments

Based on the results of earlier plot and paddock scale studies (Matthew *et al.* 1989b; Matthew 1990; da Silva 1994; Hernández Garay 1995) two independent contrasting spring grazing managements (early control and late control) were applied in this trial. Differences in average pasture cover were allowed to develop over this period to be controlled in early summer.

3.3.1 Early Control (EC)

Strict control of grazing throughout the spring and summer with average pasture cover targeted at approximately 2000 ± 100 kg DM ha^{-1} and a post-grazing residual of approximately 1500 ± 100 kg DM ha^{-1}. Control of spring pasture surpluses was maintained by a conventional (20-25 day) rotation and dropping paddocks out of the rotation for later conservation. Limits on average pasture cover in this treatment established sward conditions under which it was relatively easy to control reproductive growth and encouraged high levels of pasture utilisation by the cows in early lactation.

3.3.2 Late Control (LC)

Pastures were allowed to develop some reproductive growth (seedhead development) through October and November for removal in December. The higher pasture cover limits of this treatment encouraged higher levels of herbage mass in the post-calving period with less initial restriction on cow intakes. The average pasture cover target was 2700 ± 100 kg DM ha^{-1}, with a post-grazing residual of approximately 2 000 ± 100 kg DM ha^{-1} over spring. Average pasture cover was reduced to 2000 ± 100 kg DM ha^{-1} in December by grazing to lower residuals while at the same time removing paddocks from grazing for immediate conservation. This was done to remove reproductive growth in the early flowering stage (25 November - 15 December) and reduce average pasture cover over the whole farm.

3.4 Trial design

This section describes the resources and management changes of No 4 Dairy Unit required to implement the spring grazing management trial.

3.4.1 Paddocks

Half the total area of No 4 Dairy Unit was divided into two comparable farmlets for this trial and each of the 20-paddock farmlets was approximately 45 ha in area. Treatments were randomly allocated within pairs of paddocks between farmlets at the beginning of the trial. Paddocks were paired based on sowing date, area, and productivity. Figure 3-1 shows the layout of the property and in particular the trial area. Five representative paddocks per treatment (indicator paddocks) were chosen for detailed sward measurements. Individual paddock areas are given in Table 3-1 with bold typeface and shading denoting indicator paddocks.

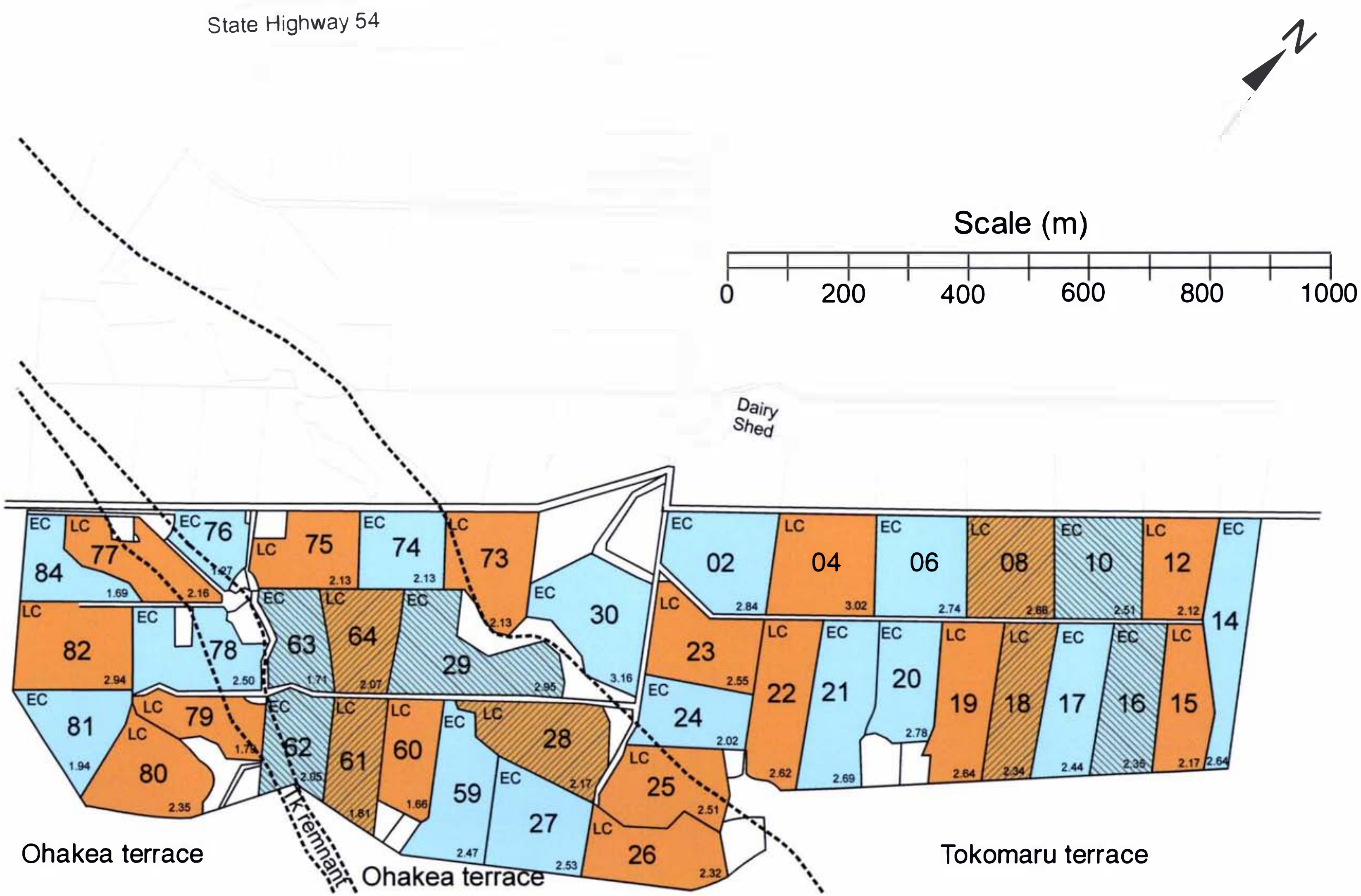
Each paddock was considered as an experimental unit, giving a completely randomised design (CRD) with either 5 or 20 replicates per treatment, depending on the measurement in question.

Table 3-1 Areas of the paddocks on No 4 Dairy Unit in the trial.

Early Control		Late Control	
Paddock	Area (ha)	Paddock	Area(ha)
2	2.94	4	3.02
6	2.74	**8**	**2.66**
10	**2.57**	12	2.12
14	2.64	15	2.17
16	**2.35**	**18**	**2.34**
17	2.44	19	2.66
20	1.18	22	2.62
21	2.69	23	2.59
24	2.02	25	2.51
27	2.53	26	2.32
29	**2.95**	**28**	**2.17**
59	2.47	60	1.66
62	**2.05**	**61**	**1.81**
81	1.94	79	1.79
78	2.5	80	2.35
84	1.69	82	1.69
76	1.27	77	2.16
63	**1.71**	**64**	**2.07**
74	2.13	75	2.13
30	3.16	73	2.13
Total	45.97	Total	44.97
Mean	2.299	Mean	2.249

Note: Bold typeface and shading denotes indicator paddocks

Figure 3-1 **Plan of No 4 Dairy Unit, Massey University. Early control (EC) and late control (LC) paddocks are shaded blue and orange, respectively. In addition, indicator paddocks are represented by diagonal lines.**



3.4.2 Animals

One hundred and twenty-five mixed age predominantly Friesian cows per treatment were allocated at the start of the trial balanced for age, calving date, and herd test result. Between years those cows that were not culled were retained on the treatments. Culling was done following normal farm practice based on reproductive performance, age, conformation and milksolids production, with 20% and 25% two-year heifers per treatment added for 1994/95 and 1995/96, respectively. Replacements were allocated to treatments balanced for calving date, liveweight and breeding index.

Stocking rates decreased marginally over the three years of the trial with herd numbers of 128 and 125 for 1993/94, 125 and 123 for 1994/95 and 118 and 120 for 1995/96 for EC and LC, respectively. Tables A3-3 through A3-5 of Appendix Three give details of changes in milking cow numbers over three years. Records represent either additions to the milking herds after cows calved, or removals from the herds by cows being culled and/or dried-off. Each cow was considered as an experimental unit, giving a completely randomised design (CRD) with 120 to 125 replicates per treatment depending on year.

Mean lactation lengths were similar for EC and LC herds in all three years (Table 3-2). Both herds were finally dried-off on 15 April 1994, 10 May 1995 and 16 April 1996.

Table 3-2 Mean lactation length for early control and late control cows over three years.

Date	Early Control	Late Control	SEM	P
1993/94	219.7	224.4	3.47	0.3457
1994/95	241.8	229.2	5.67	0.1189
1995/96	245.3	248.0	4.07	0.6389

3.4.3 Management

Differences in average farm cover, animal condition and conserved feed created by the treatments in mid to late spring were carried forward into the summer and autumn each year. However, both farmlets were returned to a common management point by the planned start of calving (01 August) each year. This was defined as a target average pasture cover of 2 000 ± 100 kg DM ha^{-1} and an average cow condition score of 5.0 ± 0.25. With the exception of spring grazing management, including the conservation strategy, and the provision of supplements used in spring to help generate cover contrasts, all management practices, including nitrogen fertiliser use, maintenance fertiliser application and summer forage crops, were balanced between the independent self-contained farmlets. In the spring the herbage conservation strategy used and the quantity of supplements fed were designed to meet the specific requirements of the treatments.

3.4.4 Grazing management

During spring, grazing management was targeted at maximising intakes consistent with good pasture control. When feed conserved on the farmlets was unavailable additional feed was purchased to maintain average pasture cover above 1 800 kg DM ha^{-1}. Herds were balanced for numbers in milk on 20 September with cows of similar age, liveweight and calving date. Herbage intake and cow production targets in summer were maximised by carrying high quality feed in front of the herd in an attempt to avert the late January/early February feed deficit often experienced in this area. When average farm cover exceeded 2 000 kg DM ha^{-1} for EC or 2 700 kg DM ha^{-1} for LC, or the rotation length exceeded 30 days, paddocks were removed from the rotation for later conservation. When cow condition fell below 4.0 or feed budgets showed calving targets were in jeopardy herds were dried-off, but not later than 20 May each year. Target pasture cover on 01 June was 2 000 ± 100 kg DM ha^{-1} and when necessary to meet the pasture cover target cows were fed silage. Winter rotations were set relative to pasture growth rates so as to either increase (90 days), maintain (75 days) or decrease (60 days) average pasture cover. During wet periods cows were fed supplements and/or stood-off pasture as separate herds.

3.5 Pasture measurements

The five representative "indicator" paddocks per treatment were used for all pasture sampling with the exception of estimates of farm cover and herbage digestibility (Section 3.5.1). Where possible sampling was done by the same person and at the same time each day to minimise bias.

3.5.1 Pasture cover, digestibility and proximate analysis

Average pasture cover for each farmlet was determined routinely throughout the trial using a rising plate meter. While walking diagonally across each paddock forty readings were taken and the total height within each paddock recorded. Readings were in front of the recorder's foot after every third step. Later, average height for each paddock was calculated by dividing total height by 40 and then converting to kg DM ha^{-1} using the dynamic calibration methodology described in Chapter Four.

Prior to the start of, and during this trial, average farm covers were recorded approximately fortnightly by the Dairy Farms Technician. During the trial, a second series of plate meter readings were taken by the Plant Science Technician. In 1993/94 and 1994/95 average farm cover was determined fortnightly and in 1995/96 weekly by the Plant Science Technician.

In conjunction with average pasture cover determination, herbage samples were collected during 1994/95 and 1995/96 from the next two paddocks in the round per treatment each week for near infrared spectrophotometer (NIRS) (Ulyatt *et al.* 1995) proximate analysis at AgResearch, Palmerston North. Walking across these paddocks pre-grazing herbage samples were clipped using hand shears to estimated grazing height. Samples were dried at 80 °C for 24 hours in a forced draught oven before being ground and stored in air-tight containers awaiting analysis. Values were returned for organic matter digestibility (OMD), metabolisable energy (ME), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), soluble carbohydrate (Sol CHO), lipid and ash content.

Pre- and post-grazing pasture covers were taken from series one and two average pasture cover measurements and grazing records for the three years of the trial. Paddocks grazed within three days of average pasture cover determination were adjusted by herbage accumulation rate (Section 5.2.5) to provide estimates of pre- and post-grazing pasture cover.

3.5.2 Pre- and post-grazing pasture cover, dry matter, digestibility and proximate analysis

At five random sites diagonally across indicator paddocks the material from two 0.1 m^2 quadrats was removed and combined (bulked) as one sample for herbage mass determination before (pre-grazing) and after (post-grazing) each grazing. Samples were cut to ground level with an electric shearing hand-piece. Cut herbage was washed and then dried at 80 °C for 24 hours in a forced-draught oven for dry weight determination (± 0.05 g). After weighing sample material was discarded.

Pre-grazing samples were taken for determination of dry matter percentage by cutting a hand-piece wide strip (75 mm) alongside each quadrat as close as practicable to ground level without the inclusion of soil. Samples were taken to the laboratory where their wet weight was accurately (± 0.05 g) determined and recorded. After 24 hours of drying in a forced draught oven at 80 °C the samples were removed from the oven and the dry weight accurately (± 0.05 g) determined and recorded.

For the last 2 years of the trial, a second strip (75 mm) was clipped alongside each quadrat as low as possible without the inclusion of soil, for digestibility analysis pre-grazing. Bulked within paddocks this herbage was taken to the laboratory and dried at 80 °C for 24 hours in a forced draught oven. The sample was mixed, a sub-sample taken, ground and stored in an air-tight container awaiting proximate analysis at AgResearch, Palmerston North using a near infrared spectrophotometer (NIRS).

In addition, 100 rising plate meter pasture height readings were taken from each paddock pre- and post-grazing while moving diagonally across the paddock. Average height from the paddock was recorded and converted to kg DM ha^{-1} using the dynamic calibration methodology described in Chapter Four.

3.5.3 Botanical composition

Samples were collected from indicator paddocks for determination of botanical composition in spring, summer, autumn and winter of 1993/94 and 1994/95. In 1995/96, samples were collected from 10 paddocks (five indicator paddocks plus five additional paddocks) per treatment pre- (December 95) and post-control (February 96) in December 1995. The paddocks sampled in 1995/96 were 2, 6, 27, 74 and 81 for EC and 15, 22, 26, 75 and 82 for LC, in addition to indicator paddocks.

At five random sites diagonally across each paddock a hand-piece wide (75 mm) strip approximately one metre long was cut to ground level with electric shears.

In the laboratory the herbage collected was mixed on the table and the sample halved. The herbage retained was again mixed and the sampled halved. This procedure was repeated until the quantity of herbage remaining was approximately 200 g fresh weight. The sub-samples were separated by hand into ryegrass leaf, ryegrass stem, ryegrass reproductive, other grass, white clover leaf, white clover stolon, white clover reproductive, red clover leaf, red clover stolon, red clover reproductive, senescent material (dead) and weed. For ryegrass, reproductive material was defined as a tiller with an emerged green seed-head. Components were dried in a forced draught oven at 80 °C for 24 hours and the dry weight accurately (± 0.005 g) determined and recorded. Subsequently, the proportion (%) of species components was calculated.

3.5.4 Species population densities

During 1993/94 and 1994/95 species population densities were monitored in spring, summer, autumn and winter from indicator paddocks. In 1995/96 tiller cores were collected from 10 paddocks (Section 3.5.3) per treatment pre- and post-control (December 1995 and February 1996, respectively) in December 1995.

Fifty tiller cores (53 mm diameter) were collected from random locations within each paddock post-grazing. In the laboratory counts were taken of ryegrass tillers, other grass tillers and weeds (tillers m^{-2}). White clover stolons were removed from the cores, bulked within paddocks, dried at 80 °C for 24 hours in a forced draught oven and weighed accurately (± 0.005 g).

3.6 Animal measurements

Where possible, the same person conducted sampling each time.

3.6.1 Liveweight and condition score

Unfasted liveweight and condition score were recorded for all animals at monthly intervals. Measurements were taken after morning milking and before the cows were returned to their respective paddocks. Cow liveweight was measured using Tru-Test electronic scales to the nearest kilogram. Condition scoring was performed by the same person throughout the trial and cows were assessed according to the visual assessment scale developed at Massey University, which is based on the degree of body fatness of the animals and ranges from 0 to 10 for thin to fat animals, respectively (Holmes & Wilson 1987).

3.6.2 Milk production and composition

Herds were milked in sequence through a 36-bail twin-style rotary platform. For most of each season herds were milked twice daily at approximately 6:30 am and 4:30 pm. Milk samples were taken fortnightly using a proportioning Milk Meter (Tru-Test Co., New Zealand) and the composition of representative milk samples was determined at the Livestock Improvement Corporation laboratory (Hamilton) by infra-red absorption (Milk-O-Scan; A/S N Foss, Denmark).

In addition, the quantity of milk obtained from each herd at each milking was recorded from the vat. Prior to 01 December 1995 this was done by reading the litres of milk in the vat off the sight glass and subsequently by recording the weight of milk in the vat using built-in load cells. Since the specific gravity of milk is slightly higher than that of water, litres of milk is obtained by dividing kilograms of milk by 1.03. Vat readings were cross checked against the volume of milk recorded on milk tanker collection chits.

3.6.3 Reproduction and calving

Reproductive performance of individual cows was recorded and monitored through the farm's use of the DairyWIN programme (DairyWIN 1998). This included calving dates and submission rates for individual cows.

3.7 Farmlet measurements

Complete records were kept of the quantities (kg) of supplements harvested from and fed out on each farmlet during the trial. Records were also kept of which paddocks were topped, the area and yield of forage crops, application of fertilisers and all other inputs.

3.8 Statistical analysis

Those data sets in which data were collected for both EC and LC on the same day were evaluated by analysis of variance (ANOVA) using the General Linear Models (GLM) procedure of SAS (SAS Institute Inc. 1995). Treatments were analysed as a completely randomised design (CRD) with paddocks or animals as replicates. Where appropriate, initial values where used as covariates.

For a number of the data sets collected conventional analysis (ANOVA and regression) was unsuitable since replicated data could not be collected for both treatments on the same day. Although it would have been possible to group data over time (weeks or months) and analyse the groups, the results of this type of analysis have not been presented here since the groups could have been arbitrary and may have affected the result. Rather, Bayesian Smoothing (Flexi 2.4, Wheeler & Upsdell 1997) was used to identify seasonal trends and detect treatment differences over time. Bayesian smoothers are mixed models with time being a random component with a high correlation between neighbouring points. Although the Bayesian smoother was instructed to look for 365 day patterns (Upsdell 1994), the frequency and amplitude of the cycles are unrestricted and sampling intervals irregular. To analyse seasonal data such as this by conventional methods would impose restrictions on these factors. Wheeler & Upsdell (1997) provide a brief comparison between conventional analysis (ANOVA and regression) and Bayesian smoothing. The covariance function was chosen to find seasonal patterns (Upsdell 1996). Bands representing the 95% confidence limits for the mean curve line were fitted and differences between treatments at 5% are indicated by separation of the bands.

3.9 Availability of raw data

Due to the size of the data set collected from No 4 Dairy Unit during the trial and used in this analysis, no attempt has been made to include the raw data in this thesis. The data is available in electronic form from the Pastures and Crops Group, Institute of Natural Resources, College of Sciences, Massey University.

Chapter Four

Development of a Dynamic Rising Plate Meter Calibration Equation which Accounts for the Seasonal Variation of Pasture Characteristics

4.1 Introduction

At the farm level accurately estimating the quantity of herbage present both pre- and post-grazing and in terms of farm average pasture cover has long been recognised as a key to achieving effective pasture management. Obtaining these measurements allows herbage accumulation rate, allowance and intake to be estimated, assisting the manager to achieve optimum use of the herbage produced. Herbage mass measurements are useful in closing the gap between pasture accumulation and pasture utilised while ensuring that cows are being fed adequately (Glassey 1983). It is therefore important to know exactly what feed is on hand or is being offered so that management can be adjusted accordingly.

While cutting to ground level (direct method) is the most accurate means of determining herbage mass, this method is both labour intensive and costly making it impractical on a farm scale (Thomson 1983). Over the last 30 years a number of indirect or non-destructive techniques have been developed and refined for quickly estimating the standing herbage mass of grazed swards. The methods most often used by researchers and farmers are visual assessment, capacitance meter (probe) and rising plate meter (RPM). Since indirect methods of sampling a pasture to measure herbage dry matter (DM) are quicker, more samples can be taken allowing large areas to be assessed. However, both the capacitance meter and rising plate meter require calibration equations to convert their readings to herbage mass and traditionally regression analysis has been used, often making use of a single equation. A number of researchers have investigated these techniques under New Zealand conditions individually (Bryant *et al.* 1971; Stephen

& Revfeim 1971; Thomson 1983) and collectively (Piggot 1986; Thomson 1986; L'Huillier & Thomson 1988; Thomson *et al.* 1997) against direct or destructive methods.

The rising plate meter is a relatively cheap, accurate and popular method of pasture assessment that reduces operator error (L'Huillier & Thomson 1988; Thomson *et al.* 1997). Researchers evaluating pasture meters recognised that the main source of variation was due to seasonal changes in the sward (Piggot 1986; Thomson 1986; L'Huillier & Thomson 1988) and L'Huillier & Thomson (1988) published a standard set of equations for seasons. While the use of the set of equations suggested by L'Huillier & Thomson (1988) for the whole of New Zealand goes some way to overcoming the problem of seasonal changes in the structure of the sward, their adoption is problematic since they involve arbitrary decisions about the time of change and the magnitude of the changes between equations. This chapter outlines a method of rising plate meter calibration which goes some way to overcoming the problems associated with seasonal changes in the sward and indicates how this technique could be used in the field and incorporated into feed budgeting and/or production recording software.

4.2 Materials and methods

As described in Chapter Three, rising plate meter heights were determined for all paddocks on a fortnightly basis, and pre- and post-grazing pasture covers were determined at each grazing for five indicator paddocks per treatment. The latter data set was used to derive a dynamic rising plate meter calibration methodology, while the former data set was used to compare average pasture cover calculated using a standard calibration equation, the set of equations provided by L'Huillier and Thomson (1988) and the dynamic calibration equation developed in this chapter.

4.2.1 Herbage mass per unit plate meter height

Historically, rising plate meter calibration equations (L'Huillier & Thomson 1988) were derived by regressing the quantity of herbage determined at individual quadrat sites against height as determined by the rising plate meter (i.e. sample based). The method developed here differed in that each pair of points represented paddock averages for both herbage mass and plate meter height (i.e. paddock based) (Section 3.5.2). The trial produced 621 pairs of herbage mass and plate meter height observations spread over three years. Winter produced fewer observations than other seasons due to the longer rotation length at this time of the year.

A preliminary evaluation of the pre- and post-grazing rising plate meter heights and herbage mass data by regression analysis (HM = a + b MR, where HM = herbage mass and MR = plate meter reading) revealed that logical groupings were difficult to detect. Weekly, fortnightly, monthly and seasonal groupings were trialed in addition to more arbitrary break points. While fortnightly and weekly groupings performed better than monthly and seasonal groupings there were simply too few observations for the period from late autumn through early spring. Grouping by month or season eliminated this problem, but caused large differences in estimated cover between equations. Consequently, a solution was sought which accounted for the seasonal variation of pasture characteristics.

In addition, this preliminary evaluation of pre- and post-grazing rising plate meter heights and herbage mass data included regression analysis without an intercept (HM = b MR) in conjunction with the procedure described above. After initially working with the data from 1995/96 followed by 1993/94 and 1994/95 separately, data from the three years was pooled since this provided more observations and it was difficult when appraised graphically to see differences between the years.

The date on which observations were recorded was converted to day of the year with day 01 representing 01 July. Winter was chosen as the "break point" since pasture structure was expected to be less changeable at this time of the year. Data was sorted first in chronological order within pre- and post-grazing sub-sets, although data were subsequently pooled. Pasture mass per unit plate meter height (mass per unit height) was determined by dividing paddock herbage mass values by mean plate meter height. One unit of plate meter height represents 5 mm semi-compressed pasture height by a 0.3 m square plate with a downward pressure of 4.5 kg m^{-2}.

Mass per unit height, as calculated above, might be thought of as the slope component (b) of a linear equation ($y = a + b\,x$) from a regression analysis without an intercept (a). A Kalman filter (Kalman 1960; Harvey 1981), with a measurement equation of $HM = a + b\ MR$, was also applied to the data. Specifying the measurement equation in this way allowed the estimates for intercept and slope to move in opposite directions (negatively correlated). The measurement equation was subsequently modified and the intercept ("a" parameter) removed since there was no apparent advantage in terms of predicted pasture cover values when the intercept was allowed to vary, or was fixed at 0, 500 or 1 000. The Kalman filter provided unbiased support for pooling the data and suggested that obtaining estimates of mass per unit height (slope) without an intercept was unbiased. Estimates were computed using the computer package "Time Series Processor" (TSP 1993).

A second data set was obtained, for comparative purposes, which had been collected at the Taranaki Agricultural Research Station (TARS), over four years commencing in February 1993 . Pasture mass cut to ground level using electric hand shears and rising plate meter heights were taken from within a 0.22 m^2 frame (i.e. sample based).

4.2.2 Fitting the Fourier model

The resultant mass per unit height values (b - slope) were modelled using a Fourier series of the form $y = a \sin x + b \cos x + c \sin 2x + d \cos 2x$, where a, b, c and d are coefficients, x is the day of the year and y is the plate meter height multiplier for that day (kg DM unit height^{-1}). That is, on any given day of the year the "b" parameter value of the plate meter calibration equation ($y = b$ MR) is given by the result of the multiplier prediction equation. Therefore, given the average plate meter reading for a paddock and the date of that reading average pasture cover can be calculated.

Regression equations were fitted using the General Linear Models (GLM) procedure of SAS (SAS Institute Inc. 1995).

4.3 Results

4.3.1 Introduction

This section presents a selection of results from the preliminary analysis which included regression analysis of weekly, fortnightly and monthly groups of observations, regression analysis and Kalman filtering with and without an intercept (a) and within and over years. Similarly, the results from separate pre- and post-grazing analyses are also presented here.

Figure 4-1 shows actual and estimated pasture cover values from calibration equations with and without an intercept in which the data has been grouped by month. To get enough data points over winter data for June, July and August were combined. Bayesian smoothing was used on the actual and estimated values to allow them to be compared. While these results suffer from the problems associated with changing from one equation to the next they are presented to illustrate that while the inclusion of an intercept value may be statistically sound its use does not for this data set result in any consistent difference in estimated mean pasture cover values. With the exception of summer 1993/94 and summer 1995/96, predicted mean pasture cover values are very similar whether the calibration equation with or without an intercept is used. During summer 1993/94 mean pasture cover from the calibration equations without an intercept is closer to the mean actual pasture cover, while in 1995/96 mean pasture cover from the calibration equation with the intercept is closest.

Figure 4-2 shows separate fitted Fourier curves for mass per unit height for EC and LC over three years. The fitted Fourier curves for EC and LC fall well within their respective 95% confidence intervals, demonstrating that, treatment had no effect and the observations were therefore combined (pooled). Similarly, Figure 4-3 shows mass per unit height and fitted Fourier curves for separate pre- and post-grazing observations over three years. While mass per unit height values (density) were marginally but consistently greater for post-grazing pasture cover than pre-grazing pasture cover, pasture cover observations were combined since the fitted Fourier curves fell within their respective 95% confidence intervals.

Figure 4-4 shows mass per unit height values and fitted Fourier curves for 1994/95 and 1995/96. Observations from 1993/94 were excluded from this particular analysis because the data set did not include observations for the first five months of the year. Observations were combined over years since there were no differences between years, as seen by the fitted Fourier curves being within their respective 95% confidence intervals.

Figure 4-1 Actual —*— and predicted, with ---•--- and without - - ○ - - an intercept pasture cover values (kg DM ha^{-1}) over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

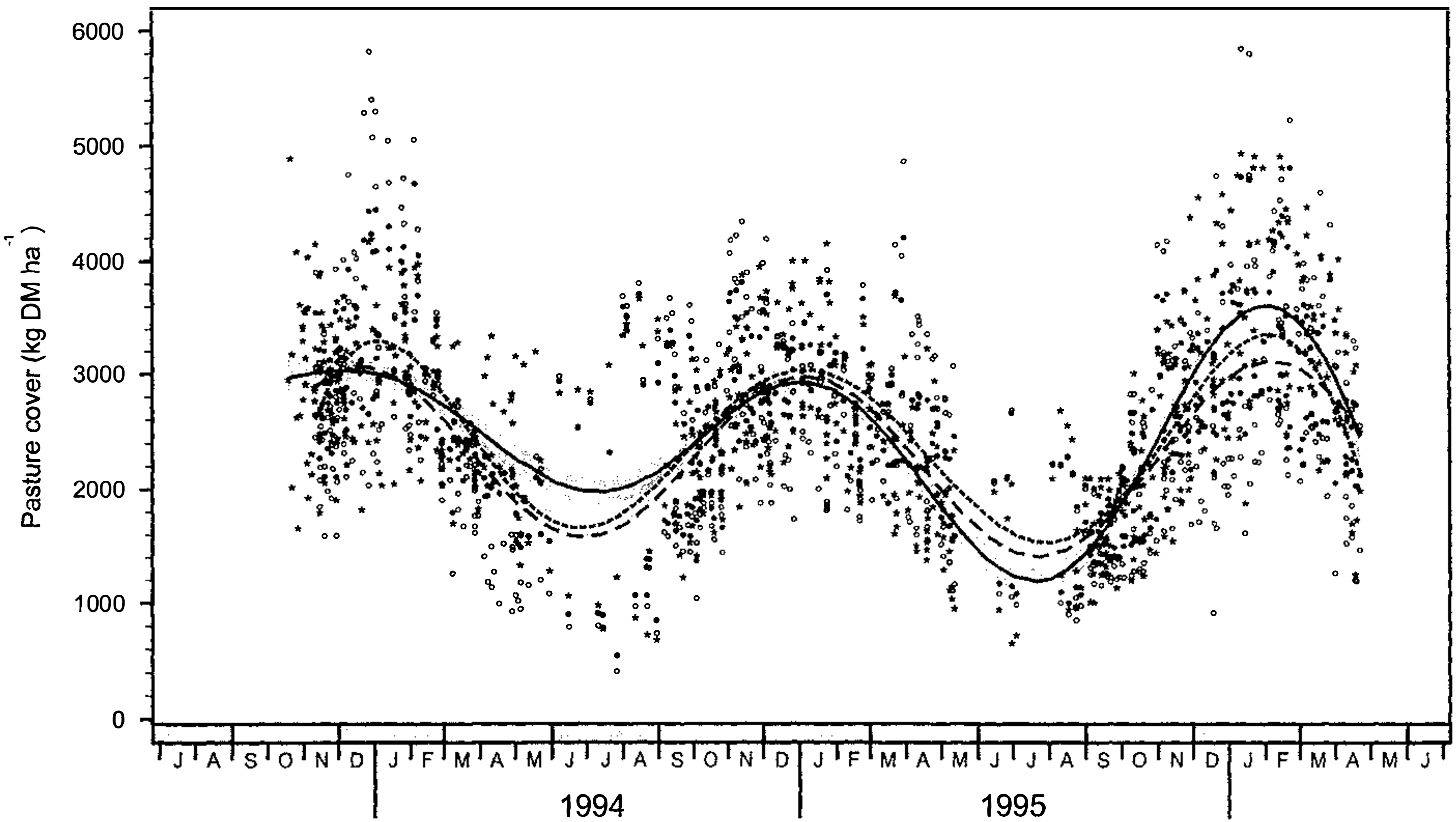
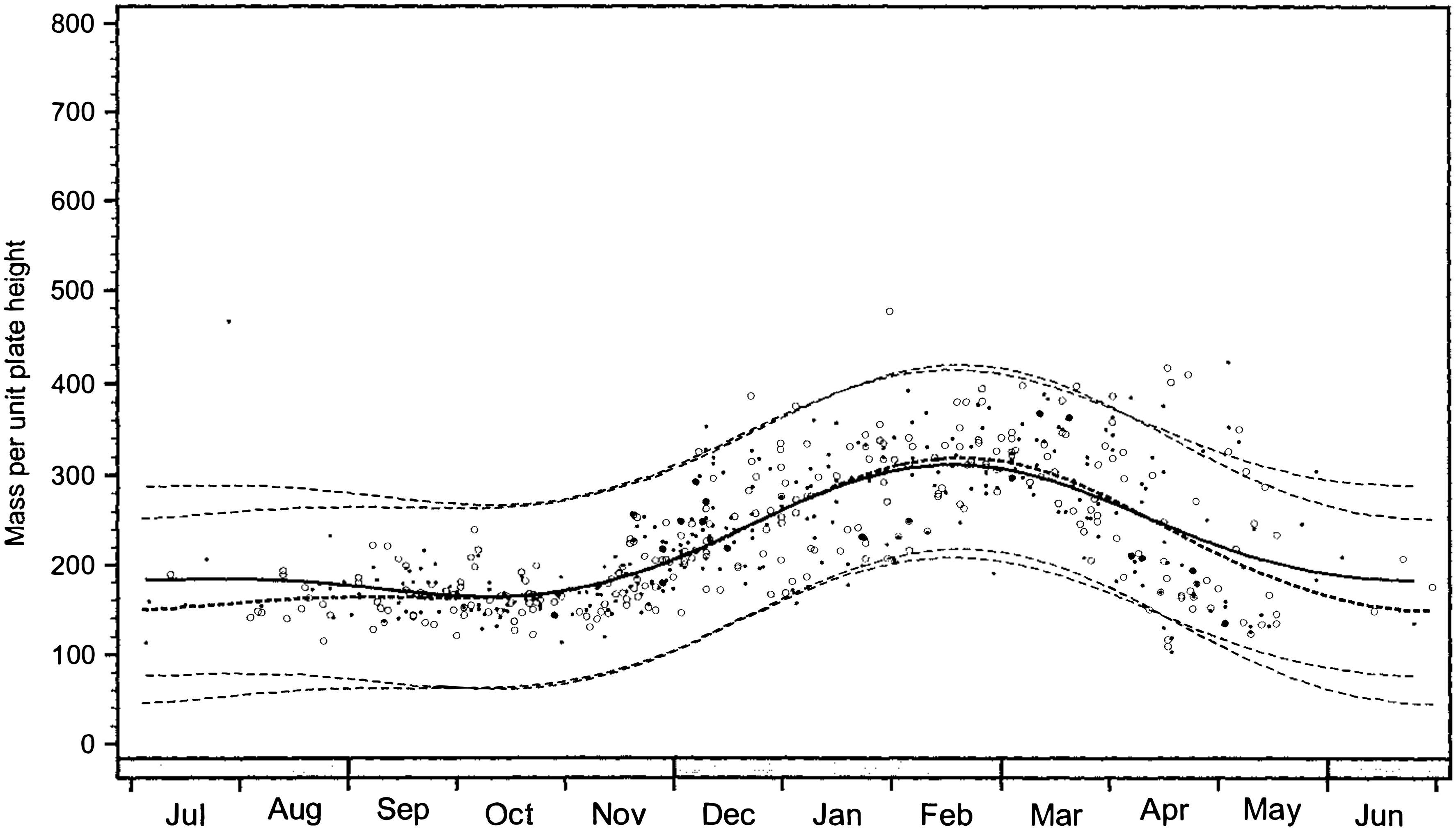


Figure 4-2 **Mass per unit height estimates and fitted Fourier curves for early control —•— and late control ---○---, and associated 95% confidence intervals - - - - for three years pooled data. Herbage mass units are kg DM ha^{-1} 5 mm^{-1} plate height (Section 4.2.1).**



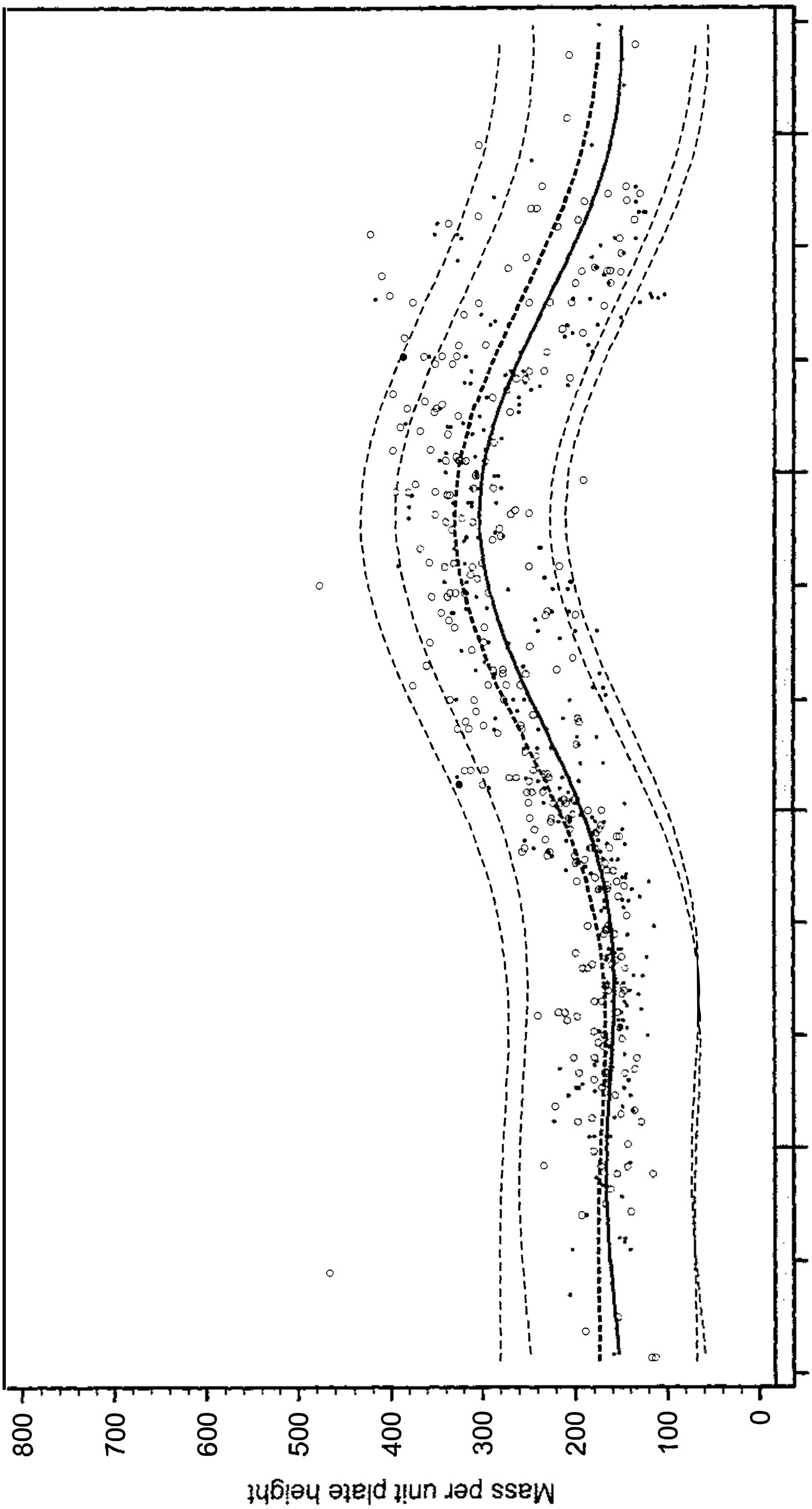
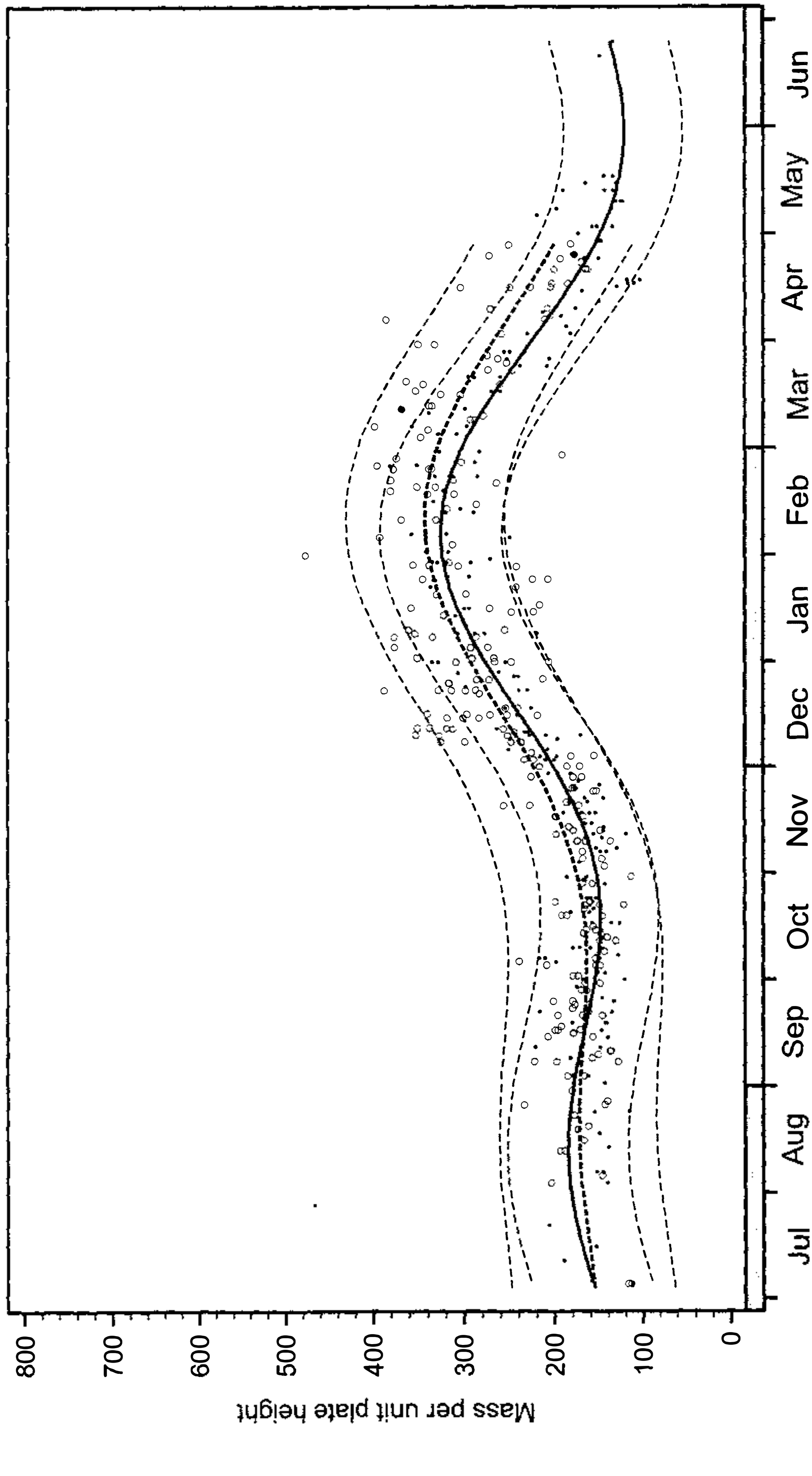


Figure 4-3 **Mass per unit height estimates and fitted Fourier curves for pre-grazing —•— and post-grazing ---○---, and associated 95% confidence intervals - - - - for three years pooled data. Herbage mass units are kg DM ha^{-1} 5 mm^{-1} plate height (Section 4.2.1).**

Figure 4-4 **Mass per unit height estimates and fitted Fourier curves for 1994/95 —•— and 1995/96 ---○--- and associated 95% confidence intervals - - - -. Herbage mass units are kg DM ha^{-1} 5 mm^{-1} plate height (Section 4.2.1).**

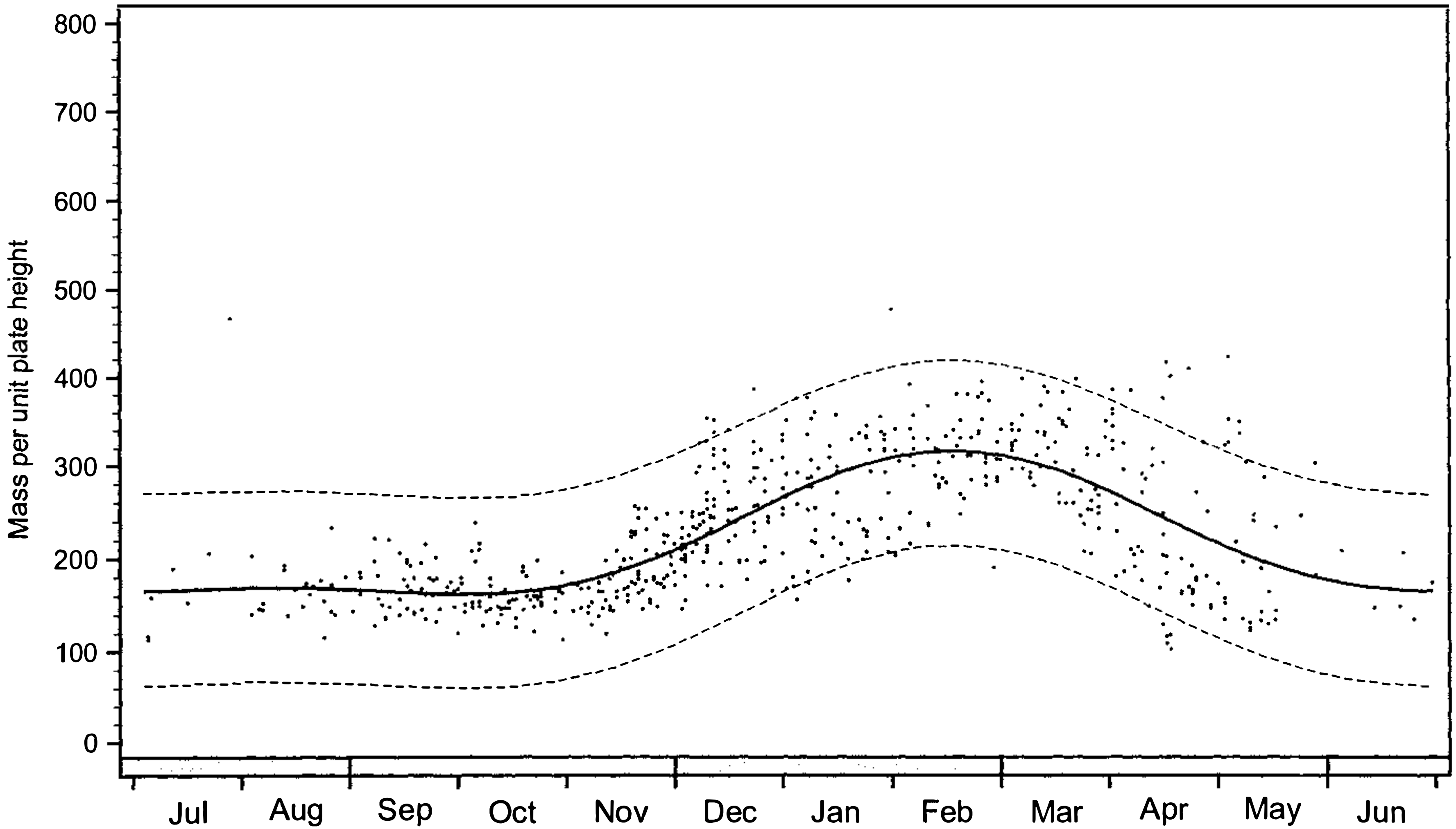


4.3.2 Model fitting

The mass per unit height estimates for each herbage mass and plate meter height observation (points) for No 4 Dairy Unit and TARS are shown in Figures 4-5 and 4-6, respectively. These points represent the quantity of herbage in each unit of plate meter height. These values were noticeably higher during summer than in winter with surprisingly few outliers, particularly for the No 4 Dairy Unit estimates (Figure 4-5). In addition to the main summer peak there was a small peak in late winter for TARS estimates (Figure 4-6). Estimates were more variable in spring and autumn than summer and winter for No 4 Dairy Unit, while least variable from mid spring to mid summer for TARS. Values were more variable for TARS than No 4 Dairy Unit, ranging from 100 to 550 and 125 to 400, respectively.

Parameter estimates for the fitted Fourier curves shown in Figures 4-5 and 4-6 are given in Table 4-1. The r^2 values for the fitted curves for No 4 Dairy Unit and TARS were 0.50 and 0.38, respectively, the lower value for TARS indicating more variability in the data set. Each unit of plate meter height represented approximately 175 kg DM ha^{-1} during winter, rising to 300 kg DM ha^{-1} in summer for No 4 Dairy Unit and 200 to 250 kg DM ha^{-1} during winter, rising to 400 kg DM ha^{-1} towards the end of summer for TARS. The Fourier curve fitted to the TARS data reflects the small peak in late winter for TARS estimates (Figure 4-6). With the exceptions of May and November mass per unit height values were higher for the data from TARS than No 4 Dairy Unit. The summer peak occurred in both data sets at the same time of year. Compared to No 4 Dairy Unit, TARS mass per unit height values increased over August relative to July and September. The Fourier intercept estimate for TARS was 20% higher than the intercept for No 4 Dairy Unit (Table 4-1).

Figure 4-5 No 4 Dairy Unit mass per unit height estimates ●, fitted Fourier curve —— and associated 95% confidence intervals - - - - for three years pooled data. Herbage mass units are kg DM ha^{-1} 5 mm^{-1} plate height (Section 4.2.1).



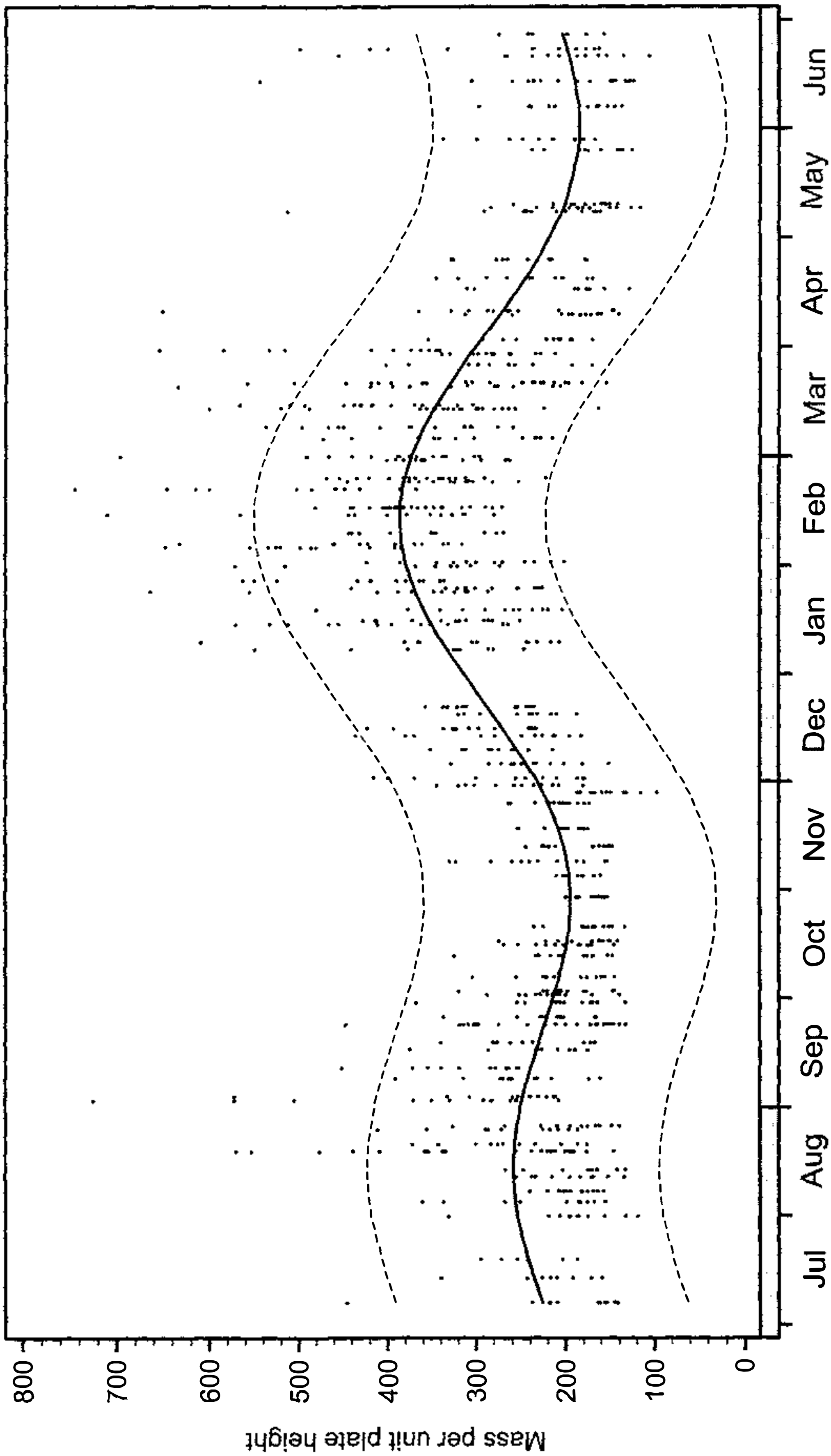


Figure 4-6 **TARS mass per unit height estimates ●, fitted Fourier curve —— and associated 95% confidence intervals - - - - for four years pooled data. Herbage mass units are kg DM ha^{-1} 5 mm^{-1} plate height (Section 4.2.1).**

Table 4-1 No 4 Dairy Unit and TARS fitted Fourier parameter estimates for three and four years pooled data, respectively.

Parameter	No 4 Dairy Unit		TARS	
	Estimate	SEM	Estimate	SEM
intercept	216.1054	2.76568	260.0754	2.65505
a	-52.3345	4.44544	-51.9092	3.92979
b	2.0286	3.56020	8.8688	3.72193
c	-51.6466	3.02767	-38.1837	3.43230
d	26.8058	3.18112	61.7051	3.59046

4.3.3 Average pasture cover

Predictions of average pasture cover taken from EC paddocks on No 4 Dairy Unit ranged from 1 250 kg DM ha^{-1} in winter to 3750 kg DM ha^{-1} in summer, 1 500 kg DM ha^{-1} during winter to 2500 kg DM ha^{-1} during summer and 1 750 kg DM ha^{-1} during winter to 3 750 kg DM ha^{-1} in summer for the dynamic calibration equation, the standard calibration equation used at No 4 Dairy Unit ($y = 405 + 166$ MR: origin unknown) and the set of equations provided by L'Huillier & Thomson (1988), respectively (Figure 4-7). Table 4-2 presents the dates covered by each of the equations taken from L'Huillier & Thomson (1988). The overall range between summer and winter was greatest for the dynamic calibration equation developed here and least for the standard equation, with the difference between summer peaks considerably larger than between the winter troughs. During summer average pasture cover peaks were up to 1 250 kg DM ha^{-1} higher from the dynamic calibration equation or the set of equations provided by L'Huillier & Thomson (1988) than for the standard equation. The dynamic calibration equation predicts average pasture cover to be 500 kg DM ha^{-1} lower than the standard calibration equation during winter, with the set of equations provided by L'Huillier & Thomson (1988) in between.

Figure 4-7 No 4 Dairy Unit average pasture covers (kg DM ha^{-1}) over three years derived using the dynamic calibration equation —●—, a standard calibration equation (HM = 405 + 166 MR) ---▵--- and the set of calibration equations from L'Huillier & Thomson (1988) -··-◇-··-. Arrows indicate change points for the set of calibration equations from L'Huillier & Thomson (1988).

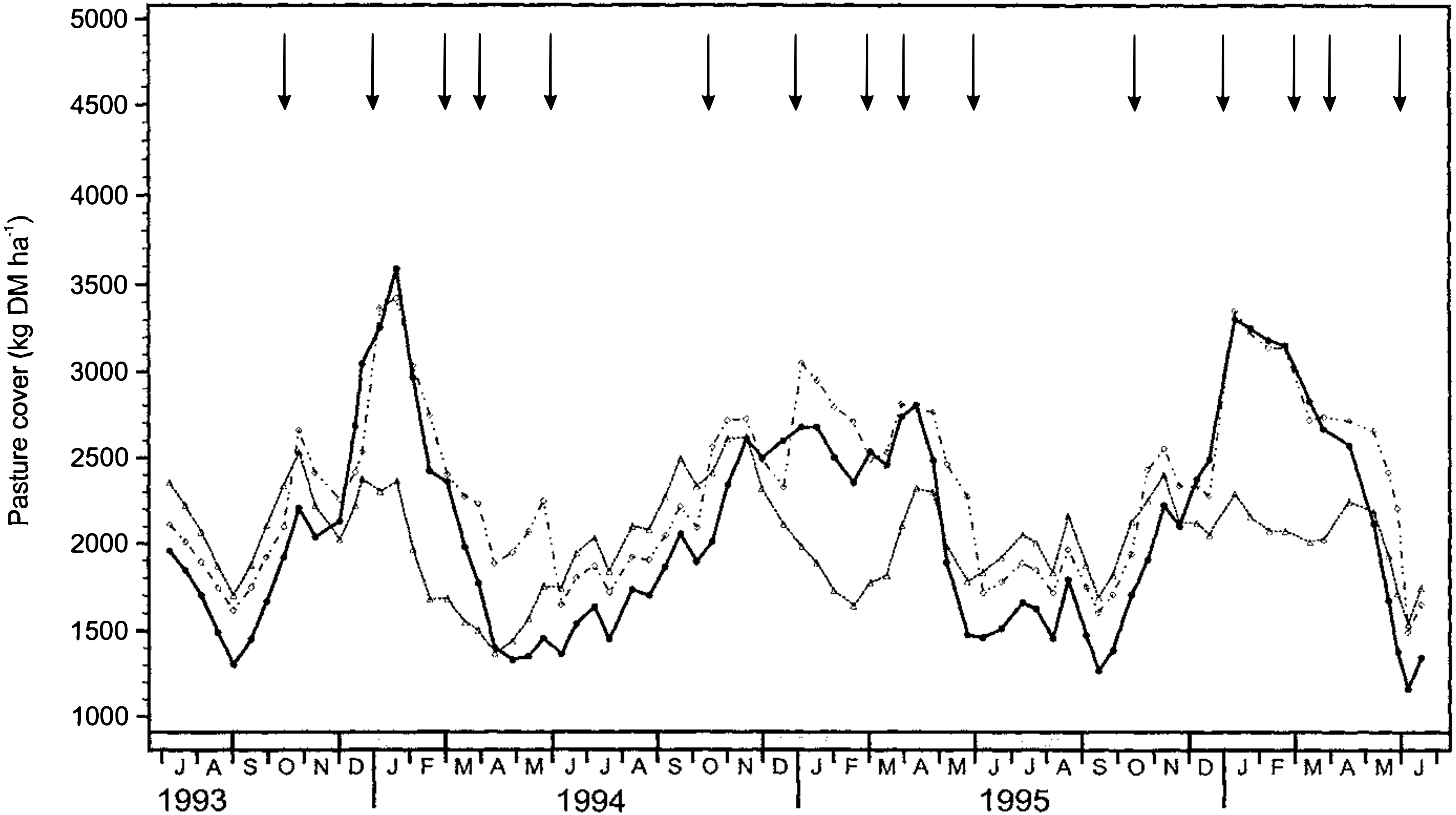


Table 4-2 Seasonal calibration equations from L'Huillier & Thomson (1988).

Season	Equation	Dates
Winter-early spring (before stem growth)	640 + 125 MR	01 Jun - 15 Oct
Late spring-early summer (during stem growth)	990 + 130 MR	16 Oct - 31 Dec
Mid summer	1480 + 165 MR	01 Jan - 28 Feb
-		
Early autumn (before autumn rain)	1180 + 159 MR	01 Mar - 31 Mar
Late autumn (after rain)	970 + 157 MR	01 Apr - 31 May

4.4 Discussion

Initially, the technique developed here was applied to observations for No 4 Dairy Unit from 1993/94, 1994/95 and 1995/96 individually. However, there was no significant difference between years when the mass per unit height values were modelled with the Fourier equation, therefore data was pooled across years. Differences between years were assessed by calculating and plotting 95% confidence intervals for the curve.

