A STUDY OF PATCHINESS IN MID-SEASON DAIRY PASTURES: CONSEQUENCES AND CONTROL

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ABSTRACT

There is interest among some dairy farmers in increasing herbage intake of cows during spring by increasing pasture cover but without compromising pasture quality into the summer. "Late control" is a grazing management strategy developed in Massey University that meets those requirements (Matthews et al., 1996). In addition, it has been demonstrated in previous trials that Late control increases pasture production in the summer-autumn period by increasing ryegrass tillering vigour. Late control requires a period of lax grazing during spring to allow some reproductive growth development on ryegrass pastures, which is then controlled by hard grazing in late spring before anthesis. However, patchiness may develop in Late control during the lax grazing period when the herbage allowance is high.

The objectives for the present experiment were to compare the pasture characteristics under Late control and conventional "Early control" spring management strategies in December-January, with particular reference to the consequences of vegetation heterogeneity to pasture production and utilisation over this period, and to discuss the implications to spring grazing management. The experiment involved detailed studies on three paddocks chosen from each of two farmlets of 22 paddocks used for a system trial comparing Early and Late control spring management on herds of 120 cows. Herbage mass distributions were estimated by taking 200 capacitance meter readings at random on each paddock. Relationships between herbage mass and utilisation and accumulation were estimated by using two 30 m permanent transects in each paddock. To determine botanical composition and tiller population variability within a sward, five tall patches and five short patches were sampled in each paddock.

Paddocks in Late control before the control phase in December had more herbage mass than paddocks in Early control (3600 vs. 5000 kg DM/ha), but the variability of herbage mass was similar (1000 vs. 1000, standard deviation in kg DM/ha). The skewness of the herbage mass distribution was positive but greater in Early control than in Late control (0.57 vs. 0.32). Botanical composition was similar between treatments and within paddocks. Pasture morphology showed tiller size-density compensation in both treatments. Pasture characteristics in late control were not an impediment for efficient pasture removal in late control and more herbage was harvested than in Early control (1900 vs. 1000 kg DM/ha), although herbage allowance was greater in Early control. Short patches in both treatments were defoliated in less proportion than tall patches, but in Late control the proportion of short patches was less than in Early control. Therefore, low herbage mass and greater proportion of short patches in Early control had a negative effect on total herbage utilisation.

Harvesting efficiency was controlled on Late control paddocks to avoid limitations to herbage intake, and the skewness of the distribution of herbage mass after grazing increased compared to Early control, as well as the proportion of tall poorly utilised patches. Topping of pastures after grazing was effective in removing poorly utilised material and in decreasing patchiness in January. In January, Late control paddocks had more herbage mass, but less patchiness than Early control paddocks (6300 vs. 4700 kg DM/ha). Sward characteristics were affected by treatment, and in general Late control increased ryegrass content and its leafiness during January compared to Early control. In January, herbage utilisation was greater in Late control than in Early control (3000 vs. 1700 kg DM/ha).

It was concluded that because Late control had greater responses in tall patches, the objective should be to modify management to a longer rotation length before controlling reproductive growth in late spring, to allow a greater proportion of the sward to achieve high herbage mass. The combination of grazing and topping of pastures gave high herbage intakes and effective pasture control. More pasture was produced in Late control than in Early control and the rotation length can also be increased during the summer in Late control, which may benefit further ryegrass tillering.

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Chapter 1. General Introduction and Objectives

In New Zealand the feeding of dairy cows is based on pastures, and efficient utilisation of herbage is important for the economic performance on a dairy farm, even though pasture production is seasonal with year to year variation. Seasonal calving of cows is one strategy used in Dairy farms to match animal requirements to pasture production, by making their peak lactation and high intake requirements coincide with high pasture production during spring (Holmes and Wilson, 1987). However, during late spring pasture becomes reproductive, and this reproductive growth must be controlled to maintain pasture quality. Different management strategies have been recommended to control reproductive growth in pastures. The most used strategy has involved hard grazing throughout the spring accompanied by conservation as required, which has been shown to maintain pasture quality and tiller density into the summer-autumn period (L'Huillier, 1987, 1988; Hoogendoorn et al., 1992). Despite these advantages, it is considered that hard grazing throughout spring limits herbage intake of dairy cows, which often results in loss of body condition that in turn will result in 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. However, to reduce the intensity of grazing has been considered undesirable because pasture quality declines, and on the other hand, the use of large amounts of supplements to better feed dairy cows is not considered economically feasible.

An alternative grazing management strategy for the spring period was developed in Massey University based on tiller dynamics studies. It was found that allowing some development of reproductive growth in ryegrass pastures but controlling it before anthesis ("Late control") increased the ryegrass tiller population, tiller weight, leafiness and growth vigour during the summer-autumn period (Matthew et al., 1989; Xia et al., 1990; Da Silva et al., 1993; Da Silva, 1994; Da Silva et al., 1994; Hernandez, 1995). In practice, Late control requires a period of lax grazing during the spring to allow some reproductive growth development on ryegrass pastures, and then control by hard grazing in late spring before anthesis. Late control has been tested experimentally with dairy cows in the past to evaluate if the extra pasture growth could be converted into extra milk production, with positive results (Da Silva, 1994). There is also interest in Late control among farmers interested in increasing the herbage intake of cows during spring without sacrificing pasture quality into the summer (Matthews et al., 1996).

It has been observed that during the lax grazing period under Late control patchiness develops on the sward, with some areas being grazed more intensively than others. As a consequence, the development stage of reproductive growth may be greater in some patches than others. Then at the time of control during late spring, different patches would be at different development stages of reproductive growth, and this may complicate management.

Patchiness develops in Late control during the lax grazing period when the herbage allowance is high and it is not likely that there is a restriction on intake during this period. But it is not known if patchiness will affect the cows intake and production during the control phase. In a system based assessment of Late control, it has been observed that to obtain an efficient pasture control it is necessary to force the cows to graze too low for too long so that intake and milk production decline during the control period, and this imposes a critical conflict for Late control management. However, the intensity of grazing between different patches during the control period may be different, and it is not known if this has any effect on ryegrass tillering and its regrowth vigour, or changes in botanical composition. It is necessary to describe the effects of patchiness during the control phase and the consequences in the next grazing period on herbage utilisation. Until the effects of patchiness under Late control are evaluated it is not possible to determine if controlling patchiness will bring extra benefits to the system.

The objectives for the present experiment were to compare the pasture characteristics of swards under Early and Late control spring management strategies in December-January, with particular reference to the consequences of vegetation heterogeneity to pasture production and utilisation over this period, and to discuss the implications to spring grazing management.

Chapter 2. LITERATURE REVIEW

The interest in this review is patchiness in grazed pastures, its causes, its consequences, and the implication in Late control spring management. The review is based on literature from intensively managed temperate pastures, but some concepts are used from range pastures and extensive grazing.