Although the No 4 Dairy Unit data set contained information on whether the observation (record) was collected pre- or post-grazing, this was not used in the final method, for practical reasons. Separate calibration equations for pre- and post-grazing would only be useful if determination of pasture cover was to be done exclusively pre- and post-grazing. With separate calibration equations, the problem of which calibration equation to use for paddocks grazed 5, 10, 15 and 25 days ago with a 30-day rotation length eventuates. Furthermore, calibration equations for pre- and post-grazing pasture cover were similar, although post-grazing mass per unit height values tended to be higher for post-grazing than pre-grazing. This is likely to be due to the removal of the upper less dense horizon and/or the cows having compressed, flattened or trampled the pastures during grazing. Based on the results of this analysis separate pre- and post-grazing pasture calibration equations would not be justified.

In the first instance, the fitted equation used in the Kalman filter was of the form HM = a + b MR, but the intercept parameter ("a") was subsequently removed. Having two parameters in the model ("a" and "b") meant that their values changed in a random and/or uncontrollable manner at each iteration while the results of the equation in terms of HM, given the same MR values, were very similar. While this alone is not a major problem, the resultant intercept parameter values were difficult to model and provided no significant improvement in predicted herbage mass values over the use of a simple y = b x model. L'Huillier & Thomson (1988) used slopes corrected to a common intercept in their analysis of seasonal variation, yet present calibration equations with both slope and intercept varying by season.

Once finalised the methodology developed was applied to the data set from TARS separately to see how well it performed on the data from another site. Data from No 4 Dairy Unit and TARS were not pooled in this analysis because one data set was paddock based while the other sample based. Ideally, additional years and sites are required to determine the applicability of both the relationships developed and the technique in general.

Mass per unit height values (slope) show a distinct seasonal pattern reflecting changes in the sward (Figures 4-5 and 4-6). As summer approaches, the proportion of reproductive material in the sward increases, the proportion of clover increases, dead material in the base of the pasture builds up and the dry matter content of pasture increases (Sections 5.2.4 and 5.2.9). This seasonal pattern was mirrored by fitting a Fourier curve providing an estimate of the slope for any day of the year (Figures 4-5 and 4-6). While L'Huillier & Thomson (1988) concluded that distinct seasonal patterns are evident and developed a method of predicting corrected slope for any day of the year they dismissed this approach as "involving too many calculations" and proposed a set of five seasonal calibration equations. The method developed here has the advantage that the calibration equation changes gradually throughout the year and is therefore more continuous than one or a series of seasonal calibration equations. This would avoid discontinuities in pasture cover estimates when changing between equations and give those who use the rising plate meter more confidence in the estimates.

The intercept estimates for the fitted Fourier equation can be thought of as the mean mass per unit height. The difference between TARS and No 4 Dairy Unit results suggest that on average pastures are denser at TARS than No 4 Dairy Unit over a whole year. Alternatively, the larger estimate from the intercept of the Fourier fitted to the TARS data could indicate that sampling was more thorough. That is, when samples were collected from TARS more material was removed from the base of the sward than from the pastures of the spring grazing management trial at No 4 Dairy Unit. However, Thomson *et al.* (1997) found no difference in sampling efficiency between Massey University and TARS technicians. The TARS technician removed 3 040 kg DM ha^{-1} and the Massey University technician removed 2 920 kg DM ha^{-1} from plots at Massey University. Therefore, differences in pasture density seem the most likely explanation for the differing mass/height relations.

The reason that the values of mass per unit height for TARS were more variable, resulting in wider 95% confidence intervals, than those for No 4 Dairy Unit may be related to the method of collection. For TARS, each observation pair (cut and plate pair) represents the herbage mass at a single sample site (sample based), whereas each observation for No 4 Dairy Unit represents the average herbage mass of five sites within a paddock (paddock based). Since taking many samples from within a paddock is often used to reduce variability, it is not surprising that paddock based sampling has reduced variability.

Predicted mean mass per unit height values for No 4 Dairy Unit were generally lower than for TARS, with the exception of May and November. Values peaked in February for No 4 Dairy Unit and TARS at almost twice those of winter and autumn. The smaller winter peak seen in TARS estimates was not seen in No 4 Dairy Unit values. The reason for this peak is unclear, although it may reflect genuine differences in seasonal management (e.g. a long rotation length), but may also be due to the greater number of sample points in winter and therefore sharper definition of the TARS data.

Average farm cover calculated using the dynamic calibration equation (the method developed in this paper), a standard calibration equation (y = 405 + 166 MR) and the set of equations from L'Huillier & Thomson (1988) are shown in Figure 4-7 for No 4 Dairy Unit EC pastures during 1993/94, 1994/95 and 1995/96. Cover values range more widely between winter and summer when the dynamic calibration equation is used. This may be expected since the standard calibration equation has to approximate pasture cover for the entire year and therefore is "correct" for only a short time. Users of the rising plate meter often lose confidence in cover estimates during summer and the differences shown in Figure 4-7 go some way to explaining this. It should be noted that the large quantity of herbage measured by the dynamic calibration equation during summer includes a large quantity of senescent material in the base of the sward. These values are also inflated due to the high dry matter percentage of the pasture at this time of the year (Section 5.2.4). The result of this is that considerably less herbage is directly available to the grazing animal than suggested by average cover and may impact on the level of intake attainable. Green herbage mass may have been a more useful measurement at that time of the year, but requires additional data to calculate, adding further complexity to herbage mass determination (L'Huillier & Thomson 1988). Furthermore, total herbage mass is often underestimated by visual assessment during late spring-early summer due to accumulation of dead material in the lower horizons of the canopy, and expressing pasture cover in green herbage mass terms can provide a better comparison for pasture targets (Butler 1986).

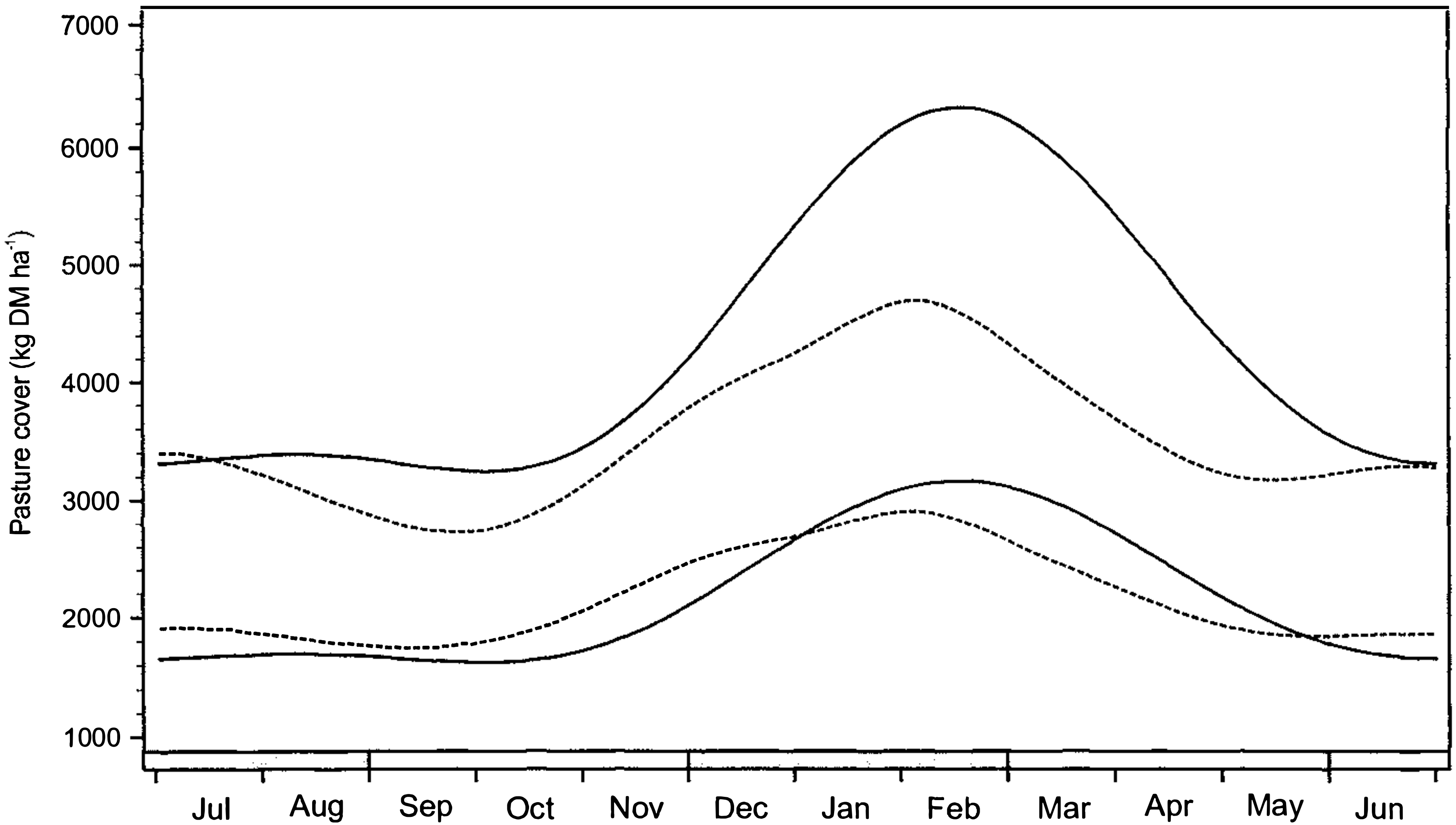
When using a set of seasonal calibration equations, such as those of L'Huillier & Thomson (1988), there is an arbitrary decision as to when to change from one equation to the next (points arrowed in Figure 4-7). On the day of change, herbage mass estimates can increase or decrease by several hundred kg DM ha^{-1} which also affects the calculated values of accumulation rates, covers, allowances and intakes (e.g. Figure 4-7, L'Huillier & Thomson (1988) series, May/June and December/January 1994). Since changing from one equation to another initially creates a data discontinuity fewer equations would be better, but potentially this also makes the difference when changing over larger and those estimates immediately before and after changing over less accurate. Furthermore, the changeover date, as specified (Table 4-2), will be different for different localities and between years.

Hainsworth (1999) recently released plate meter calibration equations for seasonal variation which include 'Multiplier' and 'Adder' components. The equations developed are based on "a massive amount of pasture calibration data from research farms in Waikato, Taranaki and Manawatu over many years". The approach, which is an improvement on previous recommendations, is similar to that developed in this chapter with the inclusion of an intercept ('Adder'), representing the amount of dry matter present when the plate meter reading is zero, that is, the pasture mass is unmeasurable by the plate meter. However, unless pastures are measured that record a zero reading on the plate meter this is an arbitrary value. Furthermore, the inclusion of both a 'Multiplier' and an 'Adder' makes the process of working out the pasture mass more complex and masks the real changes in the sward that are occurring over the year, since at some times of the year the two factors move in the same direction and at other times in opposite directions. While the inclusion of an intercept may be justifiable on statistical grounds, it was found in the systems trial to have no effect on the ability of the resultant calibration equations to estimate pasture mass.

Figure 4-8 shows average pasture cover values for a constant plate meter height of 10 and 20 units (50 mm and 100 mm respectively, Section 4.2.1) using the dynamic calibration equation and the calibration equations recommended by Hainsworth (1999). For the dynamic calibration equation developed here the summer peak in pasture cover is twice that of winter for both the 10 and 20 unit lines, while for the equations presented by Hainsworth (1999) pasture cover estimates are 1.74 and 1.61 times higher in summer than winter for 20 and 10 units, respectively. That is, compared to the system developed here the calibration equations of Hainsworth (1999) give pasture cover estimates with a smaller range between the summer peak and winter minimum and may reflect differences between regions, since the calibration equations of Hainsworth (1999) include data from Taranaki and Waikato, in addition to Manawatu. Furthermore, the pasture cover estimates from the calibration equations reported by Hainsworth (1999) dip in early spring at higher plate meter values (e.g. 20 units).

While the Fourier equation lends itself to being incorporated into computer based feed budgeting software, monthly, fortnightly, 10 day or weekly values could all be tabulated. This would allow plate meter users to calculate herbage mass in the field or without computer facilities. Since an intercept has not been included the calculation from plate meter height to herbage mass would simply require the user to multiply height by the appropriate multiplier from a set of tables. Users should be encouraged to use the tabulated value for the appropriate week rather than the appropriate month since this provides the best cover estimates and minimises differences due to changing from one equation to another. Many of the points raised here in relation to the frequency of changing the calibration equation are also applicable to the existing calibration equations used for the pasture probe.

Figure 4-8 Average pasture covers (kg DM ha^{-1}) using the dynamic calibration equation —— and the calibration equation of Hainsworth (1999) ------ at a constant plate meter height of 10 (bottom) and 20 (top) units equivalent to 50 mm and 100 mm respectively (Section 4.2.1).



The dynamic rising plate meter calibration equation for No 4 Dairy Unit developed in this chapter is used routinely in Chapter Five to predict herbage mass. Since the data collected at No 4 Dairy Unit with the rising plate meter was used to determine average pasture cover, separate pre- and post-grazing calibration equations were not pursued. Applying the methodology to observations from TARS showed that this technique could be used at other sites.

The calibration equations presented in this paper were derived from the data collected on two farms, one in the Manawatu and the other in the Taranaki region, over three and four years respectively and as such may not be applicable to other localities. The technique outlined in this paper could be extended to other locations as suitable data sets become available, either by combining data sets to give one equation for the entire country, or more likely by providing suitable parameter values on a regional basis.

4.5 Conclusions

Accurate pasture assessment is an important aid to achieving optimal production. The rising plate meter can provide a relatively cheap and potentially accurate estimate of the herbage mass of an area. Herbage mass predictions from the rising plate meter during spring are considered by users to be relatively reliable but there are severe reservations about summer predictions. Many rising plate meter users use only one calibration equation all year round, since they are unsure when to change over and do not easily accept the change in cover from one day to the next when changing equations. Using only one calibration equation provides a correct assessment of pasture cover for a relatively short period of time, since it is an average of the whole year. The method of rising plate meter calibration developed here is likely to provide users of the plate meter with a more accurate estimate of herbage mass, particularly when the plate meter height multiplier is calculated daily or reasonably frequently. The principles discussed in relation to the rising plate meter are applicable to the pasture probe and warrant further investigation.

Chapter Five

Results, Discussion and Conclusions from the Spring Grazing Management Trial

5.1 Introduction

In this chapter the results, discussion and conclusions from the spring grazing management trial described in Chapter Three are presented.

5.2 Pasture measurements

5.2.1 Grazing interval

Grazing interval was obtained by calculating the difference between the dates of successive grazings for all paddocks within each treatment. Therefore, grazing intervals as reported here represent the amount of time taken for the animals to return to a paddock and not necessarily the amount of time of the regrowth interval, particularly during winter when rotation length is longer and a herd may be on the same paddock for several days.

Figure 5-1 shows grazing interval during the trial which ranged from a minimum of 20 days during spring and summer each year and peaked at approximately 96 days in 1994 and 76 days in 1995. Grazing intervals on the LC farmlet were initially lower at 10 days. Bayesian smoothing indicates that grazing interval on the LC farmlet was longer than the EC farmlet during January 1994, May 1994, August 1995 and November 1995.

Figure 5-1 Grazing intervals (days) for early control —●— and late control --○-- paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

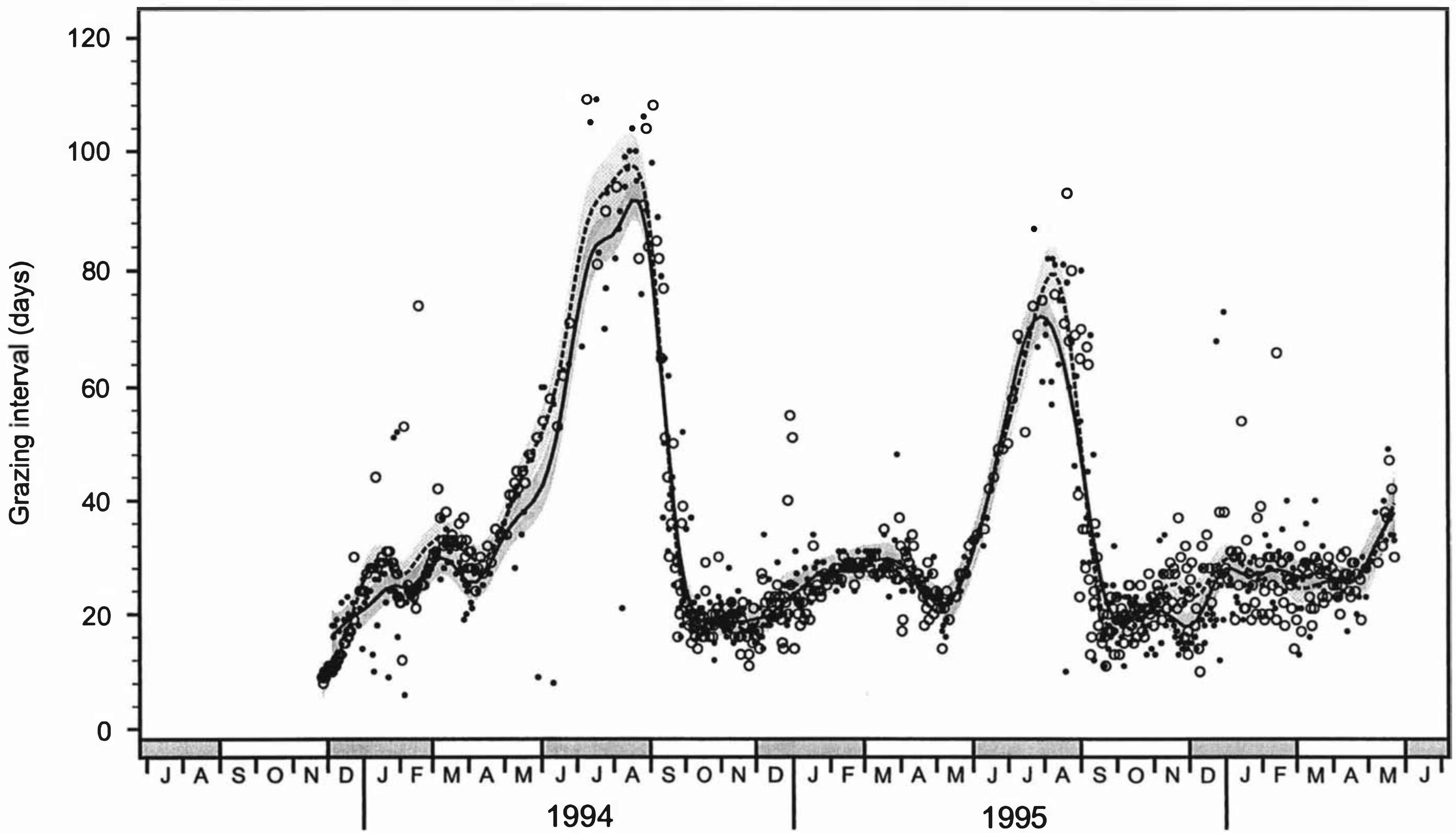


Table 5-1 Monthly grazing intervals (days) from all paddocks for early control and late control over three years.

	Treatment			
Month	Early control	Late control	SEM	P
1993/94				
November	-	9.1	0.23	-
December	18.4	14.4	0.94	0.0050
January	24.7	28.6	1.65	0.1042
February	23.6	28.6	2.75	0.2028
March	28.6	33.5	0.83	0.0002
April	27.2	30.1	1.01	0.0513
May	36.0	43.3	2.69	0.0710
June	52.0	59.6	7.22	0.4763
1994/95				
July	86.3	93.3	7.65	0.5417
August	88.6	91.0	6.79	0.8146
September	46.3	45.3	5.25	0.8900
October	20.3	19.1	0.76	0.2662
November	18.7	18.0	0.52	0.3440
December	20.3	23.0	1.38	0.1642
January	26.3	24.1	1.26	0.2221
February	27.8	27.6	0.43	0.7316
March	30.2	28.7	0.89	0.2576
April	25.5	25.4	0.81	0.8960
May	22.7	23.1	1.03	0.8228
June	39.0	40.9	2.56	0.6162
1995/96				
July	66.6	63.0	3.93	0.5280
August	63.9	65.1	5.62	0.8808
September	29.4	27.9	3.27	0.7447
October	19.1	19.8	0.61	0.4477
November	19.9	23.9	1.09	0.0114
December	23.4	25.9	2.71	0.5107
January	25.9	28.5	1.38	0.1851
February	28.3	26.1	1.82	0.3945
March	26.5	25.4	1.10	0.4685
April	25.3	25.7	0.74	0.6539
May	37.3	36.4	2.35	0.8011

Table 5-1 gives monthly grazing interval values. During spring, grazing interval fell to approximately 18 days and peaked at 90 days during the winter of 1994 and 65 days during the winter of 1995. Grazing intervals were longer on EC in December 1993, although this was subsequently reversed. During autumn 1994 grazing interval was longer on LC than EC, as it was in November 1995. Figure 5-1 and Table 5-1 showed similar results for grazing intervals.

5.2.2 Average pasture cover

Figures 5-2 and 5-3 show average pasture cover values over three years for the two series of measurements, recorded by different people (Section 3.5.1). Readings for the two series were taken on alternate weeks, with the exception of 1995/96 where additional readings were taken in series two. In general, the trends seen in Figure 5-2 are also evident in Figure 5-3, although the absolute values are not always in agreement. Average pasture cover was calculated from plate meter heights using the dynamic calibration equation presented in Chapter Four, which accounts for seasonal variation.

During 1993/94 average pasture cover ranged (Figures 5-2 and 5-3) from 1 200 kg DM ha^{-1} during winter to 3 600 kg DM ha^{-1} in summer. In 1994/95 average pasture cover ranged (Figure 5-2) from 1 300 kg DM ha^{-1} during winter to 3 100 kg DM ha^{-1} in summer. Average pasture cover values were approximately 500 kg DM ha^{-1} higher and more variable in the second series (Figure 5-2) during 1994/95. In the final year (Figure 5-2), average pasture cover ranged from 1 200 kg DM ha^{-1} during winter to 3 800 kg DM ha^{-1} in summer with values approximately 500 kg DM ha^{-1} higher in the second series (Figure 5-3).

Average pasture cover was higher on the LC farmlet than on the EC farmlet during spring in all three years. In addition, average pasture cover tended to be higher on the LC farmlet than the EC farmlet during summer of 1995/96 (Figures 5-2 and

5-3). For winter and autumn in all years average pasture covers were similar for the EC and LC farmlets.

5.2.3 Pre- and post-grazing pasture cover

Bayesian smoothing was used to analyse pre- and post-grazing pasture cover since samples were collected as and when indicator paddocks came up for grazing during the three years of the trial. A seasonal trend was imposed on the smoothing process. Treatment differences at 5% are indicated by separation of the bands. Figures 5-4 and 5-5 show pre- and post-grazing pasture cover respectively for indicator paddocks over three years. Average pre-grazing pasture cover peaked at 3700 kg DM ha^{-1} in summer 1993/94 and 1994/95, falling to 2500 kg DM ha^{-1} during the first winter. In the winter of 1995/96 pre-grazing pasture cover was only 1500 kg DM ha^{-1}, peaking at over 4500 kg DM ha^{-1} in summer. Separation of the bands in Figure 5-4 indicates that there were differences in pre-grazing pasture cover in the summers of 1993/94 (350 kg DM ha^{-1}) and 1994/95 (300 kg DM ha^{-1}) and in the spring of 1995/96 (500 kg DM ha^{-1}), with LC higher than EC.

Average post-grazing pasture cover peaked earlier for LC than EC in the summer of 1993/94 at 2900 and 2500 kg DM ha^{-1}, respectively. In the following winter post-grazing pasture cover was 1200 kg DM ha^{-1}, increasing to 2600 kg DM ha^{-1} in the spring of 1994/95. Post-grazing pasture cover was at its lowest level during the final winter at 750 kg DM ha^{-1}, increasing to its highest of 3200 kg DM ha^{-1} by summer 1995/96. There were differences in average post-grazing pasture cover between treatments in the late spring/early summer of all three years. They were 500, 200 and 350 kg DM ha^{-1} in 1993/94, 1994/95 and 1995/96 respectively, with LC higher than EC.

Figure 5-2 Series one average pasture covers (kg DM ha^{-1}) for early control —●— and late control --○-- paddocks over three years. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control ● and late control ○ means (n = 20).

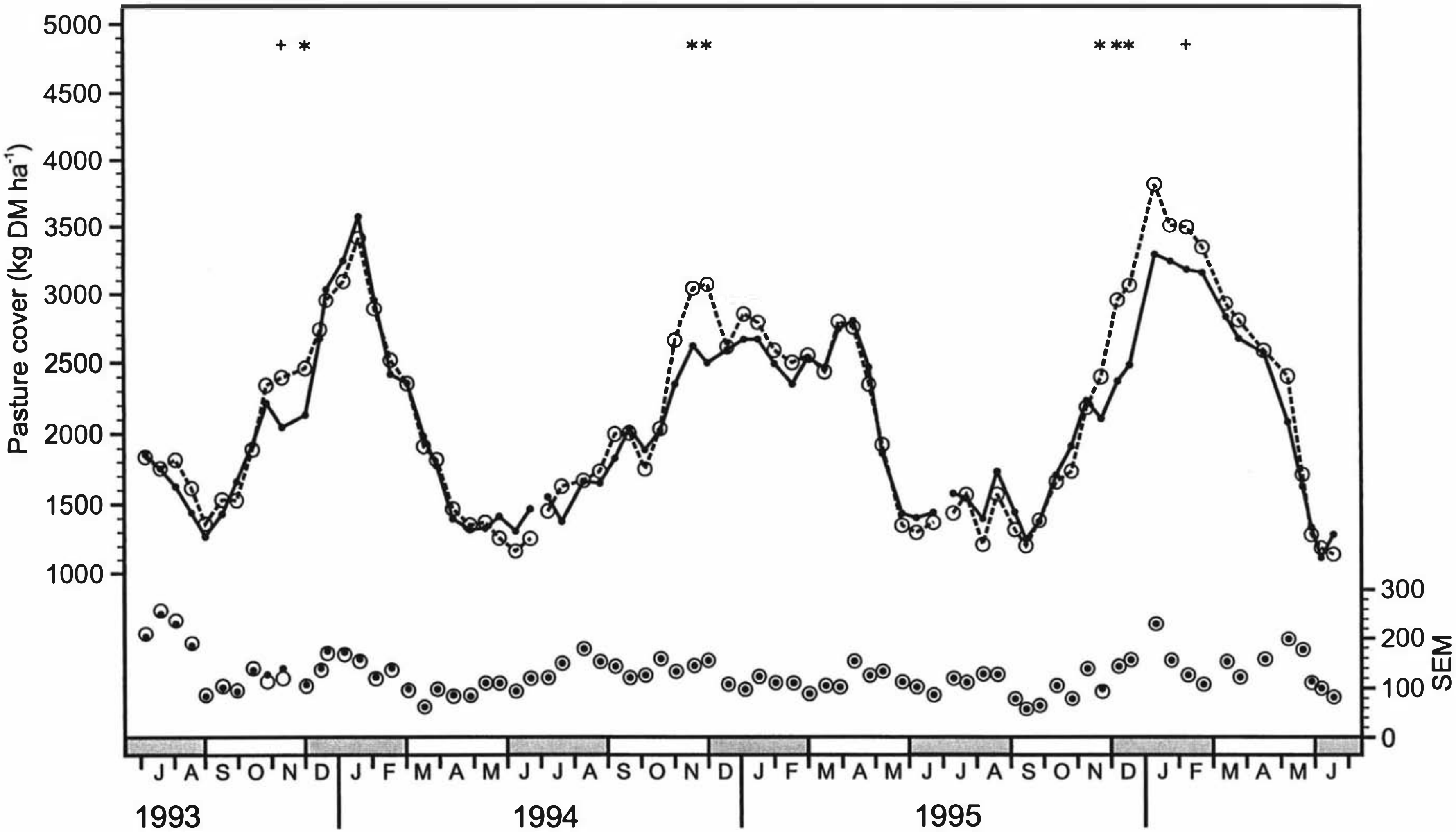


Figure 5-3 **Series two average pasture covers (kg DM ha⁻¹) for early control —●— and late control --○-- paddocks over three years. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control ● and late control ○ means (n = 20).**

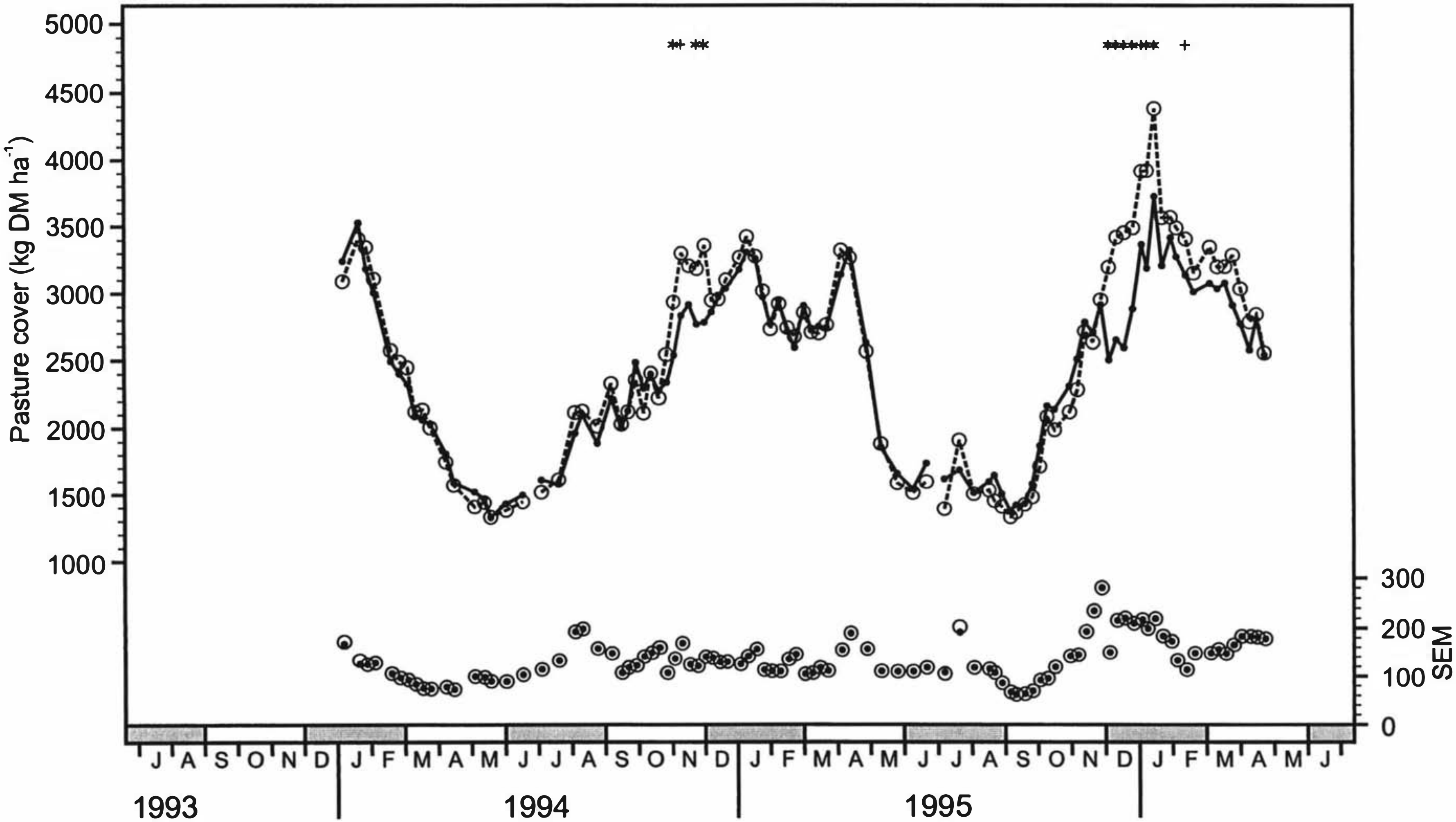


Figure 5-4 Pre-grazing pasture cover (kg DM ha^{-1}) for early control —●— and late control - -o- - indicator paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

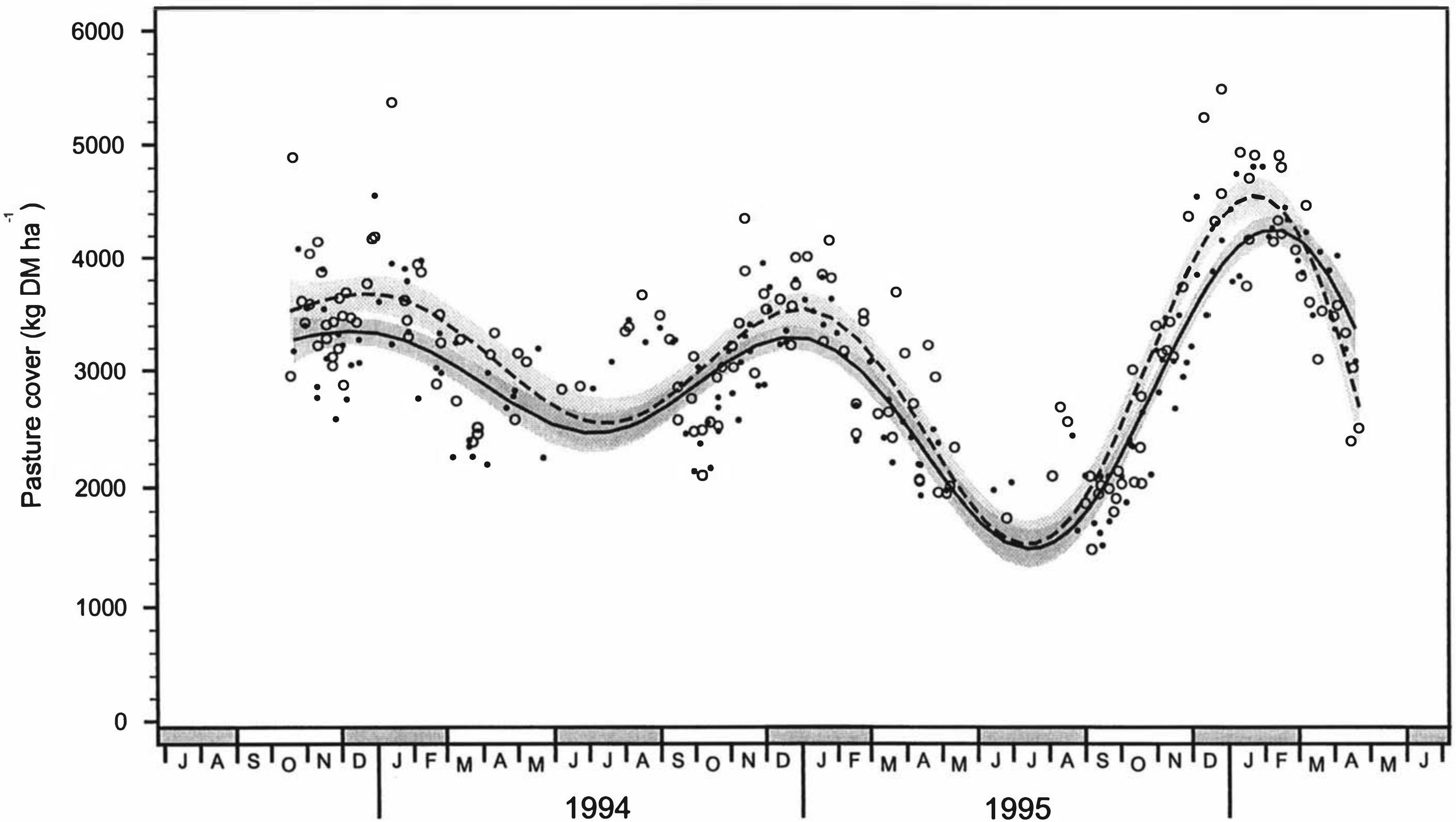


Figure 5-5 Post-grazing pasture cover (kg DM ha^{-1}) for early control —●— and late control - -o- - indicator paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

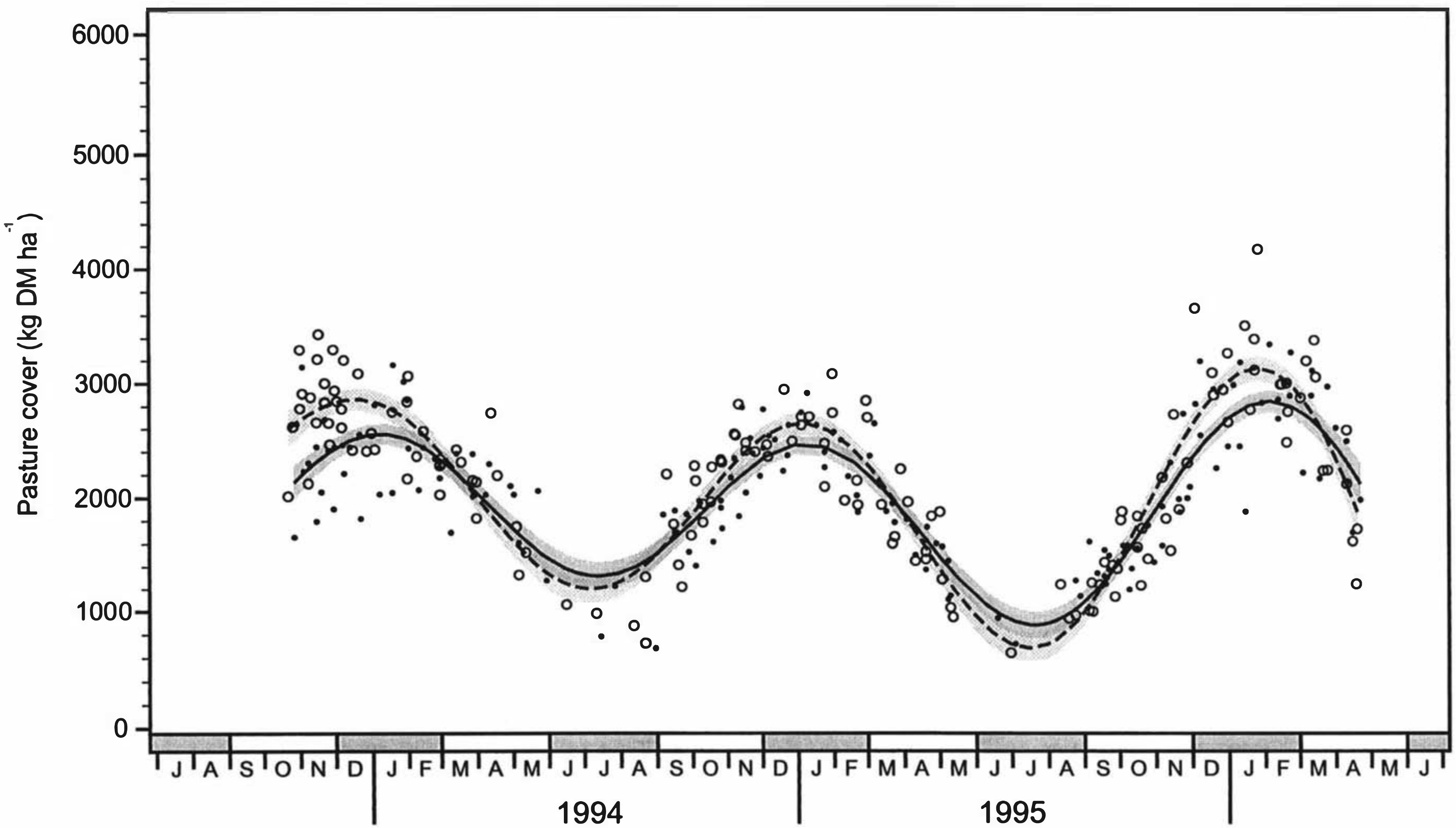


Table 5-2 gives pre-grazing (pre-control pre-grazing) pasture cover values for October and November and post-grazing (post-control post-grazing) pasture cover values for January and February over three years from indicator paddocks. Prior to December LC paddocks were intended to maintain higher pasture covers (application of treatments) after which time covers were to be equivalent on both treatments. During December pasture covers were reduced on LC to match those of EC (Section 3.3). Pre-control pre-grazing pasture covers were higher on the LC farmlet than on the EC farmlet during November each year and magnitude of the difference increased year by year. However, pre-control pre-grazing pasture covers were not different in October of any year. Post-control post-grazing pasture covers were similar on both treatments by February in all three years, although higher on LC than EC during January 1996.

Table 5-2 Pre-control pre-grazing and post-control post-grazing pasture covers (kg DM ha^{-1}) from indicator paddocks for early control and late control over three years.

Date	Treatment		SEM	P
	Early control	Late control		
Pre-control pre-grazing				
Oct 93	3630	3820	568.5	0.8284
Oct 94	2650	2590	118.0	0.7567
Oct 95	2260	2370	134.0	0.5690
Nov 93	3260	3490	113.2	0.1553
Nov 94	3110	3510	160.2	0.1030
Nov 95	3090	3490	127.4	0.0447
Post-control post-grazing				
Jan 94	2690	2460	169.7	0.3639
Jan 95	2590	2630	117.4	0.8002
Jan 96	2660	3390	232.5	0.0579
Feb 94	2290	2440	110.1	0.3419
Feb 95	2230	2230	169.8	0.9934
Feb 96	3010	2840	115.1	0.3350

Figures A5-1 through A5-4 (Appendix Five) show pre- and post-grazing pasture covers calculated from series one and two average farm cover values (Section 5.2.2). Series one pre- and post-grazing values are presented in Figures A5-1 and A5-2, respectively, and series two in Figures A5-3 and A5-4. Pre-grazing pasture cover ranged from 2 000 kg DM ha^{-1} in winter to 3000 kg DM ha^{-1} in summer 1994/95 and 3 500 kg DM ha^{-1} in summer 1995/96 for series one. Series one post-grazing pasture cover ranged from 1 000 kg DM ha^{-1} during winter, peaking at 2500 kg DM ha^{-1} in summer. There were no apparent differences between treatments in series one for either pre- or post-grazing pasture covers. For series two, pre-grazing pasture cover fell to 2000 kg DM ha^{-1} in the winters of 1994 and 1995. Both LC and EC pastures peaked at 3 750 kg DM ha^{-1} in summer 1994/95, however, LC peaked earlier than EC giving a marginal difference between the treatments. Late control peaked approximately one month before EC in summer 1995/96 and some 800 kg DM ha^{-1} higher than EC at 4 000 kg DM ha^{-1}. While pre-grazing pasture cover values were higher on the LC farmlet than the EC farmlet, there was no apparent difference between treatments in post-grazing pasture cover which ranged from 1 200 to 2 800 kg DM ha^{-1} in winter and summer respectively.

Pre- and post-grazing pasture covers showed similar seasonal trends between series one and two (Appendix Five) with the troughs (winter) and peaks (spring) occurring at roughly the same time of the year. The range of pre-grazing values was larger for series two than series one by 500 - 750 kg DM ha^{-1}, in particular the spring peaks (Figures A5-1 and A5-3 respectively). In contrast to series one, series two indicated that average pre-grazing pasture cover was higher on LC than EC during the springs of 1994/95 and 1995/96 (Figure A5-3). Average post-grazing values were similar in both series one and series two (Figures A5-2 and A5-4 respectively). Pre-grazing pasture cover from indicator paddocks (Figure 5-4) and series two pre-grazing pasture cover calculated from average pasture cover provide similar results in both absolute values and treatment differences. Series one pre-grazing pasture cover calculated from weekly pasture measurements suggested no treatment differences and lower covers in spring, in contrast to pre-grazing pasture cover from indicator paddocks and series two pre-grazing pasture cover.

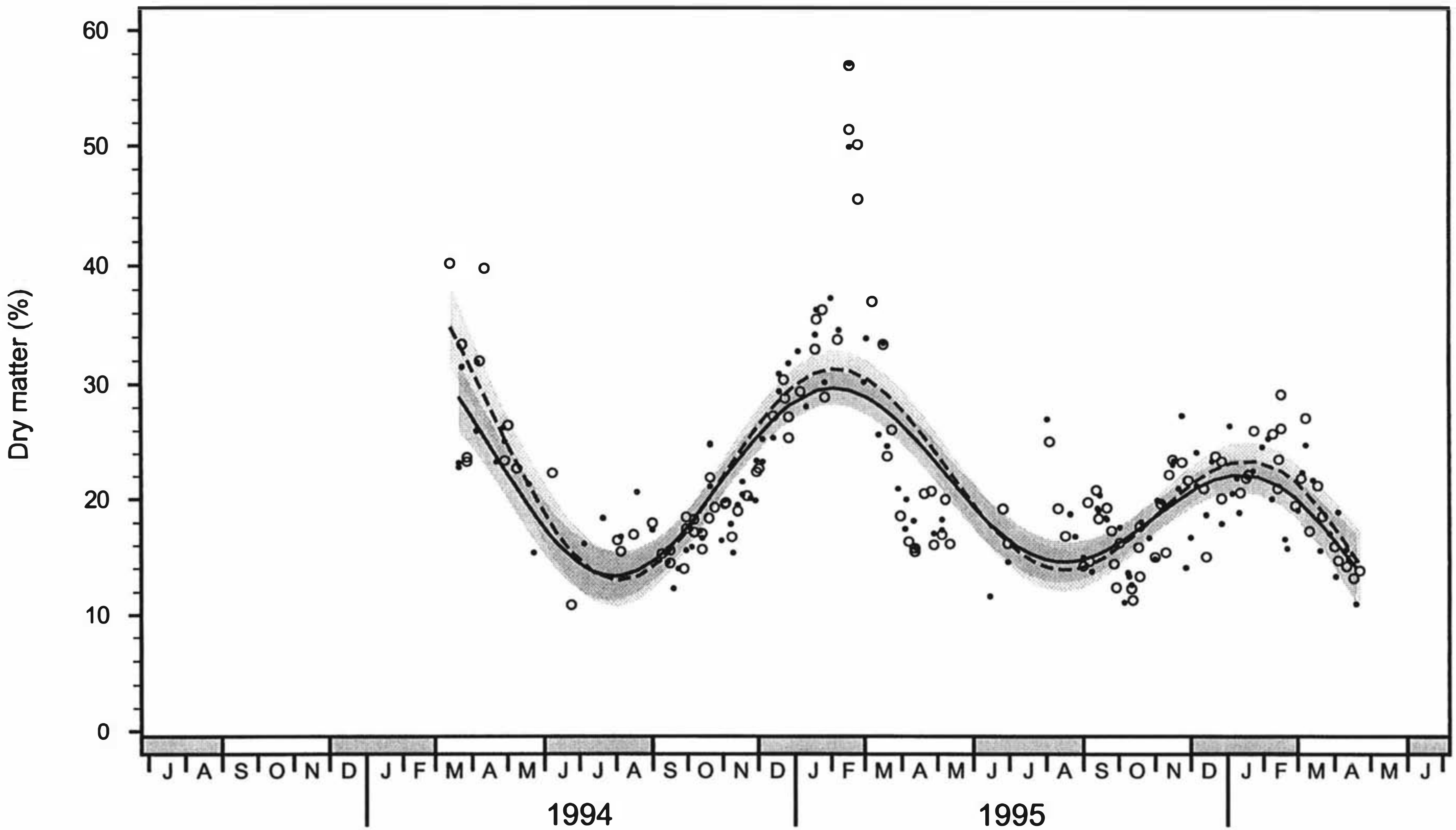
5.2.4 Pasture dry matter content

Mean dry matter percentages ranged from 15% in winter to 30% in summer for all three years (Figure 5-6), with some pastures from both EC and LC reaching over 50% during the summer of 1994/95. Treatment had no effect on the dry matter content of pastures during the trial.

5.2.5 Herbage accumulation rate

Herbage accumulation rate was calculated for indicator paddocks by dividing the difference between pre-grazing pasture cover and the preceding post-grazing pasture cover by the number of days of regrowth. Three years of daily herbage accumulation rates for indicator paddocks are shown in Figure 5-7. Average daily herbage accumulation rates for both EC and LC started at 75 kg DM ha^{-1} day^{-1} in the spring of 1993/94, fell to 10 kg DM ha^{-1} day^{-1} in the winter of 1993/94 and rose to 60 kg DM ha^{-1} day^{-1} during the spring of 1994/95. During the second winter accumulation rates fell to their lowest level over the three years of the trial on the EC farmlet at 5 kg DM ha^{-1} day^{-1}. On the LC farmlet accumulation rate was higher by 15 kg DM ha^{-1} day^{-1}. Spring 1995/96 saw accumulation rates increase to their highest values during the trial at 75 kg DM ha^{-1} day^{-1} before declining to the end of the trial. Accumulation rates were similar over all three years, although LC tended to be higher than EC, particularly during the winter of 1995.

Figure 5-6 Dry matter values (%) for early control —●— and late control - -○- - indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.



5.2.6 Seasonal and annual production

Total seasonal and annual pasture production values were calculated from pasture cover accumulation rates, calculated from pre- and post-grazing pasture covers of indicator paddocks (Section 5.2.5). Almost three years of seasonal pasture production values are given in Table 5-3. Values ranged from approximately 1 500 kg DM in autumn and winter to over 7000 kg DM in spring and summer. Late control pasture production was higher for autumn 1995 than EC and tended to be higher on LC than EC during summer and autumn 1994 and summer 1995, although production tended to be higher on EC than LC in autumn 1996. Annual pasture production values were calculated starting with summer 1994 because both spring 1993 and autumn 1996 seasonal values were not derived from a complete three month period. Annual pasture production estimates, calculated from the seasonal production values given in Table 5-3, were 12 288 kg DM and 13 043 kg DM for the period 01 December 1993 to 30 November 1994 and 12 812 kg DM and 14 463 kg DM for the period 01 December 1994 to 30 November 1995 for EC and LC, respectively.

Figure 5-7 Daily herbage accumulation rates (kg DM ha^{-1} day^{-1}) for early control —●— and late control - - ○ - - indicator paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

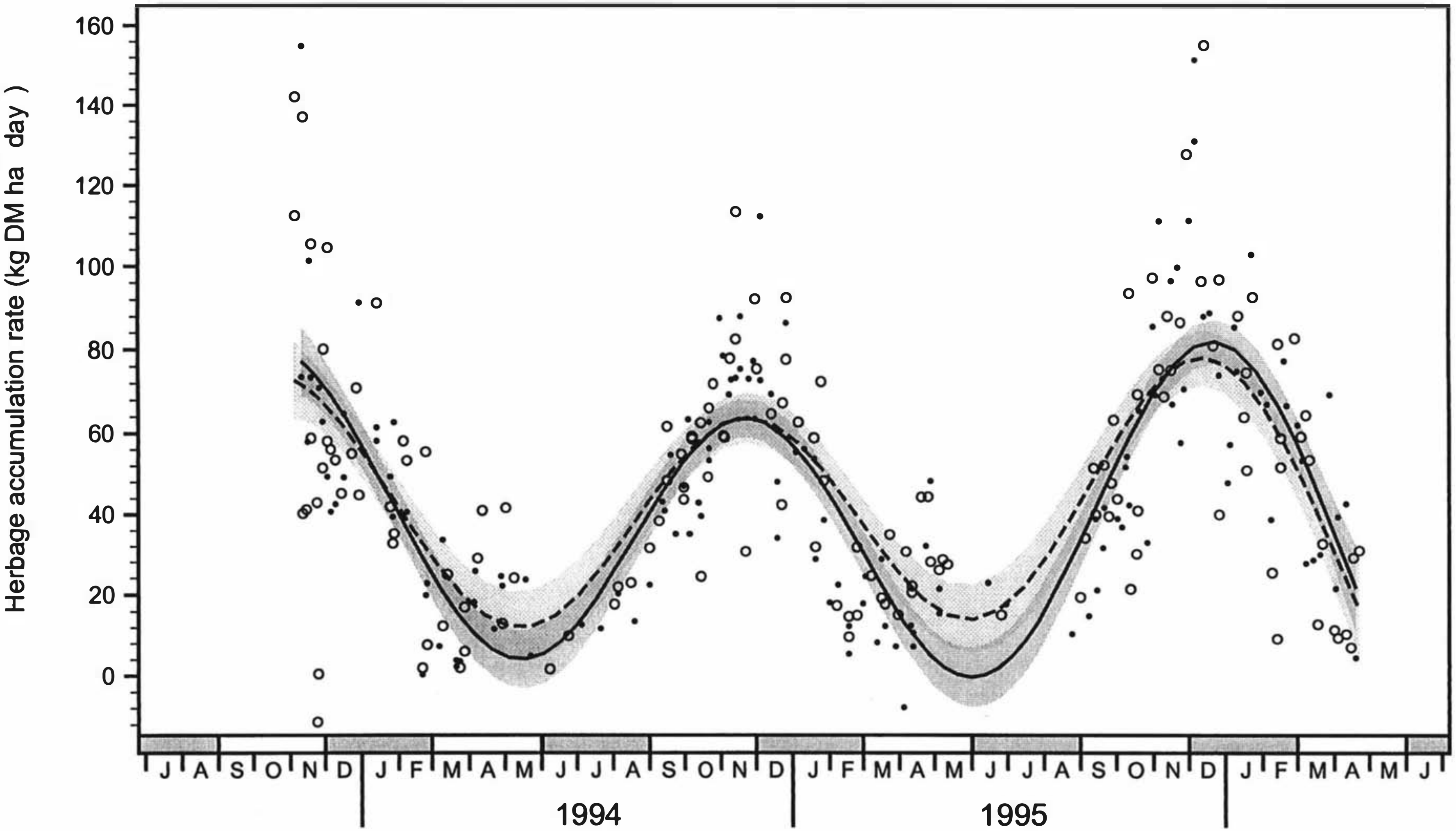


Table 5-3 Seasonal pasture production (kg DM) for early control and late control over three years.

Season	Treatment			
	Early control	Late control	SEM	P
Spring 93	7730	6720	1275.9	0.5852
Summer 94	4200	4580	470.8	0.5653
Autumn 94	1390	1940	336.8	0.2625
Winter 94	1340	1180	317.0	0.7336
Spring 94	5360	5340	382.5	0.9684
Summer 95	4290	5060	696.1	0.4409
Autumn 95	1750	2530	263.2	0.0474
Winter 95	1570	1390	456.9	0.8198
Spring 95	5210	5490	538.6	0.7160
Summer 96	7500	6470	715.0	0.3150
Autumn 96	3490	2690	584.9	0.3439

Note: Records were taken between 05 November 1993 and 22 April 1996. Seasons are as follows: Spring includes September, October and November; Summer includes December, January and February; Autumn includes March, April and May; Winter includes June, July and August.

5.2.7 Utilisation of pasture

Utilisation was calculated for indicator paddocks by dividing the difference between pre- and post-grazing pasture cover by pre-grazing pasture cover (Figure 5-8). Utilisation was variable throughout the year ranging from 5 to 50% during spring, summer and autumn and 50 to 80% in winter. Mean utilisation values peaked in winter at 40% and fell to 20% in summer. Late control had higher utilisation during autumn 1995. Monthly mean utilisation values were variable with no period of advantage to either EC or LC (Table 5-4).

Figure 5-8 Pasture utilisation values (%) for early control —●— and late control - -○- - indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

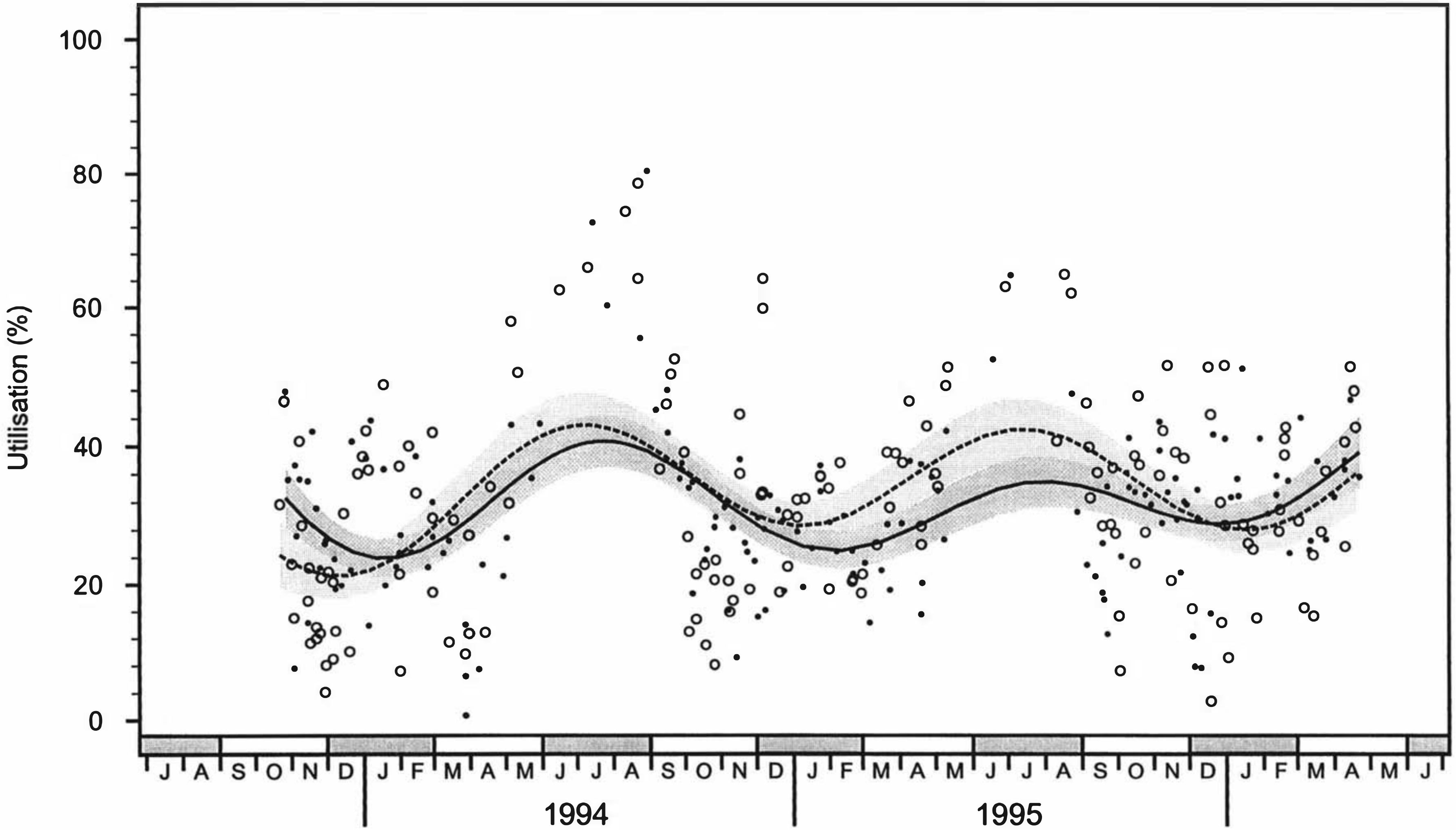


Table 5-4 Monthly mean utilisation (%) of pasture on indicator paddocks for early control and late control over three years.

	Treatment			
Month	Early control	Late control	SEM	P
1993/94				
October	41.5	39.1	6.83	0.8258
November	27.8	17.8	2.86	0.0220
December	25.2	22.5	4.27	0.6608
January	28.6	37.3	4.39	0.1928
February	28.7	28.5	4.19	0.9762
March	14.5	18.1	4.65	0.5947
April	17.2	23.6	7.15	0.5767
May	37.2	46.7	5.60	0.2819
June	-	62.6	-	-
1994/95				
July	66.4	65.9	7.47	0.9656
August	67.9	72.3	7.58	0.7058
September	41.6	44.9	2.71	0.4102
October	27.9	18.1	2.06	0.0043
November	24.7	25.7	3.89	0.8583
December	25.2	37.5	4.78	0.0936
January	28.7	31.4	2.57	0.4859
February	26.2	24.4	3.02	0.7012
March	21.5	31.4	3.00	0.0488
April	29.3	36.3	3.95	0.2408
May	34.2	42.6	4.48	0.2439
June	52.4	63.1	-	-
1995/96				
July	64.8	-	-	-
August	39.1	55.9	8.22	0.2454
September	22.0	34.6	2.44	0.0028
October	33.4	28.1	4.00	0.3648
November	32.9	38.0	2.96	0.2481
December	23.7	30.2	5.82	0.4432
January	38.7	22.1	3.39	0.0072
February	31.8	36.3	2.51	0.2408
March	32.1	25.0	3.53	0.1891
April	38.0	41.7	3.55	0.4791

5.2.8 Apparent intake of pasture

Apparent intakes were determined by calculating the amount of pasture removed (pre-grazing - post-grazing) from indicator paddocks at each grazing and dividing by the number of cows in the herd. Monthly pasture apparent intake rates are given in Table 5-5 for the three years of the trial. Pasture intakes were variable and differences between treatments inconsistent. Daily intakes of pasture ranged from 6 kg DM cow^{-1} during autumn and winter when the cows were dry to 20 kg DM cow^{-1} over spring and summer. Late control cows consumed more pasture than EC cows in September of 1994 and 1995.

Daily pasture intake values by season given in Table 5-6 ranged from 9 to 20 kg DM cow^{-1}. Differences between seasons and treatments were variable with LC cows having higher intakes in autumn 1994/95. Intake values were more variable in spring 1993/94, winter 1994/95 and winter 1995/96.

Table 5-5 Monthly pasture only intake values (kg DM cow $^{-1}$ day^{-1}) for early control and late control cows over three years.

Month	Treatment		SEM	P
	Early control	Late control		
1993/94				
November	17.0	13.1	3.56	0.4702
December	11.8	11.5	2.19	0.9210
January	13.7	16.3	2.61	0.5160
February	11.9	9.8	2.18	0.4947
March	8.5	10.1	2.94	0.7121
April	5.1	6.1	2.11	0.7472
May	8.9	15.5	3.90	0.2817
June	-	6.4	-	-
1994/95				
July	15.7	6.0	1.51	0.1406
August	18.1	27.3	8.90	0.5194
September	15.6	20.4	1.70	0.0820
October	13.7	11.6	1.66	0.3883
November	14.5	16.5	2.77	0.6083
December	13.6	15.1	1.62	0.5300
January	16.1	19.9	1.78	0.1676
February	12.8	9.0	2.14	0.2571
March	9.0	13.5	1.37	0.0488
April	12.5	19.9	2.98	0.1145
May	11.6	12.9	1.93	0.6534
June	16.1	11.7	-	-
1995/96				
July	7.7	-	-	-
August	13.8	14.7	4.60	0.9023
September	10.4	15.8	1.91	0.0686
October	14.3	12.8	2.34	0.6611
November	18.1	18.7	1.85	0.8371
December	17.0	20.9	3.62	0.4642
January	20.8	13.8	1.89	0.0313
February	20.6	26.8	2.56	0.1272
March	18.4	15.1	2.08	0.2885
April	20.9	19.3	2.70	0.6882

Table 5-6 Seasonal pasture only intake values (kg DM cow^{-1} day^{-1}) for early control and late control cows over three years.

Season	Treatment		SEM	P
	Early control	Late control		
1993/94				
Spring	17.0	13.1	3.56	0.4702
Summer	12.5	12.0	1.32	0.7645
Autumn	7.8	10.9	1.90	0.2512
1994/95				
Winter	16.9	18.9	5.98	0.8208
Spring	14.4	15.3	1.31	0.6549
Summer	14.1	15.7	1.26	0.3845
Autumn	11.1	15.6	1.44	0.0344
1995/96				
Winter	12.9	14.0	2.88	0.7959
Spring	14.6	15.6	1.27	0.5793
Summer	19.3	20.5	1.86	0.6491
Autumn	19.7	17.0	1.69	0.2820

Table 5-7 gives daily intake values of pasture only by year. Intake values tend to be higher for LC cows in 1994/95 and 1995/96, but there were no differences in 1993/94.

Table 5-7 Annual pasture only intake values (kg DM cow^{-1} day^{-1}) for early control and late control cows over three years.

Season	Treatment		SEM	P
	Early control	Late control		
1993/94	11.5	11.7	1.09	0.9100
1994/95	13.7	15.9	0.83	0.0635
1995/96	16.9	17.4	0.93	0.6842

5.2.9 Botanical composition

Tables 5-8 through 5-18 provide information on botanical composition of indicator paddocks over three years. Complete details of botanical composition are given in Appendix Five, Table A5-1.

5.2.9.1 Live herbage

The proportion of live material in the pastures ranged from approximately 70% in summer to around 90% in late winter/early spring (Table 5-8). Differences between treatments were inconsistent. In general, LC pastures had more live material present, particularly in autumn 1993/94 and early summer 1995/96. However, the advantage to LC was reversed by late summer 1995/96.

Table 5-8 Percent live (green) in total herbage for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Oct/Nov 93	82	85	1.5	0.2168
Jan/Feb 94	74	76	1.9	0.3448
Apr/May 94	73	78	1.3	0.0266
Aug/Sep 94	92	93	0.7	0.3858
Oct/Nov 94	89	90	0.7	0.3144
Jan/Feb 95	72	74	1.5	0.5340
Apr 95	82	84	2.1	0.5121
Dec 95	82	85	1.0	0.0412
Feb 96	73	65	1.2	0.0001

5.2.9.2 Clover content

Table 5-9 gives the proportion of total clover (red and white clover) in the live component from Table 5-8. For EC pastures the quantity of clover ranged from 10% in late winter/early spring to 30% in summer. The clover content of LC pastures ranged from 15% in late winter/early spring to approximately 40% in summer. Late control pastures had consistently more clover than EC pastures during spring, summer and autumn each year (Table 5-9).

Table 5-9 Percent total clover (white and red clover) in live herbage for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Oct/Nov 93	19	18	3.2	0.8856
Jan/Feb 94	30	37	3.2	0.1127
Apr/May 94	20	30	2.5	0.0124
Aug/Sep 94	11	13	1.3	0.1174
Oct/Nov 94	11	19	1.5	0.0006
Jan/Feb 95	18	33	2.4	0.0001
Apr 95	18	24	1.7	0.0198
Dec 95	14	23	1.6	0.0001
Feb 96	21	24	2.2	0.3468

Table 5-10 presents the percentage of white clover in the green (live) fraction. The white clover content of the pastures ranged from 11% to 23%, with peaks in the summers of all three years. Late control pastures had marginally ($P < 0.0897$) more white clover than EC during spring 1994 and significantly more in December 1995.

Table 5-10 Percent white clover in live herbage for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Oct/Nov 93	17	12	3.0	0.2297
Jan/Feb 94	23	21	2.3	0.5082
Apr/May 94	15	15	1.6	0.9795
Aug/Sep 94	11	12	1.2	0.4153
Oct/Nov 94	11	15	1.5	0.0897
Jan/Feb 95	14	17	2.1	0.2267
Apr 95	16	15	1.6	0.5800
Dec 95	14	22	1.5	0.0002
Feb 96	20	18	1.7	0.4150

5.2.9.3 Ryegrass

Table 5-11 gives the proportion of ryegrass within the grass fraction of the herbage from indicator paddocks pre-grazing. Percent ryegrass ranged from 60% at the start of the trial through to 90% before declining to 70% by the end of the trial. Late control tended to have more ryegrass in the grass fraction throughout the trial and the quantity of ryegrass in the sward was higher for LC than EC in spring 1994/95 and marginally higher in summer 1993/94 and autumn 1995/96.

5.2.9.4 Proportion of leaf in ryegrass

Table 5-12 gives the proportion of leaf in the ryegrass fraction of pastures over three years. During the trial percent leaf gradually increased from about 55% to approximately 75% with more leaf present during winter than summer each year. Treatment differences were variable, although LC pastures tended to have more leaf than EC in the first year while EC tended to have more leaf than LC during the last two years. Late control pastures had more leaf than EC pastures in summer 1993/94, while EC tended to have more leaf than LC during the summers of 1994/95 and 1995/96 and autumn 1994/95.

Table 5-11 Percent ryegrass in the grass fraction for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Oct/Nov 93	57	66	5.0	0.1958
Jan/Feb 94	59	67	3.0	0.0812
Apr/May 94	79	82	2.7	0.5108
Aug/Sep 94	79	79	3.3	0.9057
Oct/Nov 94	79	87	2.1	0.0087
Jan/Feb 95	87	87	2.1	0.8913
Apr 95	80	87	2.5	0.0671
Dec 95	62	61	2.5	0.7135
Feb 96	71	76	2.4	0.1595

Table 5-12 Percent leaf in the ryegrass fraction for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Oct/Nov 93	51	55	2.2	0.1918
Jan/Feb 94	63	67	1.5	0.0452
Apr/May 94	71	71	0.9	0.7828
Aug/Sep 94	77	76	0.8	0.2650
Oct/Nov 94	55	52	1.2	0.1215
Jan/Feb 95	62	64	1.2	0.2234
Apr 95	81	78	1.0	0.0326
Dec 95	68	64	1.7	0.1026
Feb 96	80	76	1.0	0.0019

5.2.10 Grass tiller and weed population densities

During the three years of the trial ryegrass tiller population densities reached their maximum during winter and minimum in summer each year (Table 5-13). There were differences between treatments during the summers of 1994/95 and 1995/96. However, these differences were inconsistent, with LC having more tillers than EC during the summer of 1994/95 while the reverse was true for the summer of 1995/96, both before and after the control phase in December.

Table 5-13 Ryegrass tiller densities (number m^{-2}) for early control and late control indicator paddocks over three years.

Date	Treatment		SEM	P
	Early control	Late control		
Nov 93	2520	2150	217	0.2343
Feb/Mar 94	4810	5070	287	0.5205
Apr/May 94	10680	10300	560	0.6338
Aug/Sep 94	10770	10670	507	0.8814
Nov 94	6520	8510	1064	0.1665
Mar 95	8310	9530	425	0.0440
Apr 95	10600	11110	283	0.2030
Dec 95	5260	4330	254	0.0094
Feb 96	4710	3790	213	0.0018

Tillers from other grasses also contributed to the total number of grass tillers in the sward (Table 5-14). Early control pastures contained more tillers of other grasses than LC pastures for the duration of the trial.

Early control pastures contained marginally more total tillers than LC in November 1993 (Table 5-15). In 1994, total tiller numbers peaked at 15000 m^{-2} on both treatments, falling sharply in November. During 1995 total tiller numbers peaked at 12000 m^2. Numbers remained high on EC through December, but declined on LC over the same period, culminating in significantly fewer grass tillers on LC. In

February 1996 EC still had more grass tillers than LC. By the end of the trial total tiller numbers had returned to levels similar to those at the start of the trial.

Table 5-14 Other grass tiller densities (number m^{-2}) for early control and late control indicator paddocks over three years.

Date	Treatment		SEM	P
	Early control	Late control		
Nov 93	7070	4450	366	0.0001
Feb/Mar 94	5910	5490	415	0.4796
Apr/May 94	4960	4490	389	0.3937
Aug/Sep 94	3270	2120	261	0.0018
Nov 94	5000	2830	703	0.0327
Mar 95	2770	2020	243	0.0312
Apr 95	1290	1040	118	0.1411
Dec 95	5940	3530	247	0.0001
Feb 96	4280	3130	208	0.0001

Table 5-15 Total grass tiller densities (number m^{-2}) for early control and late control indicator paddocks over three years.

Date	Treatment		SEM	P
	Early control	Late control		
Nov 93	9590	6600	1000	0.0660
Feb/Mar 94	10720	10570	1340	0.9373
Apr/May 94	15640	14790	1074	0.5923
Aug/Sep 94	14040	12790	686	0.2296
Nov 94	11520	11340	833	0.1900
Mar 95	11080	11550	1068	0.7621
Apr 95	11890	12150	487	0.7070
Dec 95	11200	7860	599	0.0009
Feb 96	8990	6920	475	0.0052

Table 5-16 gives the number of weeds present in both EC and LC pastures over three years, ranging from 30 m^2 to 190 m^2. The main pasture weeds during the trial were ragwort (*Senecio spathulatus*), scotch thistle (*Cirsium vulgare*), californian thistle (*Cirsium arvense*), buttercup (*Ranunculus spp.*), docks (*Rumex spp.*) and gorse (*Ulex europaeus*). Relative to ryegrass and other grass tiller numbers weeds were unimportant. Late control pastures had fewer weeds during autumn 1994 and summer/autumn 1995 and tended to have fewer for the first two years of the trial.

Table 5-16 Weed densities (number m^{-2}) for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Nov 93	189	173	27.6	0.6837
Feb/Mar 94	94	85	15.2	0.6727
Apr/May 94	132	76	19.3	0.0404
Aug/Sep 94	60	33	11.4	0.0935
Nov 94	45	34	19.5	0.6829
Mar 95	71	33	12.4	0.0308
Apr 95	70	28	9.7	0.0025
Dec 95	63	80	11.3	0.3063
Feb 96	83	86	10.7	0.8478

5.2.11 Weight of white clover stolon

White clover stolon weights in grams per square metre for EC and LC pastures are presented in Table 5-17. Values were similar for EC and LC during the first 18 months of the trial at approximately 70 g m^{-2}. During autumn 1995/96 LC pastures contained more clover stolon than EC pastures. This advantage remained apparent through the summer of 1995/96, although by February 1996 the treatment differences had disappeared.

Table 5-17 Weight of white clover stolon (g m^{-2}) for early control and late control indicator paddocks over three years.

Date	Treatment			
	Early control	Late control	SEM	P
Nov 93	56	63	19.3	0.8149
Feb/Mar 94	82	77	11.8	0.7433
Apr/May 94	78	86	10.7	0.6021
Aug/Sep 94	59	67	7.7	0.5037
Nov 94	55	63	7.2	0.4503
Mar 95	76	82	8.1	0.6217
Apr 95	36	55	5.3	0.0260
Dec 95	24	35	4.0	0.0766
Feb 96	52	51	6.6	0.9231

5.2.12 Pasture nutritive values (proximate analysis)

Changes in nutrient concentrations through time for 1994/95 and 1995/96 are represented graphically in Figures 5-9 through 5-22. For each of the nutrients there are two figures; the first in the pair shows the concentration of the nutrient in the herbage of the total pasture mass of indicator paddocks pre-grazing, and the second the concentration of the nutrient in the herbage of the next two paddocks per treatment in the grazing round cut to estimated grazing height. As would be expected, the concentrations of all nutrients, with the exception of neutral detergent fibre (NDF) and acid detergent fibre ADF, were higher in herbage removed to estimated grazing height than in the herbage of the total pasture mass.

5.2.12.1 Digestibility

Organic matter digestibility (OMD) of the total pasture mass ranged from 70% in the summers of 1994/95 and 1995/96 to 75% in the winter of 1994/95 (Figure 5-9).

During summer 1994/95 the OMD of the pasture cut to estimated grazing height fell to 74% in summer and increased to 77% during winter 1994/95 (Figure 5-10). In summer 1995/96 OMD fell to 70%, similar to the value for the herbage of the total pasture mass. Treatment had no effect on digestibility of the total pasture mass or pasture cut to estimated grazing height.

Appendix Five, Figures A5-5 and A5-6 show predicted metabolisable energy (ME) values (MJ kg DM^{-1}) for both the total pasture mass and pasture cut to estimated grazing height. Metabolisable energy values for total pasture mass ranged from 11.3 MJ kg DM^{-1} in summer to 11.6 MJ kg DM^{-1} in winter for EC and 11.0 MJ kg DM^{-1} in summer to 11.8 MJ kg DM^{-1} in winter for LC (Figure A5-5). Pasture cut to estimated grazing height ranged from 11.0 MJ kg DM^{-1} in summer to 12.3 MJ kg DM^{-1} in winter for both treatments (Figure A5-6). Since ME was calculated from OMD, treatment had no effect on ME.

Figure 5-9 Organic matter digestibility values (%) for early control —●— and late control --○-- indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

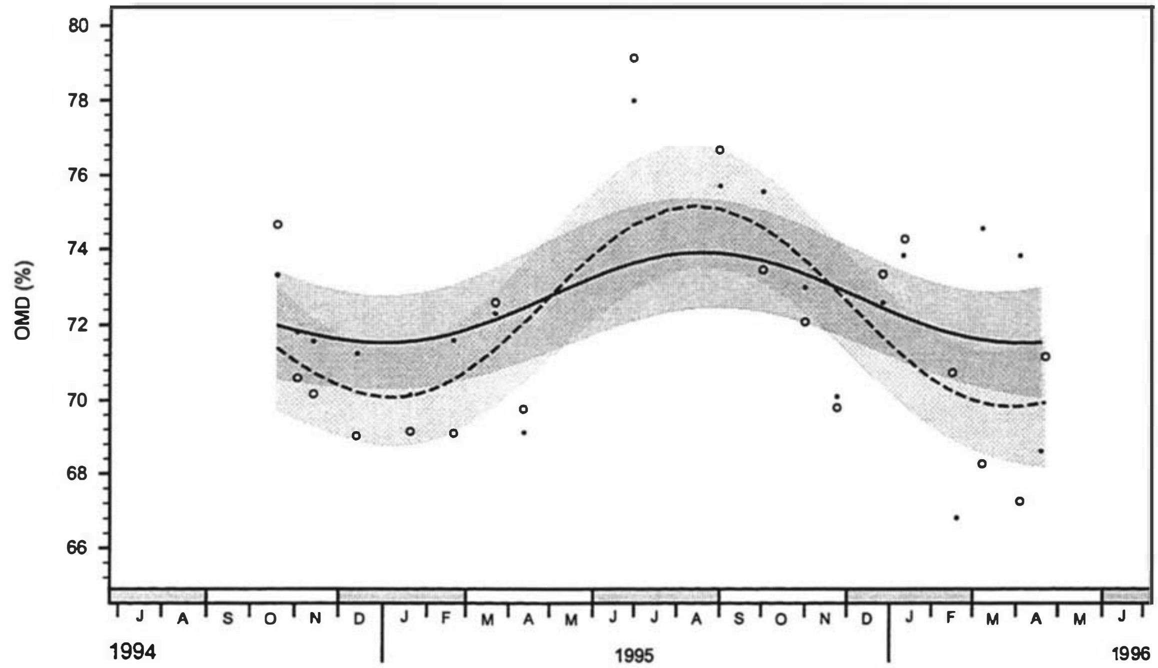


Figure 5-10 Organic matter digestibility values (%) for early control —●— and late control --○-- paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

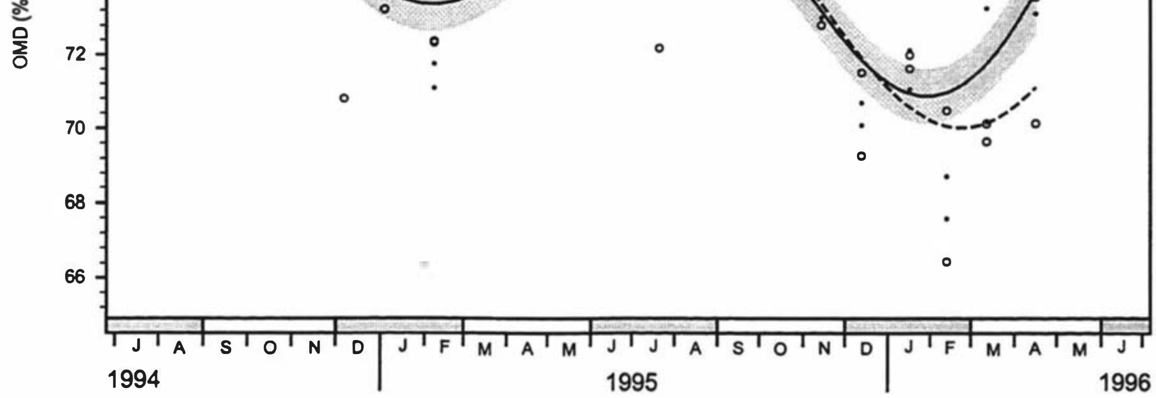


Figure 5-11 Crude protein values for early control —•— and late control --o-- indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

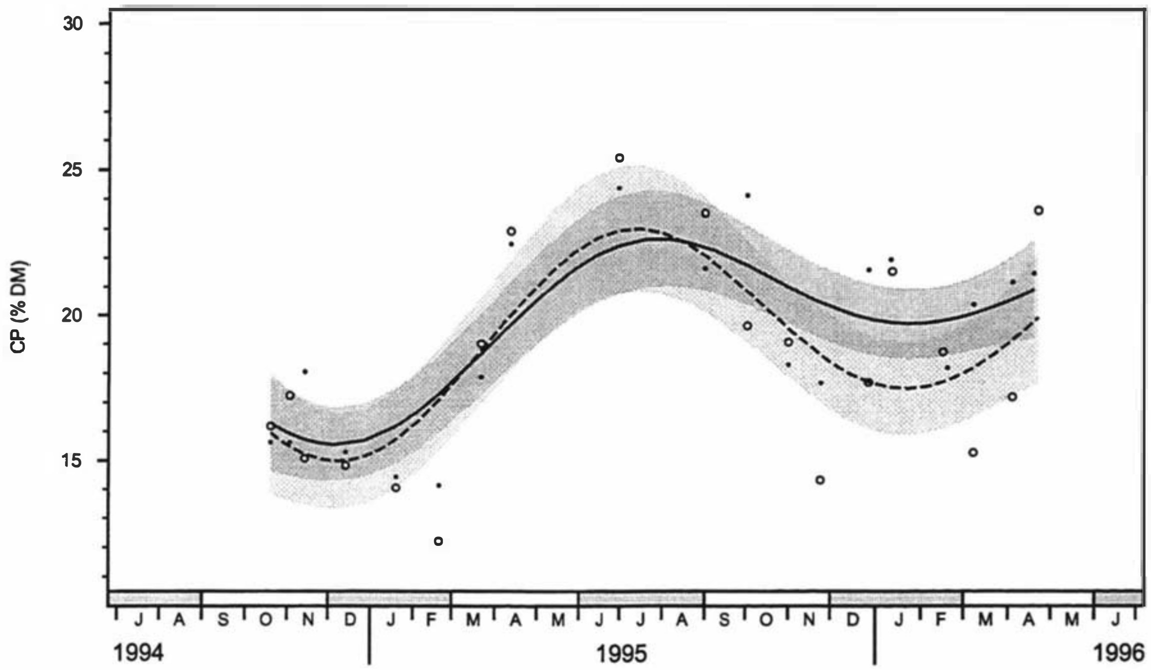
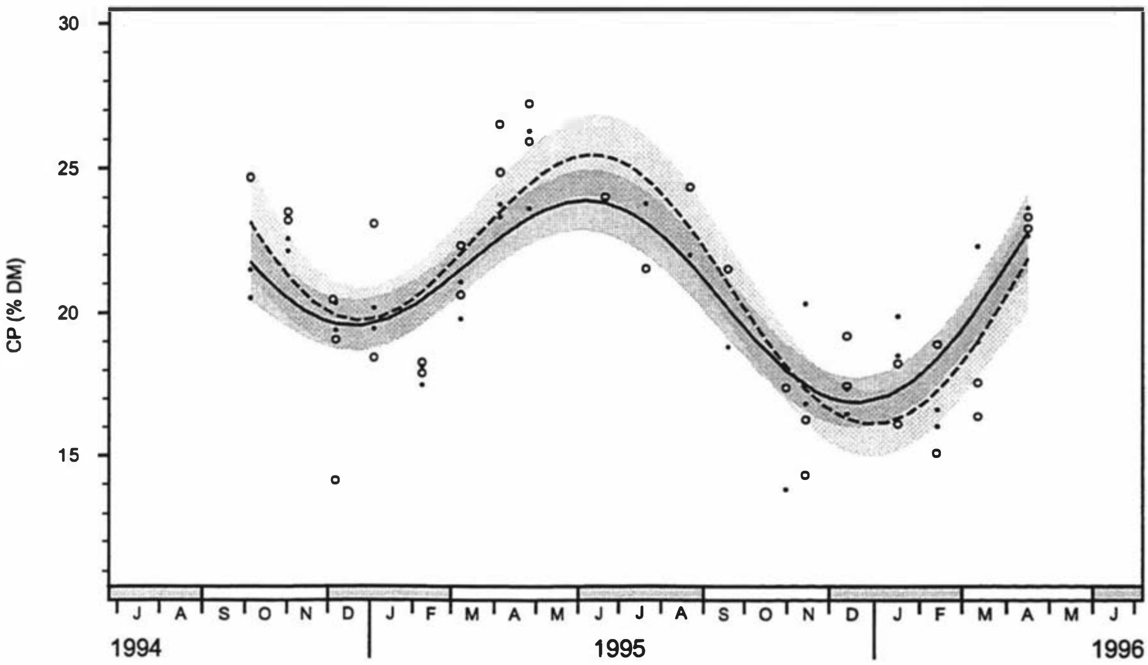


Figure 5-12 Crude protein values for early control —•— and late control --o-- paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.



5.2.12.2 Crude protein

Crude protein (CP) values in the herbage of the total pasture mass started at 15% in summer 1994/95 and increased to 23% during winter 1995/96 (Figure 5-11). In summer 1995/96 CP declined again, although not to the same extent as the previous summer. Figure 5-12 shows CP levels peaked at 25% in winter 1995/96 and declined to approximately 17% in summer 1995/96. In contrast to Figure 5-11 where CP levels gradually increase, in Figure 5-12, CP levels gradually decrease over time. Crude protein values were higher for herbage cut to estimated grazing height in 1994/96, while in 1995/96 the values were similar. Treatment had no effect on the concentration of crude protein in herbage.

5.2.12.3 Neutral detergent fibre

Neutral detergent fibre (NDF) in herbage remained constant at approximately 47.5% from October 1994 through May 1996 (Figure 5-13). Figure 5-14 shows that NDF values for herbage cut to estimated grazing height peaked at almost 50% in summer 1994/95 and 1995/96. The NDF concentration during winter 1995/96 fell to approximately 43%. Levels of NDF were lower in herbage cut to estimated grazing height than the herbage of the total pasture mass. Treatment had no effect on NDF levels.

Figure 5-13 Neutral detergent fibre values for early control —•— and late control --o-- indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

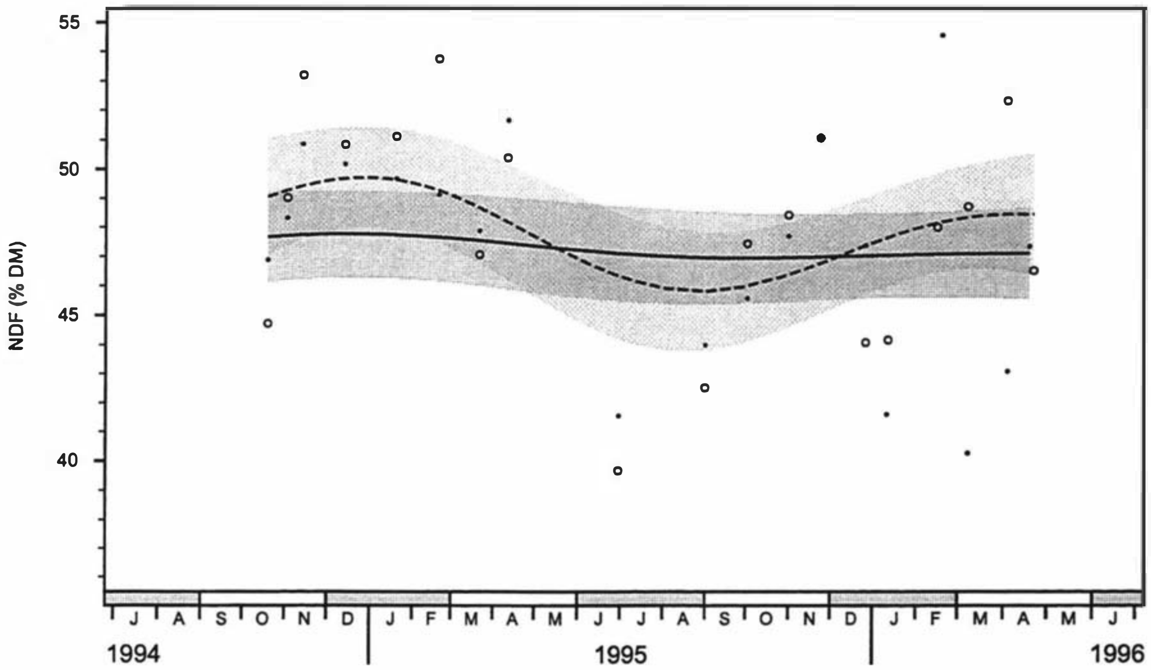


Figure 5-14 Neutral detergent fibre values for early control —•— and late control --o-- paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

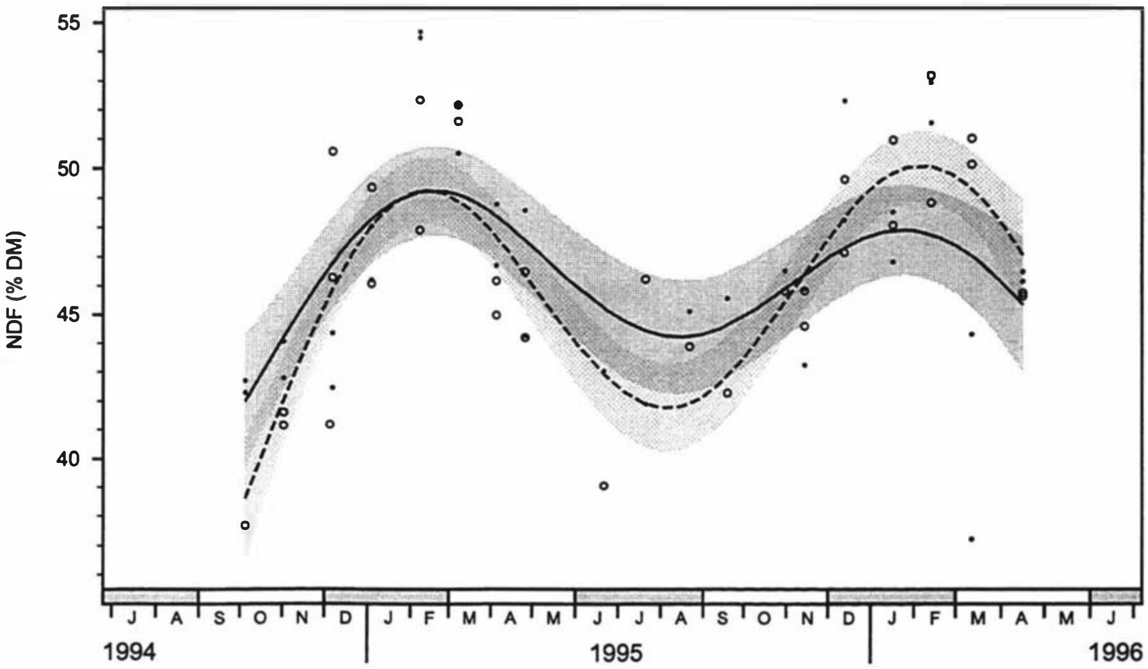


Figure 5-15 Acid detergent fibre values for early control —●— and late control --o-- indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

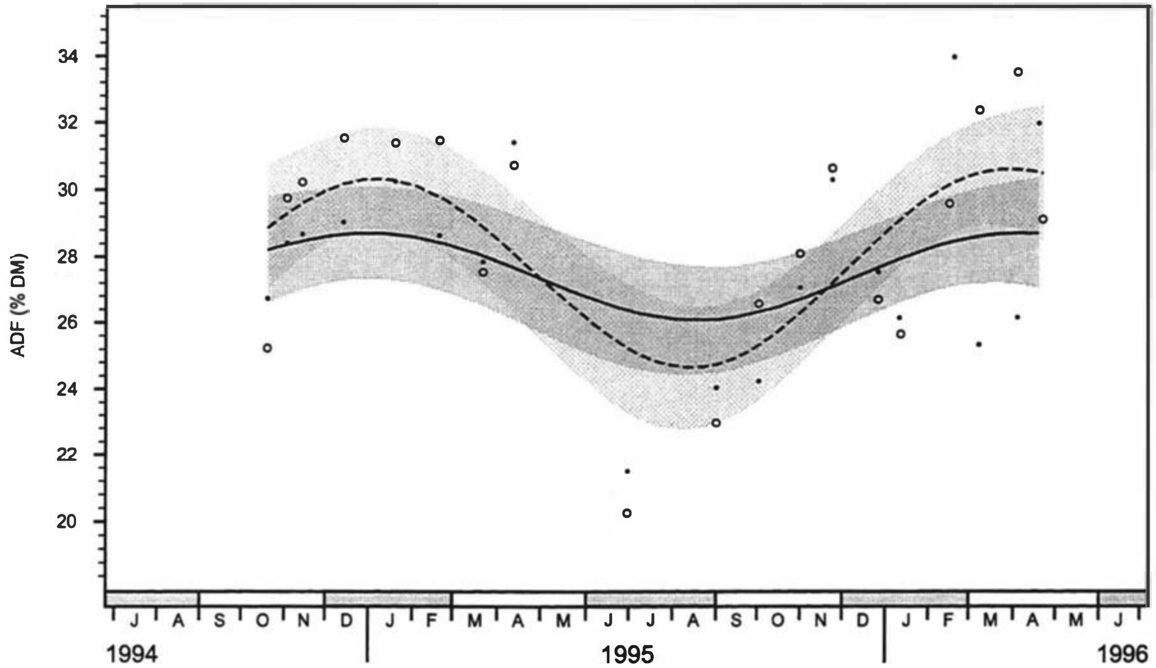
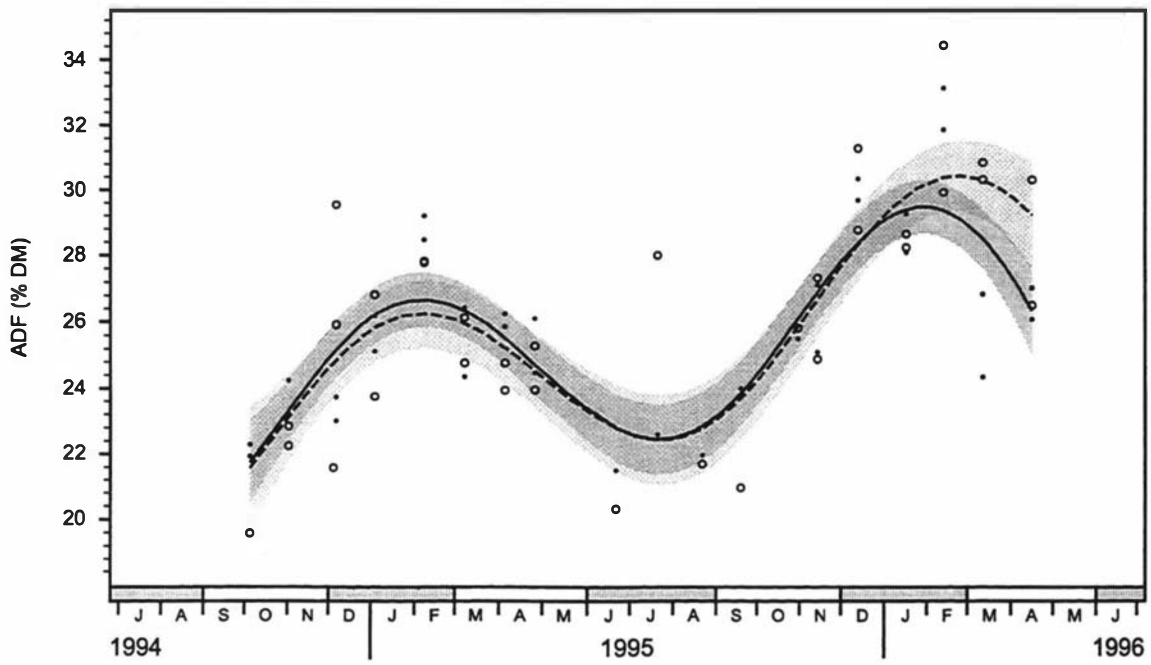


Figure 5-16 Acid detergent fibre values for early control —●— and late control --o-- paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.



5.2.12.4 Acid detergent fibre

Acid detergent fibre (ADF) values are given in Figures 5-15 and 5-16 for the herbage of the total pasture mass and herbage cut to grazing height. During summer 1994/95 and 1995/96 ADF levels were approximately 30% of dry matter (Figure 5-15). Levels declined to 26% in winter 1995/96. Acid detergent fibre values for herbage cut to estimated grazing height (Figure 5-16) were generally lower than for the herbage of the total pasture mass, ranging from 23% in winter 1995/96 to 29% during summer 1995/96. Treatment had on effect on ADF concentration.

5.2.12.5 Soluble carbohydrates

Time of year had little effect on soluble carbohydrate (Sol CHO) concentrations in herbage offered (Figure 5-17) at 7.5% over the trial period. In contrast, Sol CHO in herbage cut to estimated grazing height ranged from 7.0% in summer to 11.0% in winter (Figure 5-18). Treatment did not effect Sol CHO levels.

5.2.12.6 Lipid

Lipid concentrations ranged from 3.44% during summer 1994/95 to 4.52% in winter 1995/96 for herbage offered (Figure 5-19). By summer 1995/96 lipid concentrations were higher for EC pastures than LC pastures by 0.80%. However, treatment had no effect on lipid levels of herbage from pastures cut to estimated grazing height, although values where generally higher at any given time (Figure 5-20). Lipid levels peaked at 4.54% in winter 1995/96 and were at their lowest in summer 1995/96 (3.50%).

Figure 5-17 Soluble carbohydrate values for early control —●— and late control - -o- - indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

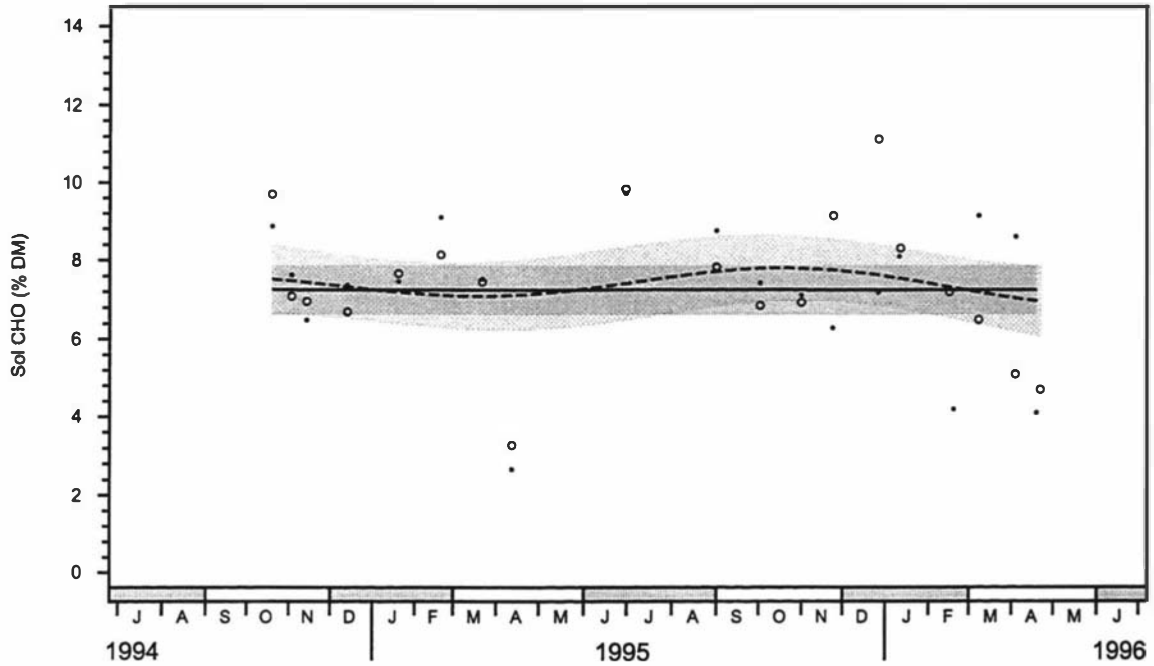


Figure 5-18 Soluble carbohydrate values for early control —●— and late control - -o- - paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

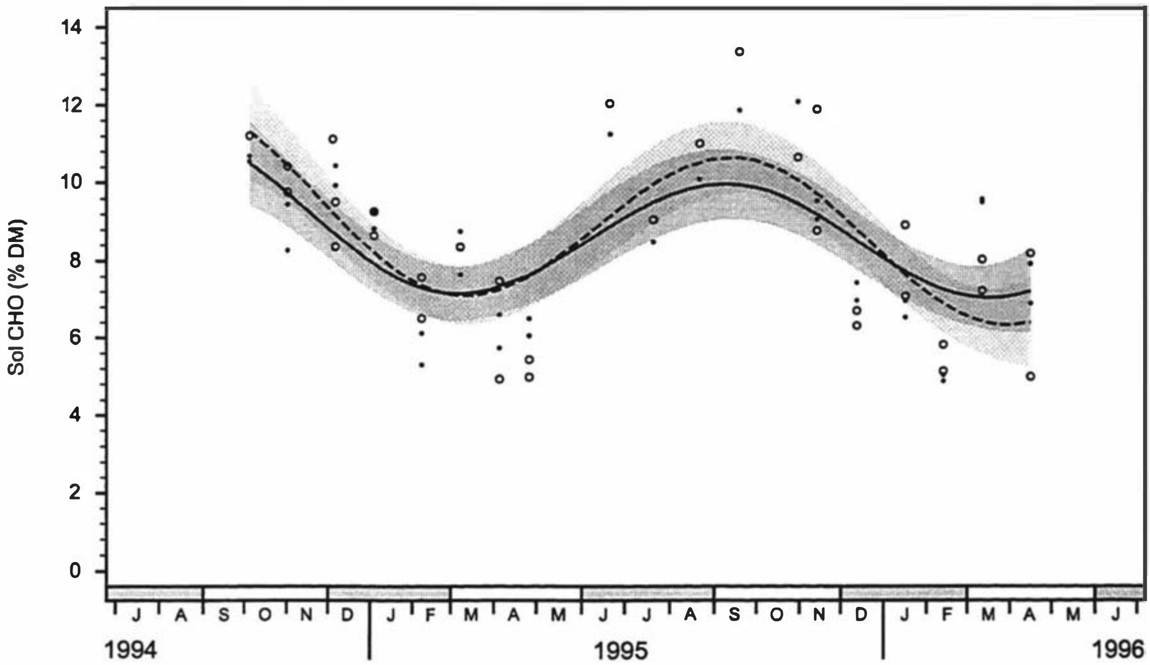


Figure 5-19 Lipid values for early control —●— and late control --○-- indicator paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

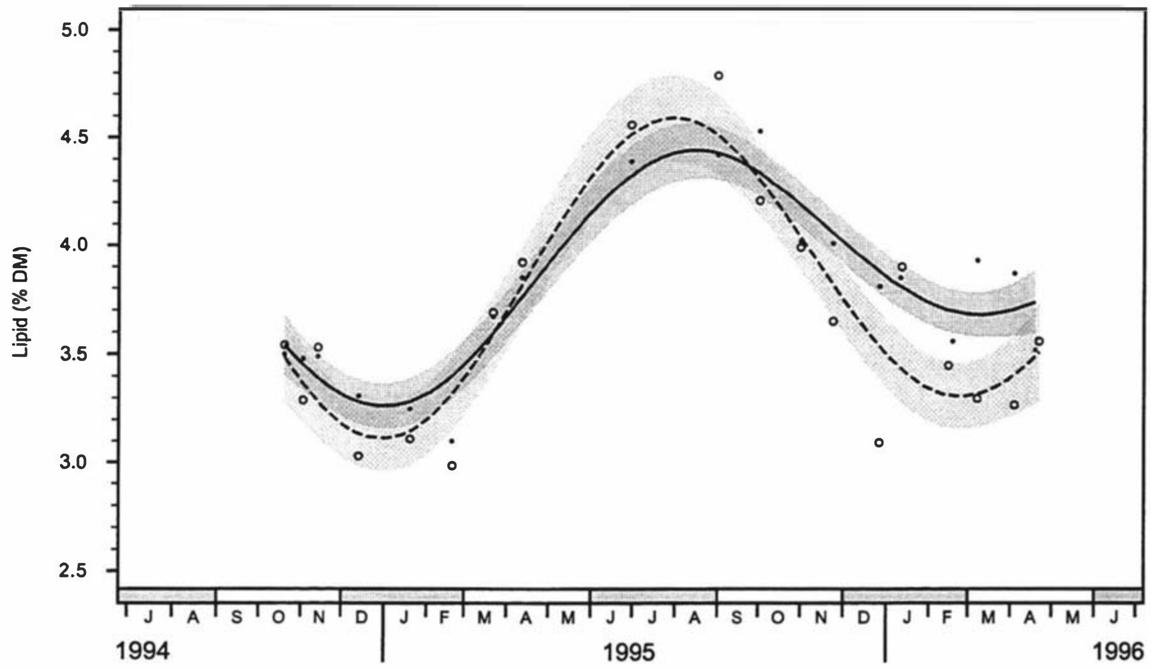


Figure 5-20 Lipid values for early control —●— and late control --○-- paddocks cut to estimated grazing height over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

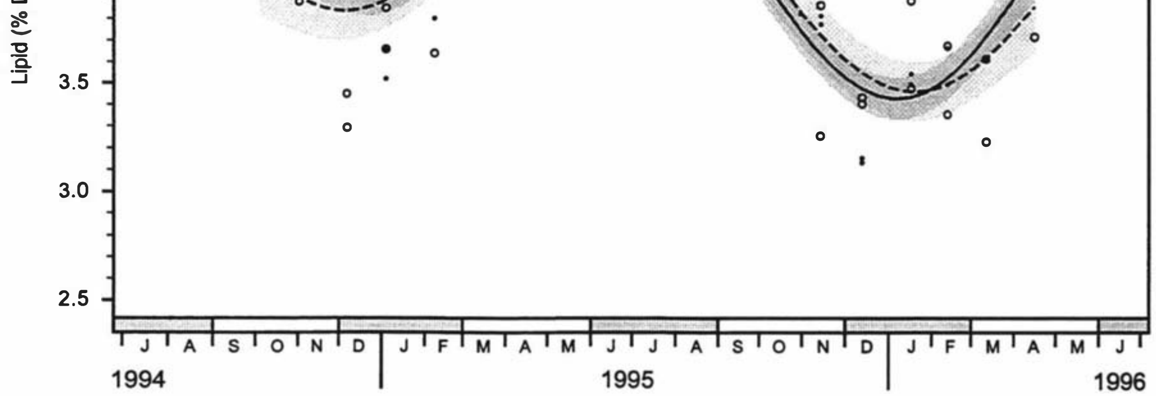


Figure 5-21 Ash values for early control —●— and late control - -○- - indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

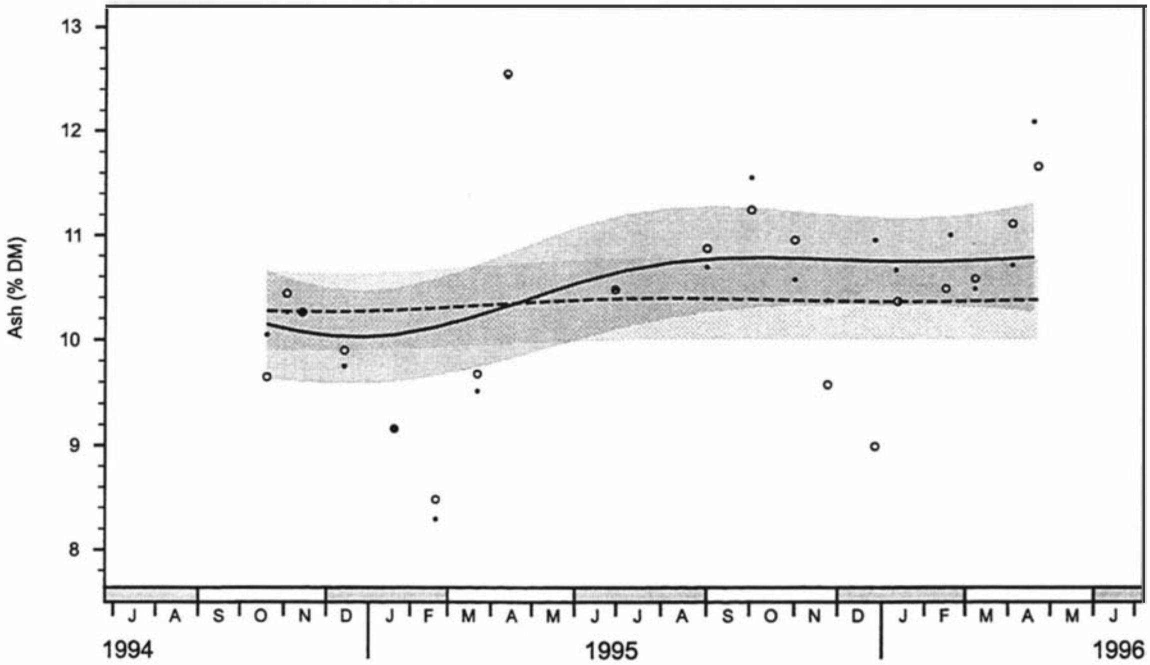
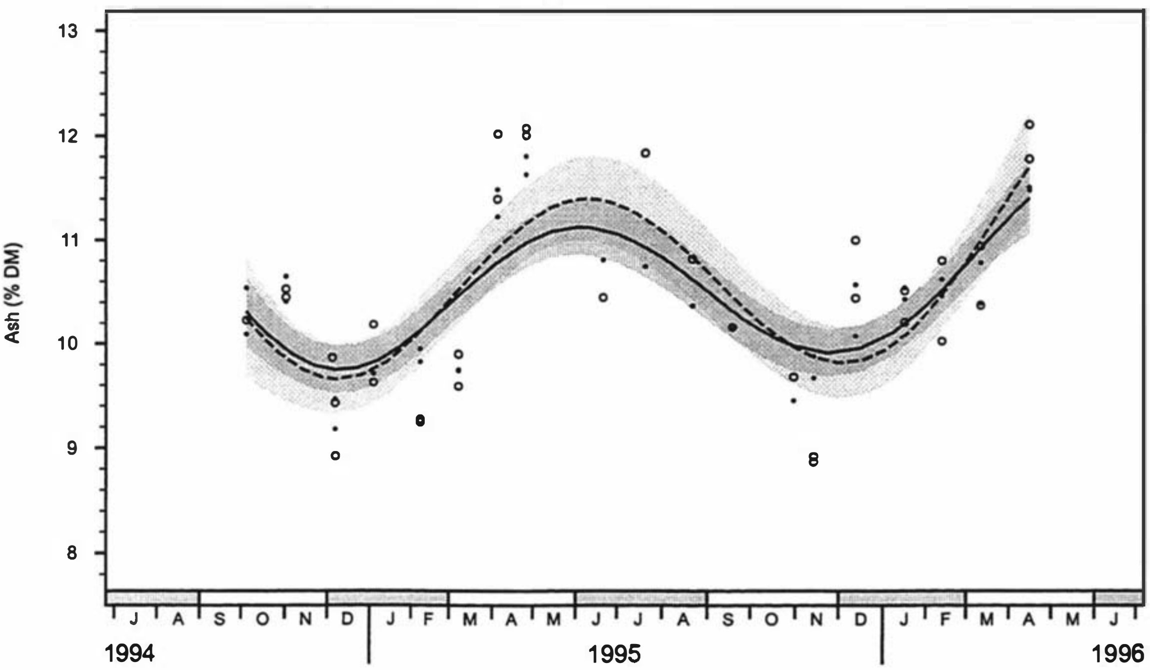


Figure 5-22 Ash values for early control —●— and late control - -○- - paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.



5.2.12.7 Ash

The concentration of ash in herbage offered was constant at 10.50% from October 1994 to May 1996 (Figure 5-21). Figure 5-22 shows the ash content of herbage from pasture cut to estimated grazing height, which ranged from 9.75% during summer to 11.50% in winter. Treatment had no effect on the ash content of either herbage on offer or herbage removed.

5.3 Animal measurements

5.3.1 Age of cows

Table 5-18 gives the mean age of the cows in the herds over four years. The mean age of cows decreased from approximately 5.0 years of age at the start of the trial to 4.6 years of age at the end. Treatment had no effect on the average age of the cows in the herds.

Table 5-18 Mean age of early control and late control cows over four years.

Year	Treatment			
	Early control	Late control	SEM	P
1993	4.81	5.00	0.221	0.5474
1994	5.07	4.98	0.226	0.7836
1995	4.93	4.71	0.234	0.4958
1996	4.66	4.58	0.227	0.7997

5.3.2 Milk yield and composition

Figures 5-23 through 5-26 show milk components over the three years of the trial. Differences between treatments were detected using ANOVA with initial milk yield used as a covariate. Many differences between the treatments were detected although in general they were variable and inconsistent with no extended period of advantage to either treatment.

5.3.2.1 Volume of milk

The volume of milk produced in 1993/94 peaked in October at 25 litres cow^{-1} day^{-1} and fell steadily to 10 litres cow^{-1} day^{-1} by drying off in April (Figure 5-23). Milk volumes in 1994/95 peaked at similar levels and time to the previous year but then fell dramatically by 50% during November and December. Volumes rallied slightly and remained constant for 3 months before falling quickly again until drying off towards the end of May. During 1995/96 milk volumes fell gradually throughout the year. Daily milk volumes for 1993/94 (Figure 5-23) were significantly higher for EC than LC in October, January and February. In 1994/95 treatment differences were again variable, although LC was at an apparent disadvantage during November and December. While treatment differences were again variable during the final year, LC had a marginal advantage in volume of milk produced during summer, although LC was at a considerable disadvantage in April.

5.3.2.2 Milk fat

Milk fat percentage (Figure 5-24) tended to increase during the time the cows were in milk and ranged from 4.2% to 5.3%. Treatment differences were apparent in all three years. In 1993/94 these differences showed no continued period of advantage to either treatment. During 1994/95 and 1995/96 fat content was lower for LC than EC during November and December, but the reverse was the case for the remainder of the season.

Figure 5-23 Mean daily milk yield (l cow^{-1} day^{-1}) for early control —●— and late control - -○- - cows over three years, adjusted using initial milk yield as covariate. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control ● and late control ○ means (n = approx. 120)

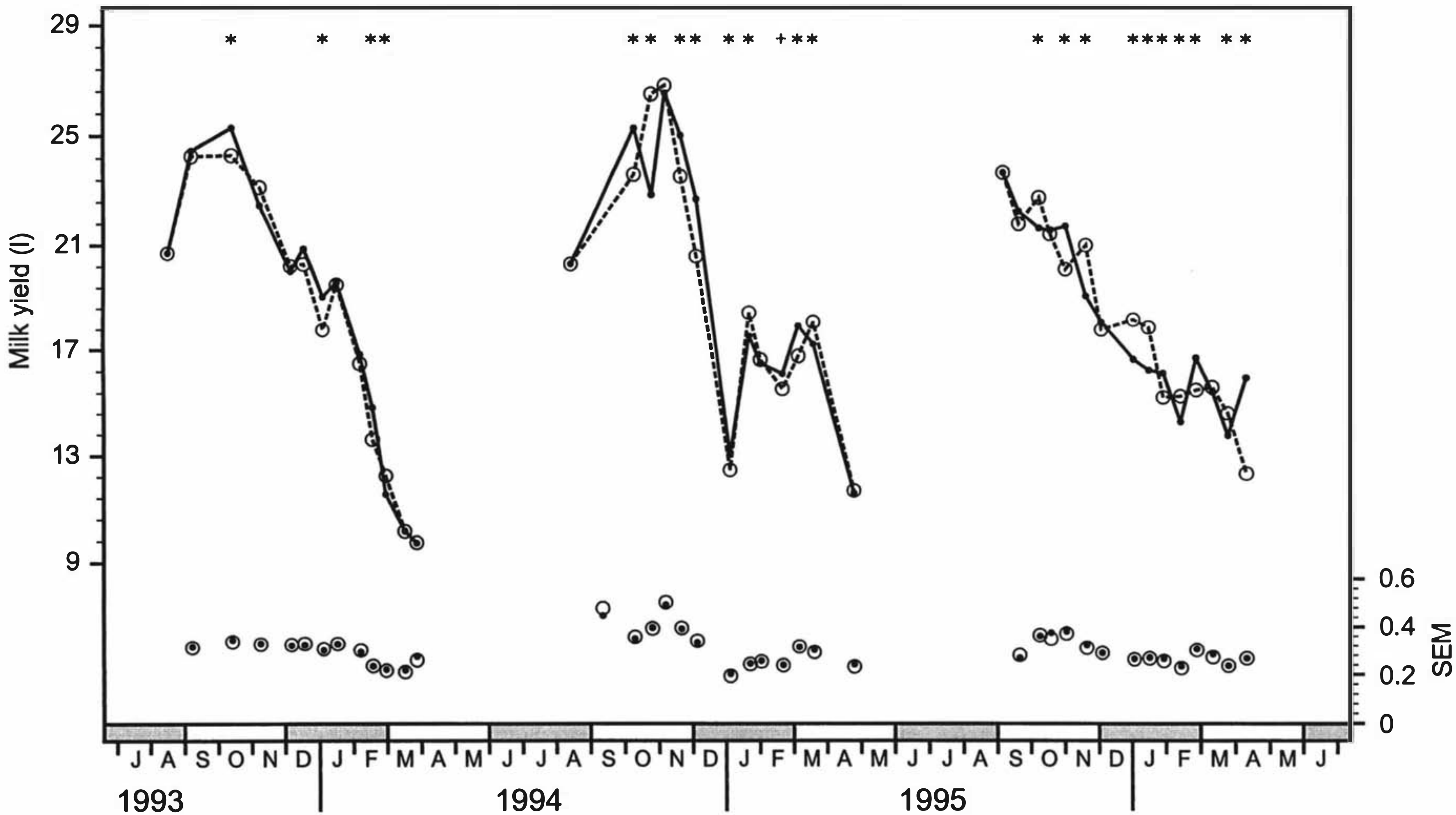


Figure 5-24 Mean daily milk fat (%) for early control —●— and late control --○-- cows over three years, adjusted using initial milk fat as covariate. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control ● and late control ○ means (n = approx. 120).