2.1. Grazing Management

Pasture production in New Zealand is seasonal in nature and will often show large variation from year to year. The main purpose of grazing management is to match animal requirements to seasonal pasture production, because livestock production in New Zealand is based on pastures. This involves a complex association of pasture utilisation, animal production per hectare, pasture production, herbage quality, and pasture composition. In practice, optimisation of grazing management objectives requires a balance to be struck between these conflicting effects, and therefore grazing management must be flexible (Holmes, 1989; Hodgson, 1990; Smetham, 1990; Humphreys, 1991). One of the major conflicts occurs between pasture utilisation and pasture growth. Pasture growth may be compromised if pasture utilisation is so intense that low LAI remains after grazing. If pasture utilisation is low, LAI increases and pasture growth may be maximised, but most of this growth will be lost via senescence. When optimum pasture utilisation is achieved, pasture production is restricted below its maximum potential because of reduced average LAI, but less growth is lost through senescence (Parsons et al., 1983). When optimum pasture utilisation is achieved, it is likely that animal production per hectare will be maximised (Parsons and Johnson, 1985), and pasture quality maintained at an optimum state. Pasture quality (nutritive value) is the result of sward structure and plant species present in the sward. Sward structure is modified according to the grazing management (defoliation) history (Davies, 1977). Botanical composition can vary seasonally, however grazing management may favour or impair one or another pasture species present in the sward (Harris, 1990), by interfering with their regrowth, competition, spreading and survival characteristics. All of these events, utilisation, growth, herbage quality, and botanical composition dynamics, are likely to occur heterogeneously on a sward, in relation to grazing management (Gordon and Lascano, 1993). This heterogeneity causes variation within a paddock, and therefore it is important to describe and analyse the pattern and intensity of this heterogeneity, to understand better the effects of grazing management on the plant-animal interaction, and therefore productivity. In the present review, the particular interest is on spring grazing management strategies on New Zealand dairy pastures, specially the management known as Late Control (Matthew, 1991).

2.1.1. Late Control Spring Grazing Management

In New Zealand, grazing management on dairy pastures during spring is aimed to control reproductive growth to maintain herbage quality and tiller population in the summer-autumn period. The timing of control of reproductive growth is traditionally applied from early spring by hard grazing (L'Huillier, 1988). In contrast, Late control is a spring grazing management strategy which aims to maintain higher average pasture covers on the farm during the early reproductive growth phase, but to control seedhead development before anthesis and loss of herbage quality (Matthew, 1991). The objectives of late control management are to increase herbage production during the spring and summer-autumn period, and improve the persistence of perennial ryegrass (Matthew, 1991). Late control management strategy has been of interest among dairy farmers not only as another alternative to control reproductive growth, but also as a management that permits full feeding of dairy cows around their peak of lactation (Matthews et al., 1996). Under the late control management, spring pasture growth rates are increased because of the laxer defoliation allowing an increased level of reproductive growth (Da Silva, 1994; Da Silva et al., 1994). It is suggested that late control spring grazing management increases pasture production during the summer-autumn period by improved tiller initiation at the base of reproductive tillers and survival of those daughter tillers after the control of reproductive growth (Matthew et al., 1989; Xia et al., 1990; Da Silva et al., 1993; Da Silva, 1994; Da Silva et al., 1994; Hernandez, 1995). It has also been observed that under the late control management, white clover content of pastures increases in the summer-autumn period, although this finding has not been consistent (Da Silva, 1994; Hernandez, 1995). Patchy grazing has been a feature under the late control management (Matthew, 1991; Da Silva, 1994; Hernandez, 1995), and it has been attributed to high herbage allowances prevailing before the late control phase. The development of patches of different height and structural characteristics has raised the question of the possible consequences of this patchy grazing upon herbage quality, regrowth and utilisation during the spring period. Also, the negative or positive effects on tiller dynamics and botanical composition caused by this patchiness upon the late control management objectives are unknown. The rest of this review is aimed to present evidence on causes and consequences of patchiness on grazed pastures, to understand its implication under the late control management.

2.2. Patchiness in Grazed Pastures.

In this section the causes and consequences of patchy grazing are reviewed as well as the interaction with defoliation disturbances and their modification by grazing management on a heterogeneous sward environment.

2.2.1. Definition of patch grazing.

Patch grazing can be defined as the close and often repeated grazing of small patches or even individual plants, while adjacent but similar patches or individual plants of the same species are left ungrazed or lightly grazed (Vallentine, 1990; p. 192). Patch grazing occurs when forage supply exceeds livestock demand and grazing animals have the opportunity to graze selectively (Vallentine, 1990; Coughenour, 1991). The level of patchiness will vary according to the initial variation in herbage mass and herbage quality, and the level of intake required per animal. Patch grazing is considered an inefficient utilisation of forage since a significant portion of the major forage plants are not grazed, or grazed only after they have deteriorated from under-utilisation, while others are damaged by repeated close grazing (Vallentine, 1990).

For a grazing herbivore, a patch is the perception of food availability in a continuous form but differing in its distribution of density. A patch is therefore a complex interaction of food distribution, animal morphological and physiological needs and capabilities, and a factor determining foraging time (Arditi and Dacorogna, 1988).

2.2.2. Causes of Patchiness.

This section covers those aspects of management, pasture and animal variables, which result on a heterogeneous distribution of herbage mass. Patchiness may be caused by any factor that promotes uneven utilisation of the herbage mass on offer. A heterogeneous defoliation pattern may be caused by active preference for some patches over others when there are marked structural or botanical differences. But uneven utilisation may also exist on relatively homogeneous swards when herbage availability exceeds demand, and defoliation pattern is left to chance according to animal distribution over the total area available. Uneven utilisation is exacerbated if both heterogeneity of herbage characteristics and an excess of herbage are present at the same time.

A heterogeneous defoliation pattern and development of patchy swards occurs when there are contrasting structural and/or botanical characteristics between patches, often resulting in a negative correlation between quantity and quality (Laca and Demment, 1991). Grazing animals foraging strategy and pattern of defoliation will be affected by pasture variables, experience and social interaction (Arditi and Dacorogna, 1988), which may be modified with the intensity of management. In any situation, grazing animals execute a sampling behaviour by which they graze every patch in a sward (Edwards, 1994; Bazeley, 1990; Illius et al., 1992; Wallis de Vries and Daleboudt, 1994), and then restrict foraging to places where food availability is higher than some threshold, developing an optimal allocation of time to each patch of the sward (Arditi and Dacorogna, 1988; Laca et al., 1993; Stephens and Krebs, 1986). There is no single rule on how animals will harvest a mosaic of patches because of interfering factors as the spatial distribution and neighbourhood of contrasting patches (Laca and Demment, 1991), hunger (Newman et al., 1994) and grazing pressure. There is still the probability that the animal does not visit a patch, if the contrast between patch characteristics is great enough that the animal can identify preferred patches visually (Bazeley, 1990) or memorise their location (Edwards et al., 1996). Grazing does not occur at random or uniformly where there is heterogeneity of plant form, and it may depend on plant size (height and biomass) (Laca et al., 1993; Norton and Johnson, 1985).