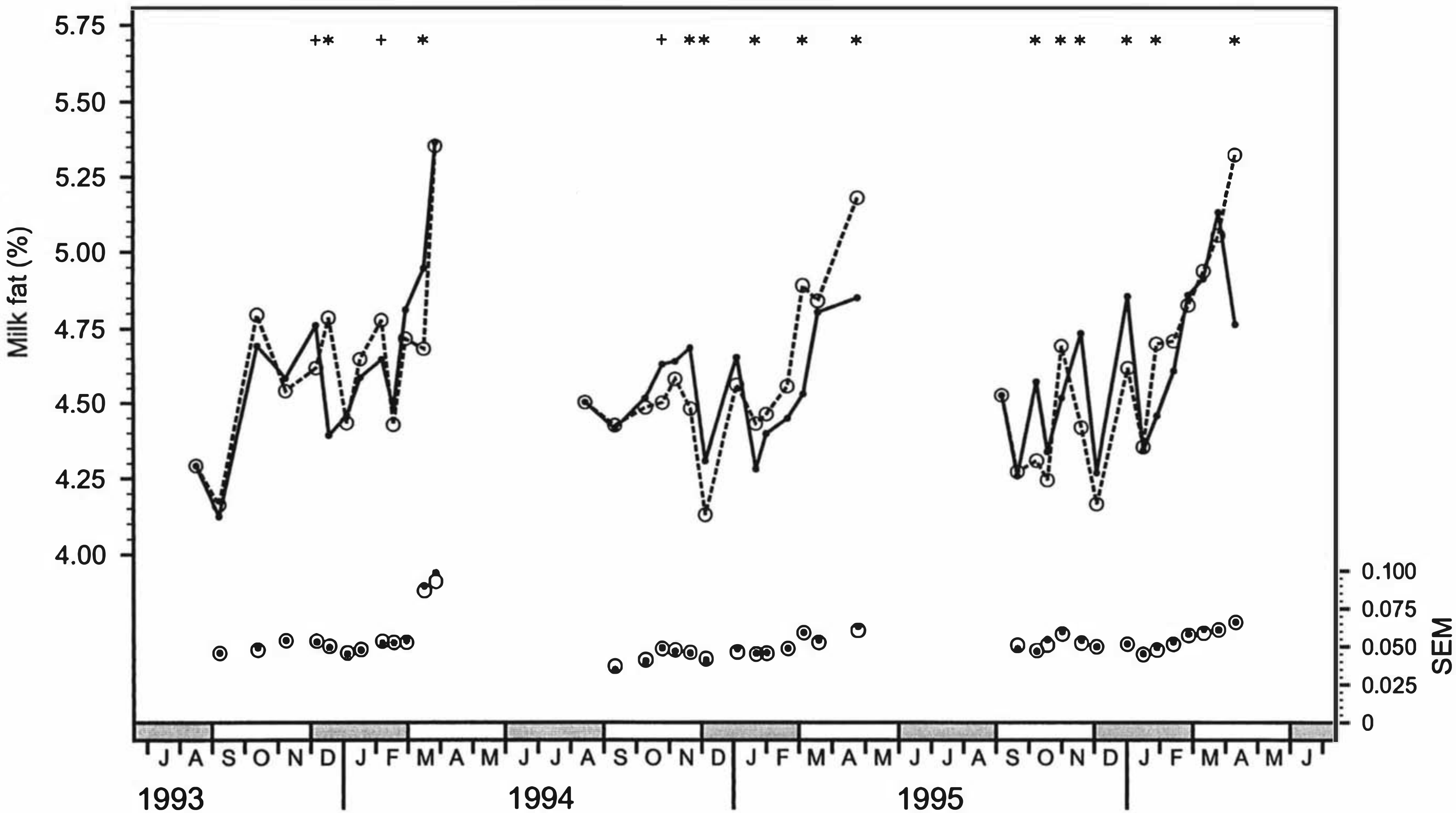
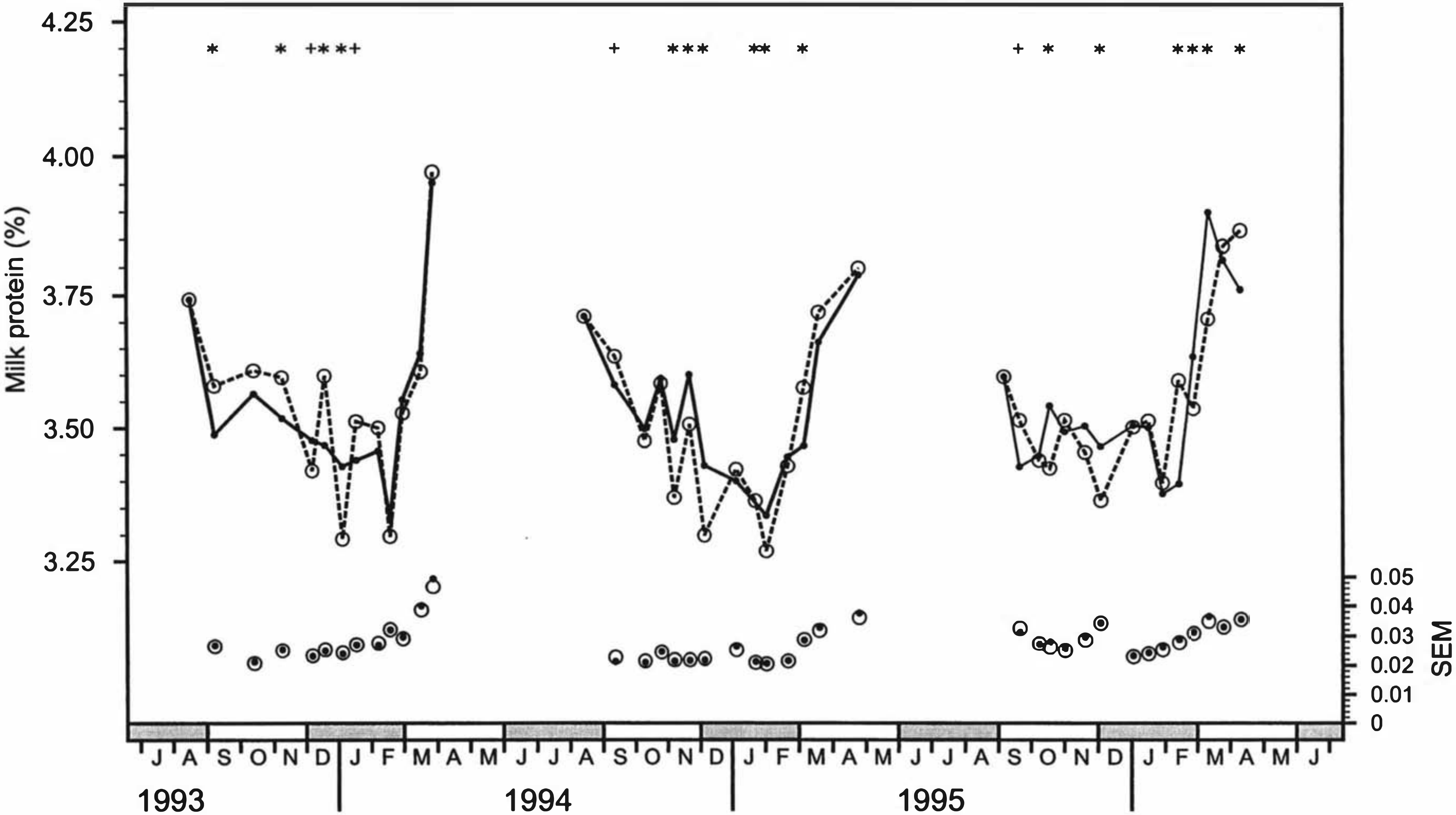


Figure 5-25 Mean daily milk protein (%) for early control —●— and late control - - ○ - - cows over three years, adjusted using initial milk protein as covariate. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control ● and late control ○ means (n = approx. 120).



5.3.2.3 Milk protein

Protein percentages (Figure 5-25) started and ended at approximately 3.7% in spring and autumn each year, and fell to approximately 3.3% during summer. Treatment differences were variable and inconsistent, with the exception of spring 1994/95 when LC was lower than EC during November and December (Figure 5-25). Milk protein percentage was less variable than milk fat percentage.

5.3.2.4 Milksolids production

Milksolids (fat and protein) production in 1993/94 peaked at 2.00 kg MS cow^{-1} day^{-1} in October 1993, gradually declining to 1.00 kg MS cow^{-1} day^{-1} in March 1994 (Figure 5-26). Production peaked one month earlier in September 1994 at 2.40 kg MS cow^{-1} day^{-1}. A rapid decline was evident during November and December 1994 with a slight recovery over late summer before a similarly rapid although less substantial decline in April 1995. During 1995/96 milksolids production gradually declined from 1.90 kg MS cow^{-1} day^{-1} in September to 1.25 kg MS cow^{-1} day^{-1} by drying off date in April 1996. Treatment differences in milksolids production during 1993/94 were variable with no extended period of advantage apparent to either treatment. In the early spring of 1994 (Figure 5-26) significant differences were again apparent although treatment effects were not consistent. During the control phase in December 1994 milksolids production was higher on EC than LC, although this advantage was somewhat reversed towards the end of lactation (Figure 5-26). In the final year (1995/96) results were again variable with no period of sustained advantage apparent.

Figure 5-26 **Mean daily milksolids production (kg MS cow^{-1} day^{-1}) for early control —•— and late control --○-- cows over three years, adjusted using initial milksolids as covariate. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control • and late control ○ means (n = approx. 120).**

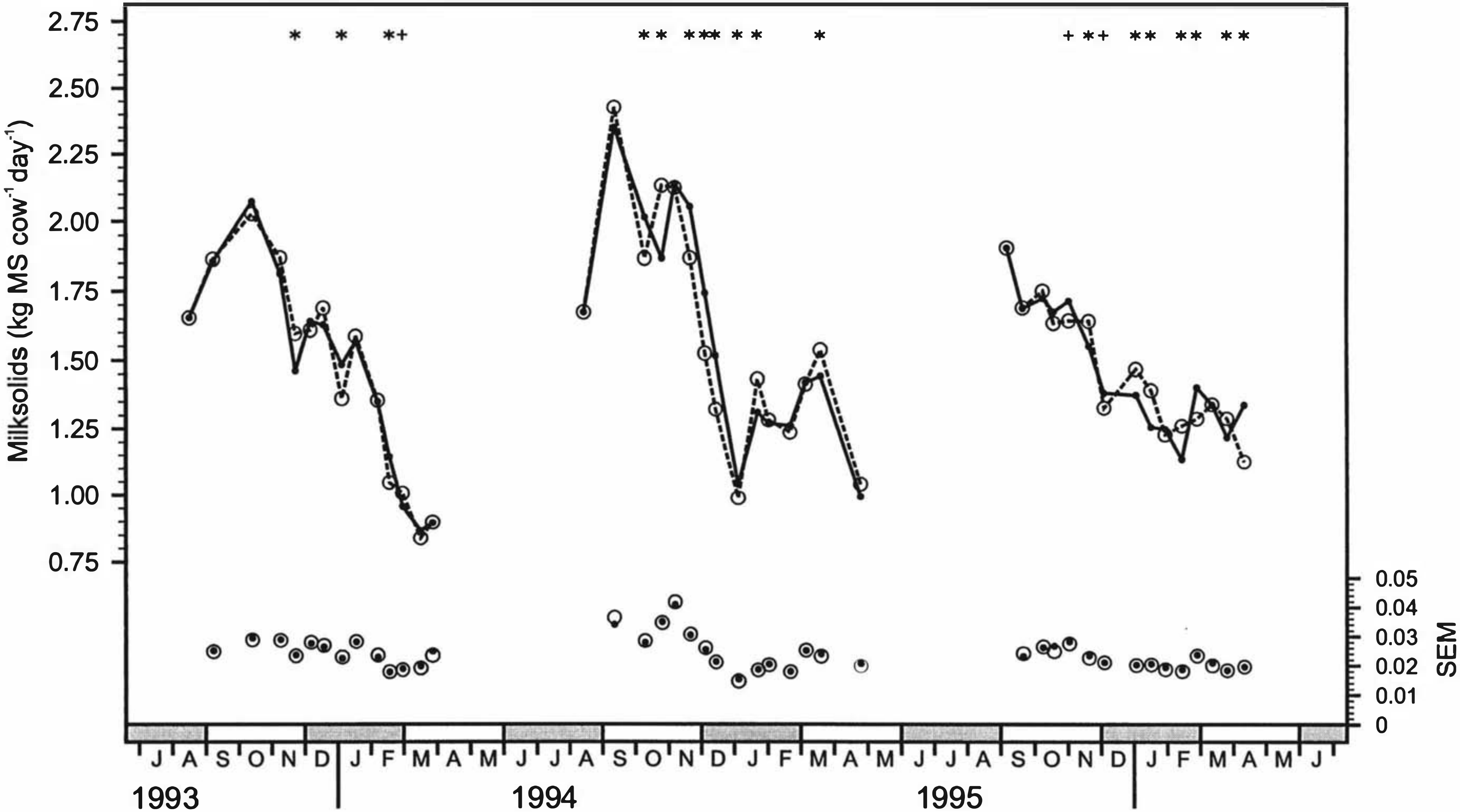


Table 5-19 Summary of annual milksolids production (kg) for early control and late control cows over three years.

	Treatment			
	Early control	Late control	SEM	P
1993/94				
No. of cows	126 (44)	125 (43)	-	-
MS cow^{-1} †	355.2	351.2	9.64	0.7712
MS ha^{-1} ‡	973.6	976.2	-	-
MS cow^{-1} §	348.7	351.2	-	-
1994/95				
No. of cows	125 (48)	123 (42)	-	-
MS cow^{-1} †	393.2	408.3	14.25	0.4567
MS ha^{-1} ‡	1 069.2	1 116.8	-	-
MS cow^{-1} §	391.7	382.5	-	-
1995/96				
No. of cows	118 (18)	120 (34)	-	-
MS cow^{-1} †	360.1	379.6	15.13	0.3729
MS ha^{-1} ‡	924.3	1 013.0	-	-
MS cow^{-1} §	369.9	380.1	-	-

Note: † Milksolids per cow calculated from cows with a complete set of production records (numbers in brackets).

‡ Milksolids per hectare calculated from milksolids per cow using 45.97 and 44.97 hectares for EC and LC, respectively.

§ Milksolids per cow calculated from herd averages.

5.3.3 Annual milksolids production

Annual milksolids production per cow and per hectare milksolids production calculated from individual cow milk yields (Section 5.3.2) and herd records (calving and drying-off dates) are given in Table 5-19. Milksolids production ranged from 350 to 400 kg cow^{-1} over the three years of the trial with no difference between treatments. Milksolids production per hectare averaged 1 010 kg during the trial.

5.3.4 Liveweight and condition score

Liveweight (LW) values for EC and LC herds over three years are given in Figure 5-27. During 1993/94 and 1994/95 mean herd LW gradually increased from 475 kg in early spring to 500 kg in winter. The initial declines in LW during August of 1994 and 1995 were the result of calving. In addition, Figure 5-27 shows herd LW increasing rapidly in late spring 1995/96 and then remaining relatively stable.

Treatment differences in LW were variable and inconsistent throughout the trial, with herds being of similar weight by calving in early August each year (Figure 5-27). In 1993/94 and 1994/95 LC cows were heavier then EC cows in December and January. Early control cows were heavier then LC cows in October and November 1995. Figure 5-27 also shows that EC cows were heavier than LC cows from May until July 1995.

During 1993/94 the condition score (CS) of the herds increased rapidly from 4.50 to 5.25 during March and April 1994 (Figure 5-28). Condition score values for the second year (1994/95) remained relatively constant at 4.75, while in the final year (1995/96), CS values decline from 4.75 to 4.25 in October and then approached 4.50 over summer and autumn. There were relatively few treatment differences in CS over the three years of the trial. Early control had an apparent advantage over LC from March through June 1994 and a real advantage in June and July 1995 (Figure 5-28).

Figure 5-27 Mean monthly liveweight (kg) values for early control —●— and late control --○-- cows over three years, adjusted using initial liveweight as covariate. Significant differences are indicated by + P < 0.10 and * P < 0.05. Standard error of the mean (SEM) for early control ● and late control ○ means (n = approx. 120).

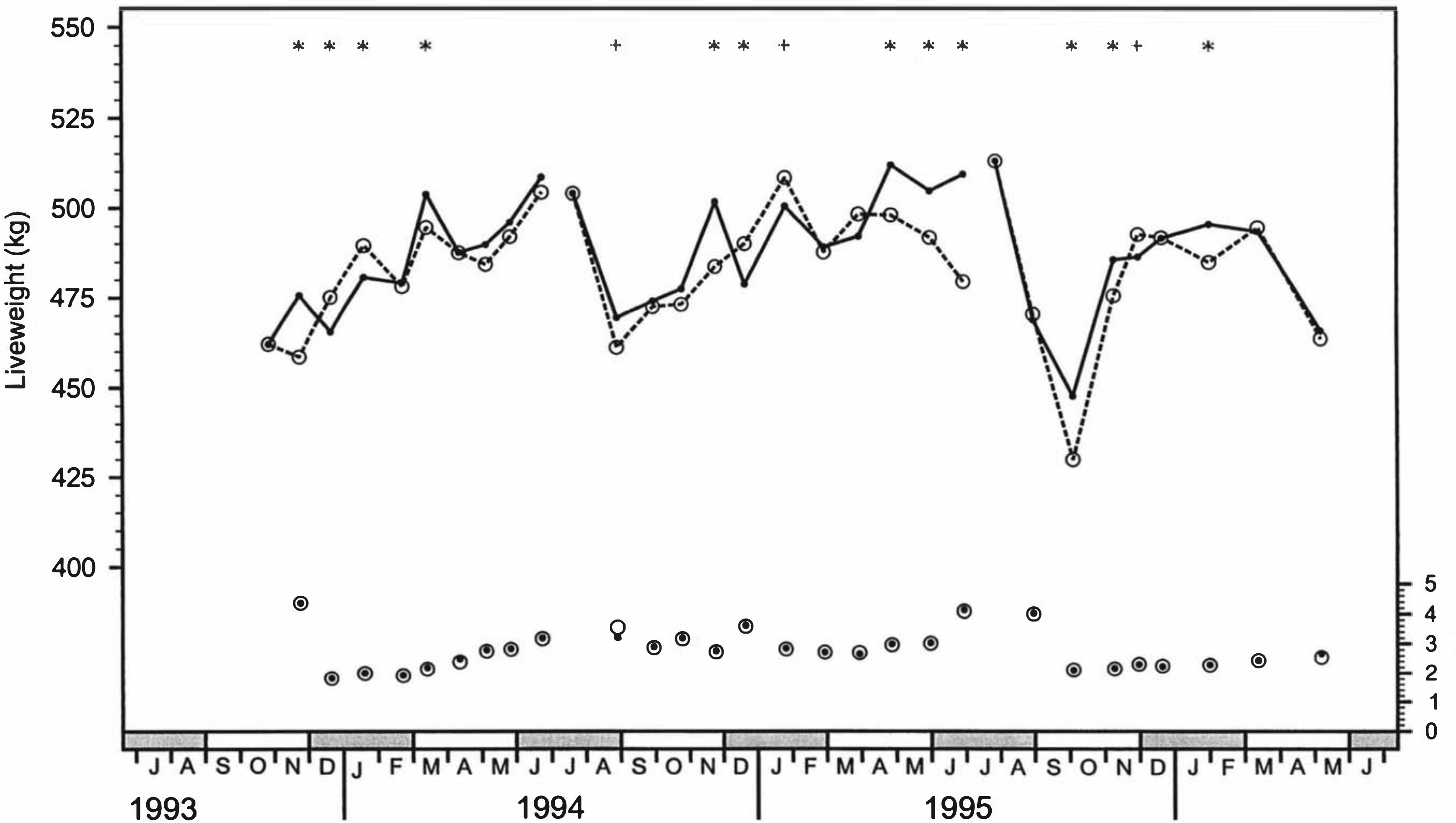
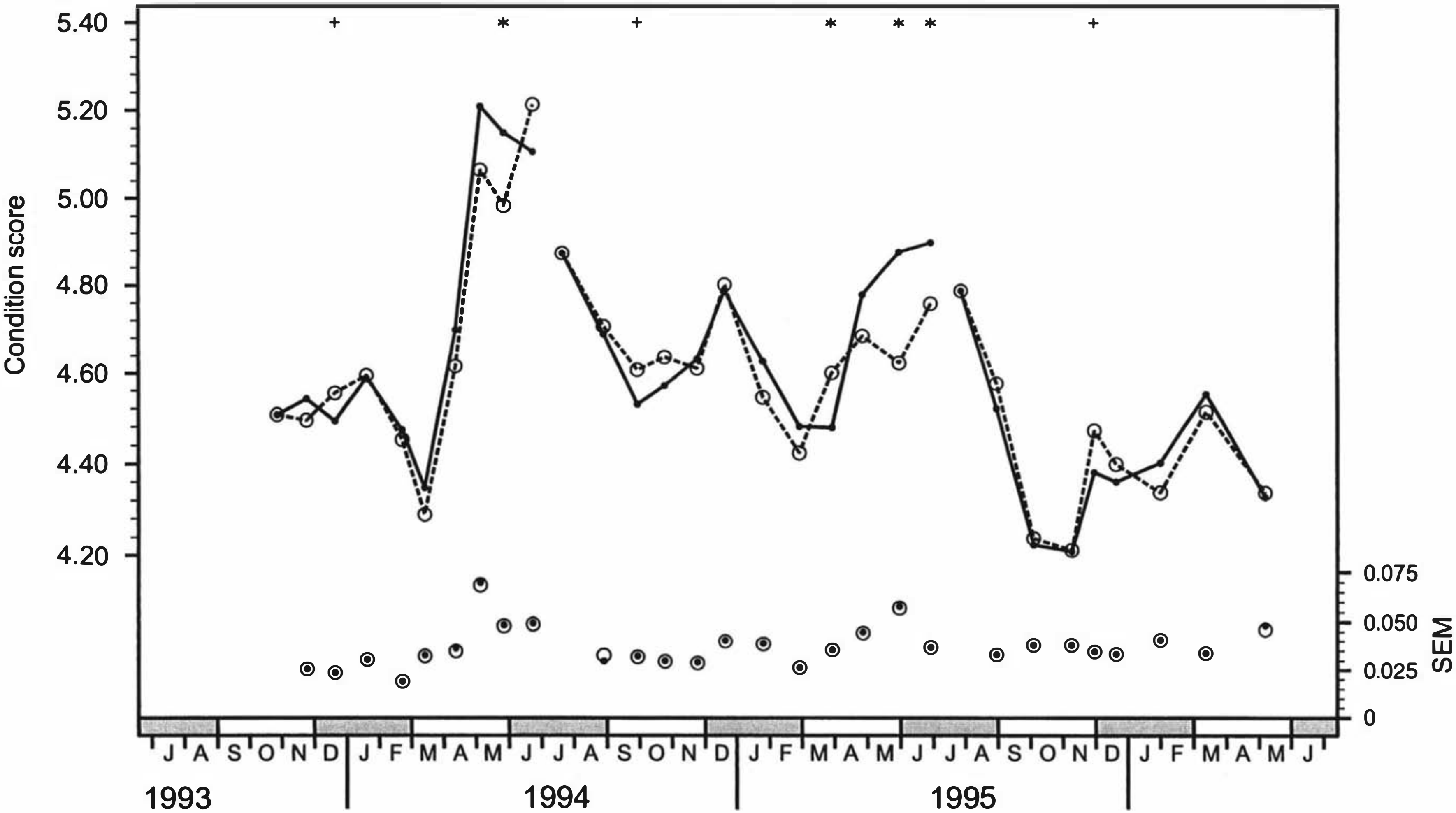


Figure 5-28 Mean monthly condition score values for early control —●— and late control - -○- - cows over three years, adjusted using initial condition score as covariate. Significant differences are indicated by + $P < 0.10$ and * $P < 0.05$. Standard error of the mean (SEM) for early control ● and late control ○ means (n = approx. 120).



5.3.5 Reproductive performance

Tables 5-20 through 5-22 give indicators of reproductive performance for EC and LC herds over four years. Although the trial was run for three years, four years of measurements were included to assess any effects on subsequent reproductive performance.

Table 5-20 Cumulative in-calf percentages (non-return after 49 days) for early control (EC) and late control (LC) cows over four years.

	1993		1994		1995		1996	
Week	EC	LC	EC	LC	EC	LC	EC	LC
1	25	15	10	17	10	16	7	6
2	45	35	21	33	22	42	13	20
3	61	61	45	46	35	56	32	32
4	70	69	56	60	49	71	41	43
5	73	76	63	69	56	74	53	52
6	79	78	68	73	66	78	63	64
7	82	81	75	81	78	86	73	70
8	82	81	78	84	84	87	80	71
9	83	83	81	88	84	88	85	76
10	83	83	84	90	84	88	88	80
P (χ^2)	0.2434		0.0051		0.0000		0.1191	

In-calf rates (cumulative percentages) for ten weeks are presented in Table 5-20 and represent cows in-calf if they did not return after 49 days. Target values for both herds were 33%, 57%, 80%, 86% and 93% at weeks 2, 4, 6, 8 and 10, respectively for all four years. Both herds were behind target values in all years. Chi-square tests indicate differences between treatments in 1994 and 1995, with the LC herd getting in-calf quicker than EC and achieving a higher final in-calf rate. The chi-square value for all four years combined was $P < 0.0003$.

Four years of calving outcomes are given in Table 5-21. In 1993 over 90% of the cows calved normally and in 1995 and 1996 the figure was over 95%. In 1994, 15% of both EC and LC were induced. Within years treatment had no effect on the proportions of animals aborted, induced or calving normally during the trial.

Table 5-21 Calving outcomes (%) of early control (EC) and late control (LC) cows over four years.

Outcome	1993		1994		1995		1996	
	EC	LC	EC	LC	EC	LC	EC	LC
Aborted	0.0	1.6	1.6	0.8	0.0	0.8	0.0	0.8
Induced	9.0	6.4	16.8	14.2	2.5	0.8	4.4	2.5
Normal	91.0	92.0	81.6	82.0	97.5	98.4	95.6	96.7
P (χ^2)	0.2840		0.6980		0.3620		0.4490	

In 1993, 1995 and 1996 treatment had no effect on calving to first service which ranged from 75 to 84 days (Table 5-22). During 1994 LC cows returned to service significantly earlier (7 days) than EC cows. The mean number of days from calving to conception was significantly less for LC than EC in 1994 and 1995, by 8 days. In 1993 and 1996 treatments had no effect on the mean number of days it took for cows to conceive after calving. Treatment had no effect on the mean number of services per cow which ranged between 1.6 and 1.8 (Table 5-22).

Mean calving dates were variable, although later for LC than EC in 1994 by 7 days (Table 5-22). Mean calving dates ranged between approximately 14 August and 24 August each year. Treatment had no effect on the mean date of first mating which was approximately 05 November each year.

Table 5-22 Mean reproductive indices of early control and late control cows over four years.

	Treatment			
Year	Early control	Late control	SEM	P
Calving to service 1 (days)				
1993	74.91	78.36	1.871	0.1939
1994	82.20	74.49	2.146	0.0118
1995	83.47	81.57	1.853	0.4699
1996	77.11	80.18	2.238	0.3339
Calving to conception (days)				
1993	92.04	97.53	2.659	0.1457
1994	92.04	83.83	2.501	0.0213
1995	95.57	88.09	1.965	0.0077
1996	90.64	93.51	2.763	0.4644
Number of services per cow				
1993	1.59	1.64	0.114	0.7376
1994	1.60	1.58	0.078	0.8804
1995	1.84	1.69	0.088	0.2463
1996	1.73	1.75	0.089	0.8387
Calving date				
1993	21/08/93	19/08/93	1.789	0.4154
1994	15/08/94	22/08/94	1.788	0.0066
1995	14/08/95	15/08/95	1.633	0.4976
1996	24/08/96	19/08/96	2.074	0.1084
Date of first mating				
1993	03/11/93	05/11/93	1.207	0.3157
1994	05/11/94	04/11/94	1.158	0.8631
1995	05/11/95	05/11/94	1.101	0.9074
1996	08/11/96	09/11/96	1.241	0.8379

5.4 Apparent intake of pasture and supplements (total)

Total daily dry matter intake (pasture and supplements) was calculated by adding daily supplements (Section 5.5) to the pasture intake values presented in Table 5-5. Monthly means of total apparent daily intake are given in Table 5-23. Apparent daily total intake ranged from 9 kg DM cow^{-1} to 25 kg DM cow^{-1}, with a maximum value of 31 kg DM cow^{-1} for LC in February 1996. During 1993/94 there were no differences between treatments. In 1994/95 LC cows had marginally higher intakes than EC in September and January. Treatment differences were variable in 1995/96 with LC cows having higher intakes than EC cows in November and February, although this was reversed in January.

Seasonal daily total (pasture and supplements) intake values are presented in Table 5-24 and ranged from 14 to 21 kg DM cow^{-1} day^{-1}. Total intake values were higher for LC than EC for the period from autumn 1993/94 to summer 1995/96 with significant differences apparent in autumn 1994/95 and spring 1995/96. Spring 1993/94 and winter 1994/95 values were more variable.

Table 5-23 Monthly pasture and supplement intake values (kg DM cow^{-1} day^{-1}) for early control and late control cows over three years.

	Treatment			
Month	Early control	Late control	SEM	P
1993/94				
November	17.0	13.1	3.56	0.4702
December	11.8	11.5	2.19	0.9210
January	14.2	16.3	2.67	0.6047
February	17.8	14.7	2.19	0.3455
March	15.6	16.7	2.87	0.7917
April	9.2	9.5	2.65	0.9313
May	14.7	22.7	4.85	0.2985
June	-	9.1	-	-
1994/95				
July	15.7	8.8	1.51	0.1933
August	20.3	27.3	8.96	0.6208
September	15.6	20.4	1.70	0.0820
October	13.7	14.8	1.89	0.6888
November	14.5	16.5	2.77	0.6083
December	13.6	15.1	1.62	0.5300
January	18.5	22.7	1.58	0.0872
February	18.3	15.1	2.00	0.2987
March	13.9	17.6	1.48	0.1152
April	12.5	19.0	2.98	0.1145
May	11.6	12.9	1.93	0.6534
June	16.1	11.7	-	-
1995/96				
July	7.7	-	-	-
August	16.2	15.1	4.31	0.8616
September	13.9	18.3	1.93	0.1340
October	14.8	15.2	2.08	0.8902
November	18.1	25.8	1.93	0.0153
December	17.0	20.9	3.62	0.4642
January	20.8	13.8	1.89	0.0313
February	23.6	31.1	2.64	0.0797
March	22.8	19.5	2.03	0.2829
April	22.0	19.6	2.58	0.5259

Table 5-24 Seasonal total (pasture and supplement) intake values (kg DM cow^{-1} day^{-1}) for early control and late control cows over three years.

Season	Treatment		SEM	P
	Early control	Late control		
1993/94				
Spring	17.0	13.1	3.56	0.4702
Summer	14.8	13.6	1.36	0.5583
Autumn	13.7	17.0	2.22	0.2968
1994/95				
Winter	18.0	20.0	5.70	0.8137
Spring	14.4	16.7	1.28	0.2203
Summer	16.4	18.4	1.21	0.2457
Autumn	12.8	17.1	1.40	0.0407
1995/96				
Winter	14.1	14.2	2.87	0.9661
Spring	15.8	19.4	1.29	0.0571
Summer	20.2	21.9	2.08	0.5854
Autumn	22.4	19.5	1.54	0.2051

Daily total (pasture and supplements) intake values by year are presented in Table 5-25 and ranged between 15 and 20 kg DM cow^{-1}. During 1994/95 LC cows had a higher intake than EC cows. This trend was repeated in 1995/96.

Table 5-25 Annual total (pasture and supplement) intake values (kg DM cow^{-1} day^{-1}) for early control and late control cows over three years.

Season	Treatment		SEM	P
	Early control	Late control		
1993/94	14.7	14.4	1.12	0.8636
1994/95	14.9	17.6	0.80	0.0174
1995/96	18.3	19.9	0.97	0.2326

5.5 Supplement balance

A summary of herbage conserved and supplements fed, in megajoules of metabolisable energy (MJ ME), is given in Table 5-26. They were calculated using the energy concentration values given in Table A5-2 of Appendix Five. Monthly supplements fed (megajoules of metabolisable energy) are given in Tables A5-3 and A5-4 of Appendix Five, for EC and LC, respectively. Both farmlets had a net inflow of supplements in all years (Table 5-26). The deficit was similar between treatments in the first two years (1993/94 and 1994/95) although over 50% higher in 1994/95 than in 1993/94. In the first year slightly more supplements were harvested on EC than LC while the opposite was the case in 1994/95. In the final year the deficit for LC was twice that of EC, the result of less forage conserved on LC and approximately 30% more supplements fed, primarily during October and November.

Table 5-26 Herbage conserved (MJ ME ha^{-1}), supplements fed (MJ ME ha^{-1}) and supplement balance (MJ ME ha^{-1}) on early control and late control farmlets over three years.

Year / Treatment	Herbage conserved ‡	Supplements fed †	Balance
1993/94			
Early control	10 670	17 775	-7 105
Late control	9 225	18 180	-8 955
1994/95			
Early control	2 990	17 720	-14 730
Late control	5 165	23 200	-18 035
1995/96			
Early control	2 465	14 440	-11 975
Late control	1 055	23 115	-22 060

‡ Herbage was conserved as either baleage or silage.

† Details are presented in Appendix Five, Table A5-3.

5.6 Discussion

This section is concerned with evaluation of the results presented in Sections 5.2 through 5.5. Initially, the research techniques used in the trial are discussed followed by the effect of the treatments on pasture, animal and farmlet production.

5.6.1 Research techniques

5.6.1.1 General

This trial consisted of two treatments, one based on common farm practice (early control) and the other on the late control spring pasture grazing management strategy. To be able to run the trial as a closed system, mimicking a commercial dairy farm, it was necessary to make each farmlet as large as possible. In practical terms, there is a trade-off between the number of units desired experimentally and the size of each unit. Furthermore, ease of setting up and running these units day to day also has to be considered. The costs, in terms of resources and financial considerations, associated with large systems trials are well known and make replication unrealistic. Therefore, the experimental design employed for this study was simple (Completely Randomised Design - CRD) with paddocks or animals used for replication.

The management structure of No 4 Dairy Unit, which was being run as a commercial enterprise, and the importance placed on maximising output contributed to the difficulties experienced in applying the treatments. During spring, when the treatments were being applied, changes in pasture production can happen quickly. To ensure the success of any farm production system the ability to respond to changes quickly and completely is critically important (Kay 1981).

Despite the availability of information to monitor the current position of the farmlets, in terms of average pasture cover and pre- and post-grazing cover, it was more difficult than expected to maintain predetermined sward conditions in this large systems trial. In contrast to the management on the EC farmlet, management on the LC farmlet aimed to delay removing paddocks from the grazing round for conservation (silage, haylage or hay) until pasture covers were higher. However, a combination of the high stocking rate imposed on the farm and the climatic conditions experienced meant that there was little extra herbage available in spring for conservation in either treatment. This was overcome to some extent in the final year by adding extra supplements into the LC farmlet. During the trial the average stocking rate was 2.75 cows ha^{-1} (Section 3.4.2) which is 10% higher than the average for Manawatu, Wellington, North Island and New Zealand at 2.5 cows ha^{-1} (Section 2.2). Per cow and per hectare production for the trial farmlets were both above average for the region and province (Section 2.2). Average milksolids production ranged between 350-400 kg cow^{-1} and 975-1 115 kg ha^{-1} during the trial compared to 293 kg cow^{-1} and 735 kg ha^{-1}, respectively for the Manawatu region.

In general the climate for 1993/94 was drier in October, cooler in November and December and drier and hotter through January and February than average when compared to the 50-year mean (Tables A3-1 and A3-2 in Appendix Three). During the second year (1994/95) spring was cooler and wetter than average and summer was drier, while in 1995/96 the spring was wetter. In an attempt to improve cow condition and increase pasture cover additional supplements were fed on the LC farmlet in the final year (26 tonnes of DM as carrots and brewers grain). Through late October and November supplements constituted almost half of the cows intake of dry matter.

5.6.1.2 Sampling Procedures

In the present study annual pasture production of approximately 12 500 kg DM ha^{-1} (Section 5.2.6) was calculated from accumulation rates derived from pre- and post-grazing pasture covers. At a stocking rate of 2.75 cow ha^{-1}, and assuming a herbage ME value of 11.5 MJ kg DM^{-1}, this equates to an ME intake of 51 750 MJ cow^{-1}. In addition, supplementary feeds accounted for a further 5400 MJ cow^{-1} (Table 5-26), giving a total annual ME intake of 57 150 MJ cow^{-1}. This is 12.8% higher than the annual requirements reported by Holmes & Wilson (1987) for a 475 kg lactating cow (Figure 5-27) producing 375 kg milksolids per annum (Table 4-19), at 50 645 MJ metabolisable energy (ME). This discrepancy may have been due to wastage of herbage, for example in damage by trampling, which was not picked up by the sward sampling procedure adopted.

The soils (Section 3.2.1) on No 4 Dairy Unit can become very wet during winter which can make herbage mass determination by the cutting, washing and drying method and the rising plate method difficult at this time. Removing all the herbage from pugged and damaged pasture is difficult since some of the herbage has been trodden into the ground, particularly post-grazing. In addition, there is considerably more soil in the sample which may also contain root/crown material. When using the rising plate meter under these conditions the uneven ground can cause erroneous readings to be obtained when the foot disappears into a hole.

Collection of samples and subsequent processing in the laboratory for determination of botanical composition and tiller densities proved to be very time consuming. In light of this, the sampling strategy was modified so that for the final three collection dates ten paddocks per treatment were sampled over one month. Furthermore, the final two collection dates were positioned to be either side of the control phase of the LC management strategy. As a result of moving the sampling dates it is not possible to compare directly the results of the first two years with the final year.

Variability was higher for pre- and post-grazing pasture cover estimates derived from those paddocks close to grazing in each of the routine sets of plate meter height measurements, as seen by the wider bands for series one (Dairy Farms Technician) and two (Plant Science Technician) pre- and post-grazing pasture covers (Figures A5-1 to A5-4, Appendix Five), than in the values from indicator paddocks (Figures 5-4 and 5-5, Section 5.2.3). However, pre- and post-grazing pasture cover estimates taken from the routine plate meter height measurements (farm walks) had significantly fewer observations than pre- and post-grazing pasture cover values (indicator paddocks, 5 paddocks per treatment). The variances contain true variation as well as random error. In addition, variability as seen by the width of the Bayesian bands was often less for post-grazing pasture cover than for pre-grazing pasture cover. Series one provided pre- and post-grazing covers similar to those obtained from indicator paddocks, while series two pre-grazing covers were lower and with less variability between seasons and post-grazing covers. Fewer treatment differences were evident in pre- and post-grazing pasture covers from routine farm walks than in the values from indicator paddocks, with the only difference being apparent in series two pre-grazing pasture cover during spring and summer 1995/96.

The rising plate meter can provide an alternative to pasture cuts, although herbage mass estimates from pasture cuts provides the best estimate of pasture cover. Average pasture cover was used for the day to day management of the trial and estimates of cover from the rising plate meter using one calibration equation all year were not in agreement with visual assessment, particularly in summer, hence the development of a dynamic calibration equation (Chapter Four). Although the rate of accumulation of herbage can be calculated using average pasture cover values from un-grazed paddocks, this was found to be extremely variable and has not been included in the thesis since pre- and post-grazing cuts provided a more reliable estimate.

The development of a calibration equation in Chapter Four which accounts for the seasonal differences in pasture density should allow clearer definition of herbage mass estimates from rising plate meter measurements. The bulk density of pasture in the summer was found to be twice that in the winter. Therefore, specifying a post-grazing pasture cover of 2000 kg DM ha^{-1} for late control, for example, was simplistic. In the original studies of LC pastures grazed by dairy cattle (da Silva 1994) residual pasture heights of 50 and 100 mm during spring were specified for EC and LC respectively. Following the dynamic pasture cover estimates from a plot similar to the one presented in Figure 4-8 of Chapter Four, which gives predicted pasture cover based on plate meter heights of 10 and 20 semi-compressed plate meter height units (0.5 cm) during spring, would provide achievable specifications. Returning to or including pasture height targets in treatment specifications would remove any confusion and allow treatments contrasts to be achieved.

5.6.1.3 Statistical analysis

Those variables for which both treatments were not measured on the same day (i.e. grazing interval, pre- and post-grazing pasture cover, pasture dry matter content, herbage accumulation rate, pasture utilisation, proximate analysis) usually did not have measurements for all replicates (paddocks or animals) at the same point in time. To analyse these variables using an analysis of variance (ANOVA) would require the observations to be arbitrarily grouped. This would most likely lead to different numbers of observations in each treatment and require the use of an ANOVA for unbalanced designs. While this is not a major problem, the choice of how the observations are grouped can influence the outcome of the analysis. For some variables, particularly those variables collected pre- and post-grazing, grouping by month for example provided sufficient observations for analysis during most of the year but not for winter, where grouping by season was necessary.

Bayesian smoothing provided an alternative to ANOVA for those variables where treatments and/or all replicates were not measured at the same point in time, and for large data sets. The computer package used allowed the results of the analysis to be plotted with their associated confidence bands so that differences between treatments could be assessed. Both Bayesian smoothing (Figure 5-1) and ANOVA (Table 5-1) were used to analyse the data on grazing interval (Section 5.2.1) and showed similar trends and absolute values for grazing interval. Since grazing interval was calculated from all paddocks (n = 20) within each treatment there were sufficient observations to use an ANOVA, even in winter, by contrast with those pasture variables measured only from indicator paddocks (n = 5), for example, pre- and post-grazing pasture mass.

All the variables analysed using Bayesian smoothing, with the exception of grazing interval, had a seasonal trend (365.25 days) imposed on them. This was considered to be a reasonable assumption for the current data since the annual cycle of seasons is the major influence on a grazed pasture dairy production system. Pre- and post-grazing pasture covers (Figures 5-4 and 5-5) are examples of variables analysed by Bayesian smoothing with a seasonal trend. Table 5-2 presents this data for the months of October and November pre-grazing and January and February post-grazing analysed by ANOVA, and both absolute values and treatment differences were reasonably consistent using either of these methods. Bayesian smoothing was a useful procedure for dealing with large data sets with seasonal variation and there was no indication of bias in treatment comparisons.

Bayesian smoothing produces mean values close to those that would be produced by conventional analysis methods, although strictly speaking it is not possible to analyse the variables in question in this analysis without some arbitrary grouping. For example, the values of grazing interval from Figure 5-1 and Table 5-1 for February 1995 are 28 days for both EC and LC. Bayesian smoothing gives means that are more dynamic (changeable) than the means from ANOVA based on arbitrary monthly groups. The figures produced as a result of analysis by Bayesian smoothing include both mean values and raw data, showing the variability of the observations associated with the mean. The size of the bands reflects the confidence in the mean which is a result of the number of observations and their scatter.

The size of this trial and the inevitable number of replicates in the analyses meant that for many variables analysis identified significant differences between the treatments. However, there was often no clear advantage to either treatment for any length of time and Bayesian smoothing was useful since it highlighted those periods of time when a variable had a clear advantage.

While simple designs do not control error very well, the relatively large number of paddocks and animals in this analysis overcame this problem so that treatment differences could be detected if present. It can be difficult to identify treatment differences in systems trials, particularly if differences in productivity are a reflection of underlying differences between the paddocks of the farm. Good control of variability is necessary if differences between treatments are to be detected. In this trial paddocks were used as replicates to provide a measure of spatial variability.

During the trial series one (Dairy Farms Technician) and two (Plant Science Technician) estimates of average pasture cover had a mean coefficient of variation of 26.5%, although the range was quite large. For series one the mean was 28.4%, ranging from 15.0% to 60.0% while for series two the mean was 24.6%, ranging from 15.0% to 45.0%. Included in the coefficients of variation reported here are measurement error and genuine variation due to paddocks being at different stages of regrowth after grazing on any particular day. da Silva (1994) reported similar levels of variability (coefficients of variation up to 64.0%) when measuring pasture traits. The difference between paddocks immediately pre-grazing and paddocks immediately post-grazing ranged from 20% in summer to 40% in winter (Table 5-2). As a result, the coefficient of variation associated with average pasture cover was large, reducing the number of treatment differences detected. Therefore, pre- and post-grazing covers should also be considered when determining the success or otherwise of the treatments.

The coefficients of variation for milksolids production measured fortnightly by herd test were 17.5%, 16.0% and 15.5% (mean = 16.3%) for 1993/94, 1994/95 and 1995/96, respectively. These values reflect both genuine measurement error and error associated with cows being at different stages of lactation and cows having different potentials, although the use of initial milksolids as a covariate removed some of the variation. Values between 10.0% and 20.0% are considered reasonable for animal measurements in designed experiments (J. Hodgson, personal communication). In a paddock-scale experiment investigating late control da Silva (1994) reported coefficients of variation for animal measurements in the range of 5.0% to 10.0%. Despite the lack of clear treatment differences in milksolids production, tight control of variability was achieved in this large systems trial, providing an objective basis for evaluation.

5.6.2 Differences between treatments in general

Overall, there was no extended period of differences between EC and LC in either pasture production or animal production during the three years of the trial. In general, mean daily milksolids per cow was variable, with the advantage frequently changing between treatments in all three years so that overall, differences in the quantity of milksolids produced per cow were small and inconsistent. However, large differences in animal performance would not be expected considering the marginal differences in pasture production achieved.

While differences between treatments in average pasture cover were achieved over late spring in all three years (Figures 5-2 and 5-3) the extent and duration of the differences achieved were limited and were not reflected in pre-grazing pasture covers, particularly in the first two years (Table 5-2, Figures 5-4 and A5-1 and A5-3 in Appendix Five). Treatment differences were not apparent until November, 5-6 weeks later than in previous experiments (da Silva 1994; Hernández Garay 1995). Recent work has shown that late control spring grazing management increases tiller population and size more after an extended spell of seed-head development

(12 weeks) when compared to a shorter spell of 6 weeks (Hemández Garay 1995). In addition, the difference in average pasture cover between treatments was less than the 700 kg DM ha^{-1} targeted. Average pasture covers were higher than the 2 000 kg DM ha^{-1} and 2 700 kg DM ha^{-1} targeted in spring for EC and LC respectively, and average pasture cover on EC was closer to that of LC in previous experiments, particularly for 1995/96 (da Silva *et al*. 1994). Silage or baleage should have been taken from EC paddocks in late October/mid November, and from LC paddocks in December. However, this was usually not possible due to the high grazing pressure imposed. For both treatments this meant the area shut up for conservation was limited and for EC conservation took place later than expected.

da Silva (1994) suggested that control of reproductive growth for the LC grazing strategy in late November/early December (anthesis) proved to be more desirable than control two weeks later (mid December), since it resulted in a higher proportion of the extra dry matter being produced during the summer/autumn period. Furthermore, a gradual removal of the reproductive stems over 2 or 3 grazing cycles proved to be more effective in increasing summer-autumn production than a more sudden approach which removed reproductive stems at the first control grazing.

Ideally, had the planned differences in average pasture cover and pre-grazing pasture cover been realised in all three years (Sections 3.3.1 and 3.3.2), there should have been a corresponding and simultaneous increase in post-grazing pasture cover during spring. This would indicate that the LC farmlet was operating at a higher average pasture cover than EC, providing the reproductive development required. As detailed above, treatment differences were not achieved in the first two years and the differences that were achieved in the final year were probably too small, too late and too short-lived to be effective.

By comparison with the paddock-scale experiments reported by da Silva (1994) where cows were grazed as required to treatment specifications, the pastures within treatments in the current trial were likely to be more variable (patchy). In this trial cows were required to remain on the closed farmlets during the study and it was therefore not possible to impose the treatments simultaneously on all paddocks. That is, application of the treatments was partially restricted by the very system being studied. The cows were locked into a grazing cycle where the options available were limited to removing paddocks from the grazing round for conservation, therefore speeding up the grazing interval on the remaining paddocks. Pastures in EC and LC were found to contain patches (Padilla 1997) and therefore EC had areas experiencing LC management and vice versa.

Based on the results of this trial it is likely that the pasture cover specifications stipulated for the treatments may have been somewhat simplistic. Large differences in the density (kg dry matter per unit plate meter height) of pasture at different times of the year also influenced the specifications. That is, pasture cover specifications should have taken into account the increase in density during spring (Chapter Four) but did not do so.

Failure to apply the treatments and realise their potential production benefits was due to several limitations. While treatments were specified in terms of average pasture cover and post-grazing pasture cover, the specifications were not applied rigorously enough. Perhaps concentrating on pre- and post-grazing pasture covers would also help to realise the required treatment differences during spring. Furthermore, the use of rotational grazing management on dairy farms implies that there is an inherent sequence of grazing of the paddocks. Since it took 20 - 30 days to complete one rotation in spring, summer and autumn, any action, such as the control of reproductive growth, had to be carried out over this time frame also. This, combined with the ability of the system to buffer changes, contributed to the difficulties in achieving treatment specifications.

Management constraints at the high stocking rate relative to the district contributed to the lack of differences achieved in spring pasture cover. A fast rate of decline of milksolids production may indicate that the stocking rate was too high.

Thomson & Holmes (1995) suggested that a rate of decline of 7% $month^{-1}$ was considered reasonable for a well fed, high BI (breeding index) herd. During 1993/94, 1994/95 and 1995/96 the monthly rates of decline in this trial were 11%, 8% and 6% respectively. During the trial the rate of decline decreased along with the stocking rate (Section 3.4.2).

5.6.3 Specific treatment differences

In the previous section overall differences between treatments were considered. This section is concerned with a more detailed examination of specific treatment effects.

5.6.3.1 Grazing interval

Grazing interval was defined as the interval between successive grazings of individual paddocks for the treatment and has been analysed using both Bayesian smoothing, without any seasonal influence imposed by the Bayesian smoothing software, and conventional analysis (ANOVA), after arbitrarily grouping observations (records) by month.

In each year of the trial grazing intervals lengthened in May and peaked in July before falling to 20 days by October. Over summer, grazing interval gradually climbed to 30 days. Winter values were two to three times longer than during the rest of the year, reflecting both the lower feed requirements of cows and lower pasture accumulation rates at this time of year. The values given in Table 5-1 and shown in Figure 5-1 suggest that grazing interval was longer on LC during autumn 1994 than EC. The reason for this difference is unclear. Both methods of analysis also indicate that grazing interval was longer for LC than EC during November 1995, perhaps reflecting differences in the conservation strategy.

During this trial, grazing interval was not intended to be manipulated directly in either EC or LC spring grazing management treatments. However, differences in grazing interval occurred due to paddocks being out of the grazing round for conservation at different times. It was farm practice to put condition on the cows during autumn by maintaining a relatively fast rotation at this time.

5.6.3.2 Average, pre- and post-grazing pasture cover

Since it was impractical, in a trial of this size, to determine average farmlet pasture cover by destructive sampling techniques a relatively cheap and quick alternative had to be found. The rising plate meter had been used on the farm before the start of the trial and was retained. Compared to other methods of non-destructive herbage mass determination the rising plate meter controls operator error and differences due to climate. Predicted average pasture cover was used throughout the trial to assist with decisions on the day to day running of the farmlets and application of the treatments. Weekly average pasture cover values showed the position of the farmlets over time and the differences between EC and LC when setting up the treatments. During the first two years of the trial the calibration equation used was HM = 405 + 166 MR, the standard No 4 Dairy Unit calibration equation. For the final year of the trial (1995/96) the calibration equation was updated regularly (fortnightly) based on pre- and post-grazing pasture cuts.

The average pasture cover estimates presented in this thesis were derived using the calibration methodology described in Chapter Four. The development and subsequent use of this calibration equation provided estimates of average pasture cover using the rising plate meter in line with those measured by taking cuts throughout the year. As noted in Chapter Four, estimates obtained with the rising plate meter based on a single calibration equation are often considered to be biased. Recently, Hainsworth (1999) reported calibration equations developed for dairy farmers throughout New Zealand that include seasonal variation in both the slope and intercept values of the linear regression of dry matter on plate readings, and the estimates of pasture cover are similar to those developed and used in this thesis (Section 4.4).

The measurement method used reflected increasing dry matter content of pastures over summer (Figure 5-6) compared to visual targets normally used in practice by farmers, which influenced the absolute values measured. For this reason the use of green herbage mass has been suggested as a more constant estimate of the feed available to the cows (Butler 1986). However, green herbage mass is currently difficult to estimate. The results shown in Section 5.2.9.1 suggested that the proportion of green herbage in the sward was as low as 70% in the summer and up to 90% in the winter. Lax grazing in late control was probably not long enough to increase dead matter content over that in EC before December, in part because the length of lax grazing was similar to the life span of leaves (Parsons & Penning 1988). Dead matter content was similar to that reported previously in similar pastures during the same season (Butler 1986).

Average pasture covers reported in Section 5.2.2 represent the total quantity of herbage present and not necessarily the quantity of green herbage available or the quantity of herbage available to the animal, particularly in summer. However, this is seen as an improvement over the previous situation where rising plate meter values represented neither the total herbage present, particularly in summer, nor the quantity of herbage available to the animal (P. N. P Matthews, personal communication), and were not comparable to estimates obtained by taking cuts or visual estimation.

5.6.3.3 Pasture production and utilisation

Herbage accumulation rates on EC and LC were similar (Figure 5-7), although in the first two years there appeared to be an advantage to LC during autumn and early winter. Previous small-plot and paddock-scale experiments have shown increased spring, summer and autumn pasture production of up to 20% during the preparation period and following late control spring pasture management (da Silva 1994; da Silva *et al.* 1993; 1994). In contrast, there was no advantage to LC over EC in this trial, partly due to the drier than normal summers, but also due to little effect in spring either. Controlling pastures on the LC farmlet later in the year (December) compared to EC (throughout spring) did not have a detrimental effect on subsequent pasture production or dry matter content (Figure 5-6), even in the first two years when relatively dry summers were experienced. Morphological differences in swards caused by differences in grazing management have been recognised to be important factors in determining herbage accumulation rates through the ability of the sward to produce new leaf (Grant & King 1983). Reduced tiller density is one such morphological difference than can reduce herbage accumulation by limiting the number of growing leaves (Hunt & Field 1979) and the ability of the plants to compete for space, light and nutrients.

Seasonal herbage accumulation values were comparable and treatment differences variable, with the exception of autumn 1995 when LC produced more pasture than EC, resulting in 12.9% (1 650 kg DM) more pasture on LC than EC for the year ending 30 November 1995. When grouped over seasons the marginal differences in herbage accumulation rates reported above resulted in a significant difference for autumn 1995. For the year ending 30 November 1994 LC produced 6.1% (755 kg DM ha^{-1}) more herbage than EC. Annual pasture production values for the years ending 30 November 1994 and 1995 were very similar for EC and LC at approximately 12 500 kg DM ha^{-1}.

In general, LC pastures tended to have higher utilisation efficiency than EC pastures. Occasional significant differences in utilisation were apparent, but there was no overall significant advantage to either EC or LC (Figure 5-8 and Table 5-4). The considerably higher values of utilisation seen during winter may be artefacts of a longer rotation length and the length of time dry cows spent on each paddock, which was often weeks compared to one or two days at other times of the year. Utilisation of pasture in one grazing should be approximately 40% (P. N. P. Matthews, personal communication). For example, a pre-grazing herbage mass of 2 500 kg DM ha^{-1} and a post-grazing herbage mass of 1 500 kg DM ha^{-1} (1 000 kg DM ha^{-1} herbage mass removed) gives 40% utilisation.

Reduced levels of herbage utilisation in spring (Figure 5-8) are often associated with an increase in the proportion of stem material in the sward and rapid accumulation of senescent material. These conditions can interfere with the quantity of herbage produced and nutrient intake of the grazing animal (Korte 1982; Korte *et al.* 1982, 1984; Thomson *et al.* 1984; Butler 1986; Bryant & L'Huillier 1986; L'Huillier 1987b, 1988; L'Huillier & Aislabie 1988; Hoogendoom *et al.* 1992; da Silva 1994). In this trial, the dry matter content of pastures (Figure 5-6) was twice as high in summer as in winter, due in part to the decrease in the proportion of live material in the pastures (Table 5-8) and leaf in the ryegrass component (Table 5-12), and an increase in the proportion of dead and stem material at this time.

5.6.3.4 Botanical composition

Although the pasture cover differences required for LC were only partially achieved during late spring, LC paddocks had more clover than their EC counterparts (Table 5-9) largely due to an increase in red clover (Tables 5-9 and 5-10). Red clover was more responsive to lax defoliation than white clover, particularly in the summer and autumns of 1993/94 and 1994/95. Other workers have reported an increase in the white clover content of swards managed under the late control strategy (da Silva 1994; Hemández Garay 1995). Lax grazing may increase the growth of clover stolons through the accumulation of ungrazed leaves (Davies 1992), resulting in larger stolons with improved carbohydrate reserves (Grant & Barthram 1991; Barthram & Grant 1994). Following the control of LC pastures in December, pastures are likely to have been relatively open as seen by lower tiller densities (Tables 5-13 and 5-15), providing space for colonisation. da Silva (1994) suggested that the control of reproductive swards probably caused most of the grass leaf blade and clover leaf to be removed after the elongation of grass leaves and sheaths during the reproductive phase. Since the regrowing petioles are short but the regrowing leaflets remain large this could have caused an increase in the clover leaf area relative to the grass leaf area and a short-term increase in the clover content of the swards (Davies 1992).

Clover plants are characterised by having a lower specific leaf area and slower pattern of unfolding of new leaves compared to grass species, giving an advantage in terms of current and future carbon acquisition during the regrowth process in summer (Parsons *et al.* 1991a, 1991b). Furthermore, the lower investment of carbon per unit area of leaf, associated with potentially higher levels of carbohydrate reserves in LC, high temperatures and low soil moisture content may have allowed clover plants to perform better than in EC. da Silva (1994) suggested that although ryegrass plants were tillering well by February they were unable to compete with the clover plants until autumn due to climatic conditions (high summer temperatures and low rainfall) which favour the clover plants.

For the remaining botanical composition variables considered in Section 5.2.9 (percent live herbage in total herbage, percent ryegrass in the grass fraction and percent leaf in the ryegrass component) differences between the treatments were variable, although LC generally had the advantage, particularly in the proportion of live material in total herbage and ryegrass in the grass component. The amount of leaf in the ryegrass fraction was higher for EC for the last year after initially being higher for LC in January/February 1994. However, consistent differences, particularly in the first two years of the trial, might not be expected considering the marginal differences in pasture production achieved. During the summer of 1995/96 Padilla (1997) also found considerable variation between paddocks within treatments but few consistent differences between EC and LC.

5.6.3.5 Population densities

There is considerable spatial diversity in the dynamics of tillers on grazed pastures because of variability in the availability of nutrients and mix of pasture species, and temporal and spatial variability in defoliation and regrowth. Ryegrass tiller numbers appeared to peak around autumn/winter each year on both treatments and fell during spring and summer. There was an overall increase in tiller population density during 1993/94 and 1994/95 but by the end of the trial both ryegrass tiller population densities and total grass tiller densities had retumed to levels similar to those at the start of the trial (Tables 5-13 and 5-15). The reason for this marked variation in tiller numbers during the trial is unclear and cannot be fully explained. Although the application of fertilisers was balanced between farmlets during the trial, an increase in nitrogen fertilisers during the early part of the trial compared with earlier farm use is one possible cause.

There tended to be a greater increase in grass tiller densities (total grass tillers) on EC pastures than LC pastures in 1993/94, and significantly higher population densities during the summers of 1993/94 and 1995/96. However, the advantage in ryegrass tiller numbers frequently changed between treatments, with the exception of summer 1995/96 when EC had more ryegrass tillers than LC. Padilla (1997) found LC pastures to have fewer, heavier tillers than EC and concluded that size-density compensation was involved in response to the intensity of defoliation before December. Hemández Garay (1995) reported that swards grazed by sheep, where higher pasture residuals had been allowed over spring, revealed an increase in tiller densities. However, large differences in tiller densities between EC and LC in the current trial would not be expected considering the marginal differences in pre-grazing herbage mass, particularly in 1993/94 and 1994/95.

Under a lax spring grazing regime there is a reduction in the number of tillers with a corresponding increase in tiller size so that total herbage accumulation remains relatively constant (Matthew *et al*. 1996). Matthew *et al*. (1995) suggest that this event is common in grass species and has been termed tiller size-density compensation.

Allowing reproductive development throughout spring can result in lower tiller population densities (da Silva 1994), one consequence of reduced tiller appearance rates without compensation by reduced rates of tiller death (Korte 1982; Korte *et al.* 1982). Reproductive swards are associated with a poor light environment (Korte 1982) and competition for assimilates between maturing seedheads and young tillers (Ong *et al.* 1978; Carton *et al.* 1989; Matthew 1991; Matthew *et al.* 1991; Thom 1991). Hunt & Field (1979) reported that the light regime within a sward was a major factor contributing to tiller death. Seedheads that are allowed to pass the stage of anthesis have been shown to reduce the number and size of newly formed tillers and increase the death of young tillers through competition between young tillers and maturing seedheads (Matthew 1991).

Delaying beyond the end of December the return of LC reproductive swards to a vegetative state and reducing average pasture cover to the same level as EC may allow animals to graze selectively, causing rejected stem and older herbage to senesce and accumulate in the base of the sward, and to interfere with the tillering process (da Silva 1994). Korte (1982) reported that the dead herbage and ryegrass stems of rank pastures can shade photosynthetic tissue and cause reduced tillering (Davies 1977). However, da Silva (1994) and Hernández Garay (1995) found that return of LC pastures to a vegetative state in a timely fashion resulted in increased tillering in autumn. However, the high late spring pasture covers that resulted in both EC and LC pastures may have resulted in poor tillering in both swards during spring in this trial.

Early control pastures consistently had higher contents of other grasses and weeds in autumn and winter than LC, as seen by both tiller densities and botanical composition (Table 5-11). The ingress of undesirable species is often attributable to open pasture following hard grazing. During the trial EC pastures were grazed harder during spring and summer, as seen by the lower post-grazing pasture covers, which may help to explain the increase in other grasses. However, EC pastures had more other grasses than LC at the start of the trial and these differences remained throughout the trial.

5.6.3.6 Feed intake and nutritive value

Neither EC nor LC showed a consistent advantage in the apparent intake of pasture or the apparent intake of pasture and supplements (total intake) during the trial. However, intakes of pasture would not be expected to be different between EC and LC since there were no differences between the treatments in the rate of herbage accumulation. Furthermore there was no apparent difference in the nutritive value of EC and LC pastures (Section 5.2.12).

The higher pre-grazing pasture covers of LC pastures in spring would be expected to provide LC cows with a higher daily herbage allowance (Combellas & Hodgson 1979; Le Du *et al.* 1979, 1981; Bryant 1980b; Glassey *et al.* 1980). However, few differences in intake were evident in this trial. Intake rates in winter were more variable than in other seasons due to the inclusion of both milking and dry cows. Hoogendoom *et al.* (1988, 1992) and da Silva (1994) reported that the herbage intake and milk production of dairy cows grazing reproductive swards were maintained by offering high herbage allowances.

Nutritive values were generally higher (OMD, CP, Sol. CHO, Lipids) or quantities of structural components (NDF, ADF) lower from herbage cut to estimated grazing height compared to herbage cut to ground level, since the dead material in the base of the sward was excluded in the former case. That is, high digestibility was associated with high protein, low ADF and NDF pasture, and low digestibility pastures with low protein and higher ADF and NDF values. Acid detergent fibre (ADF) and NDF peaked in summer at the same time as the dry matter content of pastures. All pasture nutritive values in the final two years of this trial were unaffected by treatment. Variations between years reflect differences in the climate experienced and management imposed. The limited number of observations available for analysis and the reasonably large range of the observations recorded resulted in relatively large confidence bands and only allowed large differences to be detected.

Pasture energy concentration (OMD or ME) was not affected in the spring or summer by the LC strategy. The reproductive growth that was allowed to develop during spring and removed before the end of December was palatable and nutritious. At no time during the trial did the digestibility level of the diet fall below 67% which Hoogendoorn *et al.* (1988, 1992) reported to reduce milk yield. Throughout spring and summer stems were still green and likely to be of high digestibility. da Silva *et al.* (1994) showed individual cow performance was not affected during the pasture control phase on LC despite the higher proportion of grass stem and senescent material in those swards compared with EC swards. The potential value of green stems in mixed reproductive ryegrass-white clover pastures for feeding dairy cows has been reported before (Davies 1973; Thomson *et al.* 1984; L'Huillier 1987b; 1988; L'Huillier & Aislabie 1988; Thomson & McCallum 1989). The range, pattern and absolute values for OMD and ME on indicator paddocks were similar to those reported by Moller (1997), while for samples cut to estimated grazing height values were 3-5% higher throughout.

Hodgson (1977) and Wilson *et al.* (1995) showed that forage intake is linked to the digestibility of pasture diets. The reduction in digestibility during reproductive growth in late spring is a disadvantage for spring calving cows since it coincides with the potential peak of milk production (October) when cows need to maintain high intakes. Digestibility in ryegrass/white clover pastures is dependant on temperature and stage of maturity, decreasing by 1% for every 1°C increase in temperature (Minson & Mcleod, 1970).

Although LC pastures produced consistently more clover than their EC counterparts there were no apparent differences in nitrogen content (CP) for LC.

da Silva (1994) found higher levels of nitrogen in consumed herbage were associated with increased clover content. Moller (1997) reported similar values and pattems for CP and suggested that high values are likely to result in reduced milk production and/or weight loss. Throughout this trial CP levels were generally sufficient to support milk production with the possible exception of summer. However, the addition of significant quantities of supplements with low CP contents, such as maize with 8% CP (NRC 1989) or grass silage with 10-12% CP, could reduce the CP content of the diet. Low CP levels in pasture in October/November could affect peak milk production as the highest dietary CP requirements are at peak lactation and should be near 17-18% (NRC 1989).

The NDF levels reported in this trial were approximately 10% higher than those reported by Moller (1997) although the seasonal trends are similar. Acid detergent fibre values were similar to those reported by Moller (1997). Neutral detergent fibre represents the cellulose, hemicellulose and lignin fractions while ADF represents the cellulose and lignin fraction of the diet and this indicates that approximately half of the fibre in the diet is hemicellulose. Values of both NDF and ADF were more variable in the samples cut to estimated grazing height than the samples cut to ground level. High levels of NDF are reflected by low levels of intake, through the slowing of digestion of more fibrous material in the diet, thus slowing the rate of passage in the rumen and reducing appetite (Mertens 1985). Moller (1997) suggested that NDF levels between 30% and 40% (1.4% of bodyweight) are required for high producing cows.

High NDF values are associated with reproductive development during spring and summer in response to increasing temperature and day length (Wilson *et al.* 1975; Fales 1986). Cows potentially at peak milk production eating only pasture in spring may have trouble attaining and maintaining peak production and liveweight if pasture quality is not maintained and this can contribute to the speed of the post-peak decline seen in many New Zealand herds (Moller 1997). High NDF values are likely to lead to reduced dry matter intakes, even if the cows are offered *ad lib* pasture. Declining digestibility values may further compound the problem at this time of year. The high fat content of milk produced by grass fed cows in New Zealand results from high NDF levels providing a high percentage of the rumen volatile fatty acids as acetate and butyrate rather than propionate.

Soluble carbohydrate values from samples cut to ground level showed no differences between seasons compared to samples cut to estimated grazing height. The latter were similar to those reported previously (Moller 1997). High levels of soluble carbohydrates in winter may be related to low temperature and longer rotation lengths. While growth is restricted by low ground temperature sunlight will stimulate photosynthesis (Alberda 1965). Soluble carbohydrates arise when energy surplus to immediate requirements for growth and maintenance is stored in the plant. In summer lower soluble carbohydrate levels reflect increased metabolism and respiration in warm weather, and reduced storage. Furthermore, high temperatures stimulate the plant to produce more cell wall than cell content (Wilson *et al.* 1975). Soluble carbohydrates are the most labile of the major plant nutrients in pasture and may increase by almost 0.5% per hour during sunny days while several overcast days reduce levels markedly (Fulkerson 1994).

5.6.3.7 Milk production and composition

Daily milk volume production per cow was variable, with the advantage frequently changing between treatments in all three years so that overall, differences in the volume of milk produced per cow were small and inconsistent. While recognising that the values presented in Figure 5-23 are means, for herds with a range of 60 days in calving date, the lactation curves are in general similar to those reported by Holmes & Wilson (1987). Yield of milk increased rapidly after parturition and peaked three to six weeks later. Under normal climatic conditions peak yields are followed by a gradual decline. During 1994/95 a drier than normal summer caused a temporary feed shortage and a rapid decrease in the yield of milk from the start of lactation, followed by a recovery through summer.

During the lactation of an individual cow milk fat and protein concentrations gradually increase after an initial decline (Holmes & Wilson 1987). In this trial mean daily milk fat content increased over time (4.2% to 5.3%), although the absolute values were generally lower than those suggested by Holmes & Wilson (1987) (4.5% to 5.5%). By contrast, mean daily milk protein concentrations declined to approximately 3.3% from 3.7%, returning to approximately 3.7% each year. Holmes & Wilson (1987) reported that the concentration of milk protein ranged from 3.5% three to five weeks post-partum to 4.5% by the end of lactation. Furthermore, over the season milk protein varied less than half as much as milk fat during the year at 0.5% and 1.1%, respectively, whereas Holmes & Wilson (1987) suggest that the range (1.0%) is similar for both milk fat and protein.

The chemical composition of the diet fed to the cows and their nutritional status influence the content of solids in the milk (Sutton & Morant 1989; Coulon & Remond 1991; Buttery & Beever 1992). The fat content of milk is the most responsive to changes in nutrition and increases when the animals are in a negative energy balance (weight loss) and are mobilising body fat reserves from adipose tissue to maintain milk production (Buttery & Beever 1992). Swards with a higher proportion of stem material (LC) are characterised by high levels of structural components or cell walls which are less digestible to the animal. In feeding trials Sutton & Morant (1989) found the fat content of milk to be highly correlated to ADF concentration in the diet and dry matter intake. In early lactation the conversion ratio has been reported to be 25 kg DM kg^{-1} milk fat (Holmes & Brookes 1991) and in late lactation 40 kg DM kg^{-1} milk fat (Grainger 1990). However, da Silva (1994) found the conversion of pasture to milk fat over a few months to be very variable (40 - 150 kg DM kg^{-1} milk fat). Differences in the fat content of milk may be unrelated to milk production and protein content (Coulon & Remond 1991). In the current trial EC and LC values for conversion ratio were 15.1 and 15.0 kg DM kg^{-1} milksolids, 13.8 and 15.7 kg DM kg^{-1} milksolids and 18.6 and 19.2 kg DM kg^{-1} milksolids for 1993/94, 1994/95 and 1995/96 respectively. Values were calculated from total annual dry matter intake per cow (Table 5-25) and total annual milksolids production (Table 5-19). Using a quick conversion factor of 1.74 to get from milksolids to milk fat (P. N. P. Matthews, personal communication) gives a range over treatments and years of 24.0 to 33.4 kg DM kg milk fat^{-1} (mean 28.2).

Supplying additional energy and protein together has been shown in feeding trials to increase the protein content of milk providing the increase in energy was adequate to meet the needs of the animals (Coulon & Remond 1991). Furthermore, the increase in dietary protein was found to improve the digestibility of the diet, and consequently its energy value. Therefore, animals in a negative nitrogen balance are likely to produce milk with a reduced protein concentration (Buttery & Beever 1992). Dairy cows grazing ryegrass and white clover swards offered a high proportion of white clover (1% vs 23%) have been shown to increase the protein content of milk (Wilkins *et al.* 1991). However, in this trial the additional clover present on LC pastures did not consistently result in the production of milk with more protein.

Late control cows were disadvantaged during the pasture control phase in December 1994/95 because their herbage intake was limited to ensure effective removal of relatively mature plant tissue, whereas mechanical topping was used in the 1995/96 year to help pasture control and limited the impact on milk production (Figure 5-26). da Silva (1994) reported that control of reproductive swards was best achieved by a grazing strategy which involved forage conservation (HSR) as a means of augmenting grazing pressure (30% of the area destined for silage making). Under those conditions, control of reproductive stems and removal of the extra pasture cover over the whole farm was more rapid and effective, causing swards to be brought back under close control in a shorter period of time.

Annual milksolids production per cow calculated for cows with herd test values from the time they calved until they were dried-off showed no significant difference between EC and LC. In addition, milksolids per cow calculated from herd averages showed good agreement with values calculated for cows with a complete set of production records. Consequently, annual milksolids production per hectare can be assumed to have been similar for both treatments. Production on the farmlets during the three years of the trial (Table 5-19) was 25% higher than the regional, district and national averages, as given in Section 2.2.

5.6.3.8 Liveweight and condition score

Had consistent treatment differences in pasture production been achieved as a result of LC spring grazing management, consistent differences in liveweight and condition score may have reflected differences in feeding levels (da Silva 1994). However, like milksolids production, liveweight and condition score differences between treatments were also inconsistent. Late control cows were heavier than EC cows during summer each year, and cow condition scores were higher on LC than EC in 1993/94 and 1995/96. Cow liveweight was substantially greater on EC than LC at the end of the 1994/95 year, but the difference was removed over the period of controlled winter feeding before the start of the 1995/96 lactation. The reason for this difference in unclear.

Through a year the liveweight of an individual cow is variable reflecting level of nutrition and metabolic state. Included in the mean monthly liveweight values are the growth of the calf prior to calving and associated loss in liveweight at calving. The loss of liveweight at calving is approximately 45 kg for Friesian cows (Holmes & Wilson 1987). Since calving of the herd was spread over July and August, mean monthly liveweight decreased over both of these months. After calving cows may continue to lose weight and condition if high quality pasture is not available. Holmes & Wilson (1987) report that for mature Friesian cows each unit of condition score equates to 35 kg of liveweight. In general, increased and decreased liveweight values are reflected by similar movements in condition score values throughout the trial, and in particular 1995/96. The large increase in condition score in 1993/94 was only partially reflected in liveweight, suggesting that it was artificial and the result of a change in the scoring baseline.

5.6.3.9 Reproductive performance

Like those animal production variables discussed previously, consistent differences in reproductive performance (cumulative in-calf percentages, calving outcomes, calving to service, calving to conception, number of services per cow, calving date and date of first mating) are unlikely since only marginal differences in pasture production were achieved.

Cumulative in-calf rates often fell short of target values, particularly after week six. Late control cows got back in-calf quicker than EC cows, especially in 1994 and 1995. Higher pasture covers during spring on LC than EC may be partially responsible for this increase. Despite this, mean calving date was unaffected in 1995. The planned start of calving for both herds was 01 August, the mean calving date approximately 20 August and the mean date of first mating 05 November each year. Overall, few differences in reproductive performance were evident. The majority of cows calved normally during the trial with the exception of 1994 in which it was management policy to induce some cows early. Cows calving later than the majority of the herd may be difficult to re-mate at the same time as the rest of the herd and may have a shorter lactation (Holmes & Wilson 1987). However, inducing large numbers of cows is costly and can be associated with the problems of cow health and reproduction.

5.6.3.10 Supplement balance

Over the course of the trial supplements were used in different seasons and years for different reasons. Supplements were fed to overcome feed shortages as they occurred and in spring 1995/96, and to a lesser extent 1994/95 to increase pasture cover on the LC treatment. For the most part the quantity of supplements fed was balanced across treatments in summer, autumn and winter. In October 1994 grass and maize silage were fed to LC to assist in setting up pasture cover differences, and in 1995/96 brewers grain and carrots were fed to LC over and above EC to stimulate the early development of pasture cover contrasts (Table 5-26). This was partially successful in 1995/96 with larger and longer pasture cover differences developing over November compared to previous years (Figures 5-2 and 5-3).

The quantity of supplements conserved in 1994/95 and 1995/96 was limited compared to 1993/94 due to poor spring growing conditions and a high stocking rate. The high supplement use in the LC treatment relative to the EC treatment in the final year (1995/96) was considered essential, and implemented to offset the lower liveweights of LC cows after the winter and in an attempt to realise the 700 kg DM ha^{-1} cover difference required during a cold spring. The quantity of supplements used are low for this farm type, and a net inflow of supplements is typical for this type of dairy farm at the stocking rate used (P. N. P. Matthews, personal communication).

5.6.4 Value of systems trials

Regardless of the lack of clear treatment differences in pasture and milksolids production, tight control of variability was achieved in this large systems trial, providing an objective basis for evaluation. Analysis identified many differences between treatments for both pasture and animal variables. However, there were few examples of consistent differences between EC and LC, with the exception of the clover content of the swards.

Despite the problems experienced in setting up treatment contrasts there was internal consistency within the trial so that when treatments had limited effect on pasture production this was reflected by limited responses in animal production. That is, the results of the trial showed good internal consistency between production components. Furthermore, few data sets containing such detailed recording likely exist for large systems trials, and the data set produced is valuable for use with simulation models.

Finally, there were indications of a dampening effect due to the internal balance within the system, the time sequence to initiate changes, and pasture and animal reserves. Dampening means that management changes are less effective, responses delayed or more spread out than would be normally expected. For example, a period of poor feeding would be expected to be associated with a drop in milk production, however if the cows are in good condition and/or pasture covers are slightly higher than normal then milk production may be sustained. Conversely, additional forage production may not be reflected by an increase in milk production, rather condition score and/or pasture covers rise. The benefit may be realised in terms of additional milk production some time in the future.

5.7 Conclusions

Bayesian smoothing provided an alternative to ANOVA for those variables where both treatments and/or all replicates were not measured at the same point in time. Furthermore, there was no evidence of bias in treatment comparisons and the procedure proved to be very useful for the large data sets while allowing seasonal patterns to be included in the analysis. To use ANOVA for these variables would have required arbitrary grouping of the observations before analysis which may have influenced the outcome of the analysis.

The pasture cover differences measured between treatments were smaller than intended and over a restricted time period during late spring (November/December), and as a consequence the response in animal performance was smaller than the results of previous small-plot and paddock-scale experiments have suggested.

A consequence of the farmlets being self-contained and the use of rotational grazing management was that there was an inherent sequence of grazing of the paddocks. Since it took 20 - 30 days to complete one rotation in spring, summer and autumn, any action, such as the control of reproductive growth, had to be carried out over this time frame also. This combined with the ability of a system to buffer changes contributed to the difficulties in achieving treatment specifications.

Management constraints at the high stocking rate imposed contributed to the lack of differences achieved in spring pasture cover. Pasture control was best achieved through the combined use of the grazing animal and mechanical topping. The LC treatment did not result in a significant reduction in forage digestibility.

A number of the variables (clover contents and tiller densities) measured during the trial suggest the potential for contrast in system performance between EC and LC. The clover content of LC pastures was consistently higher than EC and differences in tiller density were also evident. Seasonal pasture production values for 1993/94 and 1994/95 also suggested that LC had an advantage in accumulation rate. This trial also demonstrated that it was possible to maintain pasture feed quality on LC.

Despite the problems experienced in setting up treatment contrasts there was internal consistency within the treatments so that when treatments had limited effect on pasture production this was reflected by limited responses in animal production.

Regardless of the lack of clear treatment differences in milksolids production, tight control of variability was achieved in this large systems trial, providing an objective basis for evaluation.

Research on systems of this type needs to include tight specifications and control of pre- and post-grazing pasture cover in addition to average pasture cover. More flexibility in stocking rate or use of supplementary feeds might be needed to establish spring pasture cover contrasts in future studies.

Late control, as a management option, appeals more to farmers who are interested in decreasing stocking rates, increasing pasture cover and feeding supplements to improve the nutrient intake of dairy cows with high genetic merit to achieve high production per hectare, rather than to farmers aiming to achieve high production per hectare through higher stocking rates (Matthews *et al.* 1996). Furthermore, farmers see the benefits of LC in better feeding of cows during spring, with no negative effects on pasture quality during the summer, and attach less importance to the potential increase in pasture production over the summer.

Indications are that the LC system could have worked given more determined application of the treatments. However, in effect LC management has been overtaken by interest within the industry in more generous feeding of cows and relaxed grazing control (Matthews 1995). During the course of this trial spring grazing management on dairy farms has tended towards that of late control management, with some farmers operating grazing systems with higher average pasture covers through the spring and being more likely to use mechanical means of controlling spring pasture quality.

Chapter Six

Computer Simulation Modelling of Spring Grazing Management

6.1 Introduction

New Zealand dairy farmers are regarded internationally as being cost-effective producers of milk (Murphy 1993) due to the utilisation of pasture grown *in-situ* throughout the year and efficient use of labour. However, the high stocking rates that result, relative to annual pasture growth and cow requirement, do not allow cows to maximise their intake of pasture with the possible exception of late spring/early summer (Edwards & Parker 1994). As a result annual per cow production averages only about 300 kg MS (Holmes & Hughes 1993; LIC 1998). Consequently there is scope to increase per cow production by improving the quality of the diet, or the level of intake at critical times of the year (Muller 1993; Edwards & Parker 1994), or by extending the lactation period (Holmes *et al.* 1994). Furthermore, some producers are reaching the limit of pasture production potential (Hodgson 1989). However, the use of supplements in New Zealand, other than those derived from pasture, to increase per cow production is limited by cost (Holmes & Hughes 1993). While prolonging the length of lactation can increase total milk production for the current lactation this is often at the expense of condition score and/or pasture cover (Gray *et al.* 1992) and therefore cow performance over the next lactation (Grainger *et al.* 1982).

Previous work has demonstrated the potential for enhancing pasture production during summer and autumn by manipulating the reproductive phase of growth during spring (Section 2.3). This increase in herbage accumulation could be used to enhance feeding levels of dairy cows during the second half of lactation, a period of the year when farmers frequently cannot feed the cows fully. The trial described in Chapter Three was set up to measure the effects of conventional

(EC) and late control (LC) spring grazing management on pasture and animal production in dairy grazing systems, on independent farmlet units. However, as reported in Chapter Five the results from this trial were inconclusive primarily because of the difficulty of establishing the specified contrasts in spring pasture management. Furthermore, assuming the result of a correctly established late control treatment on a closed system would be reflected in increased pasture production as demonstrated in small-plot and paddock-scale trials (e.g da Silva 1994) then the best use of the additional pasture needs to be investigated. Since trials like the one previously described in Chapters Three and Five of this thesis are costly in terms of time and resources (including money), the obvious next step was to use the data collected from the systems trial to extend the analysis using a simulation model.

Dairy farms are dynamic systems in which management changes may be difficult to evaluate in the context of whole farm productivity. Mathematical models, which explicitly quantify dynamic interactions between system components, require the assistance of a numeric processor and are therefore usually computer based (Bywater 1990). According to Murthy *et al.* (1990), mathematical modelling is the process by which a problem as it appears in the real world is interpreted and represented in terms of abstract symbols. Alternative management strategies can be analysed relatively quickly and inexpensively using mathematical models, before they are implemented on the farm. Pasture based dairy farm simulation models can assist in determining the likely outcome of changes to the management of the farm (McKay 1994).

During the last 3 decades there have been several grazing systems models developed and subsequently improved upon (e.g. Smith & Williams 1973; Arnold *et al.* 1977; Galbraith *et al.* 1980; White *et al.* 1983; McCall 1984; Loewer *et al.* 1987; Finlayson 1989; Larcombe 1989; Marshall *et al.* 1991; Finlayson *et al.* 1995; Cacho *et al.* 1995; Freer *et al.* 1997). These models have allowed researchers to carry out experiments which would otherwise be to expensive and/or time consuming to conduct in reality (Cacho & Bywater 1994; Loewer *et al.* 1993; Clark *et al.* 1994). Earlier grazing system models were reviewed by McCall (1984). All the models mentioned above were constructed with different objectives in mind and varying degrees of complexity, and most are combinations of empirical and *ad hoc* relationships. Often one component of the system is treated in greater detail than the others. This may be due to the objectives for the model and/or the modeller's area of expertise.

The simulation model UDDER (Larcombe 1990a) was chosen for this analysis because it was thought to be the best model available with the ability to represent the relationships of interest in the analysis of alternative spring grazing managements, and has been used before to investigate management alternatives on dairy farms. There is currently no dairy farm systems model available that includes a pasture sub model capable of adequately dealing with the pasture responses predicted by the principles of the late control (LC) treatment. However, experiments were conducted using UDDER to evaluate how LC might be implemented on a self-contained production system (farm) and, assuming that LC management is applied successfully, to investigate how to make best use of the extra herbage produced, and their consequences in milk production and farm revenue. In addition, preliminary work was undertaken to investigate the way in which the principles of late control might be introduced into an interactive pasture model (Appendix Seven).

6.2 UDDER

6.2.1 A brief description of UDDER

UDDER (unnamed desktop dairy farm for extension and research) is a computer simulation model of a dairy farm where the major feed supply is pasture. The model predicts herd milk production in 10-day time steps based on specified pasture accumulation rates and management conditions for the farm. Model predictions include the growth and quality of pasture, forage intake and partitioning of energy towards milk production, maintenance, growth and pregnancy (Larcombe 1990a). The last three items are discounted from the total energy intake and the residual energy is used to predict milk production (Larcombe 1990b). The predictions are driven by monthly net pasture accumulation rates.

Cows are grouped in classes based on stage of lactation. The intake of pasture for each class is calculated using a relationship including pasture mass, pasture allowance, digestibility, stage of lactation and animal liveweight. The relationships are based on data from grazing experiments at the Ellinbank Dairy Research Institute (Victoria, Australia), Macalister Research Farm (Victoria, Australia), and Ruakura Animal Research Centre (New Zealand). Nutritive calculations are based on the movement of energy within cattle, and it is considered that protein would not be the limiting nutrient determining milk production on ryegrass-clover swards. Animal requirements for maintenance, pregnancy, growth and milk production are estimated according to the recommendations of the Agricultural Research Council (ARC 1980), (Larcombe 1990a).

The program can store the results from several simulations, which can be compared graphically by pairs. For each ten-day period, net pasture accumulation rates, herd feed intakes, milk production, body condition, and farm income are available for interpretation using 50 screens containing graphs and tabular data. The model also offers an optimization option where an optimal alternative can be calculated. UDDER has been used previously to represent the events on a dairy farm under New Zealand conditions (McLean 1993; Clarke *et al. 1994;* Uribe 1995; Clark & Harris 1996; Uribe *et al. 1996;* Ekanayake *et al.* 1996; Thomson *et al.* 1997).

6.2.2 The simulation process used by UDDER

The UDDER program runs as follows: At the start of each 10-day period take the current number of animals in each class and the current amount of pasture in each of the 50 strips into which the farm is divided irrespective of the actual number of paddocks. These would be initial values or the values generated from the previous 10-day period. Determine the number of stock on the farm and the area of the pasture to be grazed from the values entered into strategy for this 10-day period. Predict the quantity of pasture that will accumulate in each grazing area from pasture growth rates and nitrogen applications and determine the average pre-grazing mass. Predict pre-grazing pasture digestibility based on time of year, pre-grazing mass and digestibilities entered. Determine the height of the pasture available based on calibration equations and predict pasture intake, based on stage of lactation, cow size, body condition, pasture digestibility, height, density and amount of supplement being fed. Intakes for replacements are calculated based on target liveweights. Predict the digestibility of the pasture consumed and calculate energy intake including supplements. For adult cows energy is partitioned to milk production and condition score. Finally, calculate post-grazing cover, condition score, liveweight of replacements, milk production and cumulative totals.

Within UDDER pasture covers are converted to heights using sward height (plate)/herbage mass relationships and herbage intakes are calculated based on the heights of pasture.

6.3 Calibrating UDDER

The programme was run using basic “farm” data from the EC system in the trial reported in Chapters Three to Five. Data from the No 4 Dairy Unit systems trial was collated, verified and entered into UDDER and the actual situation for 1994/95 simulated to produce the "base" model for the EC farmlet. The majority of the data required by UDDER have been presented in Chapter Five. In addition, specified pre-conservation and post-conservation pasture covers were 5 500 and 2 000 kg DM ha^{-1}, respectively and milk production data as recorded by factory records is given in Table A6-1 of Appendix Six. Turnips were grown for feeding in late summer with 1.65 ha being withdrawn from grazing on 01 November. Feeding of the 75% digestibility turnip crop at 4 kg DM ha^{-1} commenced on 11 February and concluded on 11 March, with the paddock returned to grazing on 01 June. Topping has not been included in the analysis since it was found to confuse the results of conservation and there was minimal topping carried out in the field during 1994/95. Furthermore, UDDER is not capable of accurately predicting the economic returns from modifying a topping regime since UDDER cannot simulate the change in pasture composition which occurs following topping (Larcombe 1990a). The values to calculate gross margins are presented in Table A6-2 of Appendix Six.

This simulation was carried out to verify the predictions given by the model in relation to the actual data and to ensure that obvious data entry errors were corrected. If the initial predictions do not match the farm monitoring data satisfactorily, in terms of milk production, pasture cover and condition score, it is normal practice when setting up UDDER to make adjustments to calibrate the model to gain a better 'fit'. This is done by making adjustments to any number of the following: pasture allocation (rotation lengths and fodder conservation strategies), supplementary feeding, stock reconciliation, animal live weight, condition score at calving, initial pasture cover, milk composition and internal model parameters.

Monthly sward mass/height relationships were derived based on data collected from No 4 Dairy Unit (Table 6-1). "Base values", which according to the UDDER manual (Larcombe 1990a) represents the amount of pasture dry matter unavailable to grazing cows, were estimated based on the seasonal pattern of mass per unit plate meter height described in Figure 4-5. Upper and lower bounds to pasture base were estimated to be 2 000 and 1 000 kg DM ha^{-1}, respectively.

Monthly pasture density values (kg DM cm^{-1} of pasture height, indicated by rising plate meter) were taken directly from the mass per unit height relationship (Figure 4-5) for No 4 Dairy Unit proposed in Chapter Four. There remains some confusion over the unit of height required for density values in UDDER. Data entry screens request density values with the units of kg DM cm^{-1}, though the units of the rising plate meter are 0.5 cm (Section 4.2). However, experimentation suggested that density values had little effect on milk production. Average cut values, which represent the average herbage mass measured in each calibration cut, were available directly from the systems trial data set.

Table 6-1 Pasture base, average of calibration (kg DM ha^{-1}) and density (kg DM cm^{-1}) for 12 months.

Date	Base kg DM ha^{-1}	Density kg DM cm^{-1}	Ave. cut kg DM ha^{-1}
15/07/94	1 000	160	1 500
15/08/94	1 000	160	1 700
15/09/94	1 000	160	1 900
15/10/94	1 100	165	2 000
15/11/94	1 300	195	2 500
15/12/94	1 500	245	2 600
15/01/95	1 800	295	2 700
15/02/95	2 000	315	2 600
15/03/95	1 700	290	2 500
15/04/95	1 400	235	2 300
15/05/95	1 200	185	1 750
15/06/95	1 100	160	1 500

There were cumulative discrepancies between the actual pasture cover and predicted pasture cover using the measured rates of pasture accumulation. To match the output achieved from EC during 1994/95 with that predicted by UDDER under the same management, it was necessary to reduce herbage accumulation rates by 10% for the period February through July and by 15% from August through January. The reason why this reduction was required is unclear, but it is not clear from the UDDER manual what assumptions are made about the efficiency of utilisation of herbage accumulated between grazings (described as "Herbage Growth" in UDDER). Even after adjusting herbage accumulation rates it was difficult to maintain milksolids production in late lactation and match annual production. Therefore, the potential rate of herbage intake was reduced by 10% while the cows were dry (day 175 through to day 227), reduced by 5% during early and mid lactation (day 176 through to day 75), and increased by 30% during late lactation (day 76 through to day 130) where 01 January = day 1.

Condition scores were also difficult to maintain at levels similar to those measured in the trial, particularly in late lactation when a larger proportion of the energy from extra feed would be partitioned to raising condition score at the expense of milksolids production. In addition, feeding supplements in late lactation saw the substitution rate frequently rise to one kg supplement replacing one kilogram of pasture. Since the nutritive value of supplements is less than pasture this would result in a reduction in milksolids production. Before the aforementioned adjustments were made to herbage accumulation rates and herbage intakes, this was a serious impediment.

With these modifications to UDDER it was possible to obtain a reasonable good fit between actual production and production simulated by UDDER, in terms of condition score and milksolids, under the same management (Figure 6-2 and Table 6-2). Despite simulated pasture covers remaining higher than actual pasture covers in autumn, herbage intake (Figure 6-2e) and milk production (Figure 6-2f) were reasonably well predicted. Seasonal patterns were also consistent between actual and predicted values with the exception of pasture cover (Figure 6-2c). For most of the year (July - March) modelled, predicted pre-grazing pasture cover values were between 400 and 1 000 kg DM ha^{-1} higher than actual values. However, although the level of output predicted from recorded inputs exceeded measured output by 9%, there was no bias between treatments.

Table 6-2 Comparison of pasture variables, animal variables and gross margins for actual farmlet and simulated farmlets with unmodified and modified parameters.

	Actual	Simulated	
		Unmodified	Modified
Milking days	314	314	314
Milking cow days ha^{-1}	652.7	652.7	652.7
Pasture harvested (t ha^{-1})	10.5	11.3	10.7
Milkers past. eaten (t ha^{-1})	8.7	9.3	8.7
Drys past. eaten (t ha^{-1})	0.9	1.4	1.1
Conservation (t DM)	15.0	21.3	16.3
Milksolids (kg cow^{-1})	336.6	362.2	341.0
Milksolids (kg ha^{-1})	934.9	1 006.2	947.3
Gross margin ($ cow^{-1})	773.74	864.63	787.52
Gross margin ($ ha^{-1})	2 149.27	2 401.76	2 187.55

Note: Values used in gross margins are presented in Table A6-2 of Appendix Six.

Figure 6-1 Comparison of actual farmlet —●— and simulated farmlet with unmodified parameters - - ○ - - on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production.

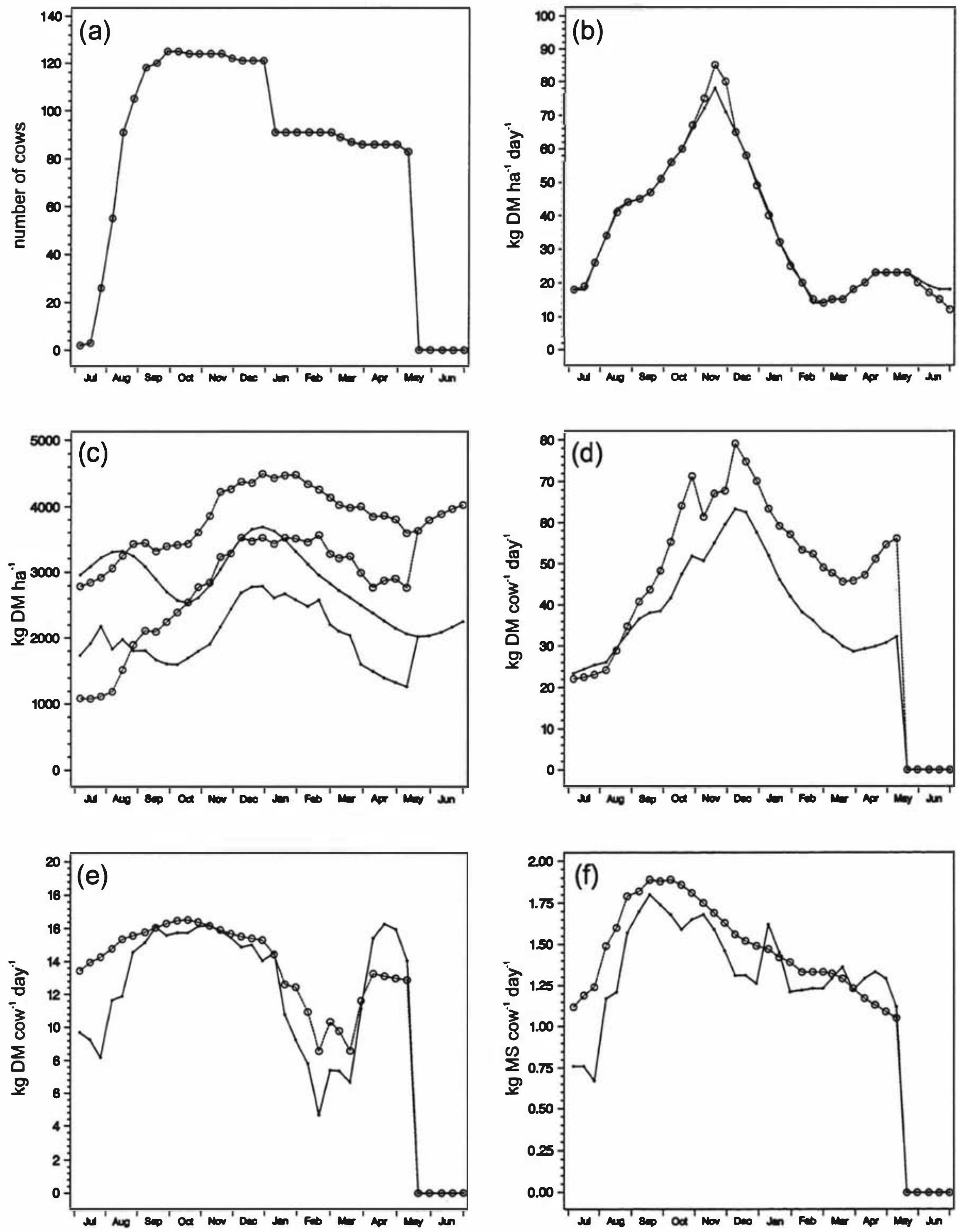
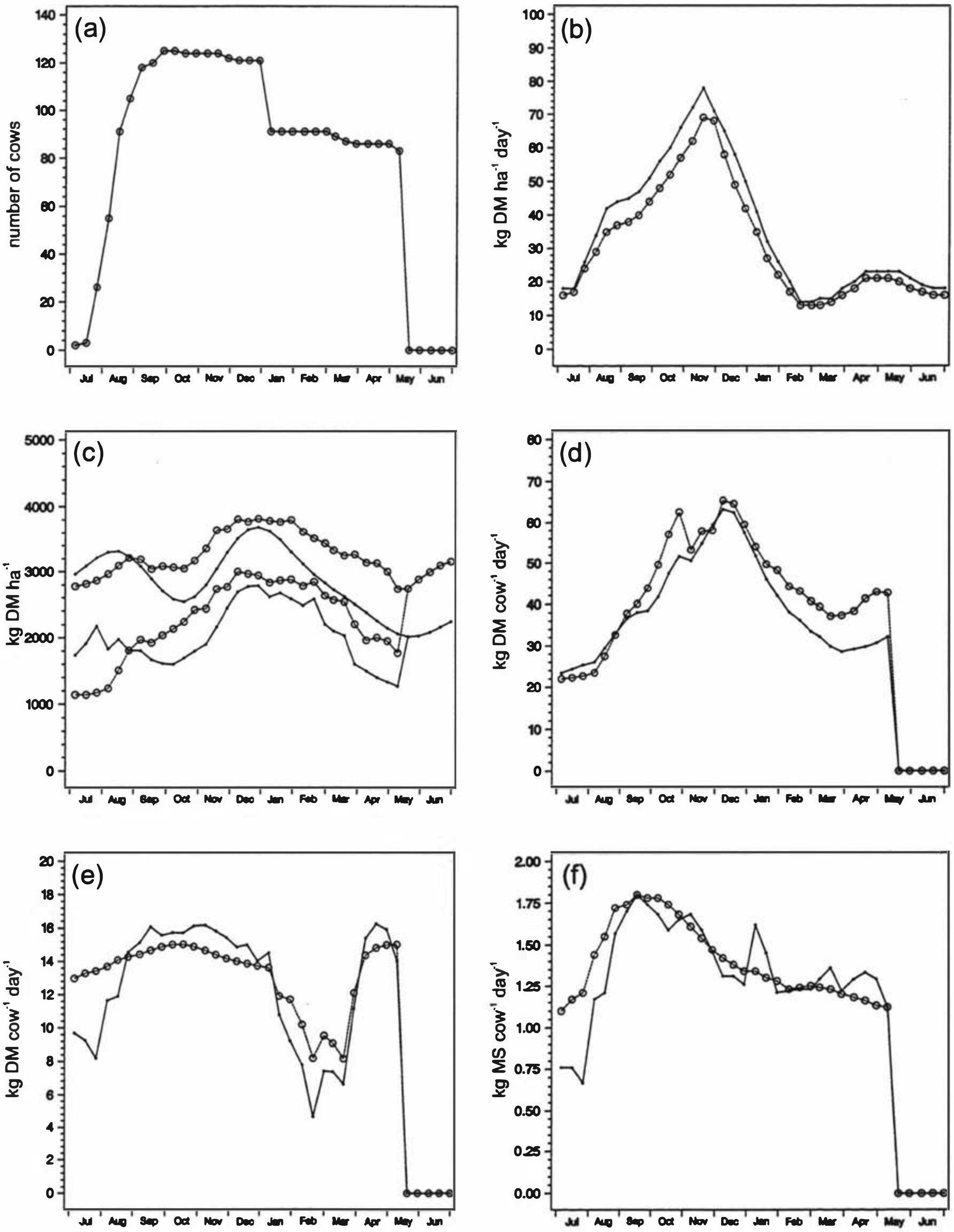


Figure 6-2 Comparison of actual farmlet —●— and simulated farmlet with modified parameters --○-- on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production.



6.4 Setting up early control and late control

6.4.1 Early control

One of the advantages of simulation models is that changes to management can be implemented and tested relatively quickly. In the field trial, pastures were controlled later in the spring than they probably should have been for an EC treatment, allowing EC to be more like LC. With UDDER set up to represent EC as applied in the field trial, changes were made to the conservation strategy to effectively control pastures earlier in the spring. In the systems trial during 1994/95, EC pastures designated for conservation were last grazed on 01/11/94, and silage made from 5 ha on 05/12/94. For the purposes of using UDDER to investigate differences between EC and LC, conservation was moved forward on EC so that pastures were last grazed on 15 September and cut for silage on 30 October. This change in conservation strategy reduced pre-grazing pasture cover by up to 200 kg DM ha^{-1} through late November and December but had no effect on animal production. The quantity of forage conserved fell by 15% from 16.6 t DM to 14.1 t DM.

6.4.2 Late control

Once a satisfactory base model had been developed for the EC farmlet, the setting up of the LC management strategy was investigated by making changes to the conservation strategy and pasture accumulation rate. Previous workers have reported that allowing some reproductive development during spring followed by a period of control at the time of anthesis increased herbage production in the following summer and autumn (Section 2.3). Allowing ryegrass plants to become reproductive without restricting cow intakes can be achieved by delaying pasture conservation until the control phase in December. Under conventional management (EC) paddocks are removed from the grazing round in early spring to maintain the swards in a vegetative state to maintain pasture quality. However, delaying the removal of reproductive material from pastures until December did not affect the nutritive value of the herbage grazed by LC cows in most seasons (Sections 2.3 and 5.2.12).

Table 6-3 Advantage (%) to accumulation rate from lax spring grazing management in three experiments reported by da Silva (1994) assuming attainment of the stipulated pasture cover contrasts between EC and LC.

Month	Experiment 1		Experiment 2		Experiment 3	
	EC-LHC	EC-VLHC	EC-LHC	EC-LLC	EC-VFR	EC-HSR
Aug	-	-	-	-	20	22
Sep	-	-	-	-	20	22
Oct	14	14	-13	0	20	10
Nov	33	48	22	34	27	21
Dec	7	11	-5	15	24	-23
Jan	-12	-4	-3	13	26	-14
Feb	10	-17	8	9	36	29
Mar	52	24	-23	16	28	45
Apr	26	49	15	22	18	55

Note: EC early control.
LHC, VLHC, LLC, VFR, HSR are variations of late control.

Compared to EC, pre-grazing pasture cover on LC was allowed to increase by 700 to 1000 kg DM ha^{-1} over spring, followed by a control phase (increased herbage intake by cows and conservation) where pre-grazing pasture covers on LC were returned to levels similar to EC. To set up LC management in UDDER, stock were removed from 5 ha of pasture on 01 November and from 6 ha on 26 November, and the herbage was cut for ensiling on 05 December and 31 December respectively, and produced 16 t DM of silage from each area. In line with previous experiments (Table 6-3) herbage accumulation rates were increased by 5% in September and 10% in October, November, January, February, March and April.

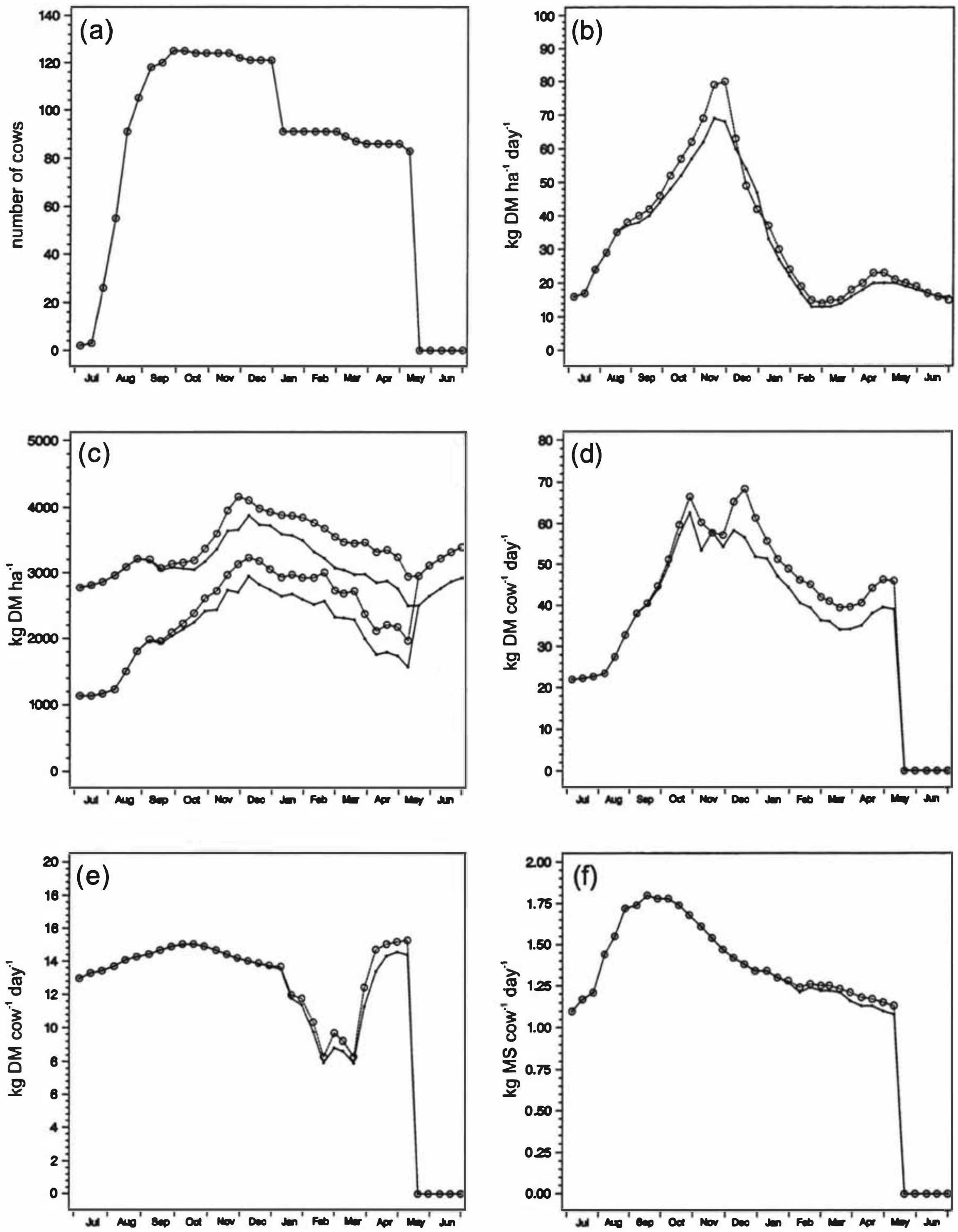
No increase in the herbage accumulation rate for December was implemented because reproductive growth is being controlled at this time and in some experiments decreased accumulation rates have been reported. The values used in UDDER were conservative when compared to the levels of response from lax spring grazing management seen in the series of experiments reported by da Silva (1994) (Table 6-3). Figure 6-3 and Table 6-4 show the effect of including an additional 5-10% to herbage accumulation rates under LC conservation management. The modified model provided the base EC and LC models used for the subsequent analysis of spring grazing management alternatives reported in the next section (Section 6.5).

Table 6-4 Effects of including an accumulation rate advantage on pasture variables, animal variables and gross margins for simulated late control farmlets.

	Simulated LC	
	No advantage	With advantage
Milking days	314	314
Milking cow days ha^{-1}	652.7	652.7
Pasture harvested (t ha^{-1})	10.8	11.1
Milkers past. eaten (t ha^{-1})	8.6	8.8
Drys past. eaten (t ha^{-1})	1.3	1.4
Conservation (t DM)	31.4	33.2
Milksolids (kg cow^{-1})	338.8	341.6
Milksolids (kg ha^{-1})	941.0	948.8
Gross margin (\$ cow^{-1})	778.73	789.74
Gross margin (\$ ha^{-1})	2 163.13	2 193.71

Note: Values used in gross margins are presented in Table A6-2 of Appendix Six.

Figure 6-3 Simulated late control without —●— and with a 5-10% increase in herbage accumulation rate --○-- for (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production.



6.5 Alternative strategies for using the extra herbage produced by late control management alternatives

6.5.1 Introduction

Assuming that it would be possible to create the sward conditions necessary for executing the LC strategy and that the expected increases in the rate of accumulation of herbage are achieved, the question remains, how best to use the additional herbage? The field trial compared one possible management alternative to conventional spring pasture management, but simulation modelling allows other options to be investigated. In this section the EC and LC base models developed in the previous section were used to evaluate alternative management strategies for using the extra herbage accumulation generated under the late control management, including timing of feeding conserved forage during summer to lactating cows or during winter to dry cows, stocking rate (decreased versus increased) and the level of conservation (none versus increased). The drying-off strategy in UDDER was controlled to ensure that pre-grazing pasture cover was near 2 400 kg DM ha^{-1} and condition score 5.0 at the end of lactation. While adjustments were made to the drying-off strategy, there were some guidelines imposed for practical reasons and to be in line with normal farm practice. The last group of cows to be dried-off was not less than 50% of the herd, and culls (approximately 20% of the herd) were dried off at the end of March. All cows were dried-off by the end of June to allow sufficient time (60 days) before the next calving.

At no time during a run was pre-grazing cover permitted to fall below approximately 2 200 kg DM ha^{-1}. For the purposes of these analyses only forages conserved during the simulation were fed back into the system. When fed to milking cows supplements were fed back into the system commencing in January, because this was the start of the feed deficit in the 1994/95 trial. Supplements were fed back to dry cows during the middle of winter for as long as possible.

Forage conservation strategies were adjusted to bring LC pastures in line with EC by the end of December.

6.5.2 Feeding supplements to lactating versus dry cows

This section investigates the timing of feeding supplements conserved on the farmlet back into the system. That is, does feeding supplements to lactating cows in summer produce more milksolids than feeding supplements to dry cows in winter for EC or LC?

6.5.2.1 Supplements fed during lactation

Figure 6-4 and Table 6-5 show the contrasts between simulated EC and LC for cows fed supplements conserved on the farmlet during mid lactation. The objective was to use all of the forage conserved on each farm on that farm during this period. On the EC farmlet forage was fed at 3 kg DM cow^{-1} day^{-1} for just over a month from 01 January to 10 February and on LC at 6 kg DM cow^{-1} day^{-1} for two months from 01 January to 28 February. Thirty percent of the cows were dried-off at the end of March for both EC and LC (Figure 6-4a). The remaining EC cows were dried-off in early May, but LC cows were able to milk for a further month. Adjustments were made to the drying-off strategy to ensure that pre-grazing pasture cover was near 2 400 kg DM ha^{-1} and condition score 5.0 at the end of lactation. Milking days and milking cow days are presented in Table 6-5. Herbage accumulation rates for EC and LC are shown in Figure 6-4b and the advantage accruing to LC can be seen. The quantities of herbage harvested, eaten and conserved on EC and LC are shown in Table 6-5.

Table 6-5 Effects of feeding conserved forage back to milking cows in summer versus feeding forage to dry cows in winter on pasture variables, animal variables and gross margins for simulated early control and late control farmlets.

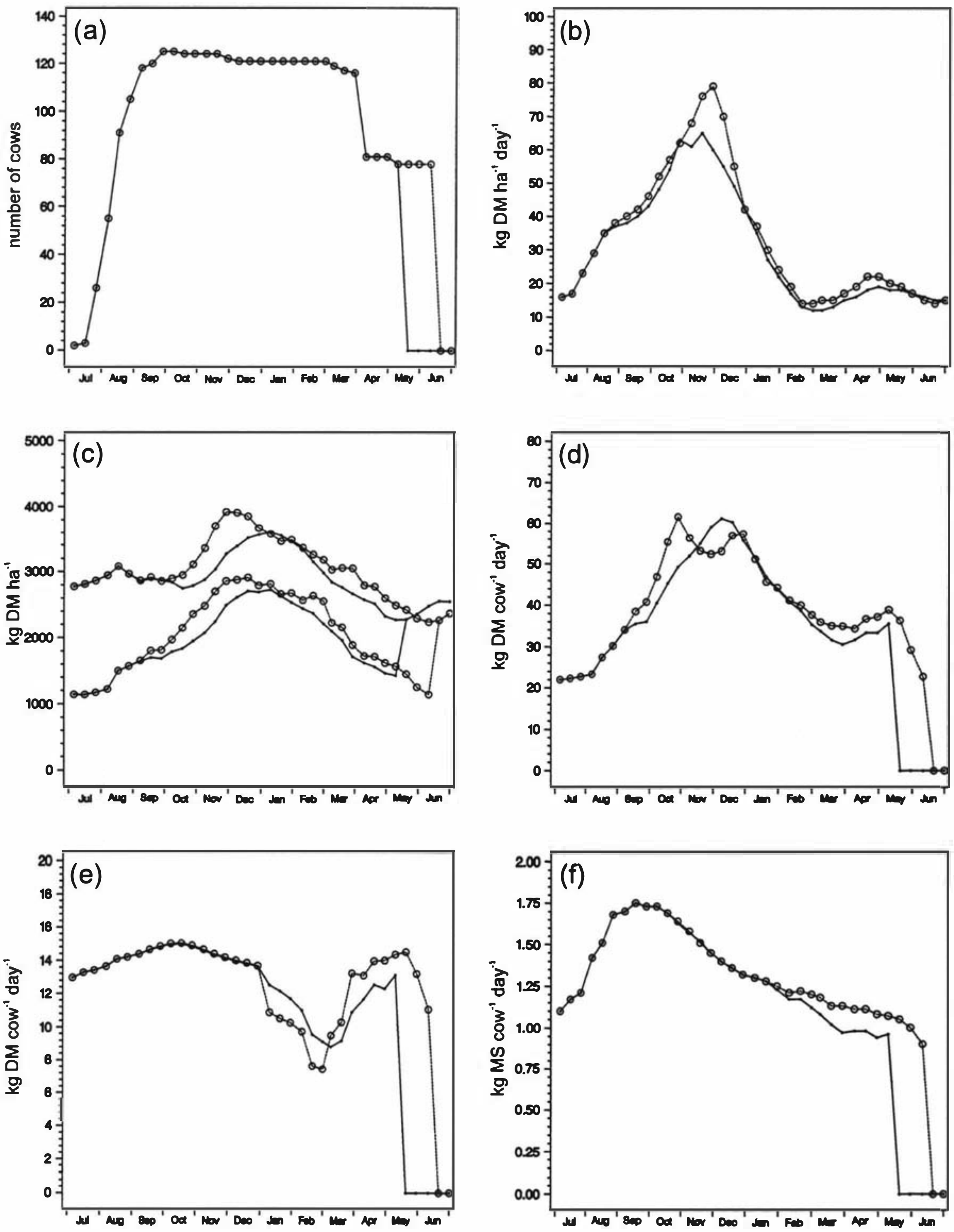
	Supplements fed during lactation		Supplements fed to dry cows in winter	
	EC	LC	EC	LC
Milking days	314	345	314	345
Milking cow days ha^{-1}	708.2	762.0	708.2	762.0
Pasture harvested (t ha^{-1})	11.0	12.0	10.9	11.9
Milkers past. eaten (t ha^{-1})	9.1	9.8	9.2	10.0
Drys past. eaten (t ha^{-1})	1.4	1.2	1.3	0.7
Conservation (t DM)	13.0	42.0	13.0	45.0
Milksolids (kg cow^{-1})	348.0	375.3	344.9	367.9
Milksolids (kg ha^{-1})	966.6	1042.4	958.0	1021.9
Gross margin ($ cow^{-1})	867.94	935.67	860.08	906.50
Gross margin ($ ha^{-1})	2410.95	2599.07	2389.12	2518.06

Note: Values used in gross margins are presented in Table A6-2 of Appendix Six.

Pre- and post-grazing pasture covers are shown in Figure 6-4c for the pastures on farmlets where conserved forage is fed during lactation. Treatment differences are achieved in spring through delaying conservation and the increased herbage accumulation rate of LC compared to EC. Post-grazing pasture covers were also higher for LC than EC (Figure 6-4c) and allowance marginally higher for LC than EC during spring and autumn (Figure 6-4d). Control was achieved through conservation in December although pre-grazing pasture covers were higher on LC than EC through late summer and autumn. Despite the higher allowance afforded LC cows during spring the pasture intakes of milkers were similar in the first half of lactation (Figure 6-4e). In the autumn, the pasture intakes of milkers were higher for LC than EC, reflecting higher pre-grazing masses for LC than EC. As a result of the longer lactation and the higher pasture intakes, annual milk production was 76 kg MS ha^{-1} higher for LC than EC, resulting in an 8% increase in the per hectare gross margin (Table 6-5). The patterns of milk production for EC and LC are shown in Figure 6-4f. Average pasture cover values have not been presented here since they closely resemble pre-grazing pasture cover with absolute values approximately 400 kg DM ha^{-1} lower.

The increase in milk production of LC over EC is largely due to the extra herbage seen to be produced in previous experiments by LC over EC during spring, summer and autumn (Table 6-3). Most of the extra herbage has been conserved and fed back into the system as supplements, commencing in January. In UDDER, the effect of feeding more supplements (42 t DM for LC versus 13 t DM for EC) in LC than EC, is to increase pasture cover and therefore pasture intakes in autumn and to allow lactation length to be extended by 30 days or 53.7 milking cow days per hectare (Table 6-5).

Figure 6-4 Effect of feeding conserved forage back to milking cows in summer on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production for simulated early control —●— and late control --○-- farmlets.



6.5.2.2 Supplements fed to dry cows in winter

The second option investigated was to feed the forage conserved from each farmlet back to the dry cows in that system in winter and not to feed any supplement to the milking cows, the opposite of the previous run where conserved feeds from the farmlet were fed back to lactating cows and dry cows received no supplementary feed. On the EC farmlet forage was fed at 3 kg DM cow^{-1} day^{-1} from 01 June to 20 July and on LC at 6 kg DM cow^{-1} day^{-1} from 21 April to 10 September. As in the previous strategy, all available conserved forage was fed back to the cows during this period. Compared to the previous system, supplements were fed over a longer period of time because intakes were lower for dry cows. Figure 6-5 and Table 6-5 show the results for EC and LC when feeding forage to dry cows in winter. The quantities of herbage harvested, eaten and conserved on EC and LC are shown in Table 6-5. Adjustments were made to the drying-off strategy to ensure that pre-grazing pasture cover was near 2 400 kg DM ha^{-1} and condition score 5.0 at the end of lactation. (Figure 6-5a). Under this management system LC performed better than EC, as in the previous analysis. Milksolids production was 65 kg ha^{-1} higher for LC than EC, resulting in a 6% increase in the per hectare gross margin.

When feeding conserved supplements back to dry cows in winter, increasing pasture cover on LC appears to be easier to achieve and the difference between treatments appears a month earlier compared to feeding conserved forage back to lactating cows (Figures 6-5c and 6-4c respectively). This difference follows through to post-grazing pasture cover (Figures 6-5c and 6-4c) and allowance (Figures 6-5d and 6-4d). However, during late summer/early autumn when feed is in relatively short supply, covers on LC pastures fell 200 - 300 kg DM ha^{-1} below those of the previous system, restricting intakes by 1 kg DM cow^{-1} day^{-1} (Figures 6-5e and 6-4e). Consequently, comparing milksolids production between feeding conserved supplements back to dry cows in winter and feeding conserved supplements back to lactating cows in summer, production was only 7 kg ha^{-1} lower on EC and 20 kg ha^{-1} lower on LC (Figures 6-5f and 6-4f and Table 6-5).