Herbage availability to the grazing animal is often assumed to be uniform across the entire sward, but it is further complicated by adding nutritional value, handling time and accessibility (Arditi and Dacorogna, 1988). Grazing animals will prefer patches with fresh vegetative growth to mature herbage patches with senescent leaves in the grazed horizon independently of their height (Illius et al., 1987; Wallis de Vries and Daleboudt, 1994; Bazeley, 1990), or with dead stems interspersed within leafy material (Ganskopp et al., 1993; Nascimento et al., 1989). Animals may discriminate between plant parts within a patch if necessary (Chacon and Stobbs, 1976), but this will increase searching time (Parsons et al., 1994), and can trigger the decision to move onto another patch (Illius et al., 1987; Wallis de Vries and Daleboudt, 1994). At low herbage availability or high grazing pressure, pseudostem can limit grazing depth (Barthram, 1981; Barthram and Grant, 1984; Flores et al, 1993), and this may be a reason for an animal to search for a new patch. In synthesis, preference for tall patches reduces heterogeneity, but preference for short patches increases it.

Botanical composition is another factor which animals show selection for. The extent of selection will depend on the vertical (Milne et al., 1982) and horizontal distribution of plant species (Edwards, 1994), and the degree to which plant species are intermixed and their proportion within a patch (Illius et al., 1992). Diet selection can be modified by the level of hunger (Newman et al., 1994) and preference may not be constant during one day (Newman et al., 1995). In cattle, selection between plant species or plant parts intermixed in one patch (Grant et al., 1985,1987; Illius and Gordon, 1990) may not be as important as the choice between patches (Wallis de Vries and Daleboudt, 1994).

The intensity of defoliation of a patch may be related to botanical composition. Legumes have a greater proportion of their vertical biomass distribution in the upper stratum of the sward, and when they are defoliated removal is greater as compared to grasses. The intensity of defoliation on a patch is also affected by the animal residence time on it, which is not depending solely on the patch characteristics but also on the neighbour patches as well (Laca and Demment, 1991; Stephen and Krebs, 1986).

Grazing management is a form of manipulation of the plant-animal interaction. By grazing management, the area allocated for grazing, stock numbers, and herbage mass and/or height are manipulated. The interaction of these three factors may determine the development, maintenance and control of patchiness. Stocking rates have much greater potential than grazing systems for altering frequency and intensity of defoliation and subsequent changes in botanical composition of range plant communities (Hart et al, 1993b).

Under continuous grazing, the proportion of patches visited within the sward on one day depends in part on the spatial scale under study. At a 1 m^2 scale, Edwards (1994) found that sheep on continuous grazing visited each block every day, but they did not eat from all the smaller quadrats within the 1 m^2 block. Edwards (1994) concluded that the interval between defoliations was random and that there was no spatial variability on the defoliation at 1 m^2 scale, but recognised that sheep discriminated between patches at a smaller scale (10 cm^2).

Frequency and intensity of defoliation of individual tillers does not give a real indication of what happens at the next level of organisation (plant or group of plants) (Heitschmidt et al, 1990; Edwards, 1994), but gives an idea of the variation that may exist in frequency and intensity of defoliation at different levels of herbage availability and/or grazing pressure, and grazing methods (allocation of area). Individual tillers (in a plant or group of plants) may be defoliated once, twice or more, or never, depending on the grazing management. Uniformity in the frequency of tiller utilisation indicates an even utilisation over the sward surface, whereas non-uniform frequency of tiller defoliated is evidence of patch grazing, resulting in an inefficient harvest of available tillers (Briske and Stuth, 1982; Volesky, 1994). Frequency of defoliation increases as stocking rate or grazing pressure increases and/or herbage allowance decreases (Briske and Stuth, 1982).

The timing on which grazing intensity is adjusted according to herbage growth will determine if poorly utilised patches develop or not. Such patches are established because animals graze only certain areas when there is more forage available than they can consume (Ring et al, 1985).

Once poorly utilised patches have established they are likely to persist if they are not controlled (Ring et al., 1985; Ruyle et al., 1986a; Willms et al., 1988). When patchiness has been established, regrowth of grazed patches becomes higher in quality than the surrounding ungrazed patches. Animals continue to select the fresh regrowth and consequently grazed patches diverge further from ungrazed patches in terms of forage quality and plant form, and a mosaic pattern develops in the pasture (Ring et al., 1985; Coughenour, 1991). The proportion, size and number of overgrazed patches may increase when herbage demand exceeds herbage growth (Ring et al., 1985).

Deposition of dung and urine can be another cause of patchy grazing (Jones and Ratcliff, 1983). Cattle avoid herbage contaminated by their own faeces and herbage growing around it. The rejection of herbage growth around dung pats varies from 5 to 12 times the area of the dung pat itself, but herbage rejection is not absolute and some grazing over dung pat areas may occur (Wilkins and Garwood, 1986). The proportion of the area covered by faeces at one time is very small (2-3%), but it can cause incomplete consumption of over 15 to 29% of the total area (Simpson and Stobbs, 1981). The proportion of area that is poorly utilised because of the dung influence decreases as grazing pressure increases. In some cases the majority of rejected patches are associated with dung deposited 3-4 weeks earlier, during the previous grazing period. In general, the effect of dung often lasts from two to several months (Wilkins and Garwood, 1986). Another effect of dung and urine is the uneven recycling of nutrients over the grazed area, which will cause some patches to have access to greater nutrient resources than the average. Extra growth and low utilisation may cause patches to develop into tall and coarse foliage that will further deter utilisation (Vallentine, 1990).

2.2.3. Effects on Pasture Production and Utilisation

The consequences of patchiness of interest in this section are the pattern of pasture utilisation and the pattern of herbage growth. Differences in utilisation between patches occur when patchiness is established on a sward, and a non-uniform pattern of defoliation develops. The pattern of defoliation is related to grazing pressure, stocking rate and animal distribution (Hart et al., 1993a; 1993b). Some patches are more utilised than others, and some others are not utilised at all. Repeated grazing of some patches may result in overgrazing (Ring et al., 1985). The proportion of patches under and over utilised will depend on the grazing pressure, which is in response to grazing method and/or temporal variation in herbage supply due to environmental effects (Ring et al., 1985). The probability of a patch being overgrazed depends on how intensively it has been defoliated in previous grazing periods (Ring et al., 1985). Utilisation can be very homogeneous on grazed patches under different stocking densities, but the proportion of these grazed patches may vary (Gibb and Ridout, 1986,1988; Nascimento et al, 1987). Severity of defoliation on a patch can be related to the size of plants (Norton and Johnson, 1985). When herbage supply is not enough to meet the animals herbage demand, new overgrazed patches develop (rather than increasing the size of present overgrazed patches) and utilisation from tall patches will still be low (Ring et al, 1985).

In some situations tall patches are proportionally less utilised than other patches, but contribute more to the total herbage mass harvested in relation to the area they cover. In one experiment, tall patches growing around dung pats represented about a third of the total area (increasing from 20% to 40% in the late summer–autumn), but tall patches contributed 50% of the total herbage mass in the sward. Tall patches were less utilised than short patches but still accounted for 38-43% of the total herbage consumed by cows, specially when growth of short patches was reduced (Fitzgerald and Crosse, 1989).

As the grazing period progresses plants are gradually defoliated but a consequence of animal selectivity and their distribution is that some proportion of the sward will be regrazed before the total area had been grazed entirely (Norton and Johnson, 1985). Under strip grazing the majority of tillers are defoliated in a short time (98% in 3 hrs), and the intensity of defoliation is greater compared to rotational or continuous grazing at similar grazing heights, although the residual height may still show dependence on the herbage height before grazing (Volesky, 1994). The average frequency of tiller defoliation can be similar under continuous and rotational grazing, when rotation length is below 21 days (Clark et al., 1984). However rotational and continuous grazing can not be compared on this basis because under continuous grazing, defoliation at different sites does not occur within a similar timing (out of phase) as under rotational grazing (Edwards, 1994). An out of phase defoliation results in a heterogeneous herbage mass distribution, because of the presence of both utilised and not utilised patches (Edwards, 1994). Intensity of defoliation is usually greater under rotational grazing compared to continuous grazing (Clark et al., 1984), but not always (Derner et al., 1994). Rotational grazing provides greater managerial control of the frequency and uniformity of tiller defoliation (Derner et al., 1994). Better use of tillers on rotational grazing is due to the indirect increase on grazing pressure rather than a result of altered duration of the grazing period (Coughenour, 1991).

In extensive grazing systems at low grazing pressure, when patchiness has been established in a sward, ungrazed patches from one year tend to be perpetuated as ungrazed patches the next year, and the majority of grazing occurs in the heavily grazed patches of the preceding year (Ring et al., 1985; Ruyle et al, 1986a; Willms et al., 1988). Although overgrazed and undergrazed patches are stable during one year, patch boundaries may fluctuate. At high grazing pressures grazed patches change from year to year, and if compared over several years, the spatial stability is less consistent (Willms et al., 1988) because in subsequent seasons new patches are formed (Coughenour, 1991), and pastures have more uniform vegetation (Ring et al, 1985). But on low stocked grazing systems, patch boundaries fluctuate little and are relatively stable between consecutive years (Willms et al., 1988). When ungrazed patches are established, their percentage of undefoliated tillers is not affected by stocking rate (Ruyle et al, 1986a).

Patchiness can have an effect on the pasture growth and average pasture production. For example, forage production was 35% less in overgrazed patches than on undergrazed patches (Willms et al., 1988). Net primary production is sometimes lower on grazed patches than in ungrazed patches, and it may be related to repeated defoliation and morphological consequences on regrowth rather than nutrient status (Coughenour, 1991). In one experiment, lightly grazed sites produced 121% as much biomass and 203% greater nitrogen yield as heavily grazed sites. Plants from the two sites had a positive response to defoliation as they increased in average 122% in nitrogen uptake per unit of root biomass and a 141% in total leaf blade nitrogen yield (Jaramillo and Detling, 1988).

Patchiness can affect plant morphology and physiology on different patches, which may affect utilisation and growth in the long term. Plants show plasticity to microsites (Miller et al, 1994). In one experiment, lightly grazed sites had an allocation of biomass and nitrogen directed primarily to the leaf sheaths and reproductive structures, whereas in heavily grazed sites it was allocated to the roots, a mechanism that reduces the effects of grazing severity rather than grazing tolerance (Jaramillo and Detling, 1988). According to the intensity of defoliation, plants may grow prostrate and their leaves may shift to lower CHO and higher N concentrations (McNaughton, 1992). If differential defoliation between patches persists, different genotypes of the same species may establish in combination to edaphic factors (McGinnies et al., 1988).

Morphology can be modified at the patch level in any plant genotype in response to canopy closure and defoliation. In an experiment, a simulated canopy closure of undefoliated plants more than doubled plant height, and reduced tiller numbers by 65% on short grasses and 90% on mid-height grasses, and changed allocation patterns towards more stem and sheath; similar effects were found in the field (McNaughton, 1992). In another case, plant height was 50% shorter on overgrazed patches than on undergrazed patches (Willms et al., 1988).

Patchiness may influence the botanical composition present in contrasting patches. Botanical composition of overgrazed patches can be different from the surrounding vegetation even if soil properties are similar. Botanical composition in overgrazed patches represents those species that are better adapted to close grazing (Ring et al, 1985). Overgrazed patches were dominated by grazing resistant species, but undergrazed patches were dominated by climax species (Willms et al., 1988). Litter was higher on undergrazed patches (Willms et al., 1988). Once selective grazing of patches begins, continued grazing pressure can lead to death of individual plants and reduced carbon inputs to the soil can accelerate degradation (Coughenour, 1991).

2.2.4. Effects on Pasture Composition

In intensively managed pastures, botanical composition has an important role in pasture and animal production. Therefore the persistence of improved plant species is a major objective when managing pastures. Plant species respond differently to environment and defoliation, and the reason why most plant communities contain many plant species is basically because environment is neither spatially uniform nor temporally constant. Plant communities are consequently spatially patchy, periodically disturbed and their constituent plant populations are subject to fluctuating competition from other species and variable levels of impact from grazing animals (Crawley, 1986; Miller et al., 1994). Pastures are organised in hierarchical levels including tiller, plant, population and community, which together influence the productivity and stability of grazed pastures (Briske, 1989). The scale of heterogeneity can vary from tillers to patches (Gordon and Lascano, 1993), and effects of heterogeneity depends on its spatial scale (Kareiva, 1990). Events happening at the patch scale are the main interest of this section.

In theory, there will be one species that grows better than any other for every combination of soil, climate, altitude, slope and aspect, so that it occupies more space (Crawley, 1986), but this is not commonly the case. Within a patch, there is a group of plants of one or more species, usually in differing proportions. Plant morphology is crucial in plant population dynamics because plant size is plastic, competition is asymmetric and mortality is size dependent (Crawley, 1990). Neighbour patches do not necessarily have the same botanical composition or structure (Tilman, 1994) and neighbour relations are crucial in population dynamics (Crawley, 1990). Botanical composition differences within and between patches arise from the combination of, plant to plant interactions (Tilman, 1994), patch microenvironment, and disturbances such as defoliation or dung and urine deposition. Each one of these features acting alone is enough to provide heterogeneity between patches, but it is more likely that they will occur simultaneously (Crawley, 1986). Habitat subdivision (patches of different characteristics) is an essential factor controlling the species dynamics and biodiversity of many communities, by allowing inferior and superior competitors to coexist as stable metapopulations (Tilman, 1994). Asynchronous fluctuation in population densities among different patches is also necessary for plant species coexistence (Kareiva, 1990). Coexistence occurs because species with sufficiently high dispersal rates persist in sites not occupied by superior competitors. Therefore, competition ability, dispersal ability between sites and longevity are all important in the coexistence of plant species, but there must be a trade-off among them (Tilman, 1994).

Competition ability, dispersal ability and longevity are caused by implicit morphological and physiological characteristics unique to every plant species (Goldwasser et al. 1994; Tilman, 1994). Each plant species has its own rate of change and dispersal (proportion of biomass that remains, moves and disappears from a particular patch) and the spread of species into adjacent patches is dependent on the specific identity of the neighbour; some species are less invaded than others (Thórhallsdóttir, 1990b). Therefore, the spatially heterogeneous pattern of plant species can be generated and maintained by the plants themselves through species-specific interactions, and environmental effects are not determinant for a pattern to develop and maintain (Thórhallsdóttir, 1990a; Tilman, 1994). When there are environmental variables affecting all patches equally, responses between patches are often determined by the degree to which variation among patches is independent from patch to patch (Kareiva, 1990). Variability among patches can have a strong influence on the outcome of community dynamics, by promoting the coexistence of species that would otherwise exclude one or the other through competition (Goldwasser et al. 1994). Effectiveness of resource acquisition is determined by both environmental resource pattern and architectural constraints (Clonal growth), which adds to the variability between patches (Oborny, 1994). Variability in patch quality may also influence the growth pattern. For stoloniferous and rhizomatous plants, branching probability should be higher in better patches and internode length should decrease with patch quality (Sutherland and Stillman, 1988). Variation in individual growth and size structure is also important for the coexistence of plant species (Hara, 1993). This means that any plants that can increase their growth can compete with bigger individuals if those are suffering from some disturbance or stress that decreases regrowth. Variation in regrowth of dominant species may occur on response to the frequency and intensity of defoliation, in association with the plant growth stage (Richards, 1993; Chapman and Lemaire, 1993). The plant population is also determined by asymmetric interspecific competition for light and self-thinning (Crawley, 1990).