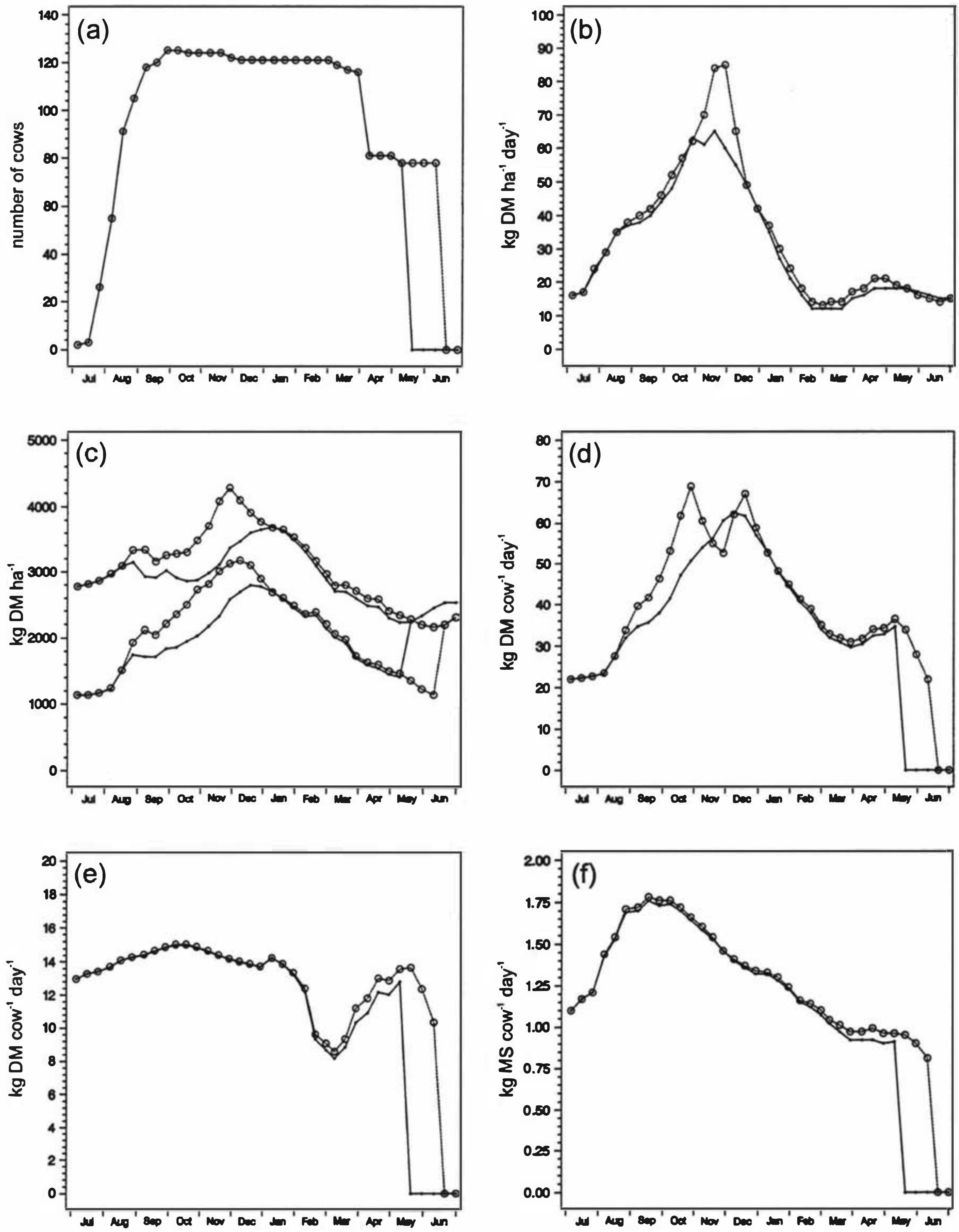
When feeding supplements to pregnant cows in winter, feed was able to be carried forward from one period to the next as pasture cover for both EC and LC. However, since the quantity of feed being carried forward was spread over the entire farm pasture covers are only marginally higher. This feed was then able to be used to fill periods of feed shortage or extend lactation and allow levels of production similar to those of feeding conserved supplements back to lactating cows in summer. On a farm this is unlikely to happen.

Gross margins were higher when feeding conserved supplements back to lactating cows in the summer than pregnant (dry) cows in the winter. However, the difference between EC and LC was greater.

6.5.2.3 Bought-in supplements

The incorporation of bought-in supplements to be fed when feed shortages occurred was investigated, but analyses of strategies by UDDER where bought-in forages were included showed that if balanced (quantity and timing) between the treatments they had no effect on the relative production from EC and LC managements. Therefore, even though bought-in forages were used in the grazing systems trial they were excluded from the analyses presented here.

Figure 6-5 Effect of feeding conserved forage back to dry cows in winter on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production for simulated early control —•— and late control --o-- farmlets.



6.5.3 Stocking rate

In this section, the effect of changing the stocking rate, compared to that used in Section 6.5.2, on EC and LC is investigated. Reducing the stocking rate allows the examination of feeding the cows better, while extra stock (higher stocking rate) utilise the additional feed *in-situ*. Changes in stocking rate were imposed on the strategy described in Section 6.5.2.1 where conserved forage was fed back to lactating cows in response to summer pasture deficits.

6.5.3.1 Low stocking rate

Figure 6-6 and Table 6-6 show the difference between simulated EC and LC when the stocking rate was reduced from 2.8 to 2.6 cows ha^{-1}; that is, the number of cows in the herd was reduced by 10 to 115 cows. To maintain control of the pastures during spring required an increase in the quantity of forage conserved on both treatments. On the EC farmlet stock were removed from 10 ha of pasture on 15 September and from a further 10 ha on 15 October and the herbage was cut for ensiling on 21 October and 30 November, respectively. On the LC farmlet stock were removed from 10 ha of pasture on the 15 October and from a further 10 ha on 15 November and the herbage was cut for ensiling on 21 November and 21 December, respectively. Table 6-6 shows that LC produced 33 t DM more silage than EC which was fed back to EC cows at 4 kg DM ha^{-1} and LC cows at 6 kg DM ha^{-1} from 01 January to 20 May. Figure 6-6a shows that both herds milked to the end of June, although 18 cows were dried-off at the end of March on EC. Cows were to be milked as long as possible providing that pre-grazing pasture cover was 2 400 kg DM ha^{-1} and condition score was 5.0 by the end of the run. Milking days and milking cow days per hectare are presented in Table 6-6 and herbage accumulation rates for EC and LC are shown in Figure 6-6b.

Pre-grazing pasture covers for both EC and LC remained relatively constant throughout the run, with cover increasing on LC through October and November and being brought back under control during December (Figure 6-6c). The spring difference in pre-grazing pasture cover for LC is reflected by a similar difference in post-grazing pasture cover. Despite the increase in cover on LC compared to EC over spring, and consequences to herbage allowance (Figure 6-6d), pasture intakes of milkers remain the same for EC and LC (Figure 6-6e). Pasture intakes of milkers are lower for LC than EC during summer and autumn due to the feeding of 2 kg DM cow^{-1} day^{-1} more silage.

Figure 6-6f shows milksolids production for EC and LC cows, with LC producing 39 kg MS ha^{-1} more than EC. However, despite the extra milksolids produced on LC the gross margins were similar for EC and LC at $2 408.00 ha^{-1} due to the additional cost associated with conserving the extra forage on LC (Table 6-6).

Table 6-6 Effects of stocking rate on pasture variables, animal variables and gross margins for simulated early control and late control farmlets.

	2.6 cows ha^{-1}		3.0 cows ha^{-1}	
	EC	LC	EC	LC
Milking days	355	355	314	335
Milking cow days ha^{-1}	733.4	764.0	648.6	698.6
Pasture harvested (t ha^{-1})	11.5	12.2	10.7	11.7
Milkers past. eaten (t ha^{-1})	9.1	9.2	8.2	8.8
Drys past. eaten (t ha^{-1})	0.9	0.8	2.2	1.9
Conservation (t DM)	57.0	90.0	6.0	36.0
Milksolids (kg cow^{-1})	383.3	398.2	294.5	321.2
Milksolids (kg ha^{-1})	979.5	1 017.6	883.6	963.7
Gross margin ($ cow^{-1})	942.93	944.92	681.17	741.33
Gross margin ($ ha^{-1})	2 409.72	2 414.80	2 043.51	2 223.99

Note: Values used in gross margins are presented in Table A6-2 of Appendix Six.

Based on the prediction of UDDER, at a stocking rate of 2.6 cows ha^{-1} it was difficult to use all of the silage conserved and to keep pasture covers down to 2400 kg DM ha^{-1} and cows at a condition score of 5.0 by the end of the run, particularly for LC.

6.5.3.2 High stocking rate

When the stocking rate was increased to 3.0 cows ha^{-1}, that is, the number of cows was increased by 10 to 135 cows, the conservation strategy had to be relaxed. For EC, 3 ha of pasture were last grazed on 15 September and cut on 31 October and produced 6 t DM. On LC 10 ha of pasture were closed on 15 November and cut on 31 December, producing 36 t DM. Conserved supplements were fed back into their respective systems commencing 01 January at the rate of 3.0 kg DM cow^{-1} day^{-1} for 20 days and 5.0 kg DM cow^{-1} day^{-1} for two months for EC and LC respectively. There were two early drying-off occasions so that less than half of the EC and LC herds remained in milk after the end of February (Figure 6-7a). Milking days and milking cow days are presented in Table 6-6 for EC and LC.

Pre- and post-grazing pasture covers, allowance and the pasture intake of milkers were kept as high as possible by relaxing the conservation strategy and by drying-off almost half the herd by 01 March (Figures 6-7c, 6-7d and 6-7e). By the end of the run condition scores were 4.2 and 4.6 for EC and LC respectively, well below the target of 5.0. Cows had to be dried-off even though pre-grazing pasture covers appeared to be reasonable, especially for EC. Figure 6-7f shows that milksolids production from EC decrease faster than LC, contributing to an advantage of 84 kg MS ha^{-1} for LC over EC for the year (Table 6-6). There was a 10% increase in the gross margin for LC over EC.

The gross margin for the high stocking rate was lower than that for the low stocking rate, reflecting the loss of production associated with feeding dry cows.

Figure 6-6 Effect of decreasing cow numbers to 115 cows on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production for simulated early control —●— and late control --○-- farmlets.

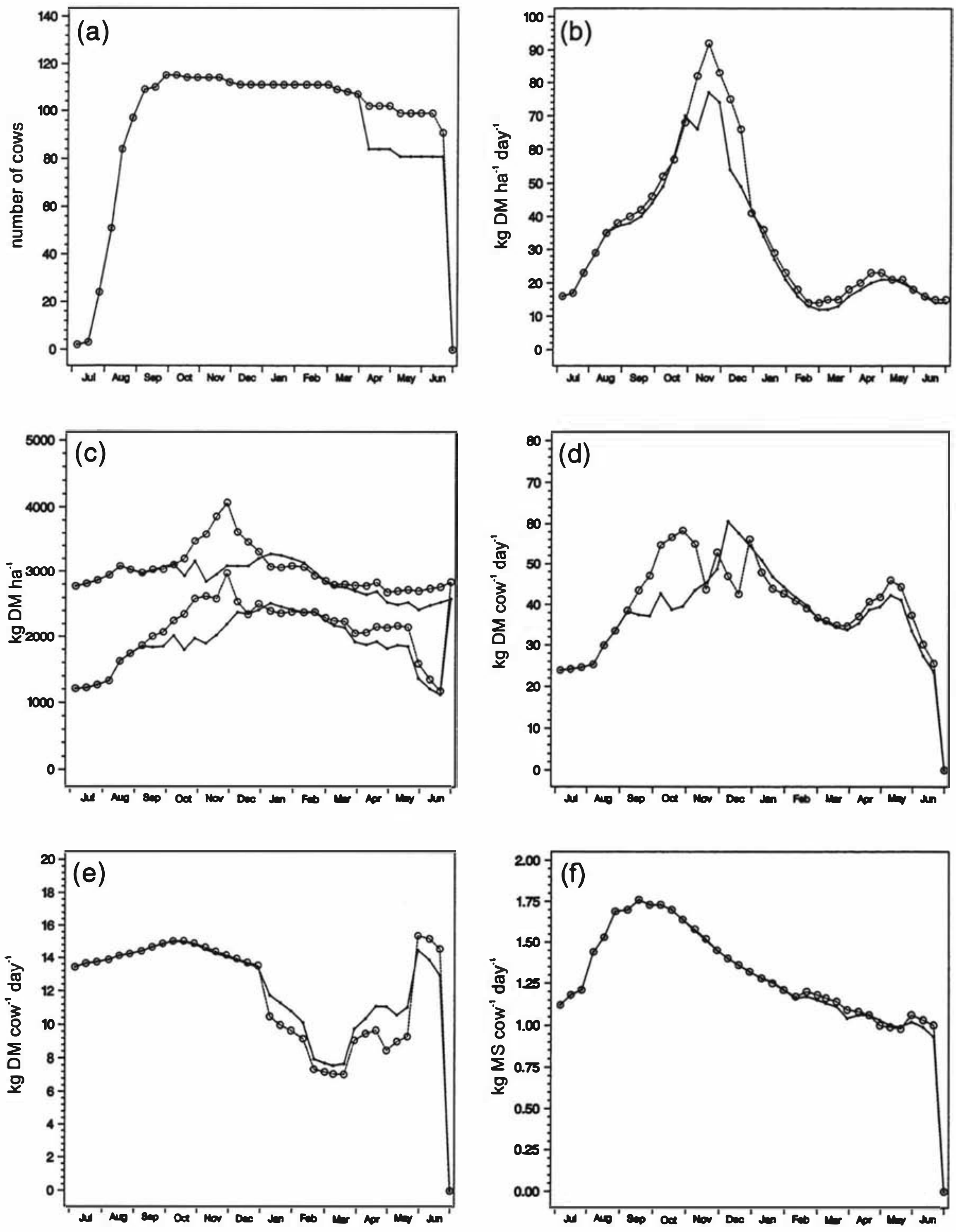
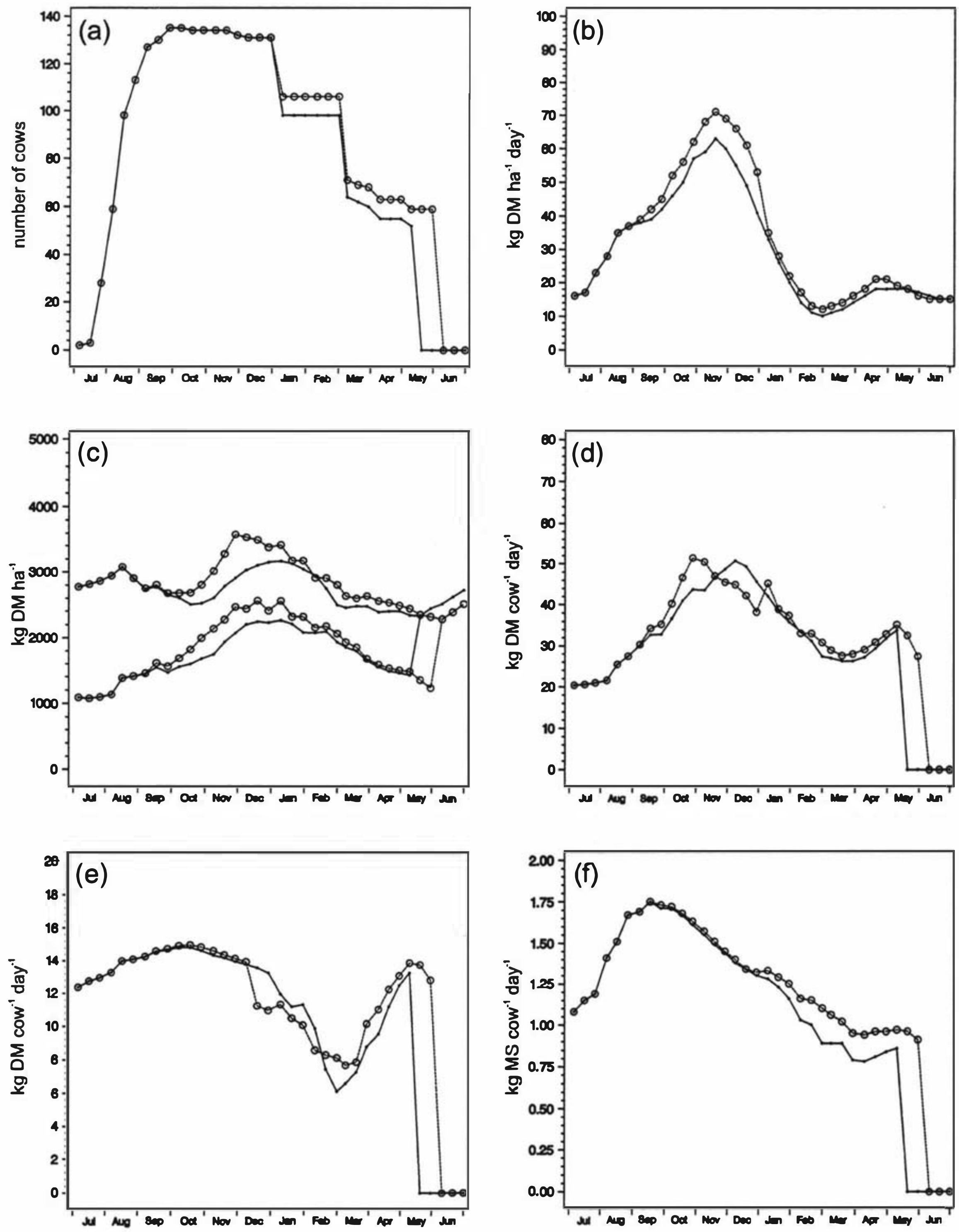


Figure 6-7 Effect of increasing cow numbers to 135 cows on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production for simulated early control —●— and late control --○-- farmlets.



6.5.4 Level of forage conservation

This section investigates the effect of the level of supplementation on EC and LC systems, firstly by examining a strategy where there is no forage conservation, followed by a strategy involving a relatively high level of forage conservation and feed-back.

6.5.4.1 No forage conservation or feeding of supplements

Figure 6-8 and Table 6-7 show the results of a management strategy which involves no-conservation and no use of conserved supplements to lactating or dry cows for EC and LC. The aim of this strategy was to allow cows to maximise the use of grazed herbage. However, without conservation, applying the treatments was difficult and resulted in similar pre- and post-grazing pasture covers for EC and LC (Figure 6-8c), which brings into question the validity of the 10% increase in LC herbage accumulation rates over EC during spring and summer. Furthermore, it was not possible to bring LC pasture covers back down to those of EC (Figure 6-8c). Although pasture quality was unaffected by the higher covers this may not be the case in the field. Since herbage accumulation rates were reduced in spring (Figure 6-8b) by the high pasture covers (Figure 6-8c), covers did not increase uncontrollably, that is, the system was self regulating. Cow numbers were similar for this strategy to those when conservation was taken and fed back into the system (Figures 6-8a and 6-4a respectively).

The intake of pasture by milkers in spring failed to increase over 15 kg DM ha^{-1}, the same upper limit to intake experienced in previous strategies (Figure 6-8e). Autumn pasture intake values were increased for LC over EC. Annual milksolids production was 88 kg ha^{-1} higher for LC than EC, resulting in a 15% increase in the per hectare gross margin (Table 6-7). Figure 6-8f shows daily milksolids production per cow for EC and LC.

6.5.4.2 High level of forage conservation and supplement feeding

The final strategy tested has a relatively high level of forage conservation (Figure 6-9). For EC, 6 ha of pasture was last grazed on 15 September and cut for silage on 31 October and 8 ha was last grazed on 15 October and cut for silage on 30 November. For LC, 10 ha of pasture was last grazed on 05 November and cut for silage on 10 December and 10 ha was last grazed on 15 November and cut for silage on 21 December.

Table 6-7 Effects of conservation policy on pasture variables, animal variables and gross margins for simulated early control and late control farmlets.

	No-conservation		High conservation	
	EC	LC	EC	LC
Milking days	314	345	304	355
Milking cow days ha^{-1}	708.2	777.8	690.9	779.3
Pasture harvested (t ha^{-1})	11.0	11.9	10.8	11.9
Milkers past. eaten (t ha^{-1})	9.4	10.6	8.2	9.0
Drys past. eaten (t ha^{-1})	1.4	1.1	1.6	1.1
Conservation (t DM)	0.0	0.0	35.0	72.0
Milksolids (kg cow^{-1})	347.8	379.2	330.8	365.1
Milksolids (kg ha^{-1})	966.2	1 053.3	918.9	1 014.2
Gross margin ($ cow^{-1})	891.08	1 020.60	769.00	850.70
Gross margin ($ ha^{-1})	2 475.23	2 835.01	2 136.12	2 363.06

Note: Values used in gross margins are presented in Table A6-2 of Appendix Six.

The number of cows lactating is shown in Figure 6-9a and milking cow days in Table 6-7. Thirty-five cows per treatment were dried-off at the end of March, with all EC cows dried-off by the end of April and all LC cows dried-off by the end of June resulting in 3 978 more milking cow days for EC than LC. Supplements were fed at 3 kg DM ha^{-1} from 01 January to 10 April on EC and at 5 kg DM ha^{-1} from 01 January to 20 May on LC.

Herbage accumulation rates are shown in Figure 6-9b. Pre-grazing pasture cover remained relatively constant for EC over winter and spring at 2 900 kg DM ha^{-1} and pre-grazing pasture covers were up to 1 000 kg DM ha^{-1} higher for LC than EC over November and December (Figure 6-9c). These differences were also reflected in post-grazing pasture cover and allowance (Figures 6-9c and 6-9d). As in previous runs, intakes did not respond to the increase in allowance over spring on LC compared to EC (Figure 6-9e).

Milksolids production, shown in Figure 6-9f, was 98 kg MS ha^{-1} (10%) higher for LC than EC over the year and the per hectare gross margin was 11% higher for LC than EC (Table 6-7).

Conserving a large proportion of either the EC or LC farmlet produced less milksolids and gave a poorer gross margin than if no forage was conserved (Table 6-7). Removing a large area of either farmlet for conservation reduced covers, allowances and consequently intakes. In addition, conserving a large area was costly both in terms of energy, through reduced digestibility, and economically. This is similar to the conclusions drawn in Section 6.5.3 where a large area of the farmlet was conserved when run at the low stocking rate.

Figure 6-8 Effect of not conserving forage on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production for simulated early control —●— and late control --o-- farmlets.

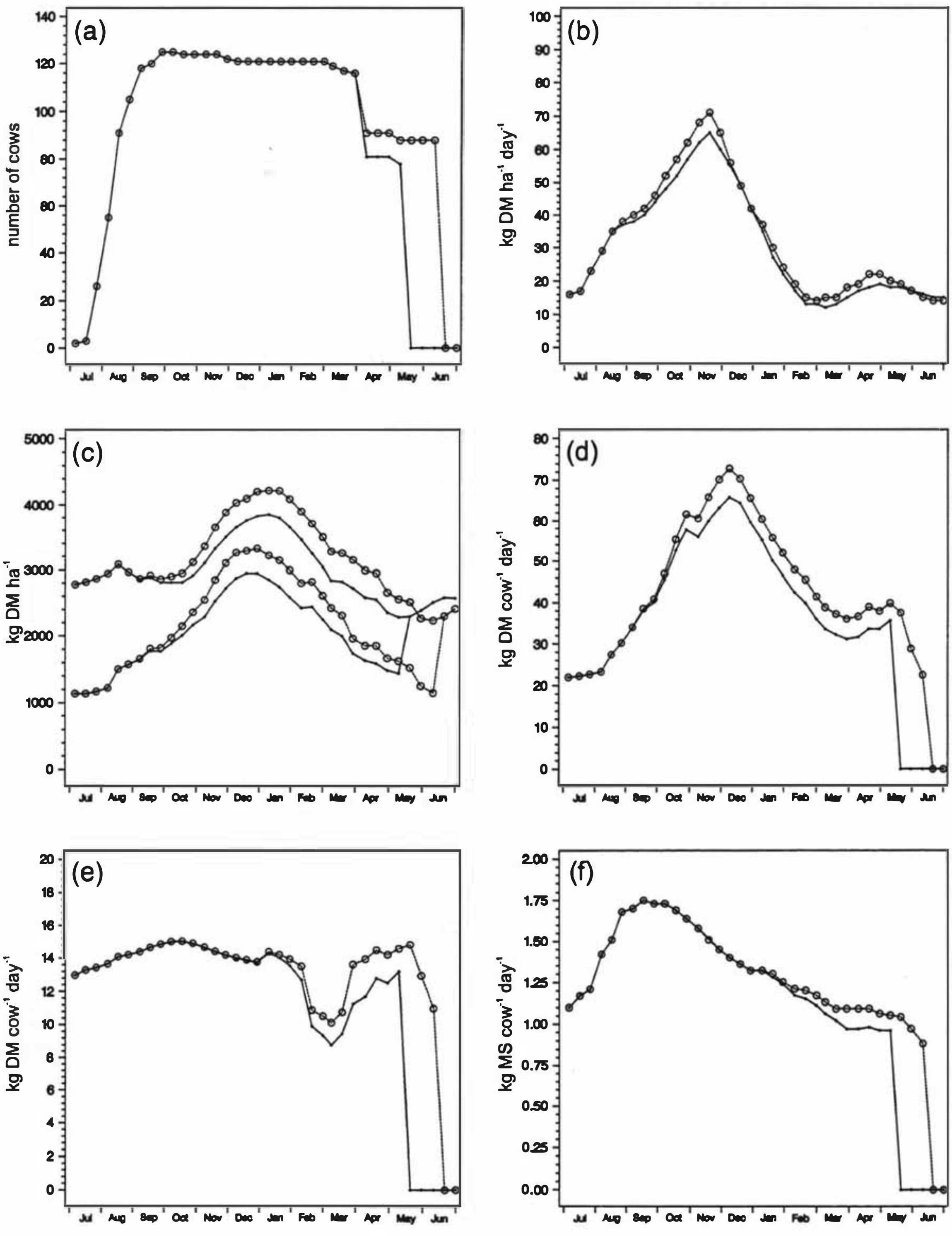
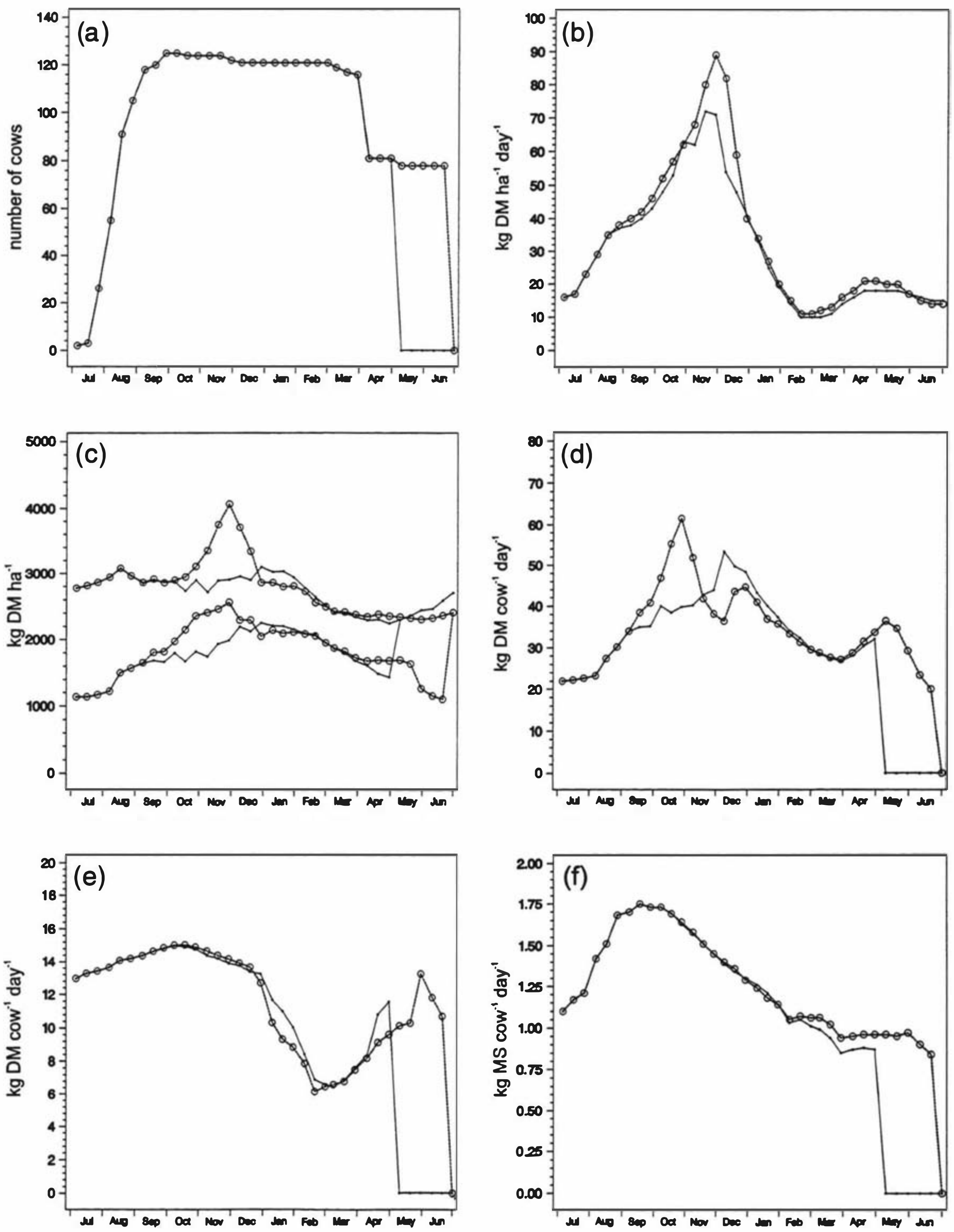


Figure 6-9 Effect of increasing the quantity of forage conserved on (a) numbers of milking cows, (b) herbage accumulation rates, (c) pre-grazing (top) and post-grazing (bottom) pasture covers, (d) herbage allowances, (e) herbage intakes and (f) milksolids production for simulated early control —●— and late control - - ○ - - farmlets.



6.6 Discussion

6.6.1 Use of UDDER

The use of simulation methods allows considerable insight into the operation and control of systems. Simulation should consider two distinct operations: the development or synthesis of a model which adequately represents the system under study, and an observation of the behaviour of the model in reaction to changes in its structure or managerial policies (Dent & Anderson 1971). Hence, simulation allows the researcher to improve the understanding of the system and its responses under different conditions, as well as the construction of the model. Hannon & Ruth (1994) suggests that the need to simulate arises from the impossibility of finding the set of desired solutions algebraically in systems governed by nonlinear and interactive relationships.

Ideally, responses from the model should be compared to those of the real system under similar conditions. However, comparing output from the model and the system as a whole may be unsatisfactory, since deviations from reality by individual components may be compensated for by others (Van Keulen 1976). McCall (1984) reviewed the methodology for comparing a model with reality and concluded that the validation process should be conducted by comparing small sections of the model with the corresponding section of the real system. Morley (1977) suggested that inconsistencies may arise only when the model is used in a different situation.

The simulation model UDDER was used to identify and evaluate late control spring grazing management on pastoral dairy farms. The simulation process makes it possible to quantify relatively quickly and economically the effect of management changes before they are implemented. The relationships in the model are based on research carried out on experimental farms which are not necessarily the same as those of the farms under study so simulations may give only an approximation to likely performance on commercial farms. However, by simulating these management alternatives the possible output can be quantified before it is actually carried out. Thus, UDDER assists in the planning process in the management of a farm. However, when analysing and evaluating the results it should be noted that the model output is given for a specific year, and does not necessarily mean that future seasons will show the same performance.

There are many ways to achieve a match between the actual data and UDDER's estimation of reality. 'Fitting' the model is reliant on the user's ability and can be achieved by manipulating many variables. The inability of UDDER to model the effects of topping on pasture quality meant that topping was not included in the analyses. Results from the final year of the trial suggest that topping may be an integral part of the control phase of LC management.

Energy-based models, such as UDDER, provide an approximation to reality and assume that under temperate grazing conditions energy is limiting production. Thus, it does not consider other important nutritional parameters (protein, fibre, minerals and vitamins) that might limit productivity. Simulation results may be misleading if factors other than energy are limiting milk production. Furthermore, UDDER does not consider the additional labour requirements associated with some management changes, therefore any changes made have to be within the bounds of the current labour supply. Selective culling cannot be simulated by UDDER and the average animal is removed from the herd. UDDER does not consider improvements in herd reproductive performance that might be achieved through the use of supplements (MacCallum *et al.* 1994). Therefore, UDDER could not be used to examine possible LC management alternatives in advance of the field trial. Because herbage accumulation rate is an input, UDDER gives the options for a given management under a particular growth curve

6.6.2 Alternative management strategies

It was not clear what would be the most appropriate way of utilising the extra feed produced from pastures subjected to late control spring grazing management. Possible options would include the enhancement of milk production per cow in the current lactation through improved levels of nutrition in early lactation, maintenance of the actual levels of milk production and lengthening of the lactation period, improvement of the body condition score of the cows, carrying reserves of pasture forward to improve pasture cover on the farm at the start of next calving, and finally, enhancement of milk production by delaying culling decisions. Computer simulation modelling was used to investigate the implementation and best use of the additional feed reported to result from LC. Before the implementation of this alternative grazing procedure in a farm systems context it is essential to integrate these principles and provide a knowledge base strong enough to support the decision making process on a whole farm basis. Since herbage intake was unresponsive to sward conditions in the model, the management strategies actually tested using UDDER included the timing of feeding the conserved herbage back to the cows, the stocking rate and the level of forage conservation.

Topping was effectively used on LC paddocks during 1995/96 to reduce the variability of herbage mass after grazing, and to guarantee full control of the reproductive growth, even though paddocks were topped relatively high (7-10 cm) and removed only 300 kg DM ha^{-1} by trimming just the tops of tall patches present after grazing and generally leaving short patches intact (Padilla 1997). Cows were not forced to graze LC pastures below the level that would result in restrictions on herbage intake and a subsequent reduction in milk production.

Because herbage intake in UDDER was unresponsive to the higher pasture covers associated with lax spring grazing management (LC) the quantity of herbage conserved on LC was considerably higher than EC. This impacted on the management options that could be trialed using the model, the milk production of

LC relative to EC, and therefore the gross margin. Had it been possible to model higher herbage intakes during spring on LC relative to EC then milk production from LC would have been higher, since conservation is inefficient due to the loss of quality when pasture is conserved and the substitution rate associated with feeding supplements is high. It was expected that the quantity of herbage conserved on LC would be similar to EC, the difference being in the timing and the area of the farmlet removed from the grazing round and cut for ensiling. On LC the area would be larger, the crop lighter and the process carried out in December rather than October as for EC. When using UDDER, to get control of LC pastures it was necessary to conserve the additional herbage produced by LC and feed it back into the system when intakes were limiting, or to increase the length of lactation.

During spring, pasture covers were inflated due to the high dry matter percentage of the pasture at this time of the year (Section 5.2.4). The result of this was that considerably less herbage was directly available to the grazing animal than suggested by average cover, and this impacted on the level of herbage intake the animals were able to achieve. Green herbage mass may have been a more useful measurement at that time of the year, but requires additional data.

A summary of the milksolids production and gross margin results from the setting up phase (Table 6-2), simulating LC (Table 6-4) and the strategies tested for both EC and LC (Tables 6-5, 6-6 and 6-7) are presented in Table 6-8. Changing the timing of conservation from early spring in the simulated modified strategy (Table 6-8, Strategy 3) to December in the no advantage strategy (Table 6-8, Strategy 4) resulted in a slight reduction in milksolids production and consequently in gross margin. This can be attributed to the removal of 15.0 t DM more silage from LC than from EC and the resultant lower pasture covers. This illustrates the effect of late control management if the advantage to herbage accumulation rates associated with LC do not eventuate. Adding the advantage expected in herbage accumulation rates to LC (with advantage (Strategy 5) or LC base) returned milksolids production and gross margin similar to those of the simulated modified system (Strategy 3). However, this farmlet (Strategy 5) also has 17.0 t DM silage over and above the simulated modified (Strategy 3) farmlet.

Table 6-8 Summary of setting up early control, simulated late control, and early control and late control management strategies on milksolids production and gross margins.

Strategy		Milksolids production		Gross margin
		kg cow^{-1}	kg ha^{-1}	\$ ha^{-1}
	Setting up early control			
1	Actual	336.6	934.9	2 149.27
2	Simulated unmodified	362.2	1 006.2	2 401.76
3	Simulated modified	341.0	947.3	2 187.55
	Simulated late control			
4	No advantage	338.8	941.0	2 163.13
5	With advantage	341.6	948.8	2 193.71
	Early control strategies			
6	Fed lactating (2.8 cows ha^{-1})	348.0	966.6	2 410.95
7	Fed dry cows	344.9	958.0	2 389.12
8	2.6 cows ha^{-1}	383.3	979.5	2 409.72
9	3.0 cows ha^{-1}	294.5	883.6	2 043.51
10	No-conservation	347.8	966.2	2 475.23
11	High conservation	330.8	918.9	2 136.12
	Late control strategies			
12	Fed lactating (2.8 cows ha^{-1})	375.3	1 042.4	2 599.07
13	Fed dry cows	367.9	1 021.9	2 518.06
14	2.6 cows ha^{-1}	398.2	1 017.6	2 414.80
15	3.0 cows ha^{-1}	321.2	963.7	2 223.99
16	No-conservation	379.2	1 053.3	2 835.01
17	High conservation	365.1	1 014.2	2 363.06

Note: Values used in gross margins are presented in Table A6-2 of Appendix Six.

For descriptions of strategies refer to Sections 6.3, 6.4 and 6.5.

While a good fit was obtained between the actual data from the trial on No 4 Dairy Unit and predicted results from UDDER under the same management, the output measured on No 4 Dairy Unit over the three seasons of the trial showed production to be at or near the maximum for that farm. The stocking rate of the farmlets (2.8 cows ha^{-1}) was higher than the district, regional or national averages (2.5 cows ha^{-1}). Furthermore, UDDER showed reducing stocking rate to be more productive and profitable. It is possible that UDDER does not account for the limitations of wet-land dairying or cooler climates such as in the Manawatu. Experimentation with UDDER has shown that herbage intake is relatively unresponsive to increased allowance, particularly during spring under either EC or LC. This suggests that the relationships in UDDER predict that the level of feeding is not limiting production.

By including the results of the strategies for feeding forage to lactating cows in summer from Section 6.5.2 (Figure 6-4 and Table 6-5) in conjunction with the results from Section 6.5.3 which have the same basic conservation strategy, it was possible to compare three stocking rates (2.6, 2.8 and 3.0 cows ha^{-1}). The management strategy for all three was to feed only forages produced within the system to lactating cows during the summer feed deficit. Cows were to be milked as long as possible providing that pre-grazing pasture cover was 2 400 kg DM ha^{-1} and condition score 5.0 by the end of the run.

Milking cow days were highest for EC at a stocking rate of 2.6 cows ha^{-1} and for LC at 2.8 cows ha^{-1} (Tables 6-6 and 6-5 respectively). Figures 6-4b, 6-6b and 6-7b show that herbage accumulation rates were depressed as the stocking rate increased, resulting in a decrease in pasture harvested (Tables 6-5 and 6-6). Furthermore, as the stocking rate increased the proportion of total annual pasture production eaten by dry cows also increased. Keeping large numbers of dry cows is inefficient since they have to be fed for no milk production. Early control and late control rates of decline in milksolids production were 5.3% and 4.9%, 5.7% and 5.0% and 6.4% and 5.7% per month for stocking rates of 2.6, 2.8 and 3.0 cows ha^{-1} respectively (Figures 6-4f, 6-6f and 6-7f). As stocking rate increased the rate of decline increased for both treatments, and at any given stocking rate the rate of decline was lower for LC than EC.

Annual milksolids production per cow and per hectare were highest for EC at a stocking rate of 2.6 cows ha^{-1}. For LC, per cow production was highest at 2.6 cows ha^{-1} and per hectare production at 2.8 cows ha^{-1}. This pattern was consistent for per cow and per hectare gross margins. That is, no measure of production or economic performance suggested that a stocking rate of 3.0 cows ha^{-1} was better, confirming the view that the stocking rate on the trial was close to the limit for the farm conditions.

As stated previously, UDDER over-predicted milksolids production compared to the field trial from the same inputs, which suggests that a stocking rate of 2.8 cows ha^{-1} for LC may be too high for wet-land dairying. Reducing the rate of decline in milk production after 01 January has been identified as an important factor, and based on this study it would seem that this aim is consistent with reduced stocking rates. In addition, at lower stocking rates there are fewer cows to maintain and more can be retained in milk for longer. With fewer cows it may be possible to grow and harvest less herbage, but still have better production (Matthews 1997).

Reducing the stocking rate may have allowed spring pasture cover targets to be met and allowed the animals to be fed nearer their genetic potential during the rest of the year. Alternatively supplements might be introduced into the system to ensure late control can be implemented successfully.

During the setting up of these runs, the highest stocking rate (3.0 cows ha^{-1}) was the most difficult to manage and hardest to maintain pasture cover and condition score targets on. The timing of conservation and drying-off were considerably more sensitive than at the lower stocking rates. At the lowest stocking rate (2.6 cows ha^{-1}) it was the cost of conservation and loss of energy associated with conserved forage that caused this strategy to be less profitable.

Results from the strategies tested using UDDER suggested that for EC, which produces less herbage annually, the low stocking rate (2.6 cows ha^{-1}) was the best option in terms of milk production. However, for the LC farm milksolids production was maximised when there were no supplements conserved or fed back. Economically the no-conservation option was superior for both EC and LC. However, due to limitations imposed by the model some strategies of interest could not be investigated. It was not possible to investigate a strategy whereby cows consume a large proportion of the extra herbage produced *in-situ* during spring. The low stocking rate option provided the most flexibility and was the easiest to manage since timing of operations was not as critical as at higher stocking rates. While the no-conservation option performed the best for LC and second best for EC, not having any supplements to fall back on may be very risky. This is particularly so for dairying on winter wet soils when the only option may be to stand cows off paddocks and feed them with supplements on a feeding pad.

In UDDER, herbage intake was insensitive to higher spring pasture covers because allowance was seldom limiting. This insensitivity forced the substitution rate of supplements for pasture to increase towards one, particularly in autumn when potential herbage intakes were lower, in turn based on lower potential milksolids production. However, where pasture supply is not limiting, a substitution rate of one seems reasonable.

The no-conservation option performed the best for both EC and LC in terms of the gross margin because there were no costs of conservation. This suggests that limiting the area of pasture conserved is likely to be the most cost effective and, had it been possible to increase intakes, also the most productive system. Purchasing additional feed was economic under the conditions tested for both EC and LC, reflecting the cost of the feed relative to the quantity of milk produced and conversion efficiency of that production.

At the high level of conservation, milksolids production was affected by the loss of energy associated with ensiling, and the economics were affected by the cost of the conservation process (contractor rates). The high stocking rate option (3.0 cows ha^{-1}) was the worst option for both EC and LC in terms of milksolids production and economics (Table 6-8). This was because the cows had to be dried-off earlier to maintain pasture cover and then fed while dry, and because there were more cows to maintain for the whole year.

Late control strategies always produced more milksolids (per cow and per hectare) than early control under similar management, reflecting the additional herbage associated with late control (Table 6-8). Consequently, the gross margin for LC was correspondingly higher than that of EC, since there is no direct cost to achieving the extra pasture production from LC. Without the herbage accumulation rate advantage of LC, milksolids production and gross margin were similar for EC and LC.

6.7 Conclusions

The simulation model UDDER offers the opportunity to identify and analyse alternative farm management practices on pastoral dairy farms. The simulation process makes it possible to quantify relatively quickly and economically the effect of management changes before they are implemented. Therefore, UDDER can be used as a tool to support the decision making process.

The system of entering ungrazable base and density (mass/height) values is difficult to substantiate. Furthermore, the model requires density values as kg DM cm^{-1} when the rising plate meter operates in kg DM 0.5 cm^{-1}. Recent evidence suggests that the expected ranges for pasture mass, particularly in spring, are too small (see Chapter Four).

The level of milk production predicted by UDDER was not achieved in the field over three years using the same inputs. This may be due to the inability of the model to cope with cold/wet winters and wet-land dairy farming. During the trial it was felt that cows were seldom fed enough to reach their intake limit but the model indicated that cows were at their limit.

It was only possible to balance actual and predicted pre- and post-grazing pasture covers by discounting measured monthly herbage accumulation rates by 10 - 15% throughout the year (Section 6.3). The implication is that the values required by UDDER are neither growth rates nor strictly herbage accumulation rates, as defined by Hodgson (1979). Including pools in the model for green and senescent herbage may overcome this confusion and simulate measured values better.

The pasture intake of lactating cows was unresponsive to higher pasture covers and the resultant increased allowances in spring. Furthermore, feeding supplements in late lactation increased condition score more than milk solids production, contrary to the trial data. It appeared as though a ceiling to intake was reached which could not be exceeded. Pasture intakes were only slightly more responsive in autumn than in spring. UDDER seemed to be unresponsive to the manipulation of herbage mass or nutritive value.

Conserving and adding silage back into the system did not increase milksolids production or gross margin, particularly when no real shortage of pasture existed. The main reason for this was the loss of quality associated with ensiling, storing and feeding and the substitution of a lower quality forage for a high quality one. However, in practice conserving herbage reduces the risk associated with poor growing years due to the climate and provides some insurance. Unlike the model, farmers do not know in advance how the year will progress. Furthermore, the model can be rerun if a poor outcome results from the management mix implemented.

The low stocking rate policy (2.6 cows ha^{-1}) was the best for EC based on milksolids production and gross margin, although the stocking rate policy with 2.8 cows ha^{-1} and conserved supplements being fed to lactating cows in summer was similar, based on per hectare gross margins. The latter policy was the best for LC based on both per hectare milksolids production and gross margins.

In general, milksolids production and gross margin were higher for LC than EC, provided the increase in herbage accumulation rate associated with lax spring grazing management (LC) was factored in.

Chapter Seven

Overview and General Conclusions

7.1 Background

The objectives of this study were to (i) evaluate whether the benefits of 'late control' spring grazing pasture management can be measured on a whole farm basis within the management constraints of a self-contained spring calving dairy production system, (ii) investigate the conditions under which late control management can be implemented, and (iii) investigate the options available for the use of additional feed over spring and summer assuming late control spring grazing management is effective in producing additional feed.

Traditionally spring grazing management (early control - EC) suppressed the reproductive growth of perennial ryegrass-white clover swards to maintain pastures in a leafy and vegetative state. Late control (LC) is defined as allowing some early seedhead development followed by hard grazing at the time of anthesis in order to remove the reproductive stems while still relatively immature and palatable (Section 2.3.2). Previous small plot and paddock scale experiments have shown that late control of reproductive growth results in increased pasture production due to an enhancement in the tillering activity of ryegrass plants, and that was associated with increased rates of herbage accumulation during the summer-autumn period. However, it remained to be seen whether the additional herbage produced could be converted into increased animal output or alternative management advantages within the management constraints of a closed production system.

7.2 Field trial

A large scale grazing systems trial to compare these alternative grazing strategies (early control and late control) conducted over three years on No 4 Dairy Unit at Massey University (Chapter Three) failed to demonstrate, at the farm level, the potential advantage from late control spring grazing management suggested by previous small-plot and paddock-scale experiments. However, the pasture cover differences required for the late control treatment were not achieved during spring (October - December), and as a consequence the response in pasture production and animal performance were smaller than the results of previous small-plot and paddock-scale experiments suggested (Chapter Five and Section 2.3.2, respectively). While treatment differences were specified in terms of post-grazing residue and average pasture covers, the specifications were not applied rigorously enough. As reported in Chapter Five the pasture cover differences that were achieved were later, smaller and of shorter duration than has been recommended previously (Section 2.3.2).

Despite the lack of clear treatment differences in animal performance (milksolids), it was concluded in Chapter Five that there were indications of the predicted sward responses in clover content, tiller population densities and some advantage in herbage accumulation rate. Had there been more determined application of the treatments, consistent treatment differences could have been realised.

Control of reproductive growth in pastures was most effectively achieved through the use of mechanical topping following grazing through December. As a result animal production was not affected during the control phase. Late control management did not significantly reduce forage digestibility.

Limitations to the effectiveness of the trial on No 4 Dairy Unit identified in Chapter Five include the high stocking rate imposed and difficulties in the timely implementation of the specifications. At the start of the trial the stocking rate was

2.8 cows ha^{-1}, reducing to 2.7 cows ha^{-1} by the third year of the trial. This was higher than the district, regional and national averages of 2.5 cows ha^{-1} (Section 2.2). As a result of the high stocking rate the opportunity for forage conservation was limited, making it difficult to manipulate pasture covers as required to set-up the treatments. An attempt was made in the final year to use supplements to separate early control and late control pasture covers. However, the level of feeding employed was too late and not sustained for long enough once differences had been achieved because the pastures had to be controlled during December.

Although there were only a few treatment differences in pasture production and no consistent differences in animal production the systems evaluation trial gave tight control of variability, providing an objective basis for the evaluation of the treatments and demonstrating the potential value of large-scale comparisons of this kind. Using paddocks and animals as replicates provided a large number of replicates (degrees of freedom, d.f.) for the comparisons.

It was concluded in Chapter Five that the grazing cycle of rotational grazing imposes constraints on the opportunity for manipulation of the management. For example, because the grazing interval is 20-30 days in December it takes at least this long to impose control on reproductive growth in late control. Furthermore, there were indications of a dampening effect due to internal balance within the system, the time sequence to initiate changes, and pasture and animal reserves. This means that management changes are less effective, responses delayed or more spread out than would be normally expected. The final limitation of system control is related to the scale of the operation which imposes constraints on measurement procedures in terms of the frequency and level of detail. As a result detailed modelling at the tiller level based on the results from this trial met with only marginal success (Appendix Seven).

Systems research of this type must include pre-determined and agreed upon tight specifications and control of pre- and post-grazing pasture cover to ensure that treatments are applied at the appropriate time. The specifications should include decision rules so that the daily management of the farmlets is clear to all involved. Regular monitoring and reporting procedures should be put in place before the start of the trial and used to ensure adherence to the specifications.

In this trial, accurate determination of total daily milk production per herd was not obtained. Trials of this type need to include separate vats for each herd so that the separate quantities and composition records can be obtained from the factory. While herd testing is useful to indicate relative differences in production and composition between farmlets, this procedure frequently overestimates production as determined from factory payments.

The development of a calibration equation in Chapter Four which accounts for the seasonal differences in pasture density should allow clearer definition of herbage mass estimates from rising plate meter measurements. The bulk density of pasture in the summer was found to be twice that in the winter. Therefore, specifying a post-grazing pasture cover of 2000 kg DM ha^{-1} for late control, for example, was simplistic. Rather, the specifications need to allow for changes in density over time and pasture cover targets would need to be dynamic. Returning to or including pasture height targets in treatment specifications would remove any confusion and allow treatment contrasts to be achieved.

7.3 Systems modelling

In Chapter Six an empirical deterministic whole farm simulation model (UDDER) was used to investigate alternative management strategies for utilising grazed and conserved herbage under early control and late control. However, it was first necessary to modify UDDER in order to achieve effective matching between predicted and measured levels of pasture production and animal performance. Without modifying herbage accumulation rate, pasture covers increased throughout the year, and to match daily and annual milksolids production it was necessary to modify potential herbage intake. The level of milk production predicted by UDDER was not achieved in the field over three years using the same inputs, possibly due to the inability of the model to cope with the limitations of colder/wet winters and wetland dairy farming.

It was concluded in Chapter Six that herbage intake was insensitive to higher spring pasture covers and the resultant increase in allowance. For most of the year UDDER predicted the herbage intake of lactating cows to be at or near their potential. Therefore, feeding supplements, particularly during spring, resulted in high substitution rates. Existing models and in particular UDDER are unable to simulate the plant/animal interface adequately enough to enable managements such as late control, which are essentially fine-tuning of the dairy production system, to be modelled.

The system of entering ungrazable base and density (mass/height) values is difficult to substantiate and recent evidence suggests that the expected ranges for pasture mass, particularly in spring, are too small (see Chapter Four).

It was concluded in Section 6.7 that the herbage production values required by UDDER are neither growth rates nor strictly herbage accumulation rates, as defined by Hodgson (1979). Including pools in the model for green and senescent herbage may overcome this confusion and allow actual and predicted pre- and post-grazing pasture covers to be predicted by measured herbage accumulation rates.

The adjustments made to the parameters of UDDER were in general successful, allowing daily and annual milksolids production to be modelled. However, the consequences of these changes to the validity of the model to predict the response of the system to management strategies are uncertain and could only be tested by simultaneously running a systems trial under the same conditions.

Since a search of the literature failed to identify a model capable of predicting the response of pastures to late control spring grazing management, an attempt was made in Appendix Seven to develop a tiller-based model. Such a model would allow the late control system to be investigated further, while at the same time represent a step forward in current understanding. The model developed estimates equilibrium tiller density based on size or mass of ryegrass tillers at the environmental ceiling leaf area based on daily levels of photosynthetically active radiation. However, there was insufficient detailed sward data available to provide conclusive evidence for the validity of the tiller model.

7.4 Modelled systems outcomes

Early control and late control base models were used to evaluate alternative management strategies for using the extra herbage accumulation generated under the late control management, including feeding conserved forage during summer to lactating cows or during winter to dry cows, stocking rate (decreased versus increased) and the level of conservation (none versus increased).

The loss of quality associated with feeding conserved supplements back meant that conserving and adding silage back into the system did not increase milksolids production or gross margin, particularly when UDDER predicted that no real feed shortage existed (Chapter Six). However, in practice conserving herbage reduces the risk associated with poor growing years. Unlike the model, farmers do not know in advance how the year will progress and cannot re-run the year if a poor outcome results.

The low stocking rate policy was the best for early control, although the stocking rate policy with 2.8 cows ha^{-1} and conserved supplements being fed back to lactating cows in summer was similar. The latter policy was the best for late control, based on both per hectare milksolids production and gross margins. At the high stocking rate the flexibility of the system was reduced.

In general, milksolids production and gross margin were higher for late control than early control, provided the increase in herbage accumulation rate associated with lax spring grazing management (late control) was factored in.

7.5 Conclusions

Despite the lack of consistent treatment differences obtained from the trial and the difficulties experienced when modelling late control management alternatives, this project has provided a comprehensive data set and considerable insight into the dairy production system.

Late control spring grazing management can potentially increase the overall productivity of the seasonal dairying systems of New Zealand. In practical terms the main requirement is for a change in conservation management over spring with no other direct costs involved. However, the timing limitations which are an inevitable consequence of rotational grazing systems restrict the opportunity to impose late control management with the rigorous timing that component research suggests may be necessary.

In recent years spring grazing management within the dairy industry has tended towards that of late control spring grazing management and operating grazing systems with higher average pasture covers, although the objectives of farmers are somewhat different to those of late control and involve maximising per hectare production through higher per cow production.

Bibliography

Alberda, T. 1965: The influence of temperature, light intensity and nitrate concentration on DM production and chemical composition of *Lolium perenne L. Netherlands Journal of Agricultural Science 13*: 335-360.

Agricultural Research Council (ARC) 1980: The nutrient requirements of ruminant livestock. Farnham Royal, UK: Commonwealth Agricultural Bureaux. 351 p.

Arnold, G. W.; Campbell, N. A.; Galbraith, K. A. 1977: Mathematical relationships and computer routines for a model of food intake, liveweight change and wool production in grazing sheep. *Agricultural Systems 2:* 209-226.

Barrett, J. R.; Nearing, M. A. 1998: Humanization of decision support using information from simulations *In*: Peart, R. M.; Curry, R. B. *eds.* Agricultural Systems Modelling and Simulation. Published New York : Marcel Dekker. 696 p.

Barthram, G. T.; Grant, S. A. 1994: Seasonal variation in growth characteristics of *Lolium perenne* and *Trifolium repens* in swards under different managements. *Grass and Forage Science 49*: 487-495.

Bonhomme, R. 1993: The solar radiation: characterization and distribution in the canopy. *In:* Varlet-Grancher, C.; Bonhomme, R.; Sinoquet, H. *eds.* Crop Structure and Light Microclimate: Characterizations and Applications. Workshop, Saumane, 23-27/09/1991, INRA, Paris. Pp. 17-28.

Bonhomme, R. 1994: Les rayonnements solaires et le fonctionnement du couvert végétal. *In*: El Hassani, T. A. and Persoons, E. *eds*. Agronomie Modeme. Basses Physiologigues et Agronomiques de la Production Végétale. Hatier-Aupelf. Uref, Paris. Pp. 26-48.

Brookes, I. M.; Holmes, C. W. 1988: The assessment of pasture utilisation on dairy farms. *Proceedings of the New Zealand Grassland Association 49*: 123-126.

Brougham, R. W. 1958: Interception of light by the foliage of pure and mixed swards of pasture plants. *Australian Joumal of Agricultural Research 9*: 39-52.

Bryant, A. M. 1980a: Maximizing milk production from pasture. *Proceedings of the New Zealand Grassland Association 42*: 82-91.

Bryant, A. M. 1980b: Effect of herbage allowance on dairy cow perfomance. *Proceedings of the New Zealand Society of Animal Production 40*: 50-58.

Bryant, A. M.; L'Huillier, P. J. 1986: Better use of pastures. *Proceedings of the Ruakura Farmer's Conference 38*: 43-51.

Bryant, A. M.; Parker, O. F.; Cook, M. A. S.; Taylor, M. J. 1971: An evaluation of the performance of the capacitance meter for estimating yield of dairy pastures. *Proceedings of the New Zealand Grassland Association 33*: 83-89.

Burtt, E. S. 1996: Financial Budget Manual. Canterbury, New Zealand, Lincoln University. 582 p.

Butler B. M. 1986: The effect of grazing intensity and frequency during spring and early summer on the sward characteristics of a ryegrass-white clover pasture. Unpublished M. Agr. Sc. thesis, Massey University, Palmerston North, New Zealand.

Buttery, P. J.; Beever, D. E. 1992: Altering protein and fat content of milk. *In:* Dairy symposium proceedings, Dairy Research Foundation, University of Sydney, Australia. Pp. 28-36.

Bywater, A. C. 1990: Exploitation of the system approach in technical design of agricultural enterprises. *In*: Jones, J. G. W. and Street, P. R. *eds.* Systems Theory Applied to Agriculture and Food Cchain. London: Elsevier Applied Sciences. 365 p.

Cacho, 0. J.; Bywater, A. C. 1994: Use of a grazing model to study management and risk. *Proceedings of the New Zealand Society of Animal Production 54*: 377-381.

Cacho, 0. J.; Finlayson, J. D.; Bywater, A. C. 1995: A simulation model of grazing sheep: II. Whole farm model. *Agricultural Systems 48*: 27-50.

Carton, O. T.; Brereton, A. J.; O'Keeffe, W. F.; Keane, G. P. 1989: Effect of tumout date and grazing severity in a rotationally grazed reproductive sward. 2. Tissue tumover. *Irish Joumal of Agricultural Research 28*: 165-175.

Clark, D. A.; Carter, W.; Walsh, B.; Clarkson, F. H.; Waugh, C. D. 1994: Effect of winter pasture residuals and grazing off on subsequent milk production and pasture performance. *Proceedings of the New Zealand Grassland Association 56*: 55-59.

Clark, D. A.; Harris, S. L. 1996: White clover or nitrogen fertiliser for dairying? *In*; Woodfield, D. R. *ed.* White Clover: New Zealand's Competitive Edge. Joint Symposium. Agronomy Society of New Zealand Special Publication No. 11/Grassland Research and Practice Series No. 6. Pp. 107-114.

Combellas, J.; Hodgson, J. 1979: Herbage intake and milk production by grazing dairy cows. 1. The effects of variation in herbage mass and daily herbage allowance in a short-term trial. *Grass and Forage Science 34*: 209-214.

Coulon, J. B.; Remond, B. 1991: Variations in milk output and milk protein content in response to the level of energy supply to the dairy cow: a review. *Livestock Production Science 29*: 31-47.

Crawford, H. K.; Gray, D. I.; Parker, W. J.; Edwards, N. 1995: Characteristics of seasonal dairy farms achieving high per cow production in the lower North Island of New Zealand. *Proceedings of the New Zealand Society of Animal Production 55*: 72-75.

DairyWIN 1998: DairyWIN User Guide, version 98.1, Massey University, Palmerston North, New Zealand and Livestock Improvement Corporation Limited, Hamilton, New Zealand. 110 p.

da Silva, S. C. 1994: A study of spring grazing management effect on summer-autumn pasture and milk production of perennial ryegrass x white clover dairy swards. Unpublished PhD thesis, Massey University, Palmerston North, New Zealand.

da Silva, S. C.; Hodgson, J.; Matthews, P. N. P.; Matthew, C.; Holmes, C. W. 1994: Effect of contrasting spring grazing management on summer-autumn pasture and milk production of mixed ryegrass-clover dairy swards. *Proceedings of the New Zealand Society of Animal Production 54*: 79-82.

da Silva, S. C.; Matthew, C.; Matthews, P. N. P.; Hodgson, J. 1993: Influence of spring grazing management on summer and autumn production of dairy pastures. *Proceedings of the XVII International Grassland Congress*, Palmerston North, New Zealand. Pp. 859-860.

Davies, A. 1977: Structure of the grass sward. *In*: Gilsenan, B. *ed*. Proceedings of an International Meeting on Animal Production from Temperate Grassland. An Foras Taluntais, Dublin, 36-44.

Davies, A. 1992: White clover. *Biologist 39* (4): 129-133.

Davies, I. 1973: Regrowth characteristics of an S23 perennial ryegrass sward defoliated at early stages of reproductive development. *Journal of Agricultural Science, Cambridge 80*: 1-10.

Dent, J. B.; Anderson, J. R. 1971: Systems Analysis in Agricultural Management. Sidney: John Wiley and Sons. 394 p.

Dent, J. B.; Blackie, M. J. 1979: Systems Simulation in Agriculture. London: Applied Science Publishers. 180 p.

Dillon, J. L. 1976: The economics of systems research. *Agricultural Systems 1*: 5-22.

Dillon, J. L.; Anderson, J. R. 1990: The Analysis of Response in Crop and Livestock Production. 3rd Edition. Oxford: Pergamon Press. 251 p.

Doyle, C. J. 1990: Application of systems theory to farm planning and control: modelling resource allocation. *In*: Jones, J. G. W.; Street, P. R. *eds*. Systems Theory Applied to Agriculture and Food Chain. London: Elsevier Applied Sciences. Pp. 89-112.

Edwards, N. J.; Parker, W. J. 1994: Increasing per cow milksolids production in a pasture based dairy system by manipulating the diet: a review. *Proceedings of the New Zealand Society of Animal Production 54*: 267-273.

Ekanayake, P. M. B.; Matthew, C.; Bailey, W. C. 1996: bST: an assessment of potential response for pasture based dairy farms in New Zealand. *Proceedings of the New Zealand Society of Animal Production 56*: 289-291.

Fales, S. L. 1986: Effects of temperature on fibre concentration, composition, and *in-vitro* digestion kinetics of tall fescue. *Agronomy Joumal 78*: 963-966.

Finlayson, J. D. 1989: A simulation study of out of season lamb production. Unpublished M. Agr. Sc. thesis, Lincoln University, Canterbury, New Zealand.

Finlayson, J. D.; Cacho, 0. J.; Bywater, A. C. 1995: A simulation model of grazing sheep:1. Animal growth and intake. *Agricultural Systems 48*: 1-25.

Freer, M. ; Moore, A. D.; Donnelly, J. R. 1997: GRAZPLAN: Decision support systems for Australian grazing enterprises - II. The animal biology model for feed intake, production and reproduction and the GrassFeed DSS. *Agricultural Systems 54* (l):77-126.

Fulkerson, W. J. 1994: Effect of redefoliation on the regrowth and water soluble carbohydrate content of *lolium perenne*. *Australian Joumal of Agricultural Research 45*: 1809-1815.

Galbraith, K. A.; Arnold, G. W.; Carbon, B. A. 1980: Dynamics of plant and animal production of a subterranean clover pasture grazed by sheep: part II - structure and validation of the pasture growth model. *Agricultural Systems 6*: 23-43.

Glassey, C. 1983: Monitor your farms pasture cover. *New Zealand Dairy Exporter*. May 11-13.

Glassey, C. B.; Davey, A. W. F.; Holmes, C. W. 1980: The effect of herbage allowance on the dry matter intake and milk production of dairy cows. *Proceedings of the New Zealand Society of Animal Production 40*: 59-63.

Grainger, C. 1990: Effect of stage of lactation and feeding level on milk response by stall-fed dairy cows to change in pasture intake. *Australian Joumal of Experimental Agriculture 30*: 495-501.

Grainger, C.; Wilhelms, G. D.; McGowan, A. A. 1982: Effect of body condition at calving and level of feeding in early lactation on milk production of dairy cows. *Australian Joumal of Experimental Agriculture and Animal Husbandry 22*: 9-17.

Grant, S. A.; Barthram, G. T. 1991: The effects of contrasting cutting regimes on the components of clover and grass growth in microswards. *Grass and Forage Science 46*: 1-13.

Grant, S. A.; King, J. 1983: Grazing management and pasture production: the importance of sward morphological adaptations and canopy photosynthesis. Hill Farming Research Organisation, Biennial Report. Pp. 119-129.

Gray, D. I.; Lynch, G. A.; Lockhart, J. C.; Parker, W. J.; Todd, E. G.; Brookes, I. M. 1992: A conceptual framework for an expert system to improve drying off decisions on seasonal supply dairy farms. *Proceedings of the New Zealand Society of Animal Production 52*: 11-12.

Hainsworth, R. 1999: Pasture assessment - talking the same language. *Livestock Improvement, FarmAdviser 3*:2 18-19.

Hannon, B.; Ruth, M. 1994: Dynamic Modelling. New York: Springer-Verlag. 248 p.

Harris, S. L.; Clark, D. A.; Jansen, E. B. L. 1997: Optimum white clover content for milk production. *Proceedings of the New Zealand Society of Animal Production 57*: 169-171.

Harvey, A. C. 1981: Time Series Models. Phillip Allen, London. 384 p.

Hay, M. J. M.; Chapman, D. F.; Hay, R. J. M.; Pennell, C. G. L.; Woods, P. W.; Fletcher, R. H. 1987: Seasonal variation in the vertical distribution of white clover stolons in grazed swards. *New Zealand Journal of Agricultural Research 30*: 1-8.

Hernández Garay, A. 1995: Defoliation management, tiller density and productivity in perennial ryegrass swards. Unpublished PhD thesis, Massey University, Palmerston North, New Zealand.

Hernández Garay, A.; Matthew, C.; Hodgson, J. 2000: Tiller size-density compensation in ryegrass miniature swards subject to differing defoliation heights and a proposed productivity index. *Grass and Forage Science* (in press).

Hodgson, J. 1977: Factors limiting herbage intake by the grazing animal. *Proceedings of the International Meeting, on Animal Production from Temperate Grasslands*. Dublin, Ireland. Pp.70-75.

Hodgson, J. 1979: Nomenclature and definitions in grazing studies. *Grass Science 34*: 11-18.

Hodgson, J. 1989: Increases in milk production per cow and per hectare: pasture production. *Massey Dairyfarming Annual 41*: 76-82.

Hodgson, J. 1990: Grazing Management - Science into Practice. Longman Scientific & Technical. 203 p.

Holmes, C. W. 1996: NZ's systems of milk production from grazed pasture: focus on strengths. *Dairy Exporter*. Feb 1996.

Holmes, C. W.; Brookes, I. M. 1991: The cost and value of extra feed. *Massey Dairyfarming Annual 43*: 102-106.

Holmes, C. W.; Edwards, N. J.; Parker, W. J. 1994: The use of supplementary feeding to extend lactation. *Massey Dairyfarming Annual 46*: 191-193.

Holmes, C. W.; Hughes, T. P. 1993: New Zealand dairying farming in 2010 - implications for nutrition of dairy cattle. *In*: Edwards, N.; Parker, W. *eds.* Improving the Quality and Intake of Pasture Based Diets for Lactating Dairy Cows. Occasional Publication No 1, Department of Agricultural and Horticultural Systems Management, Massey University, Palmerston North. 105 p.

Holmes, C. W.; Wilson, G. F. 1987: Milk Production from Pastures. Butterworths Agricultural Books, Wellington New Zealand. 319 p.

Hoogendoorn, C. J.; Holmes, C. W.; Chu, A. C. P. 1988: Grazing management in spring and subsequent dairy cow performance. *Proceedings of the New Zealand Grassland Association 49*: 7-10.

Hoogendoorn, C. J.; Holmes, C. W.; Chu, A. C. P. 1992: Some effects of herbage composition, as influenced by previous grazing management, on milk production by cows grazing on ryegrass/white clover pastures. 2. Milk production in late spring/summer: effects of grazing intensity during the preceding spring period. *Grass and Forage Science 47*: 316-325.

Hunt, W. F.; Field, T. R. O. 1979: Growth characteristics of perennial ryegrass. *Proceedings of the New Zealand Grassland Association 40*: 104-113.

Hutchings, M. J. 1983: Ecology's law in search of a theory. *New Scientist 98*: 765-767.

Jones, J. W.; Luyten, J. C. 1998: Simulation of biological processes *In*: Peart, R. M.; Curry, R. B. *eds.* Agricultural Systems Modeling and Simulation. Published New York : Marcel Dekker. 696 p.

Judd, T. G.; Thomson, N. A.; McCallum, D. A. 1990: Pasture management and pasture species for improved dry matter production in south Taranaki. *Proceedings of the New Zealand Grassland Association 51*: 109-112.

Kalman, R. E. 1960: A new approach to linear filtering and prediction problems. *Transactions of the ASME - Journal of Basic Engineering.* Pp. 35-45.

Kay, R. D. 1981: Farm Management Planning, Control and Implementation. McGraw-Hill International, Japan. 370 p.

Korte, C. J. 1981: Studies of late spring grazing management in perennial ryegrass dominant pasture. Unpublished PhD thesis, Massey University, Palmerston North, New Zealand.

Korte, C. J. 1982: Grazing management of perennial ryegrass/white clover pasture in late spring. *Proceedings of the New Zealand Grassland Association 43*: 80-84.

Korte, C. J. 1986: Tillering in 'Grasslands Nui' perennial ryegrass swards. 2. Seasonal pattern of tillering and age of flowering tillers with two mowing frequencies. *New Zealand Journal of Agricultural Research 29*: 629-638.

Korte, C. J.; Harris, W. 1987: Stolon development in grazed 'Grassland Nui' perennial ryegrass. *New Zealand Journal of Agricultural Research 30*: 139-148.

Korte, C. J.; Watkin, B. R.; Harris, W. 1982: Use of residual leaf area index and light interception as criteria for spring-grazing management of a ryegrass dominant pasture. *New Zealand Journal of Agricultural Research 25*: 309-319.

Korte, C. J.; Watkin, B. R.; Harris, W. 1984: Effects of the timing and intensity of spring grazings on reproductive development, tillering, and herbage production of perennial ryegrass dominant pasture. *New Zealand Journal of Agricultural Research 27*: 135-149.

Korte, C. J.; Watkin, B. R.; Harris, W. 1985: Tillering in 'Grasslands Nui' perennial ryegrass swards. 1. Effect of cutting treatments on tiller appearance and longevity, the relationship between tiller age and weight, and herbage production. *New Zealand Journal of Agricultural Research 28*: 437-447.

Larcombe, M. T. 1989: The effects of manipulating reproduction on the productivity and profitability of dairy herds which graze pasture. Unpublished PhD thesis, University of Melbourne, Australia.

Larcombe, M. T. 1990a: UDDER 8: A Desktop Dairyfarm for Extension and Research. Operating manual. Agricultural Business Associates, Hamilton. 93 p.

Larcombe, M. T. 1990b: UDDER: A desktop dairyfarm for extension and research. Dairy Cattle Society of the New Zealand Veterinary Association. *Proceedings of the Society's 7th Seminar*. Pp. 151-152.

Le Du, Y. L.; Baker, R. D.; Newberry, R. D. 1981: Herbage intake and milk production by grazing dairy cows. 3. The effect of grazing severity under continuous stocking. *Grass and Forage Science 36*: 307-318.

Le Du, Y. L.; Combellas, J.; Hodgson, J.; Baker, R. D. 1979: Herbage intake and milk production by grazing dairy cows. 2. The effects of level of winter feeding and daily herbage allowance. *Grass and Forage Science 34*: 249-260.

Lemaire, G.; Chapman, D. 1996: Tissue flows in grazed plant communities. *In:* Hodgson, J.; Illius, A. W. *eds.* The Ecology and Management of Grazing Systems. CAB International, Wallingford, Pp. 4-36.

L'Huillier, P. J. 1987a: Tiller appearance and death of *Lolium perenne* in mixed swards grazed by dairy cattle at two stocking rates. *New Zealand Journal of Agricultural Research 30*: 15-22.

L'Huillier, P. J. 1987b: Spring grazing management: effects on pasture composition and density and dairy cow performance. *Massey Dairyfarming Annual 39*: 63-69.

L'Huillier, P. J. 1987c: Effect of dairy cattle stocking rate and degree of defoliation on herbage accumulation and quality in ryegrass-white clover pasture. *New Zealand Journal of Agricultural Research 30*: 149-157.

L'Huillier, P. J. 1988: Reduced input spring-summer pasture management options. *Proceedings of the Ruakura Farmer's Conference 40*: 19-25.

L'Huillier, P. J.; Aislabie, D. W. 1988: Natural reseeding in perennial ryegrass/white clover dairy pastures. *Proceedings of the New Zealand Grassland Association 49*: 111-115.

L'Hullier, P. J.; Thomson, N. A. 1988: Estimation of herbage mass in ryegrass/white clover dairy pastures. *Proceedings of the New Zealand Grassland Association 49*: 117-122.

LIC 1997: 1996/97 Dairy Statistics. Livestock Improvement Corporation, Hamilton. 44 p.

LIC 1998: 1997/98 Dairy Statistics. Livestock Improvement Corporation, Hamilton. 45 p.

Loewer, O. J. 1998: GRAZE: A Beef-Forage Model of Selective Grazing *In*: Peart, R. M.; Curry, R. B. *eds.* Agricultural Systems Modelling and Simulation. Published New York : Marcel Dekker. 696 p.

Loewer, 0. J.; Parsch, L. D.; Scott, H. D.; West, C. P.; Goetsch, A. L. 1993: GRAZE model: importance of simulating conceptual grazing areas within a paddock. *Proceedings of the XVII International Grassland Congress.* Pp. 774-776.

Loewer, 0. J.; Turner, L. W.; Gay, N.; Muntifering, R.; Brown, C. J. 1987: Using the concept of physiological age to predict the efficiency of growth in beef animals. *Agricultural Systems 24*: 269-289.

Marshall, P. R.; McCall, D. G.; Johns, K. L. 1991: STOCKPOL: A decision support model for livestock farmers. *Proceeding of the New Zealand Grassland Association 53*: 137-140.

Martin, R. J.; Korte, C. J.; McCall, D. G.; Baird, D. B.; Newton, P. C. D.; Barlow, N. D. 1991: Impact of potential change in climate and atmospheric concentration of carbon dioxide on pasture and animal production in New Zealand. *Proceedings of the New Zealand Society of Animal Production 51:* 25-33.

Matthew, C. 1990: Translocation from flowering to daughter tillers in perennial ryegrass (*Lolium perenne* L.). Unpublished internal report. Agronomy Department, Massey University, Palmerston North, New Zealand.

Matthew, C. 1991: "Late Control" - What is it, and why should it work? *Massey Dairyfarming Annual 43*: 37-42.

Matthew, C. 1992: A study of seasonal root and tiller dynamics in swards of perennial ryegrass (*Lolium perenne* L.). Unpublished PhD thesis, Massey University, Palmerston North, New Zealand.

Matthew, C.; Black, C. K.; Butler, B. M. 1993: Tiller dynamics of perennation in three herbage grasses. *Proceedings of the XVII International Grassland Congress*, Palmerston North, New Zealand. Pp. 141-143.

Matthew, C.; Chu, A. C. P.; Hodgson, J.; Mackay, A. D. 1991: Early summer pasture control: what suits the plant? *Proceedings of the New Zealand Grassland Association 53*: 73-77.

Matthew, C.; Hernández-Garay, A.; Hodgson, J. 1996: Making sense of the link between tiller density and pasture production. *Proceedings of the New Zealand Grassland Association 57*: 83-87.

Matthew, C.; Lemaire, G.; Sackville Hamilton, N. R.; Hernández-Garay, A. 1995: A modified self-thinning equation to describe size/density relationships for defoliated swards. *Annals of Botany 76*: 579-587.

Matthew, C.; Quilter, S. J.; Korte, C. J.; Chu, A. C. P. & Mackay, A. D. 1989a: Stolon formation and significance for tiller dynamics in perennial ryegrass. *Proceedings of the New Zealand Grassland Association 50*: 255-259.

Matthew, C.; Xia, J. X.; Hodgson, J.; Chu, A. C. P. 1989b: Effect of late spring grazing management on tiller age profiles and summer-autumn pasture growth rates in a perennial ryegrass (*Lolium perenne* L.) sward. *Proceedings of the XVI International Grassland Congress*, Nice, France. Pp. 521-522.

Matthews, P. N. P. 1995: Grazing management principles and targets: a case study. *Massey Dairyfarming Annual 47:* 171-174.

Matthews, P. N. P. 1997: Feeding practices on commercial farms: recent changes in attitudes, their reasons and effects. *Massey Dairyfarming Annual 49*: 67-71.

Matthews, P.N.P., Hodgson, J.; Matthew C. 1996: Dairy grazing systems study with contrasting spring grazing managements. Unpublished internal report. Pastoral Science Group, Massey University, Palmerston North.

Matthews, P. N. P.; Phillips, R. M. C. 1994: Pasture targets: their practical application. *Massey Dairyfarming Annual 46*: 153-157.

McCall, D. G. 1984: A systems approach to research planning for North Island hill country. Unpublished PhD thesis, Massey University, Palmerston North, New Zealand.

McCallum, D. A.; Thomson, N.; Clough, J. 1994: Meal feeding at high stocking rates at Waimate West demonstration farm. *Massey Dairyfarming Annual 46: 50-54.*

McCallum, D. A.; Thomson, N. A.; Judd, T. G. 1991: Experiences with deferred grazing at the Taranaki Agricultural Station. *Proceedings of the New Zealand Grassland Association 53*: 79-83.

McKay, B. 1994: The field use of UDDER: A desktop dairyfarm for extension and research. Dairy Cattle Society of the New Zealand Veterinary Association. *Proceedings of the Society's 11th Seminar.* Pp. 124-130.

McLean, N. R. 1993: Applying management strategies to increase profit. *Massey Dairyfarming Annual 43*:142-150.

Mertens, D. R. 1985: Factors influencing feed intake in lactating cows: from theory to application using neutral detergent fibre. *Proceedings 1985 Georgia Nutrition Conference for the Feed Industry*. 188 p.

Minson, D. J.; Mcleod, M. N. 1970: The digestibility of temperate and tropical grasses. *In*: Norman, M. J. T. *ed. Proceedings of the 11th International Grassland Congress*, Surfers Paradise, Australia. University of Queensland, St. Lucia. Pp. 719-722.

Moller, S. 1997: An evaluation of major nutrients in dairy pasture in New Zealand and their effects on milk production and herd reproductive performance. Unpublished PhD thesis, Massey University, Palmerston, New Zealand.

Morley, F. H. W. 1977: An overview of agricultural modelling. *In*: De Boer, A. J.; Rose, C. W. *eds.* Applications in Agricultural Modelling, Australian Institute of Agricultural Science. Pp. 1-13.

Morley, F. H. W.; Spedding, C. R. W. 1968: Agricultural systems and grazing experiments. *Herbage Abstracts 38*: 297-287.

Muller, L. D. 1993: Limitations of pastures for high production for dairy cows - a US perspective. *In* Edwards, N. J.; Parker W. J. *eds.* Improving the Quality and Intake of Pasture Based Diets for Lactating Cows. Occasional Publication No 1, Department of Agricultural and Horticultural Systems Management, Massey University, Palmerston North. Pp. 33-58.

Murphy, M. 1993: An intemational perspective of dairying in New Zealand. *In*: *Proceedings of the XVII Intemational Grassland Congress*, Palmerston North, New Zealand. Pp. 1585-1586.

Murthy, D. N. P.; Page, N. W.; Rodin, E. Y. 1990: Mathematical Modelling: A Tool for Problem Solving in Engineering, Physical, Biological and Social Sciences. Oxford: Pergamon Press. 330 p.

NRC 1989: The Nutrient Requirements of Dairy Cattle, 6th revised edition, National Academy Press, 1988. 157 p.

Ong, C. K.; Marshall, C.; Sagar, G. R. 1978: The physiology of tiller death in grasses. 2. Causes of tiller death in a grass sward. *Joumal of the British Grassland Society 33*: 205-211.

Padilla, M. J. 1997: A study of patchiness in mid-season dairy pastures: consequences and control. Unpublished M. Appl. Sc. thesis, Massey University, Palmerston North, New Zealand.

Parsons, A. J.; Penning, P. D. 1988: The effect of the duration of regrowth on photosynthesis, leaf death and the average rate of growth in a rotationally grazed sward. *Grass and Forage Science 43*: 15-27.

Piggot, G. J. 1986: Methods for estimating pasture dry matter on dairy farms in Northland. *Proceedings of the New Zealand Grassland Association 47*: 243-247.

Pinares, C.; Holmes, C. W. 1996: Effects of feeding silage and extending lactation on the pastoral dairy system. *Proceedings of the New Zealand Society of Animal Production 56*: 239-241.

Ring, C. B.; Nicholson, R. A.; Launchbaugh J. L. 1985: Vegetational traits of patchgrazed rangeland in west-central Kansas. *Joumal of Range Management 38*: 51- 55.

Rothemberg, J. 1989: The nature of modelling. *In*: Widman, L. E.; Loparo, K. A.; Nielsen, N. R. *eds.* Artificial Intelligence: Simulation and Modelling. New York: John Wiley and Sons. Pp. 75-92.

Rountree, J. H.1977: Systems thinking - some fundamental aspects. *Agricultural Systems 2*: 247-254.

Sackville Hamilton, N. R.; Matthew, C.; Lemaire, G.; 1995: In defence of the -3/2 boundary rule: a re-evaluation of self-thinning concepts and status. *Annals of Botany 76*: 569-577.

SAS Institute Inc. 1995: SAS User's Guide, release 6.12 edition. Statistical Analysis System Institute. Cary, North Carolina, USA. 1030 p.

Shannon, R. E. 1975: System Simulation: the Art and Science. Prentice-Hall, Englewood Cliffs, N.Y. 387 p.

Sinclair, T. R. and Seligman, N. G. 1996: Crop modelling: from infancy to maturity. *Agronomy Joumal 88*: 698-704.

Smith, R. C. G.; Williams, W. A. 1973: Model development for a deferred-grazing system. *Journal of Range Management 26* (6): 454-460.

Spedding, C. R. W. 1975: The study of agricultural systems. *In*: Dalton, G. E. *ed.* Study of Agricultural Systems. Applied Science Publishers. Pp. 3-19.

Spedding, C. R. W. 1988: An Introduction to Agricultural Systems. 2nd Edition. London: Elsevier Applied Science. 189 p.

Stephen, R. C.; Revfeim, K. J. A. 1971: A comparison of three pasture measurement techniques. *Proceedings of the New Zealand Grassland Association 33*: 76-82.

Sutton, J. D.; Morant, S. V. 1989: A review of the potential of nutrition to modify milk fat and protein. *Livestock Production Science 23*: 219-237.

Thom, E. R. 1991: Effect of early spring grazing frequency on the reproductive growth and development of a perennial ryegrass tiller population. *New Zealand Journal of Agricultural Research 34*: 383-389.

Thomson, N. A. 1983: Factors affecting the accuracy of herbage mass determinations with a capacitance meter. *New Zealand Journal of Experimental Agriculture 11*: 171-176.

Thomson, N. A. 1986: Techniques available for assessing pasture. *Massey Dairyfarming Annual 37*: 113-121.

Thomson, N. A.; Exton, N. R.; McLean, N. R.; Gawson, J. E. 1997: The impact of turnips on dairy production as evaluated by component trials, modelling and farm systems research. *Proceedings of the New Zealand Society of Animal Production 57*: 165-168.

Thomson, N. A.; Holmes, C. W. 1995: Supplementary feeding for increased milk production. *Massey Dairyfarming Annual 47*: 20-27.

Thomson, N. A.; Lagan, J. R.; McCallum, D. A. 1984: Herbage allowance, pasture quality and milk fat production as affected by stocking rate and conservation policy. *Proceedings of the New Zealand Society of Animal Production 44*: 67-70.

Thomson, N. A.; McCallum, D. A. 1989: Is making hay or silage worth the effort? *Proceedings of the Ruakura Farmer's Conference 41*: 50-56.

Thomson, N. A.; McCallum, D. A.; Howse, S.; Holmes, C. W.; Matthews, P. N. P.; Matthew, C. 1997: Estimation of dairy pastures - the need for standardisation. *Proceedings of the New Zealand Grassland Association 59*: 221-225.

Thornley, J. H. M.; France, J. 1984: Role of modelling on animal production research and extension work. *In*: Baldwin, R. L.; Bywater, A. C. *eds.* Modelling Ruminant Digestion and Metabolism. Proceedings of the 11th International Workshop. Davis, University of California. 578 p.

Townsley, R. J. 1973: Discussion *In*: Proceedings of Agricultural Systems Research Conference. Massey University. Pp. 150.

TSP 1993: Time Series Processor, version 4.2. Reference Manual. California USA, TSP International. 304 p.

Ulyatt, M. J.; Fennessy, P. V.; Rattray, P. V.; Jagusch, K. T. 1984: The nutritive value of supplements. *In*: Drew, K. R. & Fennessy, P. F. *eds.* Supplementary Feeding: A Guide to the Production and Feeding of Supplements for Sheep and Cattle in New Zealand. 2nd Edition. New Zealand Society of Animal Production. Occasional Publication No. 7. C/- Invermay Research Centre, Mosgiel, New Zealand. 197 p.

Ulyatt, M. J.; Lee, J.; Corson, D. 1995: Assessing feed quality. *Proceedings of the Ruakura Farmers' Conference 47*: 59-62.

Upsdell, M. P. 1994: Bayesian smoothers as an extension of non-linear regression. *The New Zealand Statistician 29*: 66-81.

Upsdell, M. P. 1996: Choosing an appropriate covariance function in Bayesian smoothing. *In*: Bayesian Statistics. Proceedings of the 5th Valencia International Meeting, 1994. Clarendon Press, Oxford. Pp. 747-756.

Uribe, J. V. 1995: Ration balancing in New Zealand dairy farm management: a case farm simulation study. Unpublished M. Agr. Sc. thesis, Massey University, Palmerston North, New Zealand.

Uribe, J. V.; Parker, W. J.; Dake, C. K. G.; McDonald, A. 1996: A whole farm approach to feed planning and ration balancing using UDDER and CAMDAIRY. *Proceedings of the New Zealand Society of Animal Production 56*: 285-288.

Van Dyne, G. M.; Abramsky, Z. 1975: Agricultural systems models and modelling: an overview. *In*: Dalton, G. E. *ed.* Study of Agricultural Systems. Applied Science Publishers. Pp. 23-106.

Van Keulen, H. 1976: Evaluation of models. *In*: Amold, G. W.; Wit, C. T. *eds.* Critical Evaluation of Systems Analysis in Ecosystems Research and Management. Pudoc, Wageningen. Pp. 22-29.

Wheeler, D. M.; Upsdell, M. P. 1997: Flexi 2.4 Bayesian Smoother Reference Manual. New Zealand Pastoral Agricultural Research Institute Ltd. 305 p.

White, D. H.; Bowman, P. J.; Morlley, F. H. W.; McMamus, W. R.; Filan, S. J. 1983: A simulation model of a breeding ewe flock. *Agricultural Systems 10*: 149-189.

Wilkins, R. J.; Huckle, C. A.; Clements, A. J. 1991: Effects of concentrate supplementation and sward clover content on milk production by spring calving dairy cows. *In*: Mayne, C. S. *ed.* Management Issues for the Grassland Farmer in the 1990's. British Grassland Society Occasional Symposium 25. Pp. 218-221.

Wilson, G. F.; Moller, S.; Parker, W. J.; Hodgson, J. 1995: Seasonal differences in pasture composition and nutritional implications. Symposium: Profitable feeding - composition of the diet. *Massey Dairyfarming Annual 47*: 46-61.

Wilson, J. R.; Taylor, A. O.; Dolby, G. R. 1975: Temperature and atmospheric humidity effects on cell wall content and dry matter digestibility of some tropical and temperate grasses. *New Zealand Journal of Agricultural Research 19*: 41-46.

Wright, A. 1973: A systems research approach to agricultural research and the study of grazing systems. *In*: Proceedings of Agricultural Systems Research Conference. Massey University, Palmerston North. Pp. 5-11.

Xia, J. X.; Hodgson, J.; Matthew, C.; Chu, A. C. P. 1990: Tiller population and tissue turnover in a perennial ryegrass pasture under hard and lax spring and summer grazing. *Proceedings of the New Zealand Grassland Association 51*: 119-122.

Appendix One

A preliminary report of the dairy systems grazing trial (Chapters 3 and 5) published in the *Proceedings of the New Zealand Grassland Association 59*: 209-214 (1997).

Dairy systems study of the effects of contrasting spring grazing managements on pasture and animal production

G.J. BISHOP-HURLEY[1], P.N.P. MATTHEWS[1], J. HODGSON[1], C. DAKE[2] and C. MATTHEW[1]
[1]*Department of Plant Science, Massey University, Palmerston North*
[2]*Department of Agribusiness and Resource Management, Massey University, Palmerston North*

Abstract

This paper reports the results of a dairying systems study at No. 4 Dairy, Massey University, investigating whether the benefits of contrasting spring grazing managements previously measured in small-scale experiments could be measured within the management constraints of a self-contained farm production system. Management contrasts were early control (EC), in which pastures were closely controlled throughout spring and summer, with average pasture cover kept at approximately 2000 kg DM/ha, and late control (LC), in which average pasture cover was increased to 2700 kg DM/ha, allowing some reproductive growth through October and November before returning average pasture cover to 2000 kg DM/ha in December. Average pasture cover and pre- and post-grazing cover differences between treatments were achieved over late spring in all three years. However, average pasture cover during summer did not differ between treatments. Milksolids (MS) production per cow during the spring phase was higher for the LC treatment than for EC, but the differences disappeared over the December control phase and overall differences were small and inconsistent. The use of mechanical topping in December 1995/96 reduced the penalty to LC MS production experienced in previous years. Late control spring grazing management did not significantly increase pasture or MS production within the confines of a closed production system, contrary to the results of previous small-plot and paddock-scale experiments.

Keywords: dairy cow, dairy systems, *Lolium perenne*, milksolids production, pasture production, spring grazing management, *Trifolium repens*

Introduction

Traditionally, the emphasis in dairying systems has been on maintaining pasture quality in late spring through increased grazing pressure (speeding up the round and forage conservation) and sometimes topping. Recent studies have reported an increase in summer and autumn herbage production by allowing some reproductive development, followed by a period of control at the time of anthesis when seed-heads are immature and still palatable (late control), through effects on tiller population and size (da Silva *et al.* 1993, 1994; Hernández Garay 1995; Matthew *et al.* 1989). A series of small-plot and paddock-scale trials supported the hypothesis, suggesting late control can be achieved through grazing management, and animal performance could be enhanced as a consequence of sward conditions which lead to higher clover and total pasture growth rates in summer (da Silva *et al.* 1993, 1994). However, it remained to be seen whether the additional herbage produced could be converted into increased animal output or alternative management advantages within the constraints of a closed production system. This paper summarises the results of a dairy systems study carried out at No. 4 Dairy, Massey University to determine whether the benefits of late control can be measured in animal production.

Experimental design

Two 20-paddock perennial ryegrass–white clover dominant farmlets of 45 ha were each stocked with 120 spring calving Friesian cows in October 1993. Treatments were randomly allocated within pairs of paddocks between farmlets at the beginning of the trial which ran for three lactations until May 1996. Initially, cows were allocated to treatments balanced for age, calving date and herd test. Between years cows were retained on treatments and replacements, 20% and 25% for the 1994/95 and 1995/96 years respectively, were allocated to treatments balanced for calving date, liveweight and breeding index.

The first treatment, designated early control (EC), involved strict control of grazing throughout spring and summer, aiming for average pasture cover of approximately 2000 kg DM/ha and post-grazing residual of approximately 1500 kg DM/ha. Spring pasture surplus was controlled by a conventional (20- to 25-day) rotation and dropping paddocks out of the rotation for later conservation. Limits on average pasture cover in this treatment encouraged high levels of pasture utilisation by the cows in early lactation. Pastures in the second treatment (late control – LC) were allowed to develop some reproductive growth through October and November for removal in December. Average pasture cover target was 2700 kg DM/ha, with post-grazing residual approximately 2000 kg DM/ha over spring. Average pasture cover was reduced to 2000 kg DM/ha in December by grazing to lower residuals while at the same time removing paddocks from grazing for immediate conservation.

Differences in average farm cover, animal condition and conserved feed created by the treatments in mid to late spring were carried forward into summer, autumn and winter. However, both farmlets were returned to a common management point by the planned start of calving (1 August) each year. This was defined as a target average pasture cover of 2000 ± 100 kg DM/ha and an average cow condition score of 5.0 ± 0.25. With the exception of spring grazing, all management practices were balanced between the self-contained farmlets.

Plate meter readings of pasture cover were made weekly for all paddocks with ground level reference cuts and plate meter readings pre- and post-grazing from 5 representative "indicator" paddocks per treatment. Each week, pre-grazing herbage samples were clipped to grazing height from 2 paddocks per treatment for near infrared spectrophotometer (NIR) analysis of digestibility at AgResearch Grasslands, Palmerston North. Records were kept of supplements harvested from and fed out on each farmlet. Fortnightly herd tests were used to measure milk production. Unfasted liveweight and condition score were recorded monthly.

The data were evaluated by analysis of variance using the General Linear Models (GLM) procedure of SAS (SAS Institute Inc. 1988). Treatments were analysed as a completely randomised design (CRD) with paddocks and animals as replicates.

Results

Over the three years of the trial average pasture cover (Figure 1) ranged from 1200 to 1700 kg DM/ha during winter and 2400 to 3800 kg DM/ha in summer (SEM 128). Average pasture cover was always higher on the LC farmlet than on the EC farmlet during spring. During summer 1995/96 pre-grazing pasture cover was greater for LC than EC ($p<0.05$) (Table 1). Post-grazing pasture cover for LC exceeded EC by 1440 kg DM/ha ($p<0.10$) in spring 1993/94.

Monthly herbage accumulation rates from indicator paddocks ranged from 5 kg DM/ha/day in winter to over 100 (SEM 8.7) kg DM/ha/day in spring of 1995/96 year (Figure 2). In 1993/94 and 1994/95 (SEM 7.95 and 4.72, respectively), accumulation rate tended to be higher for LC, although the only significant difference was in autumn of 1995. In the final year (1995/96) neither treatment appeared to have an advantage, with the exception of LC in September 1995 when the differences approached significance ($p<0.10$).

In 1994/95 seasonal mean estimates of organic matter digestibility (OMD) were 76.7 and 77.9% (SEM 0.68) for spring, 73.9 and 73.8% (SEM 0.92) for summer, 74.2 and 75.0% for autumn (SEM 0.32) and 77.3 and 76.4% for winter (SEM 1.20) for EC and LC, respectively. In 1995/96 seasonal mean estimates of OMD were 74.5 and 75.1% (SEM 0.89) for spring, 70.0 and 70.2% (SEM 0.77) for summer and 73.9 and 70.9% for autumn (SEM 0.73) for EC and LC, respectively. Values did not differ significantly between treatments with the exception of autumn 1996 ($p<0.05$).

Treatment differences in milksolids (MS) production in 1993/94 were variable (Figure 3), with no extended period of advantage apparent to either treatment. In early spring 1994 significant differences were again apparent although treatment effects were not consistent. During the control phase in December MS production was higher on EC than LC, although this advantage was reversed towards the end of lactation. In the final year (1995/96) results were again variable.

During the first year (1993/94) treatment had no effect on liveweight or condition score (Table 2). In the second year (1994/95) EC cows were heavier and had

Table 1 Seasonal pre- and post-grazing pasture covers (kg DM/ha) and SEM for early and late control indicator paddocks over three years.

Season	----- Pre-grazing -----			----- Post-grazing -----		
	Early control	Late control	SEM	Early control	Late control	SEM
1993/94						
Spring	-	-	-	1,410	2,850	136+
Summer	3,310	3,190	366	2,470	2,250	368
Autumn	1,810	2,320	243	1,690	1,560	520
1994/95						
Winter	-	2,470	332	630	1,070	188
Spring	2,430	2,420	284	1,880	2,170	243
Summer	2,560	2,710	249	2,360	2,550	136
Autumn	2,920	2,670	228	1,750	1,790	357
1995/96						
Winter	2,160	1,880	110	1,050	1,110	153
Spring	1,900	2,140	216	1,800	1,600	156
Summer	2,930	3,740	198*	2,610	2,810	257
Autumn	4,000	3,550	512	1,840	1,900	332

For all tables: NS = not significant, + = P < 0.10, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

Figure 1 Average pasture cover (kg DM/ha) for early control and late control paddocks over three years. For all figures: early control —•— and late control --o--. Significant differences are indicated by + p<0.10 and * p<0.05.

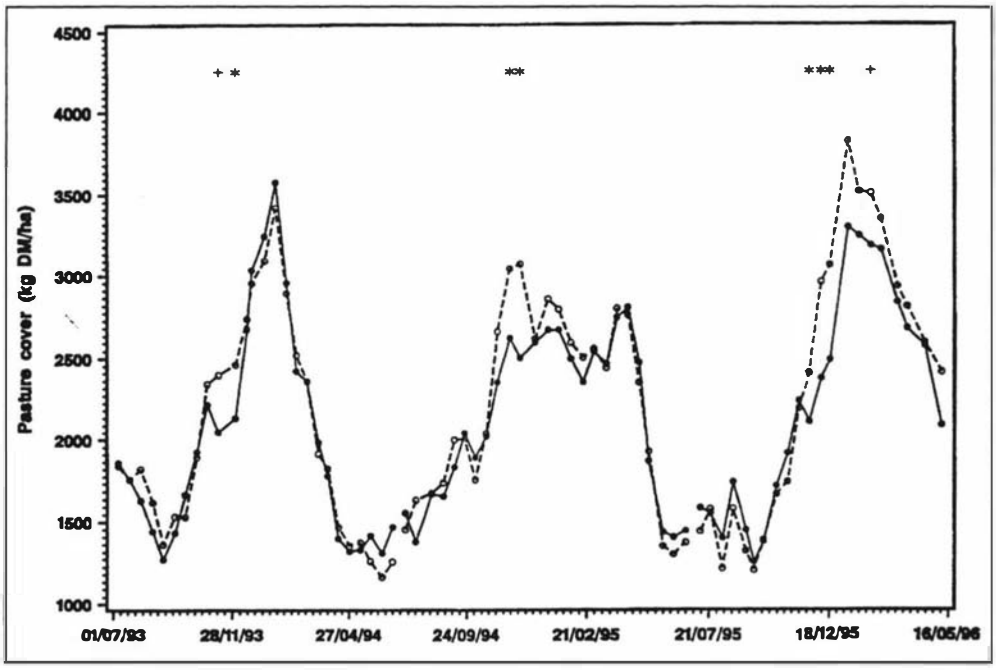


Figure 2 Effect of treatment on monthly herbage accumulation rate (kg DM/ha/day) in indicator paddocks over three years.

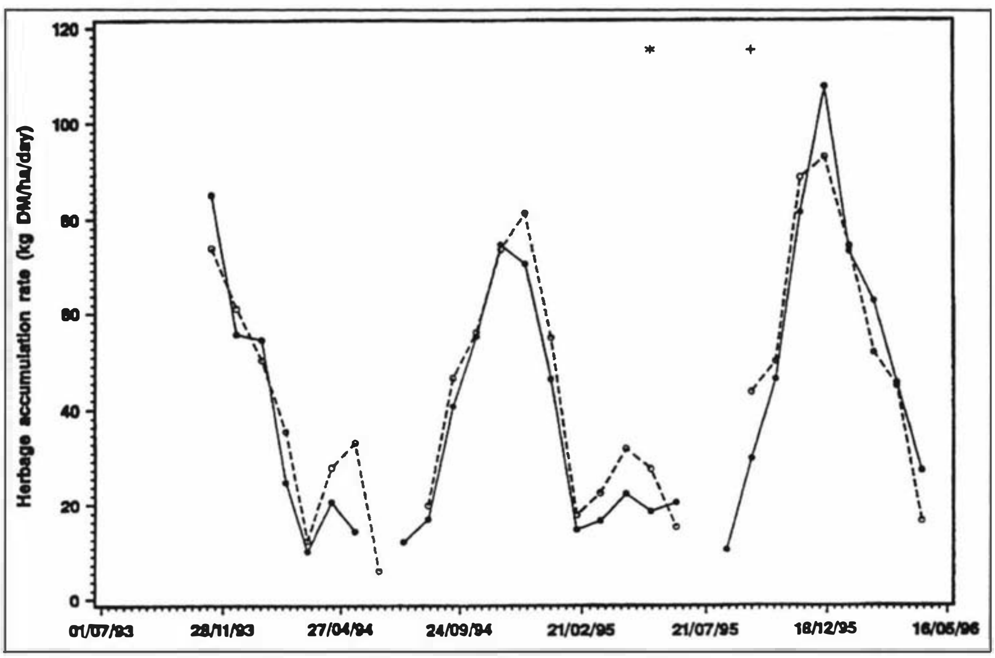


Figure 3 Mean daily milksolids production (kg MS/cow/day) for early control and late control herds over three years, adjusted by using initial milksolids as covariate. Overall SEM was 0.025.

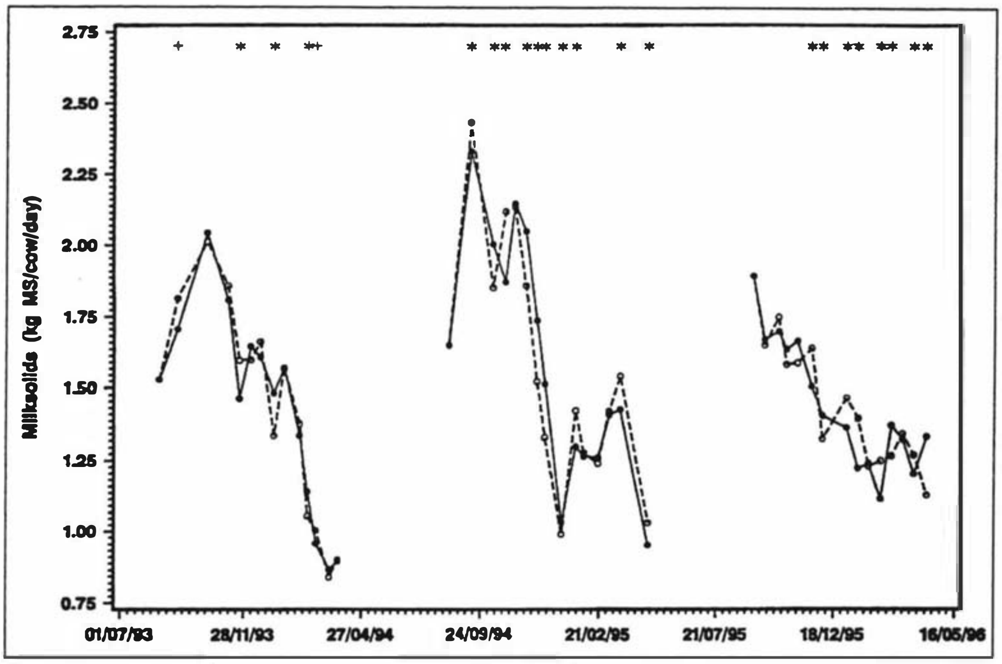


Table 2 Liveweight (kg) and condition score values post-calving and at drying off over three years, adjusted by using initial liveweight and condition score as covariates.

Year	-- 1993/94 --		-- 1994/95 --		-- 1995/96 --	
	Post-calving	Drying off	Post-calving	Drying off	Post-calving	Drying off
Liveweight						
Early control	465	488	474	505	448	466
Late control	460	488	473	492	430	464
SEM	5.22	2.44	2.86	3.02	2.10	2.60
	NS	NS	NS	**	***	NS
Condition score						
Early control	4.49	4.69	4.53	4.88	4.22	4.33
Late control	4.52	4.62	4.61	4.62	4.23	4.34
SEM	0.031	0.044	0.032	0.057	0.038	0.047
	NS	NS	+	**	NS	NS

Table 3 Herbage conserved and supplements fed (kg DM/ha) and supplement balance (kg DM/ha) over three years.

Year	Herbage conserved	Supplements fed†	Balance
1993/94			
Early control	1,185	1,825	640
Late control	1,025	1,881	856
1994/95			
Early control	332	1,750	1,418
Late control	574	2,139	1,565
1995/96			
Early control	274	1,368	1,094
Late control	117	2,139	2,022

† Supplements fed; maize, silage and crop by-products.

higher condition score than LC cows when dried off. However, LC cows tended to have a higher condition score after calving. In the final year (1995/96) EC cows were heavier than LC cows post-calving, although their condition scores were similar. The liveweight difference disappeared by drying off.

Both farmlets had a net inflow of supplements in all years (Table 3). The deficit was similar between treatments in the first two years (1993/94 and 1994/95) although over 50% higher in 1994/95 than in 1993/94. In the first year slightly more supplements were harvested on EC than LC, but the opposite was the case in 1994/95. In the final year the deficit for LC was twice that of EC, the result of less forage conserved on LC and approximately 30% more supplements fed.

Discussion

In practice it was more difficult than expected to maintain predetermined sward conditions based on average pasture cover and post-grazing residues. Average pasture cover differences between treatments were achieved over late spring every year (Figure 1). However, the extent and duration of the differences achieved were limited and were not reflected in pre-grazing covers, particularly in the first two years (Table 1). Treatment differences were not apparent until November, 4–6 weeks later than in previous experiments (da Silva 1994; Hernández Garay 1995). Recent work has shown that late control spring grazing management increases tiller population and size more after an extended spell of seed-head development (12 weeks) when compared to a shorter spell of 6 weeks (Hernández Garay 1995). In addition, the difference between treatments was less than the 700 kg DM/ha target. Average pasture covers were higher than the 2000 kg DM/ha and 2700 kg DM/ha targets in spring, and EC pasture cover was closer to that of LC in previous experiments, particularly for 1995/96 (da Silva *et al.* 1994). It appears that the measurement method used reflected increasing dry matter content of pastures over summer compared with visual targets normally used in practice by farmers, and therefore influenced the absolute values measured.

In the first two years, there were no differences between treatments in average pasture cover and pre- and post-grazing herbage mass during summer. Average pasture covers were also similar in the summer of the final year, although pre-grazing pasture cover was higher on LC then EC (Table 1). Herbage accumulation rates were also similar (Figure 2), although in the first two years there appeared to be an advantage to LC, particularly in autumn. Previous small-plot and paddock-scale experiments have shown increased summer and autumn pasture production after LC spring pasture management (da Silva *et al.* 1993, 1994).

LC management did not affect pasture quality (OMD) in spring or summer. Da Silva *et al.* (1994) showed individual cow performance was not affected during the "control phase" of reproductive growth on LC despite the higher proportion of grass stem and senescent material in those swards compared with EC swards.

The advantage in MS production per cow frequently changed between treatments (Figure 3) so that, overall, differences were small and inconsistent. Large differences in animal performance would not be expected, considering the marginal differences in pasture production achieved. LC cows were disadvantaged during the pasture control phase in December 1994/95, whereas mechanical topping was used in the 1995/96 year and limited the impact on milk production. Liveweight and condition score differences between treatments were also small and inconsistent.

The high supplement use in the LC treatment relative to the EC treatment in the final year (1995/96) was considered essential to offset the lower liveweights of LC cows after winter and in an attempt to realise the 700 kg DM/ha cover difference required during a cold spring. A net inflow of supplements is typical for this type of dairy farm at the stocking rate used.

Conclusions

The pasture cover differences required for the LC treatment were not achieved during late spring (November–December), and as a consequence the response in animal performance was smaller than the results of previous small-plot and paddock-scale experiments suggested. Management constraints at the high stocking rate imposed contributed to the lack of differences achieved in spring pasture cover. Pasture control was best achieved through the combined use of the grazing animal and mechanical topping. The LC treatment did not significantly reduce forage digestibility.

Despite the lack of clear treatment differences in MS production, tight control of variability was achieved in this large systems trial, providing an objective basis for evaluation. Systems research of this type needs to include tight specifications and control of pre- and post-grazing pasture cover in addition to average pasture cover. More flexibility in stocking rate or use of supplements may be needed to establish spring pasture cover contrasts in future studies. During the course of this trial spring grazing management on dairy farms has tended towards that of LC management, with farmers operating grazing systems with higher average pasture covers through spring and being more likely to use mechanical means of controlling spring pasture quality (Matthews 1995).

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REFERENCES

da Silva, S.C.; Matthew, C.; Matthews, P.N.P.; Hodgson, J. 1993. Influence of spring grazing management on summer and autumn production of dairy pastures. *Proceedings of the XVII International Grassland Congress*: 859–860.

da Silva, S.C.; Hodgson, J.; Matthews, P.N.P.; Matthew, C.; Holmes, C.W. 1994. Effect of contrasting spring grazing management on summer-autumn pasture and milk production of mixed ryegrass-clover dairy swards. *Proceedings of the New Zealand Society of Animal Production 54*: 79–82.

Hernández Garay, A. 1995. Defoliation management, tiller density and productivity in perennial ryegrass swards. PhD Thesis, Massey University, 228pp.

Matthew, C.; Xia, J.X.; Hodgson, J.; Chu, A.C.P. 1989. Effect of late spring grazing management on tiller age profiles and summer-autumn pasture growth rates in a perennial ryegrass *(Lolium perenne* L.) sward. *Proceedings of the XVI International Grassland Congress*: 521–522.

Matthews, P.N.P. 1995. Grazing management principles and targets: a case study. *Dairyfarming Annual* 47: 171–174.

SAS, 1988: SAS user's guide, release 6.03 edition. Statistical Analysis System Institute. Cary, North Carolina, USA.

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Appendix Three

Table A3-1 Summary of climate conditions from January 1993 to December 1996, at AgResearch climate station two kilometres northwest of the trial site (40⁰23'S 175⁰37'E,34m asl).

Date	Temperature		Rainfall	Pan	Wind	Sunshine	Relative
	Air (°C)	Soil 10cm (°C)	(mm day^{-1})	evap. (mm day^{-1})	run (km day^{-1})	(hrs)	humidity (%)
1993							
Jan	15.7	16.4	53.9	141.8	306	205	79
Feb	16.3	16.3	43.7	122.3	236	198	84
Mar	14.7	14.6	79.8	91.1	184	172	83
Apr	12.6	12.1	53.7	50.6	149	141	85
May	11.4	10.4	78.4	31.1	151	112	86
Jun	10.5	9.3	102.6	21.6	213	75	85
Jul	8.5	7.1	11.5	25.3	146	103	89
Aug	9.5	7.6	63.1	41.0	165	147	87
Sep	9.5	9.3	60.3	56.6	222	109	79
Oct	12.9	12.4	60.0	102.6	273	178	79
Nov	12.3	13.7	138.2	105.4	204	187	75
Dec	15.3	16.2	81.3	125.3	224	157	76
1994							
Jan	18.1	18.6	33.3	162.6	235	212	76
Feb	19.1	19.0	24.6	149.0	179	263	80
Mar	14.9	15.2	58.3	93.1	145	196	87
Apr	13.8	13.1	53.1	67.8	157	177	86
May	12.2	11.1	121.9	38.0	216	107	84
Jun	8.5	8.1	91.8	21.7	147	86	89
Jul	7.9	6.5	73.8	20.9	164	106	87
Aug	9.7	8.3	82.0	39.4	174	111	84
Sep	10.2	9.7	172.7	49.6	190	112	83
Oct	11.9	11.5	69.8	86.4	218	184	80
Nov	13.7	14.1	179.7	121.8	311	168	76
Dec	15.9	17.2	45.5	144.0	226	200	81

Table A3-1 continued

Date	Temperature		Rainfall	Pan	Wind	Sunshine	Relative
	Air (°C)	Soil 10cm (°C)	(mm day^{-1})	evap. (mm day^{-1})	run (km day^{-1})	(hrs)	humidity (%)
1995							
Jan	17.8	18.4	53.5	181.4	197	258	82
Feb	18.9	18.9	57.9	129.4	192	286	80
Mar	17.1	16.6	142.4	105.8	236	188	80
Apr	16.0	15.3	103.7	54.2	154	134	85
May	11.5	11.2	107.5	37.2	131	123	88
Jun	9.5	8.4	93.5	17.8	149	79	90
Jul	8.2	6.8	120.8	21.2	193	133	87
Aug	8.7	7.3	72.8	32.9	195	116	86
Sep	11.2	9.8	106.4	52.4	207	118	82
Oct	12.7	12.9	139.6	68.7	176	135	84
Nov	13.6	14.7	102.4	101.8	209	176	78
Dec	17.6	18.0	101.0	146.5	217	187	79
1996							
Jan	18.8	19.4	50.5	158.5	170	195	81
Feb	18.3	18.5	128.7	127.8	183	206	81
Mar	15.3	15.5	79.1	81.8	164	166	81
Apr	15.3	15.0	160.4	44.4	136	112	86
May	11.0	11.1	114.6	30.3	147	120	87
Jun	8.6	7.6	98.5	15.8	146	103	88
Jul	9.1	8.0	104.8	15.8	120	96	87
Aug	9.0	8.1	82.3	35.4	163	134	85
Sep	12.4	11.5	102.8	60.8	164	140	82
Oct	13.1	13.7	95.6	93.9	207	170	80
Nov	13.2	14.4	100.5	117.2	286	167	76
Dec	15.9	16.7	91.1	149.6	220	199	77

Table A3-2 Fifty year mean climate conditions at AgResearch climate station, two kilometres northwest of the trial site (40^{0}23'S 175^{0}37'E,34m asl).

Date	Temperature		Rainfall	Pan	Wind	Sunshine	Relative
	Air (°C)	Soil 10cm (°C)	(mm day^{-1})	evap. (mm day^{-1})	run (km day^{-1})	(hrs)	humidity (%)
Jan	17.5	18.3	73.9	151.0	268	208	75
Feb	17.8	18.1	80.4	125.9	252	190	76
Mar	16.5	16.2	73.9	100.5	233	170	77
Apr	13.9	13.2	75.3	60.9	218	138	81
May	11.2	10.2	88.3	38.8	271	109	85
Jun	9.0	7.9	94.1	24.8	198	87	87
Jul	8.3	6.8	93.9	24.3	196	100	87
Aug	9.2	7.7	94.8	37.7	218	119	84
Sep	10.9	9.8	74.9	56.3	249	129	79
Oct	12.6	12.5	87.7	83.3	267	152	77
Nov	14.3	15.0	79.6	112.5	278	172	74
Dec	16.1	17.2	88.4	141.4	268	187	74

Table A3-3 Numbers of cows in milk during 1993/94.

Date	Early control	Late control
01/07/93	0	2
07/07/93	1	2
22/07/93	3	2
23/07/93	3	3
25/07/93	5	4
26/07/93	6	6
27/07/93	7	7
28/07/93	7	8
29/07/93	10	10
30/07/93	11	11
01/08/93	14	14
02/08/93	21	20
03/08/93	25	24
04/08/93	26	26
05/08/93	28	28
06/08/93	29	29
07/08/93	32	32
08/08/93	36	36
09/08/93	44	43
10/08/93	48	46
11/08/93	54	52
12/08/93	56	53
13/08/93	58	55
14/08/93	62	61
15/08/93	64	63
16/08/93	69	67
17/08/93	73	72
19/08/93	78	75
20/08/93	80	79
21/08/93	83	84
22/08/93	86	86
24/08/93	88	88
25/08/93	95	93
27/08/93	96	94
28/08/93	97	96
29/08/93	97	98
30/08/93	100	100
31/08/93	102	103
01/09/93	103	103
02/09/93	104	104
05/09/93	106	107
06/09/93	106	108
11/09/93	107	109
13/09/93	108	111

Table A3-3 continued.

Date	Early control	Late control
15/09/93	109	112
16/09/93	111	112
17/09/93	111	113
18/09/93	111	114
19/09/93	112	114
20/09/93	113	114
22/09/93	115	116
24/09/93	116	116
25/09/93	117	117
27/09/93	119	120
28/09/93	120	120
29/09/93	124	122
30/09/93	125	125
01/10/93	125	124
02/10/93	125	125
07/10/93	125	124
08/10/93	125	125
16/10/93	128	125
30/10/93	127	125
09/11/93	126	125
01/02/94	126	124
04/02/94	121	118
12/02/94	115	115
24/02/94	114	115
25/02/94	104	109
28/02/94	103	108
07/03/94	103	107
17/03/94	83	88
15/04/94	51	59
17/04/94	3	4
18/04/94	0	0

Table A3-4 Numbers of cows in milk during 1994/95.

Date	Early control	Late control
01/06/94	0	1
04/06/94	1	1
18/06/94	2	1
20/07/94	3	1
22/07/94	3	2
23/07/94	7	4
24/07/94	11	6
25/07/94	13	8
26/07/94	14	11
27/07/94	17	14
28/07/94	18	15
29/07/94	24	19
30/07/94	25	21
31/07/94	26	22
01/08/94	27	23
02/08/94	28	23
03/08/94	30	24
04/08/94	36	26
05/08/94	38	28
06/08/94	41	30
08/08/94	47	35
09/08/94	48	37
10/08/94	55	37
11/08/94	60	41
12/08/94	62	44
13/08/94	65	48
14/08/94	67	49
15/08/94	68	49
16/08/94	70	52
17/08/94	73	57
18/08/94	87	65
19/08/94	91	66
20/08/94	91	67
21/08/94	92	72
23/08/94	93	73
24/08/94	93	74
26/08/94	95	74
27/08/94	99	77
28/08/94	102	78
29/08/94	103	79
31/08/94	105	82
01/09/94	108	85
02/09/94	109	87
03/09/94	109	88
04/09/94	109	89
05/09/94	110	91
06/09/94	111	93
07/09/94	113	93

Table A3-4 continued

Date	Early control	Late control
08/09/94	117	98
09/09/94	117	101
10/09/94	118	101
11/09/94	118	102
12/09/94	118	103
13/09/94	117	104
17/09/94	119	107
18/09/94	119	108
19/09/94	120	110
20/09/94	120	111
22/09/94	120	112
23/09/94	121	117
24/09/94	121	119
25/09/94	121	120
26/09/94	123	121
27/09/94	125	121
28/09/94	125	120
29/09/94	125	121
30/09/94	125	122
10/10/94	125	123
11/10/94	124	122
14/10/94	125	122
10/11/94	125	121
14/11/94	124	121
28/11/94	122	120
02/12/94	121	119
09/01/95	101	100
31/01/95	101	99
14/02/95	101	98
07/03/95	99	96
10/03/95	97	93
23/04/95	96	93
10/05/95	93	88
11/05/95	0	0

Table A3-5 Numbers of cows in milk during 1995/96.

Date	Early control	Late control
13/07/95	0	1
15/07/95	1	2
18/07/95	1	3
19/07/95	4	4
20/07/95	3	4
21/07/95	5	5
22/07/95	6	10
23/07/95	9	10
24/07/95	13	15
26/07/95	19	15
27/07/95	21	18
28/07/95	23	20
29/07/95	24	21
30/07/95	25	27
31/07/95	29	28
01/08/95	34	32
02/08/95	34	34
03/08/95	37	37
04/08/95	39	37
05/08/95	39	40
06/08/95	40	40
07/08/95	45	47
08/08/95	47	49
09/08/95	48	55
10/08/95	51	62
11/08/95	56	64
12/08/95	57	66
13/08/95	63	70
14/08/95	67	72
15/08/95	69	74
16/08/95	72	75
17/08/95	81	75
18/08/95	82	76
19/08/95	85	76
20/08/95	86	77
21/08/95	90	82
22/08/95	90	86
24/08/95	91	88
25/08/95	93	90
26/08/95	93	91
27/08/95	96	91
29/08/95	98	93
31/08/95	99	93
02/09/95	100	95
04/09/95	104	99
05/09/95	104	100
06/09/95	105	103
08/09/95	106	103

Table A3-5 continued.