Disturbance caused by grazing animals is another factor important in species coexistence and creating variability between patches. Biodiversity and the stability of plant population depends in part on the body size, number, mobility and distribution of grazing animals, and their preference in association with plant palatability; the plant survival to grazing depends on its competitive ability and grazing tolerance (Pacala and Crawley, 1992; Crawley, 1990). Grazing animals can deplete preferred plant species if they effectively graze them as soon as they colonise vacant patches (Kareiva, 1990).

The degree to which a plant will compensate for defoliation will vary according to the microsite conditions. Intraspecific compensatory responses result from the presence or absence of neighbours, availability of nutrients and length of time a plant has to recover from grazing. Morphological and physiological factors that also influence compensation to defoliation are growth form, carbon allocation patterns (shoot-root), photosynthetic rate, growth rate and meristem limitations. The herbivore impact on the plant interacts with the environment and if external factors are considered, response of plants to grazing is probabilistic (Maschinski and Whitham, 1989).

There is no typical pattern in population dynamics, which varies from virtual stasis to year to year variation, modified by habitat differences, intensity and frequency of disturbance, and plant life history (Crawley, 1990). Patterns in population dynamics are established seasonally rather than on a yearly period (Thórhallsdóttir, 1990a). Because plant population dynamics is specific to every plant species, the concept of a static or dynamic community pattern has no meaning unless referred to a particular species and viewed from a particular scale (Thórhallsdóttir, 1990a). Most species which are spatially associated also show significant interactions in time (Thórhallsdóttir, 1990a).

2.3. Literature Review Conclusions

There is evidence in the literature that pasture availability and sward characteristics determine animal behaviour and pattern of defoliation, and that the heterogeneity of herbage mass and sward structure occurs in response to the pattern of defoliation. Animal behaviour and pasture characteristics are sensitive one to each other, and management will have a great effect on this relation. There is enough evidence to prove that grazing management must be flexible in response to changes in herbage growth and pasture availability, in order to maintain plant-animal relations rather constant. By doing so, herbage growth and its utilisation may be maximised. By increasing the intensity of management, the control of defoliation distribution is improved.

Patch botanical composition is the result of association between species in space and time. Plant species contribution at the paddock scale (group of patches) is the result of patch neighbour relations between plant species, as influenced by the microenvironment. Grazing animals apply the most important disturbance to the plant ecology by defoliation and deposition of faeces and urine.

Late control management is an option during spring that may increase pasture production in late spring and the summer-autumn period. Patchiness of grazed pastures is an issue under the Late control management during late spring. The positive or negative effects that the development of patchiness under Late control might have on herbage utilisation, pasture production, animal production and sward botanical composition are unknown. It is necessary to evaluate the effects of patchiness in Late control, and if necessary identify ways of utilising lax grazed pastures more homogeneously.

Chapter 1. METHODOLOGY

1.1. Site description

The experiment was conducted during December 1995 and January 1996, at No 4 Dairy Brogden block, Massey University at an altitude of approximately 40 m above sea level. Pastures comprised a mixture of perennial ryegrass (*Lolium perenne* L.), white clover (*Trifolium repens* L.), with some red clover, and poa, browntop and yorkshire fog. The soil was Tokomaru silt loam, a poorly drained compact clay loam with a compact subsoil and tendency for drying out in the summer. Soil fertility is naturally moderate, but had an Olsen P value of 20-30 mg P/kg soil. Fertiliser application was (units/kg per ha) 115 Nitrogen, 40 Phosphorus, 55 Potassium and 43 Sulphur. The area is characterised by an average annual rainfall of approximately 1000 mm with prevailing westerly winds.

1.2. Experimental design

The experiment was conducted as part of a major system comparison designed to compare the milk production of spring-calved cows under contrasting spring grazing management. The treatments applied were Early Control and Late Control, which are outlined below.

1) Early Control treatment:

The purpose of this treatment is to control reproductive growth throughout spring, and encourage high pasture utilisation levels by grazing dairy cows in early lactation. To achieve these goals, the average pasture cover was targeted at 2000 ± 100 kg DM/ha. The reproductive growth control was maintained by adjusting the rotation length and dropping paddocks out of the rotation for hay and silage as required.

2) Late Control treatment:

The purpose of this treatment is to allow reproductive growth to occur during October and November and then control reproductive growth from anthesis during December. The average pasture cover was targeted at 2700 ± 100 kg DM/ha during the spring. Pasture cover was aimed to be reduced during the control period to 2000 ± 100 kg DM/ha. For the 1995/1996 cycle, topping of pastures (75-100 mm height) was used for effective control of reproductive growth in December to prevent a drop in herbage intake and milk production over this control phase as had taken place in previous years.

Two farmlets each of 45 hectares were used. Twenty paddocks were randomly allocated in pairs to each treatment. Each farmlet was stocked with 120 milking cows. Five (5) sample paddocks were selected on each farmlet for long term detailed pasture measurement. Three (3) of these paddocks were selected as sample paddocks in this current experiment. The sample paddocks in the main trial were chosen in pairs (one of each treatment) so that they were balanced within the entire farm across microclimate and soil characteristic differences.

For the current experiment, just two pairs of sample paddocks could be chosen, and one paddock under the Early control treatment was located in the south-east end of the farm while another paddock under the Late control treatment was located at the north-west end. Within each paddock, two microsite types were selected, identified as Tall patches and Short patches. Tall and short patches were identified subjectively over each paddock. Five randomly selected patches for each category were sampled in each paddock before and after grazing during the late control period in December 1995, and again one grazing cycle later in January 1996. Two permanent 30 metre transects were identified on each sampling paddock to measure the spatial distribution of herbage mass.

One paddock under the late control treatment could not be sampled during January, and was substituted by another paddock under the same treatment for the same month. The paddocks and dates of sampling are presented in Table 1.

The paddock size was not equal between paddocks within treatment. The area of paddocks in Early control was in average 2.58 ha (ranged between 2.05 ha and 2.95 ha), and in Late control average paddock area 2.33 ha (ranged between 2.17 ha and 2.66 ha).

Paddocks were grazed over a period of 2 to 3 days depending on the grazing rotation. The entire paddock was offered in half-day grazings. The number of half-day feeds during December were two for paddocks 29 and 62 and three in paddock 6 of Early control, and three in paddock 15, four in paddock 8 and five in paddock 28 of Late control. The number of half-day grazings were three for all paddocks in January except paddock 8 in Late control that had four.