Date	Early control	Late control
09/09/95	107	107
10/09/95	109	107
12/09/95	110	109
14/09/95	110	111
15/09/95	110	112
16/09/95	111	113
19/09/95	114	117
20/09/95	116	117
21/09/95	115	117
22/09/95	117	118
25/09/95	117	118
30/09/95	118	118
01/10/95	118	119
05/10/95	118	120
21/10/95	117	120
25/10/95	117	119
26/11/95	116	119
26/01/96	114	117
06/02/96	113	116
25/02/96	109	112
04/03/96	108	112
06/03/96	108	111
03/04/96	107	111
16/04/96	103	107
17/04/96	0	0

Figure A5-1 Series one pre-grazing pasture cover (kg DM ha^{-1}) calculated from average pasture cover for early control —●— and late control - - ○ - - paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

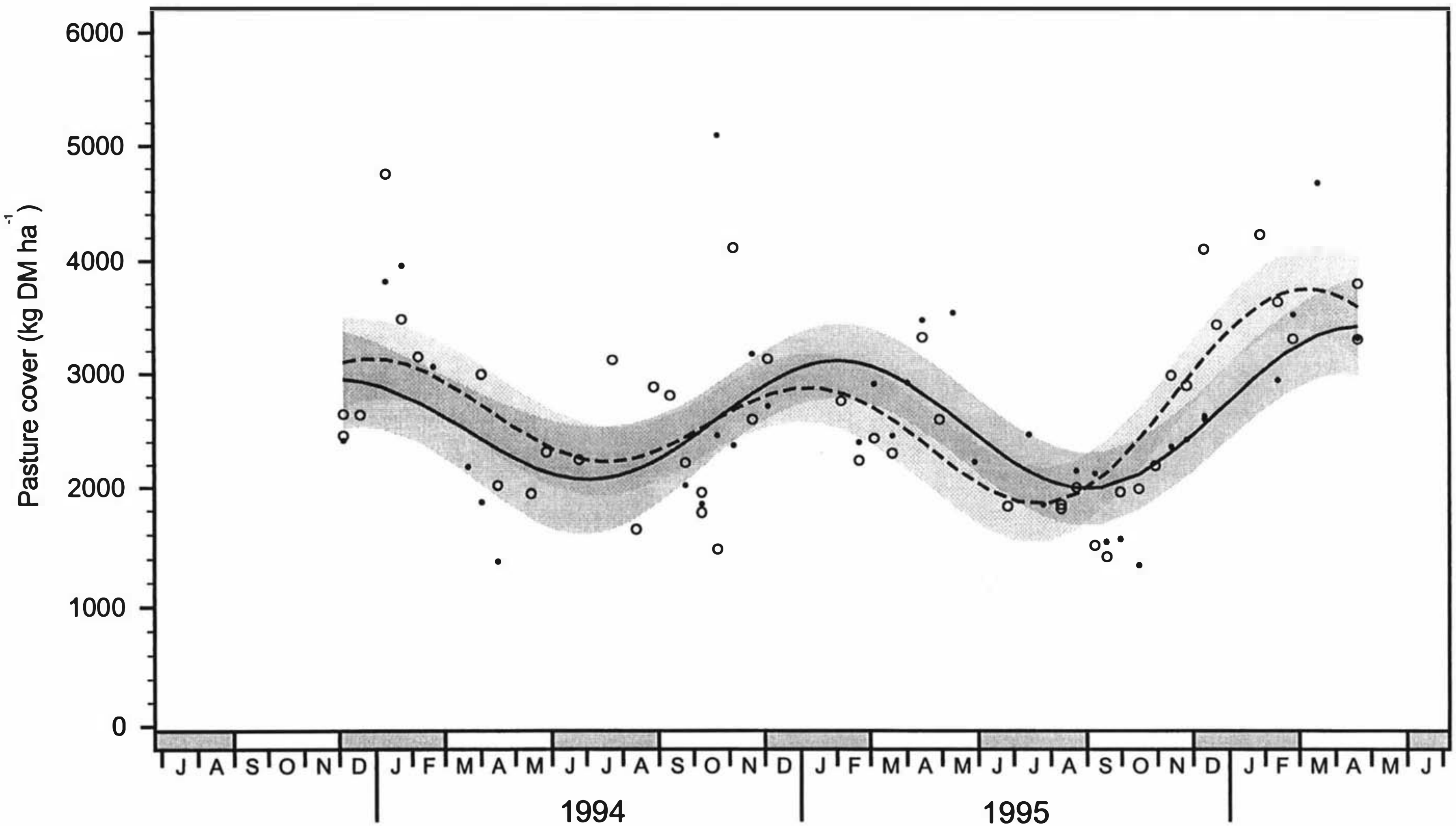


Figure A5-2 Series one post-grazing pasture cover (kg DM ha^{-1}) calculated from average pasture cover for early control —●— and late control - - ○ - - paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

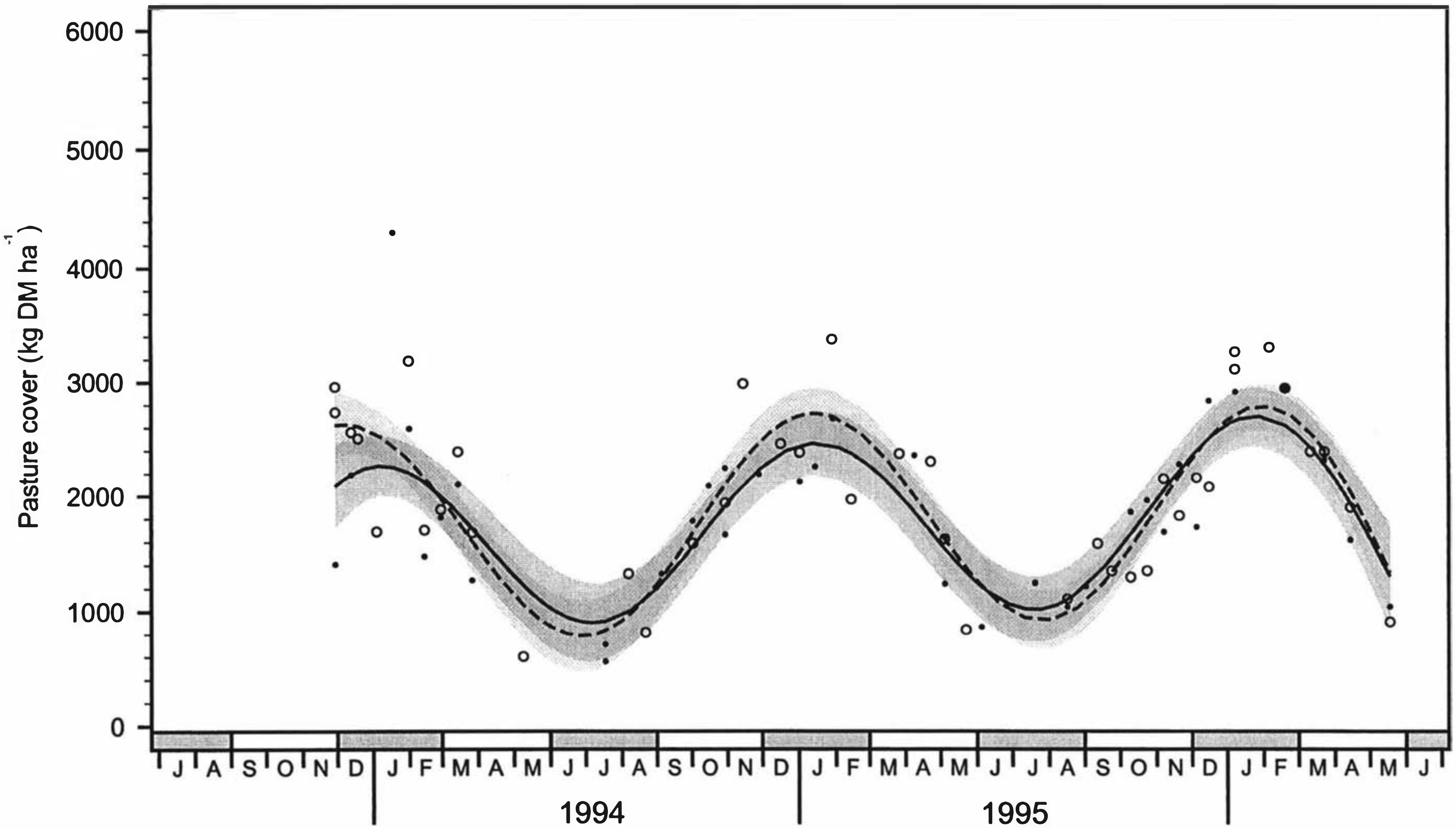


Figure A5-3 Series two pre-grazing pasture cover (kg DM ha^{-1}) calculated from average pasture cover for early control —●— and late control --o-- paddocks over three years. Significant differences at $P < 0.05$ are indicated by separation of the bands.

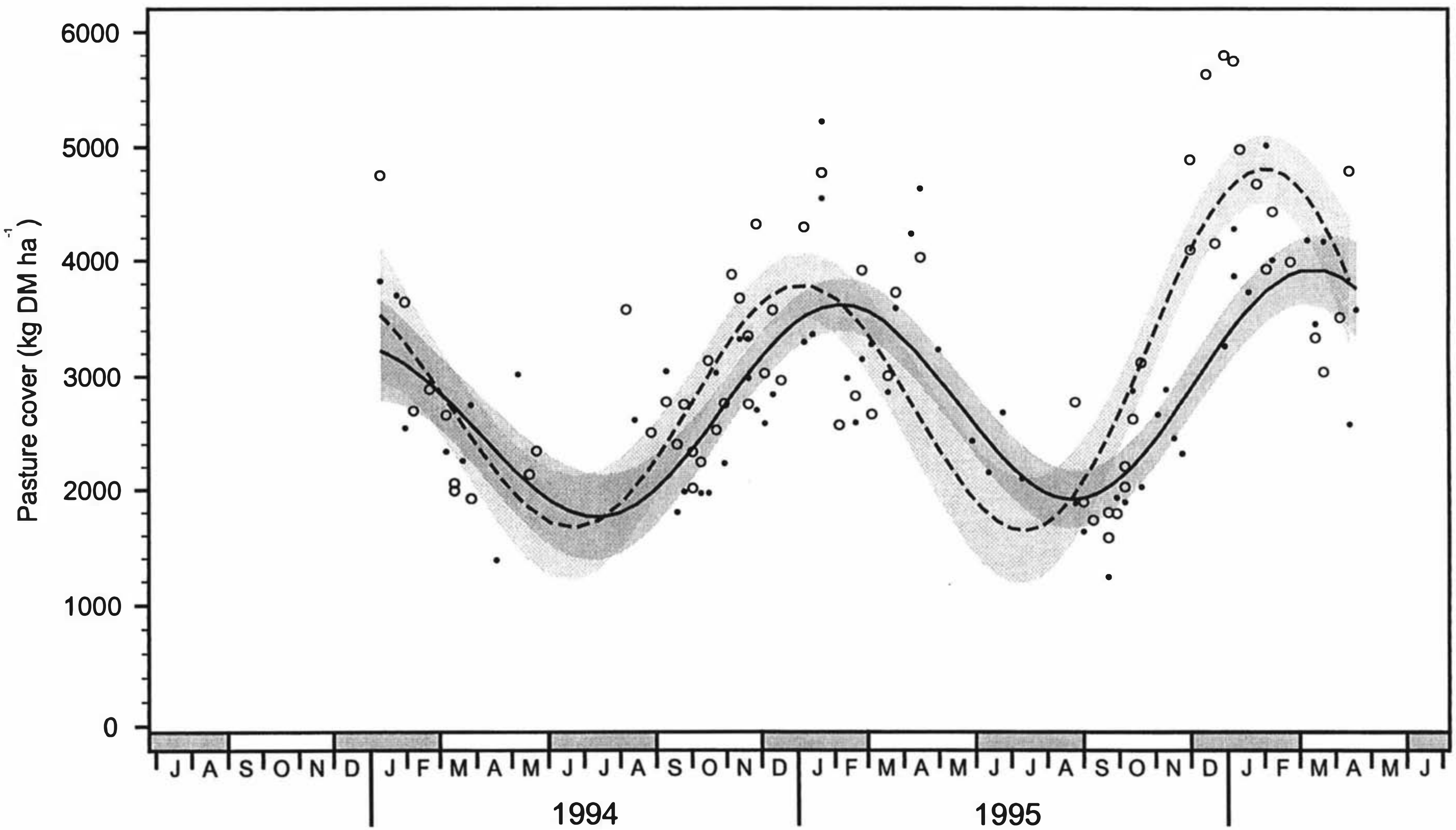


Figure A5-4 **Series two post-grazing pasture cover (kg DM ha^{-1}) calculated from average pasture cover for early control —●— and late control - - o - - paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.**

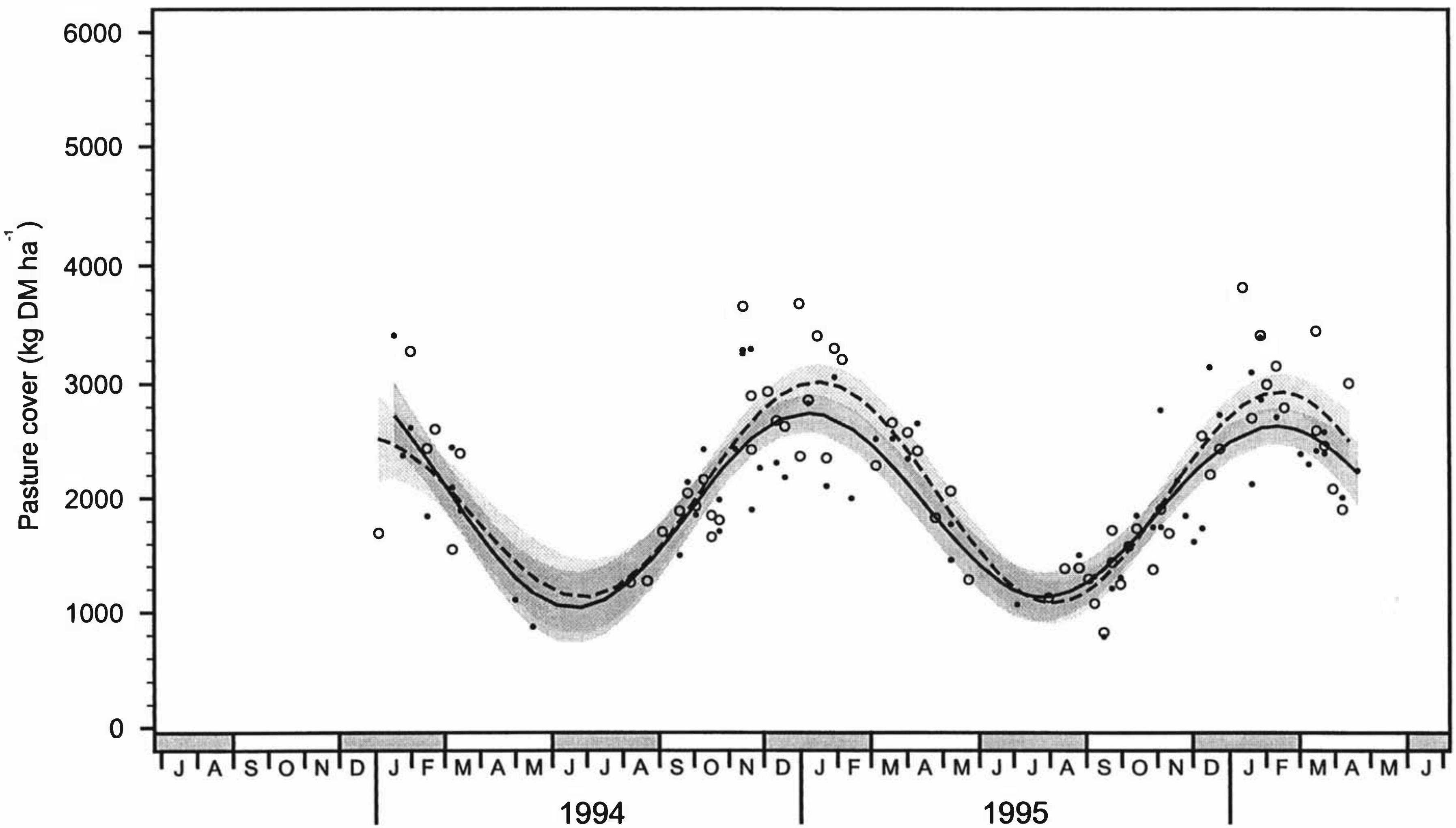


Table A5-1 Detailed botanical composition (%) for early control and late control pastures.

Component	Treatment		SEM	P
	Early control	Late control		
	October/November 1993			
Ryegrass leaf	17.1	24.8	2.90	0.0086
Ryegrass stem	17.1	20.3	2.81	0.2524
Ryegrass reproductive	0.0	0.0	-	-
Other grass	27.9	21.8	4.96	0.2014
White clover leaf	13.1	9.2	3.47	0.2446
White clover stolon	1.6	1.1	0.51	0.3726
White clover repro.	0.0	0.0	-	-
Red clover leaf	1.0	4.2	1.35	0.0175
Red clover stolon	0.3	1.2	0.58	0.1124
Red clover repro.	0.0	0.0	-	-
Senescent material	17.9	15.3	2.11	0.2168
Weeds	4.0	2.2	1.09	0.0941
	January/February 1994			
Ryegrass leaf	17.2	19.3	1.47	0.1409
Ryegrass stem	7.3	7.3	0.78	0.9634
Ryegrass reproductive	3.1	2.3	1.12	0.4637
Other grass	19.4	14.9	2.41	0.0511
White clover leaf	14.0	12.7	2.29	0.5413
White clover stolon	1.7	1.4	0.52	0.6675
White clover repro.	1.7	2.0	0.64	0.6157
Red clover leaf	3.7	8.5	2.10	0.185
Red clover stolon	1.9	4.6	1.50	0.0552
Red clover repro.	0.0	0.2	0.09	0.0277
Senescent material	26.4	23.9	2.81	0.3448
Weeds	3.6	2.8	0.85	0.3158
	April/May 1994			
Ryegrass leaf	31.4	30.6	2.14	0.6995
Ryegrass stem	12.7	12.2	0.74	0.4766
Ryegrass reproductive	0.0	0.0	-	-
Other grass	11.8	10.4	2.55	0.5666
White clover leaf	7.0	8.2	1.10	0.2406
White clover stolon	3.7	2.9	0.96	0.3902
White clover repro.	0.2	0.1	0.15	0.8104
Red clover leaf	2.5	7.9	1.83	0.0033
Red clover stolon	1.9	2.5	1.05	0.5332
Red clover repro.	0.1	1.5	0.71	0.0488
Senescent material	26.5	22.4	1.90	0.0266
Weeds	2.2	1.2	0.42	0.0176

Table A5-1 continued.

Component	Treatment: Early control	Late control	SEM	P
	July - September 1994			
Ryegrass leaf	49.0	47.6	3.29	0.6568
Ryegrass stem	14.4	15.2	1.13	0.4567
Ryegrass reproductive	0.0	0.0	-	-
Other grass	17.4	16.4	4.14	0.7914
White clover leaf	9.3	10.9	1.68	0.3309
White clover stolon	0.4	0.3	0.21	0.6912
White clover repro.	0.0	0.0	-	-
Red clover leaf	0.1	1.2	0.43	0.0064
Red clover stolon	0.0	0.2	0.09	0.09
Red clover repro.	0.0	0.0	-	-
Senescent material	8.0	7.2	1.06	0.3858
Weeds	1.3	1.0	0.46	0.5327
	October/November 1994			
Ryegrass leaf	33.4	32.4	1.89	0.5848
Ryegrass stem	24.5	24.2	1.67	0.8512
Ryegrass reproductive	2.8	5.1	1.52	0.1268
Other grass	16.6	9.9	2.49	0.0062
White clover leaf	9.1	12.4	1.76	0.0501
White clover stolon	0.6	0.5	0.31	0.6832
White clover repro.	0.0	0.3	0.13	0.0817
Red clover leaf	0.0	2.8	0.80	0.0006
Red clover stolon	0.0	0.7	0.39	0.0557
Red clover repro.	0.0	0.0	-	-
Senescent material	11.2	10.2	1.08	0.3144
Weeds	1.8	1.7	0.58	0.8534
	January/February 1995			
Ryegrass leaf	31.2	26.5	1.82	0.0079
Ryegrass stem	13.7	11.9	0.96	0.0493
Ryegrass reproductive	5.2	2.9	1.02	0.0242
Other grass	7.8	6.2	1.77	0.3294
White clover leaf	5.3	6.5	1.05	0.2392
White clover stolon	2.9	4.2	1.09	0.2012
White clover repro.	1.9	2.0	0.71	0.8126
Red clover leaf	1.8	7.1	1.49	0.0004
Red clover stolon	0.7	3.5	0.88	0.0014
Red clover repro.	0.0	1.5	0.81	0.0693
Senescent material	27.7	26.4	2.21	0.534
Weeds	1.8	1.3	0.61	0.3883

Table A5-1 continued

Component	Treatment: Early control	Late control	SEM	P
	March/April 1995			
Ryegrass leaf	41.5	42.3	2.66	0.7437
Ryegrass stem	10.0	11.9	0.77	0.0108
Ryegrass reproductive	0.0	0.0	-	-
Other grass	13.6	8.6	2.74	0.0579
White clover leaf	11.8	11.1	1.95	0.6819
White clover stolon	1.2	1.4	0.68	0.7919
White clover repro.	0.0	0.1	0.07	0.631
Red clover leaf	1.2	4.6	1.22	0.004
Red clover stolon	0.3	1.5	0.58	0.0238
Red clover repro.	0.3	0.8	0.61	0.392
Senescent material	18.0	16.1	3.10	0.5121
Weeds	2.1	1.6	0.62	0.3962
	December 1995			
Ryegrass leaf	28.5	23.8	1.92	0.0117
Ryegrass stem	5.8	4.6	0.50	0.0197
Ryegrass reproductive	7.7	9.3	1.50	0.2643
Other grass	26.5	24.1	2.82	0.3832
White clover leaf	9.4	16.6	1.66	0.0001
White clover stolon	0.7	0.4	0.15	0.0248
White clover repro.	0.8	1.5	0.31	0.0172
Red clover leaf	0.0	1.1	0.44	0.0095
Red clover stolon	0.0	0.3	0.14	0.0678
Red clover repro.	0.0	0.0	-	-
Senescent material	18.2	15.3	1.51	0.0412
Weeds	2.5	3.1	0.68	0.3431
	February 1996			
Ryegrass leaf	30.4	27.1	1.88	0.0616
Ryegrass stem	6.5	8.1	0.59	0.0051
Ryegrass reproductive	1.4	0.8	0.48	0.2169
Other grass	16.6	11.4	2.13	0.0118
White clover leaf	13.0	10.9	1.68	0.184
White clover stolon	1.0	1.1	0.30	0.7633
White clover repro.	0.9	0.4	0.23	0.0221
Red clover leaf	0.4	3.1	0.98	0.0061
Red clover stolon	0.0	0.6	0.30	0.0277
Red clover repro.	0.2	0.1	0.22	0.8566
Senescent material	26.8	34.8	1.72	0.0001
Weeds	2.9	1.8	0.67	0.0983

Figure A5-5 Metabolisable energy values (MJ kg DM^{-1}) for early control —●— and late control --○-- indicator paddocks over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

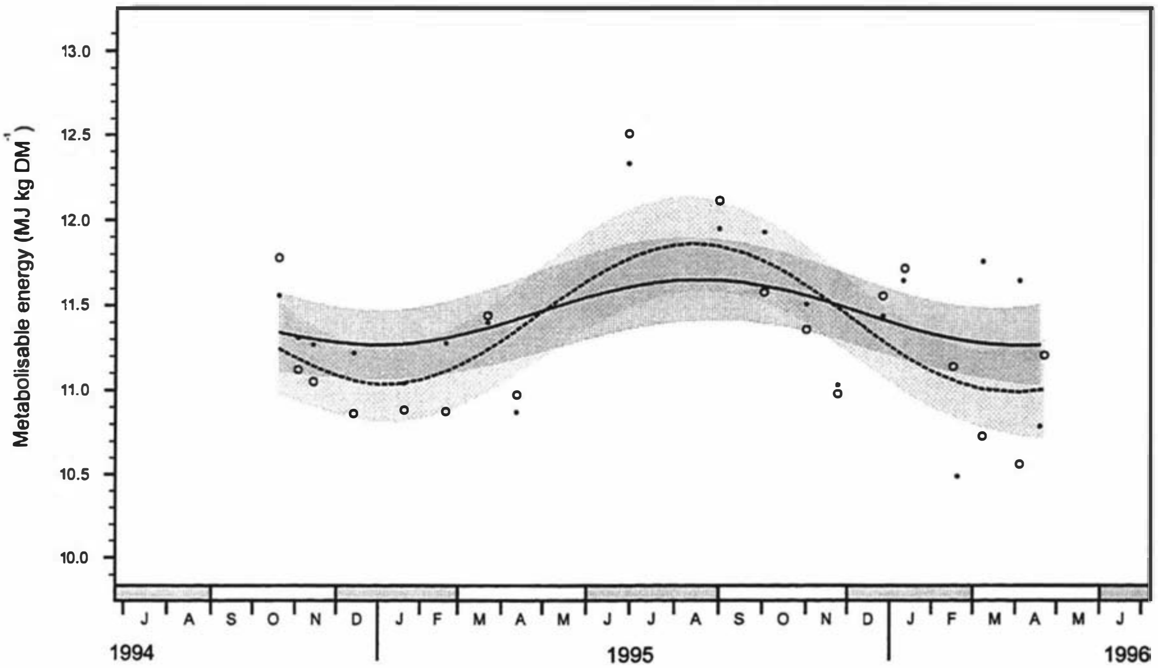


Figure A5-6 Metabolisable energy values (MJ kg DM^{-1}) for early control —●— and late control --○-- paddocks cut to estimated grazing height over three years. Significant differences at P < 0.05 are indicated by separation of the bands.

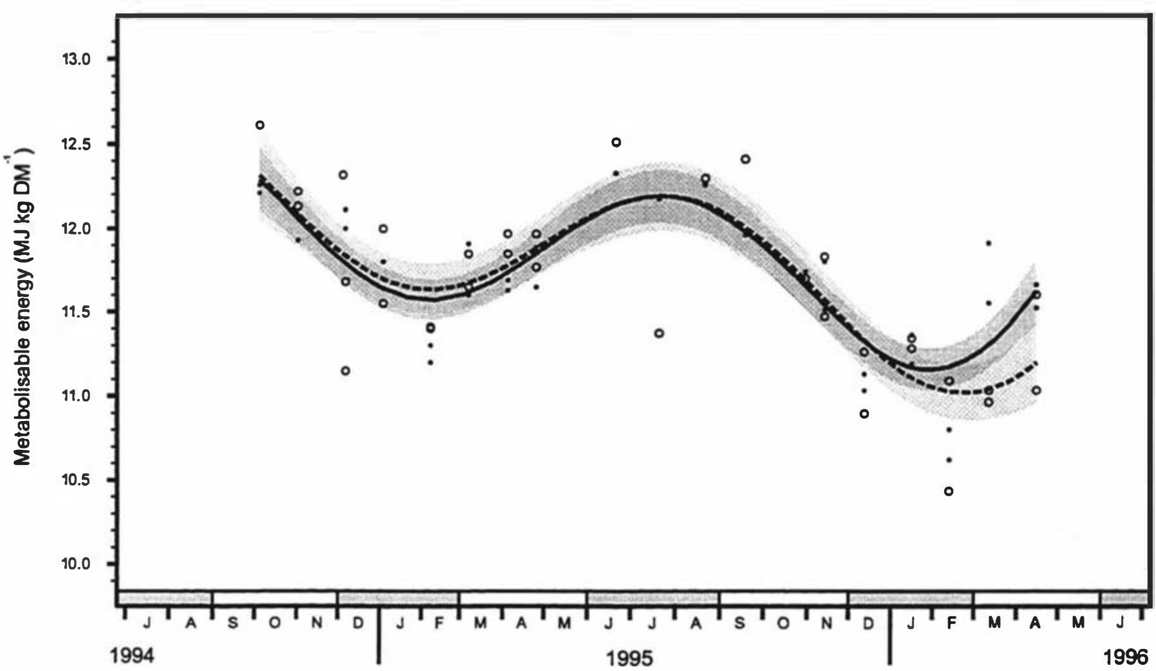


Table A5-2 Metabolizable energy (MJ kg DM^{-1}) and dry matter (%) values used to calculate supplement balance.

Forage	Metabolizable energy (MJ kg DM^{-1})	Dry matter (%)
Baleage	9.0	25
Grass silage	9.0	25
Hay	8.5	85
Maize silage	10.3	30
Brewers grain	10.0	22
Turnips	12.6	10
Green maize	10.0	22
Carrots	12.8	8

Note: Dry matter percentages for carrots, brewers grain, grass silage and maize silage were measured. All other values are taken from Holmes & Wilson (1987), except the energy value for carrots (Ulyatt *et al.* 1984).

Table A5-3 Monthly supplements fed (MJ ME) for the early control herd.

Month	Baleage	Grass silage	Hay	Maize silage	Brewers grain	Turnips	Maize crop	Carrots
Nov 93								
Dec 93								
Jan 94	13500							
Feb 94	64800						130000	
Mar 94	4050	151200					29600	
Apr 94		64800	66640					
May 94	120150		19040					
Jun 94	13500		76160	46350				
	216000	216000	161840	46350	0	0	159600	0
	799790							
Jul 94				131325				
Aug 94				49440				
Sep 94				12360				
Oct 94								
Nov 94								
Dec 94								
Jan 95		91800						
Feb 95		108000			4000	52920		
Mar 95		28810			51000	70585		
Apr 95								
May 95		11700		15450				
Jun 95				169950				
	0	240310	0	378525	55000	123505	0	0
	797340							
Jul 95		12600		123600				
Aug 95		74250	7140					
Sep 95		50400	4760	61285				
Oct 95				7725				
Nov 95								
Dec 95								
Jan 96								
Feb 96	1980					124740		
Mar 96	25740					117810		
Apr 96	29700		4080					
May 96			4080					
Jun 96								
	57420	137250	20060	192610	0	242550	0	0
	649890							

Table A5-4 Monthly supplements fed (MJ ME) for the late control herd.

Month	Baleage	Grass silage	Hay	Maize silage	Brewers grain	Turnips	Maize crop	Carrots
Nov 93								
Dec 93								
Jan 94	13500							
Feb 94	67500						135000	
Mar 94	4050	132300					59200	
Apr 94		64800	66640					
May 94	120150		19040					
Jun 94	13500		76160	46350				
	218700	197100	161840	46350	0	0	194200	0
	818190							
Jul 94				154500				
Aug 94				55620				
Sep 94								
Oct 94		63000		82400				
Nov 94								
Dec 94								
Jan 95		91800						
Feb 95		108000			4000	52920		
Mar 95		18035			51010	90710		
Apr 95								
May 95	4500	18900		32445				
Jun 95				216300				
	4500	299735	0	541265	55010	143630	0	0
	1044140							
Jul 95		12600		149350				
Aug 95		81450	7140					
Sep 95		50400	4760	61285				
Oct 95				12360				43585
Nov 95					64000			257280
Dec 95								
Jan 96								
Feb 96	3960					113400		
Mar 96	31680					107100		
Apr 96	29700		4080					
May 96			6120					
Jun 96								
	65340	144450	22100	222995	64000	220500	0	300865
	1040250							

Appendix Six

Table A6-1 Ten-day milk production (l) and composition (%) values used in UDDER, taken from records of milk delivered to the factory.

Date	Production l	Fat %	Protein %
01/07/94 - 10/07/94	174	4.90	3.82
11/07/94 - 20/07/94	261	4.90	3.82
21/07/94 - 31/07/94	2204	4.90	3.82
01/08/94 - 10/08/94	7399	4.90	3.82
11/08/94 - 20/08/94	12861	4.80	3.74
21/08/94 - 31/08/94	21700	4.64	3.73
01/09/94 - 10/09/94	24520	4.51	3.66
11/09/94 - 20/09/94	26780	4.50	3.60
21/09/94 - 30/09/94	26624	4.59	3.55
01/10/94 - 10/10/94	25918	4.53	3.56
11/10/94 - 20/10/94	24554	4.55	3.48
21/10/94 - 31/10/94	28018	4.52	3.52
01/11/94 - 10/11/94	25600	4.58	3.52
11/11/94 - 20/11/94	24248	4.62	3.54
21/11/94 - 30/11/94	22145	4.57	3.48
01/12/94 - 10/12/94	20114	4.48	3.43
11/12/94 - 20/12/94	20126	4.46	3.44
21/12/94 - 31/12/94	21144	4.52	3.42
01/01/95 - 10/01/95	18239	4.62	3.42
11/01/95 - 20/01/95	16534	4.56	3.40
21/01/95 - 31/01/95	15668	4.42	3.33
01/02/95 - 10/02/95	14348	4.46	3.32
11/02/95 - 20/02/95	14286	4.48	3.38
21/02/95 - 28/02/95	11290	4.51	3.40
01/03/95 - 10/03/95	14298	4.62	3.45
11/03/95 - 20/03/95	14420	4.71	3.52
21/03/95 - 31/03/95	13872	4.74	3.61
01/04/95 - 10/04/95	13053	4.90	3.64
11/04/95 - 20/04/95	12967	5.02	3.77
21/04/95 - 30/04/95	12582	5.02	3.84
01/05/95 - 10/05/95	9995	5.37	3.93
11/05/95 - 20/05/95	2185	5.77	4.08

Table A6-2 Values used in gross margins.

	Price	Units
Milksolids price	3.83	$ kg^{-1} MS
Purchase price of grass silage	200.00	$ t^{-1} DM
Sale value of grass silage	150.00	$ t^{-1} DM
Conservation cost of grass silage	60.00	$ t^{-1} DM
Marginal cost of running a cow	350.00	$
Marginal cost of extra milking	100.00	$
Cost of crop (Barkant tumips)	300.00	$ ha^{-1}
Agistment		
at 3 months	0.50	$ d^{-1}
at 12 months	0.75	$ d^{-1}
for 2 years up	0.75	$ d^{-1}

Source: Burtt (1996) and LIC (1997)

Appendix Seven

A Step Closer to the Development of a Tiller-based Model

7.1 Introduction

Although the current trial failed to provide conclusive evidence to support or dismiss the LC strategy, previous trials have shown lax spring grazing management to increase both pasture production and animal performance (Section 2.3). In Chapter Six the simulation model UDDER (Larcombe 1989, 1990a) was used in an attempt to investigate the conditions under which late control (LC) spring grazing management can be implemented and the options available for the use of additional feed over spring and summer, assuming LC spring grazing management is effective. However, UDDER does not model the pasture production system from first principals (e.g. climatic variables). One of the inputs into UDDER is the accumulation rate of pasture (Chapter Six) and the only pool included in the model is total herbage mass. Furthermore, UDDER provides limited pathways for feedback from the animal sub-model to the pasture sub-model (animal/plant interaction). Therefore, since the pasture component of the model is relatively simple and does not represent the pasture component of the dairy production system in sufficient detail to respond to the relatively subtle changes in pasture production attributable to late control spring grazing management (Chapter Two) it was necessary to input directly the herbage accumulation rate advantage of LC pastures in spring and summer.

A search of the literature failed to identify any models of grazed pastures, let alone whole farm system simulation models, currently available at the appropriate level of aggregation capable of predicting the response of pasture plants to late control spring grazing management. Since the response of pastures subjected to LC strategy has been measured and shown to be mediated through changes in tiller size and density and birth and death (Chapter Two), it is likely that to successfully simulate the response the model would also have to be at this level of aggregation (i.e. tillers) and be responsive to the same management variables.

The model described by McCall (1984) included a mass flow model of pasture with separate green and dead pools. It was proposed in the first instance at least, to simultaneously model ryegrass tillers along with the herbage mass pools currently modelled, and use the tiller model to modify herbage mass. It was postulated that it should then be possible to move forward in time to predict future tiller density if the values for base tiller density and birth and death coefficients are known. While this model (McCall 1984) was initially developed for sheep and beef cattle, a dairy cow system was included in a subsequent development of the model and used by Martin *et al.* (1991).

Based on data collected from a series of experiments at Massey University the aim was to investigate the development of a tiller-based model to modify the mass flow model of McCall (1984). It became clear that these objectives could not be met since there was insufficient data available to parametise and test under dairy grazing conditions the tiller-based model proposed. However, such a model would advance understanding of tillers as production units in dairy grazing production systems, and could be suitable for inclusion into an existing whole farm systems simulation model, allowing further investigation of how best to achieve LC and how to make best use of the extra pasture produced. Furthermore, being able to model pastures at the tiller level successfully would represent a step forward from current understanding.

This chapter presents the development of a model outline with the objective of modelling the factors affecting tiller population density and predicting limitations to herbage production from sub-optimal tiller populations.

7.2 Model development

In this section the development of a tiller model is presented, commencing with a brief overview and followed by a detailed description of the model.

7.2.1 Overview

The basis for the development of this tiller model was work done in the Pastures and Crops Group, Institute of Natural Resources, College of Sciences, Massey University, the result of an extended period of interest in tiller dynamics in grazed swards (Matthew *et al.* 1989a, 1989b; Xia *et al.* 1990; Matthew 1992; da Silva *et al.* 1993, 1994; da Silva 1994; Hemández Garay 1995). The proposed model estimates tiller density based on size or mass of ryegrass tillers at the environmental ceiling leaf area (LAI_c) throughout the year. Environmental ceiling leaf area has been defined as the maximum or ceiling leaf area sustainable by a particular species in a particular environment (Matthew *et al.* 1995).

A successful grass is one which can increase its leaf area with increasing light levels in late winter and early spring, and tillers are the means by which swards adapt to a different equilibrium leaf area. Tiller density is seen as more plastic than tiller size, and appears to be the primary mechanism to optimise leaf area index (LAI). The ryegrass tiller model developed uses predictions of photosynthetically active radiation (PAR) to predict LAI_c and from this the position of the tiller size-density compensation line (SDC). Matthew *et al.* (1996) provide a detailed discussion of size-density compensation. Having set the position of the SDC line and having measured herbage mass of the sward, then optimum tiller density can be estimated. The model could have equally well been formulated on the basis of tiller weight or herbage mass, herbage mass was used here for industry relevance.

The model described here only attempts to model perennial ryegrass tillers. The dairy pastures used in the farmlet study (Chapter Three) included perennial ryegrass, red and white clovers, other grasses and weeds. Perennial ryegrass was the major contributor to total live pasture mass in this trial, ranging from 40% at the start and end of the trial to 70% during the trial (Section 5.2.9).

7.2.2 Model development

Ceiling leaf area was represented mathematically by combining Equations 1.1 and 1.2 of Lemaire & Chapman (1996), defining the quantity of light at ground level ($PAR_{gr} = PAR_0 - PAR_a$) in a canopy at equilibrium, or the compensation point at which leaves can no longer survive, and making LAI_c the subject:

$$LAI_c = \frac{\ln\left(\left(\frac{(PAR_o\ k_1) - PAR_{gr}}{PAR_{gr}\ k_1}\right) - 1\right)}{k_2} \qquad (7\text{-}1)$$

where PAR_0 is incident photosynthetically active radiation, PAR_a is the quantity of photosynthetically active radiation absorbed by green leaf material, k_1 is a coefficient determined by the optical properties of leaves, and k_2 is the light extinction coefficient, which depends on sward structure characteristics.

The compensation point (PAR_{gr}) represents the point at which no more leaf area will be accumulated because the leaf area below that level in the canopy does not receive enough radiation to sustain itself. While there is little experimental data to support either the absolute value or the trend over time of PAR_{gr}, values are likely to be lower in the winter than in the summer.

Having obtained a measure of the maximum leaf area the environment can sustain at any time of year, the position of the intercept *(Int)* of the population boundary line can be fixed using Equation 2 from Matthew *et al.* (1995):

$$Int = 3/2 \log(LAI_c) + \log(k'') - \log(R) - k_3 \quad (7\text{-}2)$$

where k'' is the mean biomass per unit volume of shoot tissues (kg m^{-3}), R is a dimensionless constant reflecting an inherent area:volume ratio, corrected for the different dimensionality of volume and area, and k_3 is a correction factor to account for those factors not explained by the model, for example, root/shoot respiration and dark/light cycles. Environmental ceiling leaf area index fluctuates with seasonal changes in insolation levels.

When comparing tiller size and tiller population density, tiller density is seen as being the most fluid variable and the one primarily used to optimise leaf area index. That is, pastures grow following grazing to intercept the available light through increasing their tiller population density.

With the position of the intercept determined and given tiller size or biomass, tiller density can be calculated at the boundary line using Equation 1 of Sackville Hamilton *et al.* (1995):

$$w = k\, d^{-3/2} \quad \text{or equivalently} \quad B = k\, d^{-1/2} \quad (7\text{-}3)$$

where w is mean shoot biomass per tiller, B the shoot biomass per unit area, d the population density of tillers, and k is a constant whose value depends on growth form and environment.

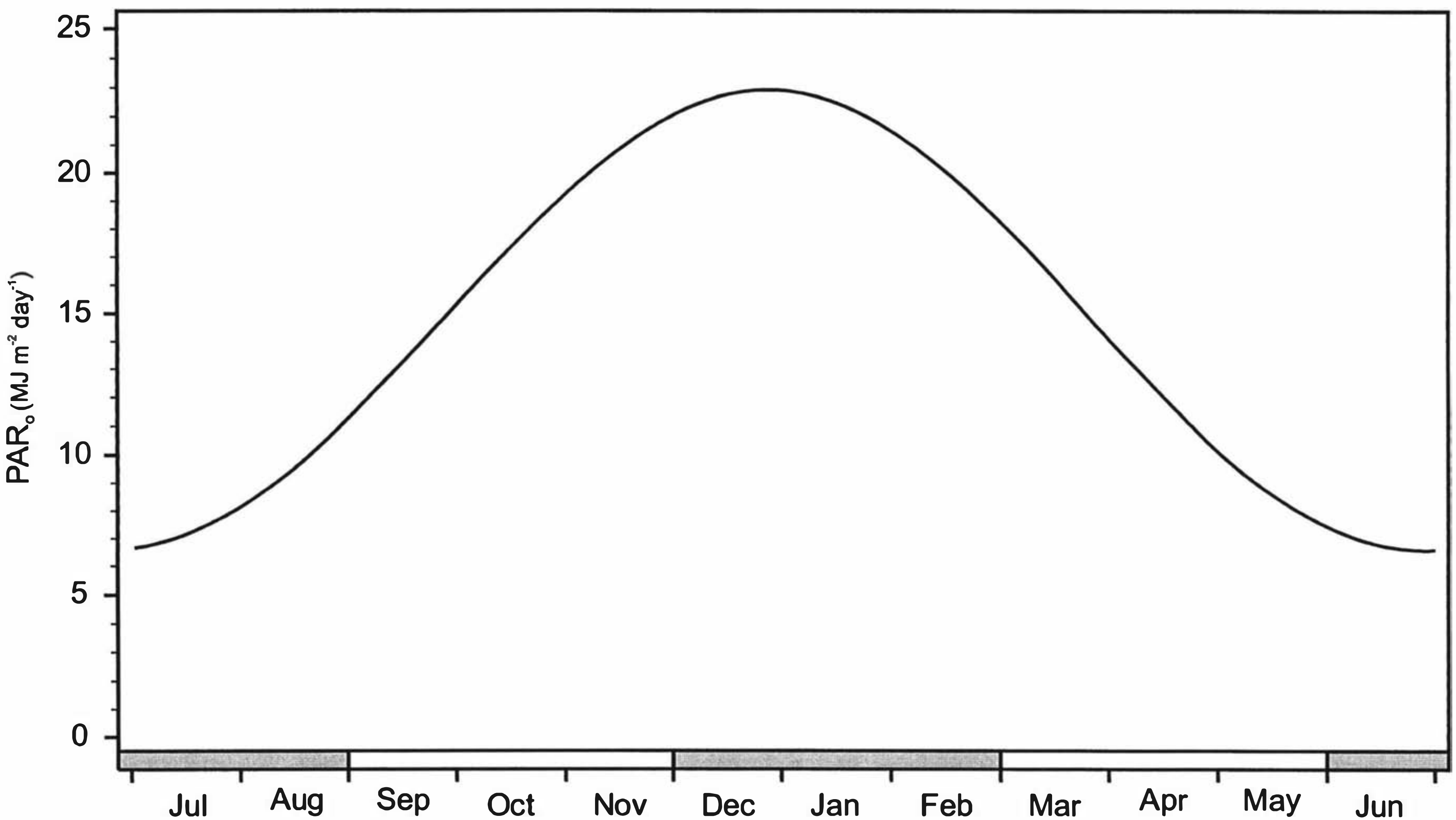
7.2.3 Parameter estimates

Daily solar radiation (SRAD) was estimated based on the relationships reported by Bonhomme (1993, 1994) and 1 J PAR = 0.45 - 0.50 J SRAD. Figure A7-1 shows the values obtained from this model for the central North Island of New Zealand. On this basis daily PAR_o values ranged from 6.58 MJ m^{-2} day^{-1} on 22 June to 22.93 MJ m^{-2} day^{-1} on 22 December.

A value for k_1 of 0.95 was used as suggested by Lemaire & Chapman (1996). The value of k_2 was modified over a year using a cosine function to represent the changes in the structure of the canopy associated with seasonal change in solar elevation and ranged from a minimum value of 0.65 in winter to a maximum value of 0.75 in summer. Brougham (1958) suggested a value of 0.66 for a mixture of perennial ryegrass and white clover. A small improvement in the model could result from adjusting the value of k_2 for reproductive growth. Initially, a value of 0.5 MJ m^{-2} day^{-1} was used for the compensation point of leaves (PAR_{gr}) (equivalent to approximately 50 μmol photons m^{-2} sec^{-1} over a 12 hour day, C. Matthew, personal communication). Mean biomass per unit volume of shoot tissues (k^*) was estimated at 900 kg m^{-3} (fresh weight/tissue volume) for this analysis (Sackville Hamilton *et al*. 1995).

Hemández Garay *et al*. (2000) provide estimates of R over a range of herbage masses for ryegrass mini-swards. A linear fit ($R = 32.115 + 0.0051\ HM$, $r^2 = 0.56$) of herbage mass (HM) was used to provide estimates of R. Reproductive tillers are larger in size, but lower in area:volume ratio than vegetative tillers. The value for k_3 was estimated at 1.1, since this positioned the intercept of the -3/2 boundary line within the range (0.5 - 1.3) reported by Hutchings (1983) and therefore in a position to provide estimates for tiller density within the range measured (Table 5-13).

Figure A7-1 Daily photosynthetically active radiation values (PAR_o) for one year ($MJ\ m^{-2}\ day^{-1}$).



7.3 Tiller-based model prediction of sward equilibrium

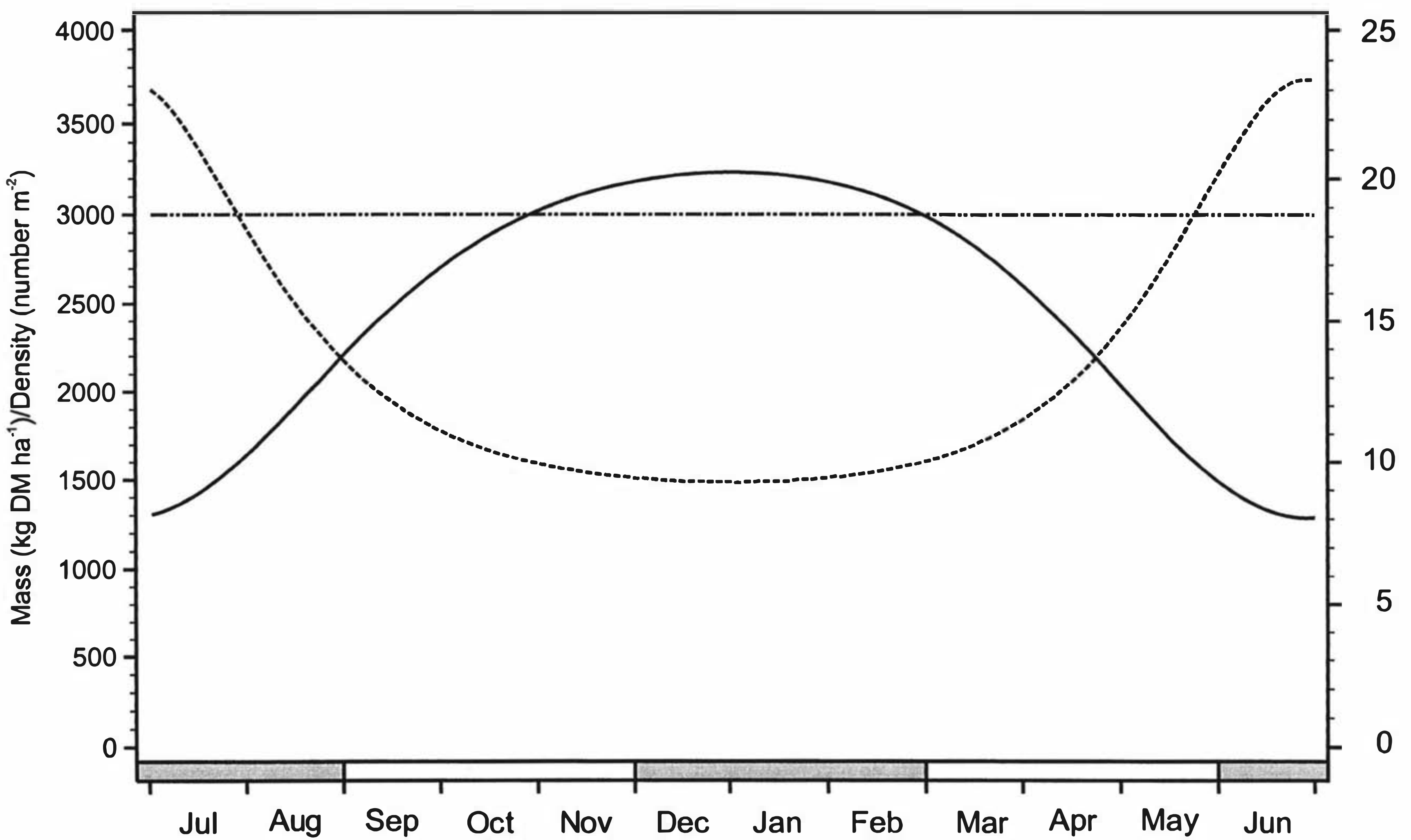
The model shows interactions of herbage mass, associated change in shape parameter *R*, seasonal light level, and one of a number of possible size-density solutions to this "environmental equilibrium". This solution represents constant mass, an altemative is to allow mass to vary at constant tiller size producing an altemative equilibrium solution. The question is: do swards attain stability with constant mass or with constant shoot size?

Figure A7-2 shows seasonal variation in predicted equilibrium tiller density and tiller size at a constant herbage mass of 3000 kg DM ha^{-1}. Under these conditions the maximum number of tillers the environment is able to support ranges from 1 200 m^{-2} in winter to 3 100 m^{-2} in summer. Tiller size, which is the reciprocal of tiller density, ranges from 9 mg during summer to 24 mg during winter (Figure A7-2).

7.4 Using the model with field data

In the field herbage mass rarely remains constant throughout the year, and therefore the cycles seen in Figure A7-2 are modified by seasonal changes in herbage mass as the result of grazing management. Pre-grazing herbage mass values over three years were taken from the systems trial reported earlier (Figure 5-4) and the tiller-based model developed above used to predict tiller density based on this seasonal variation (Figure A7-3). Using EC pre-grazing herbage mass values (Figure 5-4) and predicted equilibrium tiller density values calculated by the model, tiller size has been calculated and plotted on Figure A7-3.

Figure A7-2 Predicted values for tiller density (number m^{-2}) ——— and tiller size (mg) -------- from the tiller model for a constant pre-grazing herbage mass of 3000 kg DM ha^{-1} -··-··-··-.



Within the range of pre-grazing herbage mass in the first year predicted equilibrium tiller density is relatively stable, ranging between 1 800 to 3 000 m^{-2}. However, with more extreme variation in pre-grazing herbage mass in the third year predicted equilibrium tiller densities increase to peak at 8 000 m^{-2} during the winter of 1995, followed by a fall to a minimum of 1 000 m^{-2} in late summer. Based on herbage mass and predicted equilibrium tiller density, predicted tiller size ranged between 20 and 45 mg over the three years. However, from the start of the period modelled until late summer 1995 the range was considerably less at 10 to 20 mg, reflecting the smaller range of pre-grazing herbage masses recorded. Predicted tiller size and population density were also reciprocal of each other in this run and show how one compensates for the other to obtain a particular herbage mass. It is unlikely that these extreme perturbations occurred in practice, so it is necessary now to investigate the implications of predicted equilibrium (ideal) values not being met. Currently there is insufficient data available to model this dampening effect.

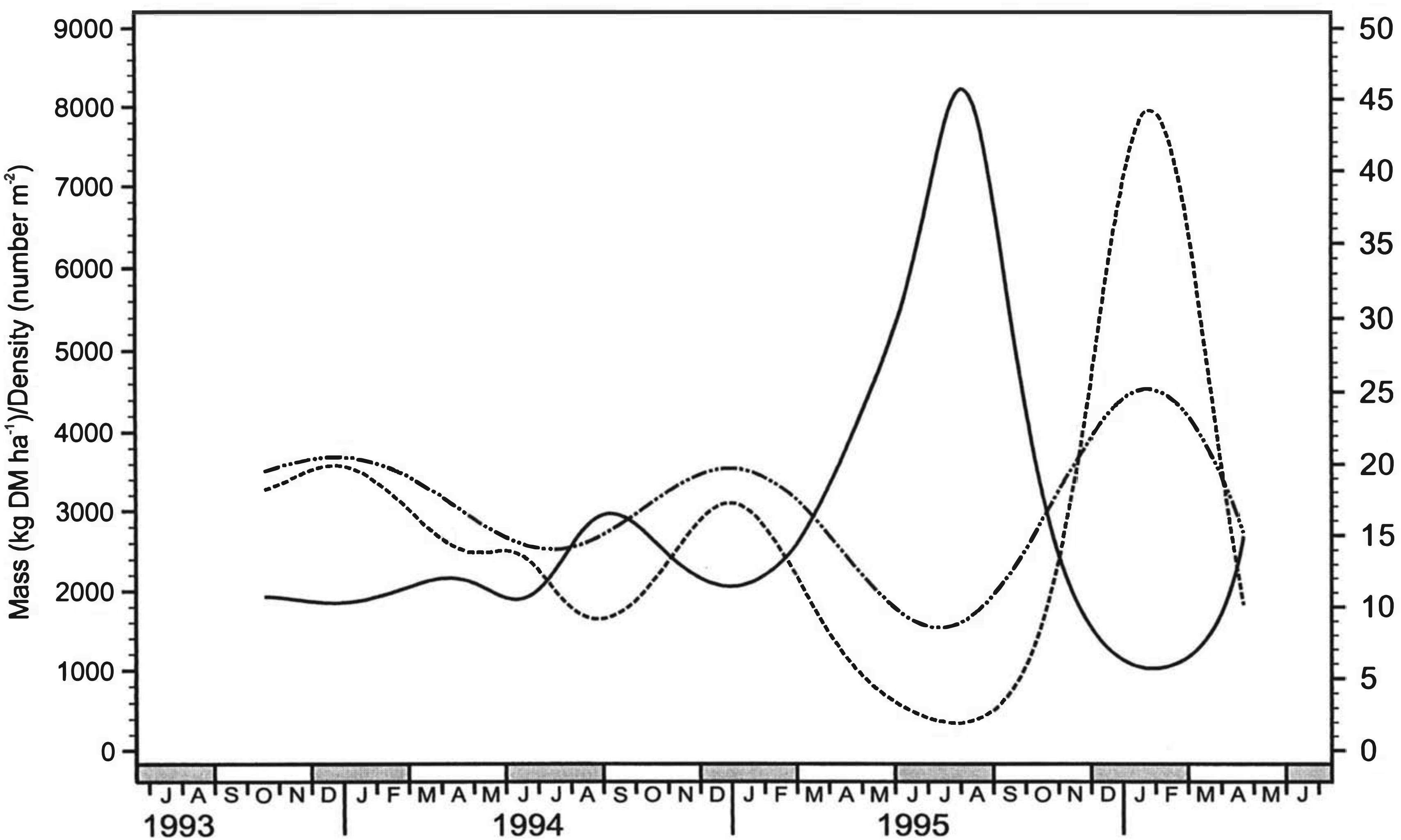
Figure A7-4 shows herbage mass and predicted equilibrium tiller density values for the model and actual values measured in the field trial over three years for EC, plotted on a log biomass:log tiller density plot. Actual values represent herbage mass (Figure 5-4) and tiller population densities (Table 5-13) from the trial. The first two observations of tiller population density and herbage mass from the trial have been omitted due to possible bias. Tiller population densities from the trial (Table 5-13) were timed either side of reproductive development and therefore largely exclude these effects on tiller size. It should be noted that this preliminary model also ignores the effects of reproductive development on tiller size. The increase in the size of tillers during reproductive development allows plants to take advantage of the increase in solar radiation at this time (Figure A7-1). Predicted values were taken from the model over the same period of time as the actual values they were matched with and reflect seasonal variation. Actual and predicted values followed a similar trajectory (-½ boundary line), indicated by the similarity of the slopes of a linear regression line, -0.4173 and -0.4642 for actual and predicted respectively. Although these regression slopes are close to the theoretical value of -½ (Matthew *et al.* 1996), it should be noted that the values shown in Figure A7-4 reflect between season as well as within-season variation, whereas the theoretical relationship relates only to between-treatment, within-season variation.

The positions of the actual and predicted values in Figure A7-4 are largely a function of the value of k_3 which was used to account for factors not modelled directly. The value of k_3 was chosen to achieve sensible values of equilibrium tiller density. While decreasing the value of k_3 would move actual and predicted points together on Figure A7-4, this also increases the values of tiller population density to unrealistic levels.

In this preliminary investigation the model did not predict equilibrium tiller density from herbage mass particularly well and this may be due to inadequacy of the relationships in the model, or choice of the wrong solution, or lack of time for pastures/swards to attain equilibrium, or alternatively and just as likely insufficiently detailed field data. This exercise shows that validation of a tiller-based model requires a detailed set of tiller population density and size data and would be logistically very difficult to provide in a large scale grazing trial. The measurements taken from the systems trial on No 4 Dairy Unit were designed to provide information at the farm level on the success or otherwise of early control and late control and not to enable the calibration and validation of a detailed tiller model.

Environmental ceiling leaf area represents the maximum leaf area a given environment is able to support according to the structure of the sward, the light extinction profile and the incident radiation. Further experiments are needed to provide detailed data on tiller size, tiller density and herbage mass of grazed swards to allow the environmental ceiling leaf area model to be calibrated and validated. In addition, research is needed to calibrate and validate a morphogenetic ceiling leaf area so that the two models can be compared. Morphogenetic ceiling leaf area represents the maximum leaf area developed by a population of adult tillers according to its morphogenetic characteristics. For a vegetative grass sward in which only leaves are produced, plant morphogenesis can be described by three main characteristics: leaf elongation, leaf appearance and leaf lifespan (Lemaire & Chapman 1996).

Figure A7-3 Predicted values for tiller density (number m^{-2}) —— and tiller size (mg) -------- from the tiller model using pre-grazing herbage masses (kg DM ha^{-1}) -··-··-··- taken from EC.



7.5 Conclusions

Available models make no provision for the sequential effects of management during the reproductive phase on the behaviour of pastures in a subsequent vegetative phase.

Defining the ceiling leaf area and pre-grazing herbage mass was used here in an attempt to define the dynamics of tiller density. The tiller model allows the calculation of the environmental equilibrium tiller density that can occur as the light levels increase in spring or decrease in autumn.

While this preliminary evaluation failed to provide conclusive evidence for the validity of the tiller model, it highlighted the need for and the focus of detailed research on tiller dynamics.

Although it has not been possible to develop the tiller-based model to a stage where its application could be tested, the model has provided valuable insights into the tiller dynamics of grazed swards. Based on this model the system is predicted to be very sensitive to changes in herbage mass.

The model has multiple solutions and requires further investigation to explore other possible solutions.

While tiller size and density and herbage mass data are available for pastures grazed by sheep there is no comparable data for dairy swards. Therefore, detailed experiments need to be carried out on grazed pastures which provide data on tiller dynamics at regular intervals following grazing by dairy cattle.

Figure A7-4 Tiller size-density plot (log:log) for actual • and predicted ○ values from the tiller model using pre-grazing herbage masses (kg DM ha^{-1}) taken from EC. Actual and predicted regression equations are $y = -0.4173x + 5.1424$ ($r^2 = 0.89$) and $y = -0.4642x + 5.0545$ ($r^2 = 0.86$), respectively.