The grazing interval length between December and January was in average 25 days in Early control (29 days for paddock 6, 23 days for paddock 29 and 22 days for paddock 62), and 27 days in Late control (26 days in paddock 8 and 27 days in paddock 28, paddock 15 missing in January).

Table 1. Sample paddocks and sampling dates under Early and Late control treatments, before and after grazing during December and January.

		December		January	
	Paddock	Pregrazing	Postgrazing	Pregrazing	Postgrazing
Early Control	29	14/12/95	19/12/95	8/1/96	13/1/96
	62	19/12/95	21/12/95	11/1/96	14/1/96
	6	21/12/95	26/12/95	21/1/96	26/1/96
Late Control	28	12/12/95	17/12/95 [a]	12/1/96	14/1/96
	8	22/12/95	26/12/95	20/1/96	23/1/96
	15	23/12/95	27/12/95	*	*
	18	*	*	24/1/96	26/1/96

Note: * Paddock 15 was replaced by paddock 18 in January.
[a] was not the last grazing (one feed before the last)

3.3. Sward Measurements

Two patch categories, Tall and Short patches, were identified visually on every paddock. The criterion for selection of patches was based only on their height before grazing with no distinction on the potential botanical or structural differences. Short patch height was around 10 cm and tall patches height was over 17 cm. The Tall and Short patches were selected randomly at the beginning of the experiment on every sample paddock. Throughout the experiment, sampled patches were taken from the same area (when patch size allowed sampling of four quadrats) which was chosen randomly at the beginning of the experiment. In December 1995, before the late control phase, five paired patches were selected for each patch category (Tall and Short) in each paddock. One of each paired patch was sampled before grazing and the second patch was identified with a wood peg driven into the ground, and sampled after grazing. Another five paired patches were identified with wood pegs driven into the ground for each patch category (Tall and Short) after the December 1995 grazing (Late control phase); they were sampled during January 1996, one grazing cycle after the late control phase. Again, one patch of every pair was sampled before grazing and the other after grazing.

3.3.1. Herbage Mass.

Herbage mass per patch was measured by cutting the herbage within a 0.1 m^2 quadrat to ground level with an electric shearing hand-piece. The 0.1 m^2 quadrat was sited at random within the patch. The samples were washed to remove contaminating soil and then oven dried for 24 hrs at 80 °C. Dry weight was recorded. At least ten pasture probe (Mosaic Systems, model 4) readings were taken on each quadrat before cutting to calibrate a herbage mass predictive equation for the capacitance meter.

On both Early and Late control treatments, paddock herbage mass was indirectly measured with a Pasture Probe capacitance meter before and after grazing during December (control phase) and January (post-control phase). Two hundred readings were recorded individually at approximately one metre interval across each paddock.

To estimate the spatial distribution of herbage mass, two transects of 30 metres each were located randomly on each sample paddock, away from gates, fences and water troughs. The transects were identified by wood pegs driven into the ground on the extremes of each transect, just above ground level to avoid their disturbance by the cows. Herbage mass was estimated on the transects using the Pasture Probe Capacitance Metre every 25 cm in duplicate. The measurements were made before and after grazing during December 1995 and January 1996. Transect measurements were guided by a cord drawn tightly between the pegs. A metric tape was placed beside the cord for reference.

Herbage mass estimations for paddocks and transects were made with equations calibrated from the cut quadrats. The equations used are presented in the results (Section 4.1). Test statistics (comparing mean square errors) were performed between different sets of equations, and linear and quadratic models, to choose the set with the best fit.

During the month of December 1995 (control phase), the paddocks under the late control treatment were topped after grazing. The sampling of patches after grazing was done before topping, as well as the selection of the five paired samples for each patch category to be sampled in the next grazing rotation (January 1996). Herbage mass was again indirectly measured with the Pasture Probe after topping, over the whole paddock, on the transects and on every paired sample.

Herbage mass distributions were calculated for every paddock on both treatments from the predicted herbage mass obtained from individual pasture probe readings taken all over the paddock. Herbage mass mean, standard deviation and skewness were calculated to describe the distribution shape (Hutchings, 1986) and submitted to an analysis of variance. The mean is simply the average herbage mass, standard deviation describes the variability in herbage mass, and skewness indicates whether the distribution has long tails to the left (skew<0) or to the right (skew>0), or whether the distribution is symmetrically bell shaped (skew=0). Skewness is calculated on the basis of the cubes of the residuals.

Herbage mass variation in space and time was analysed on the estimates from the transects. Profile plots between herbage mass before and after grazing for both December and January were used to visualise a pattern of utilisation in relation to herbage mass before grazing and any evidence on the stability of the pattern of herbage mass spatial distribution during one grazing event. Profile plots between herbage mass after grazing in December and before grazing in January were used to visualise a pattern of regrowth in relation to herbage mass after grazing. Profile plots between herbage mass before grazing on both December and January were used to visualise any evidence on the stability of the pattern of herbage mass spatial distribution from one grazing period to the other.

Regression analysis was used to determine the relationships between herbage utilisation and herbage mass before grazing, and herbage accumulation in relation to herbage mass after grazing. Test statistics (comparing mean square errors) were performed between different sets of equations (considering treatment, month and paddocks), and linear and quadratic models, to choose the set with the best fit.

Frequency analysis was used to estimate the probability of utilisation according to herbage mass before grazing, and the probability of herbage accumulation according to residual herbage mass. Frequency analysis was also used to estimate the probability of high and low herbage mass patches to remain in the same category from on grazing period to the next one.

Pattern analysis (quadrat variance analysis) was applied to the sequence of herbage mass sites obtained from the transects (Dale and MacIsaac, 1989), to determine if there was a common pattern between transects within a paddock, and between treatments and months. Pattern analysis was also used to evaluate the evolution across time of any possible pattern of spatial distribution of herbage mass (before and after grazing and from December to January). The pattern analysis method used was the two term quadrat local variance (TTQLV) (Hill, 1973) as recommended by Dale and MacIsaac (1989). The method basically consists on comparing the average variance at different block sizes. One block size unit in the pattern analysis represented 50 cm in this experiment, because estimations of herbage mass were done every 25 cm (a minimum of two estimations are needed to estimate variance in one block). Where there is a peak in variance, it is interpreted to be a possible pattern at that block size. Whenever a pattern is found, it represents the average distance between the centre of a patch (above a threshold) and the centre of a gap (below a threshold). The variance of block size was plotted against block size to interpret the results of the TTQLV pattern analysis.

3.3.2. Botanical Composition

The botanical composition of Tall and Short patches was estimated on every paddock before and after grazing during December 1995 and January 1996, from pooled samples of five Tall and five Short patches, cut to ground level with an electric shearing machine alongside the cut quadrat placed at every selected patch.

Herbage dissection was done by hand for each of the Tall and Short patch pooled samples. Each of these pooled samples were mixed thoroughly and then quartered successively, discarding two quarters every time, until the sample was approximately 200-250 g fresh weight. The material was separated into ryegrass leaf, ryegrass stem, ryegrass reproductive stem, white clover leaf (including the petiole), white clover stolon, white clover seed head, red clover leaf, red clover stem, red clover flower, dead material, other grasses and weeds. Each dissected component was oven dried at 80 °C for 24 hours. Once dried, each component was weighed with an accuracy of (±0.005 gram) and the weight recorded.

For the statistical analysis of botanical composition, proportion of live material (vs. dead), proportion of legume (vs. grass) within the live fraction, proportion of ryegrass (vs. other grasses) in the grass fraction, and proportion of leaf (vs. stem) in the ryegrass fraction were considered.

3.3.3. Grass Tiller Population, Tiller Weight and White Clover Stolon Dry Weight

Tiller populations were estimated for Tall and Short patches on every sample paddock during December 1995 and January 1996. Five tiller cores (50 mm diameter) were taken from each of the 5 paired sample sites for Tall and Short patches. Tiller cores were taken close to the cut quadrat, before and after grazing. Ryegrass, other grasses and weeds were counted. The white clover stolons found within the tiller cores, with petioles and leaves removed, were washed and then oven dried at 80 °C for 24 hours. The White Clover stolon dry weight was recorded with an accuracy of (±0.005 g).

For statistical analysis, before and after grazing tiller cores counts were combined into one sample per patch (Tall and Short), for every paddock on both treatments, for December and January.

Tiller dry weight was obtained by dividing the weight of ryegrass or other grasses by the corresponding tiller numbers per m^2. The weight of ryegrass and other grasses per m^2 was calculated from the proportion of ryegrass and other grasses obtained from the botanical composition, multiplied by the dry matter per m^2 obtained from the cut quadrats.

3.4. Statistical Analysis

An analysis of variance was performed using a 2*2 factorial model with paddocks within treatment as replicates for the analysis of mean herbage mass before and after grazing, their standard deviation and skewness. The main factors were the sampling months with two levels (December and January) and treatment with two levels (Early control and Late control). The analysis of variance was performed on untransformed data because differences in variance of main effects were only marginal.

For botanical composition, tiller population, tiller and stolon weight, an analysis of variance was performed using a 2*2*2 factorial model with paddocks within treatment as replicates. The main factors were the month effect with two levels (December and January), the treatment effect with two levels (Early control and Late control) and patches with two levels (Tall and Short). Treatment main effect was tested using paddocks within treatment as error term. The variance was homogeneous and no transformation of data was needed.

Statistical analyses were performed with SAS (SAS Institute Inc., 1991). Analysis of Variance was performed with the general linear model procedure (proc glm). Regression analysis was performed with the regression procedure (proc reg) and the general linear model procedure. Frequency analysis was performed with the frequency procedure (proc freq). Means, standard deviation, skewness used for the analysis of variance analysis, and quartiles used in the frequency analysis, were obtained using data exploratory analysis procedures (proc univariate and proc means).

Chapter 4. RESULTS

4.1. Herbage mass predictive equations

Four linear equations of the form 'y = a + bx' were used, before and after grazing in both December 1995 and January 1996, to estimate herbage mass (kg DM/ha) from the capacitance meter readings taken with the pasture probe. The four equations were chosen based on the best statistical fit of the data as determined by test statistics (comparing the residual sum of squares) of several sets of regression equations considering the two treatments (Early and Late control), before and after grazing, during December 1995 and January 1996. Regressions were tested for quadratic effects, but were statistically no better than the linear fit. The regressions used are presented in Table 2.

Table 2. Herbage mass (Kg DM/ha) predictive equations used for the Pasture Probe capacitance metre readings (CMR).

	Intercept*	Slope*	Significance		r^2
			Intercept	Slope	
December					
Pregrazing	159 (± 329)	19 (± 1.35)	ns	0.0001	0.77
Postgrazing	-794 (± 217)	30 (± 1.63)	0.0005	0.0001	0.86
January					
Pregrazing	-848 (± 501)	29 (± 2.39)	0.0961	0.0001	0.71
Postgrazing	-15 (± 312)	26 (± 2.09)	ns	0.0001	0.73

* SE in parenthesis
ns = not significant

4.2. Herbage Mass Distribution

Estimates of herbage mass derived from pasture probe measurements taken at random from each paddock were used for the analysis of variance of mean herbage mass, standard deviation, skewness and the estimation of herbage mass removal.

The means for treatment, month and grazing are presented in Table 3. The frequency and cumulative distributions for individual paddocks in Early and Late control for December before grazing are shown in Figure 1, for December after grazing in Figure 2, for after topping in Late control during December in Figure 3, for January before grazing in Figure 4, and for January after grazing in Figure 5.

4.2.1. Mean Herbage Mass.

The mean herbage mass before grazing was greater in Late Control than in Early Control (5600 v 4100, s.e.180 kg DM/ha) and greater in January than in December (5500 s.e.190 v 4300 s.e.160 kg DM/ha)(Table 3). There was no significant treatment by month interaction.

The mean herbage mass after grazing was similar between Early Control and Late Control (2800 v 3200, s.e.100 kg DM/ha) and between December and January (2900 s.e.100 v 3200 s.e.110 kg DM/ha). The mean herbage mass after grazing was lower in Early Control during December than in January, but similar in Late Control, though there was no significant treatment by month interaction. Approximately 300 kg DM/ha was removed by topping (Table 3).

The mean herbage mass removed during grazing was significantly greater in Late Control than in Early Control (2400 v 1300, s.e.210 kg DM/ha) and in January than in December (2300 s.e.230 v 1400 s.e.200 kg DM/ha). There was no treatment by month interaction.

Total herbage accumulation from December to January was greater in Late than Early control (3500 v 2100 kg DM/ha), but the difference was not significant. There were low degrees of freedom and the analysis was unbalanced because one paddock from Late control was missing.

Table 3. Estimates of herbage mass (kg DM/ha) before and after grazing and amount removed during grazing, for early and late control treatments in December and January. Least square means (±SE).

	December		January	
	Early Control	Late Control	Early Control	Late Control
Before grazing	3600 (250)	5000 (210)	4700 (250)	6300 (280)
After grazing	2600 (150)	3100 (130)	3000 (150)	3300 (170)
Removal	1000 (300)	1900 (260)	1700 (300)	3000 (340)
After topping		2800		
	Significance Pr > F			
	Month	Treatment	Month*Treatment	Padd(tx)
Before grazing	0.0085	0.0414	0.8609	0.0748
After grazing	0.1217	0.1969	0.5133	0.1317
Removal	0.0397	0.0763	0.6391	0.1850

4.2.2. Within Paddock Variation

The standard deviation of herbage mass estimated from individual pasture probe measurements is shown in Table 4. The standard deviation was analysed to determine the spread of variation between treatments and months.

The standard deviation of the herbage mass before grazing did not vary significantly between Early Control and Late Control (1300 v 1200, s.e.60 kg DM/ha). The standard deviation of the herbage mass before grazing was greater in January than in December (1500 s.e.70 v 1000 s.e.60 kg DM/ha). There was no treatment by month interaction.

As before grazing, the standard deviation of the herbage mass after grazing did not vary significantly between Early Control and Late Control (1000 v 1100, s.e.50 kg DM/ha). But the standard deviation of the herbage mass after grazing was greater in December than in January (1100 s.e.50 v 900 s.e.60 kg DM/ha). There was no treatment by month interaction. The standard deviation of the herbage mass after topping in Late Control during December was approximately 300 kg lower than after grazing.

The standard deviation of the herbage mass before grazing was significantly greater than after grazing (1300 v 1000, s.e.35 kg DM/ha, $p<0.0005$). There was also a significant grazing by month interaction ($p<0.0005$). The standard deviation of the herbage mass before grazing was lower in December than in January (1000 v 1500, s.e.50 kg DM/ha), but after grazing it was greater in December than in January (1100 v 900, s.e.50 kg DM/ha). The grazing by treatment interaction was not significant ($p>0.10$).

Table 4. Standard deviation of the estimated herbage mass distribution (kg DM/ha) before and after grazing, for early and late control treatments in December and January. Least square means (±SE).

	December		January	
	Early Control	Late Control	Early Control	Late Control
Before grazing	1000 (90)	1000 (80)	1600 (90)	1500 (100)
After grazing	1000 (70)	1200 (60)	900 (70)	1000 (80)
After topping		900		

	Significance Pr > F			
	Month	Treatment	Month*Treatment	Padd(tx)
Before grazing	0.0047	0.1969	0.5264	0.9345
After grazing	0.0791	0.2018	0.5935	0.4534

The skewness of the distribution of herbage mass estimated from pasture probe measurements is shown in Table 5 and Figure 1 to 5. The skewness was analysed to determine the deviation from normality between treatments and months.

Before grazing, Early Control had a greater positive skewness than Late Control (0.54 v 0.18, s.e.0.01) and skewness was greater in December than in January (0.45 s.e.0.09 v 0.28 s.e.0.10). These differences on skewness were not significant at a 10% significance level because there was great variability in the skewness value for the herbage mass distribution before grazing (C.V. 60%). The skewness of the herbage mass distribution before grazing was similar in the Early Control for both December and January, but in Late Control it decreased from December to January, but the treatment by month interaction was not significant.

The skewness value for the herbage mass distribution after grazing was not significantly different between Early Control and Late Control (1.02 v 0.96, s.e.0.001) and between December and January (0.95 v 1.04, s.e.0.001). The after grazing herbage mass skewness was greater in Late Control during December but in January it was greater in Early Control, but the treatment by month interaction was not significant. The skewness of the herbage mass distribution after topping in the Late Control treatment during December, decreased compared to the after grazing value (Table 5).

The skewness of the estimated herbage mass distribution before grazing was significantly less than after grazing (0.38 v 0.96, p<0.0001). There were no significant grazing by month or grazing by treatment interactions.

Table 5. Skewness of the estimated herbage mass distribution (kg DM/ha) before and after grazing, for early and late control treatments in December and January. Least square means (±SE).

	December		January	
	Early Control	Late Control	Early Control	Late Control
Before grazing	0.57 (0.13)	0.32 (0.12)	0.51 (0.13)	0.04 (0.15)
After grazing	0.82 (0.17)	1.09 (0.15)	1.24 (0.17)	0.83 (0.19)
After topping		0.54		
	Significance Pr > F			
	Month	Treatment	Month*Treatment	Padd(tx)
Before grazing	0.2750	0.1414	0.4383	0.2142
After grazing	0.6591	0.6079	0.1159	0.7646

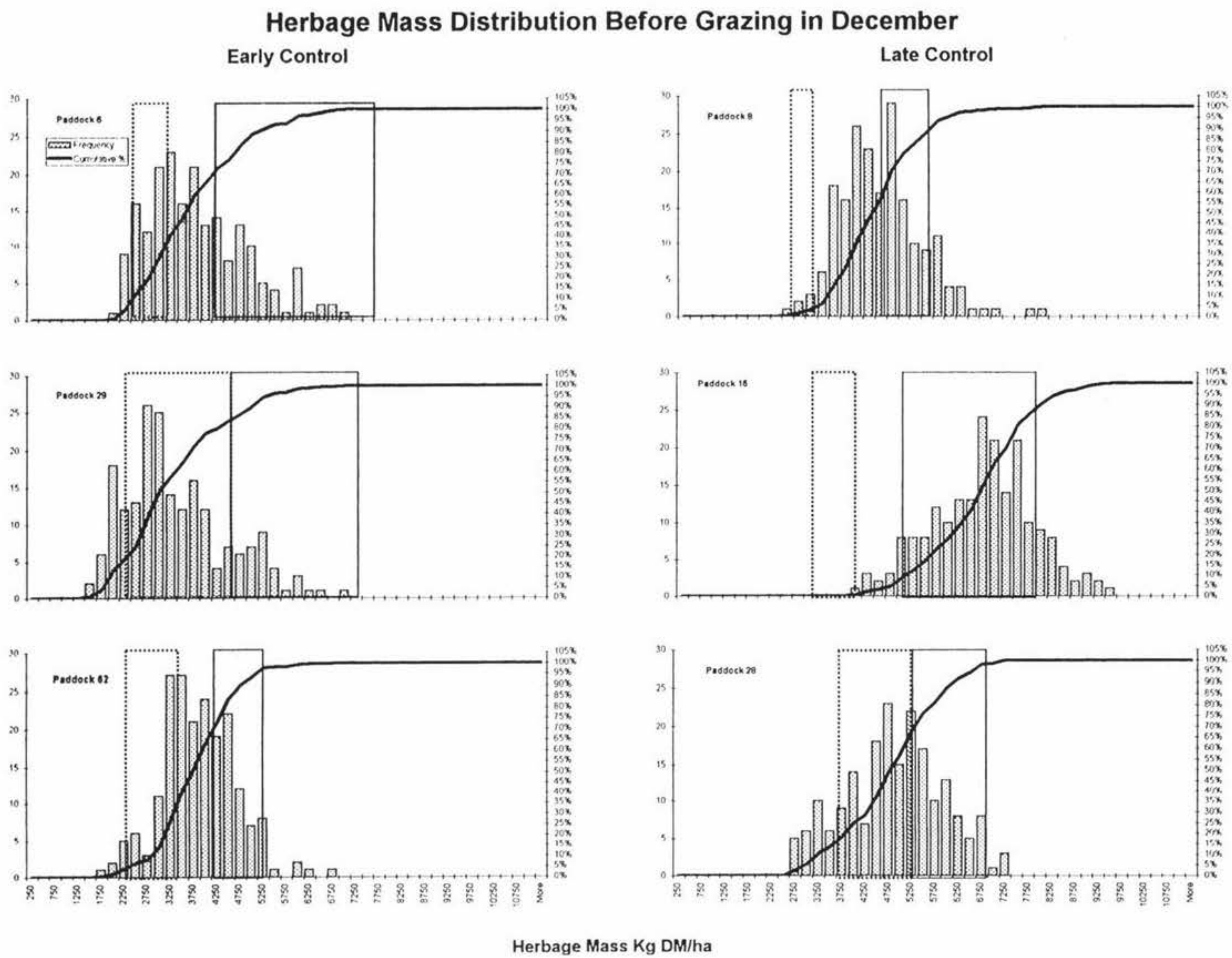


Figure 1. Herbage mass frequency and cumulative distribution in Early and Late control before grazing during December. The dotted box represents the location in the distribution of the sampled short patches. The line box represents the location in the distribution of sampled tall patches.

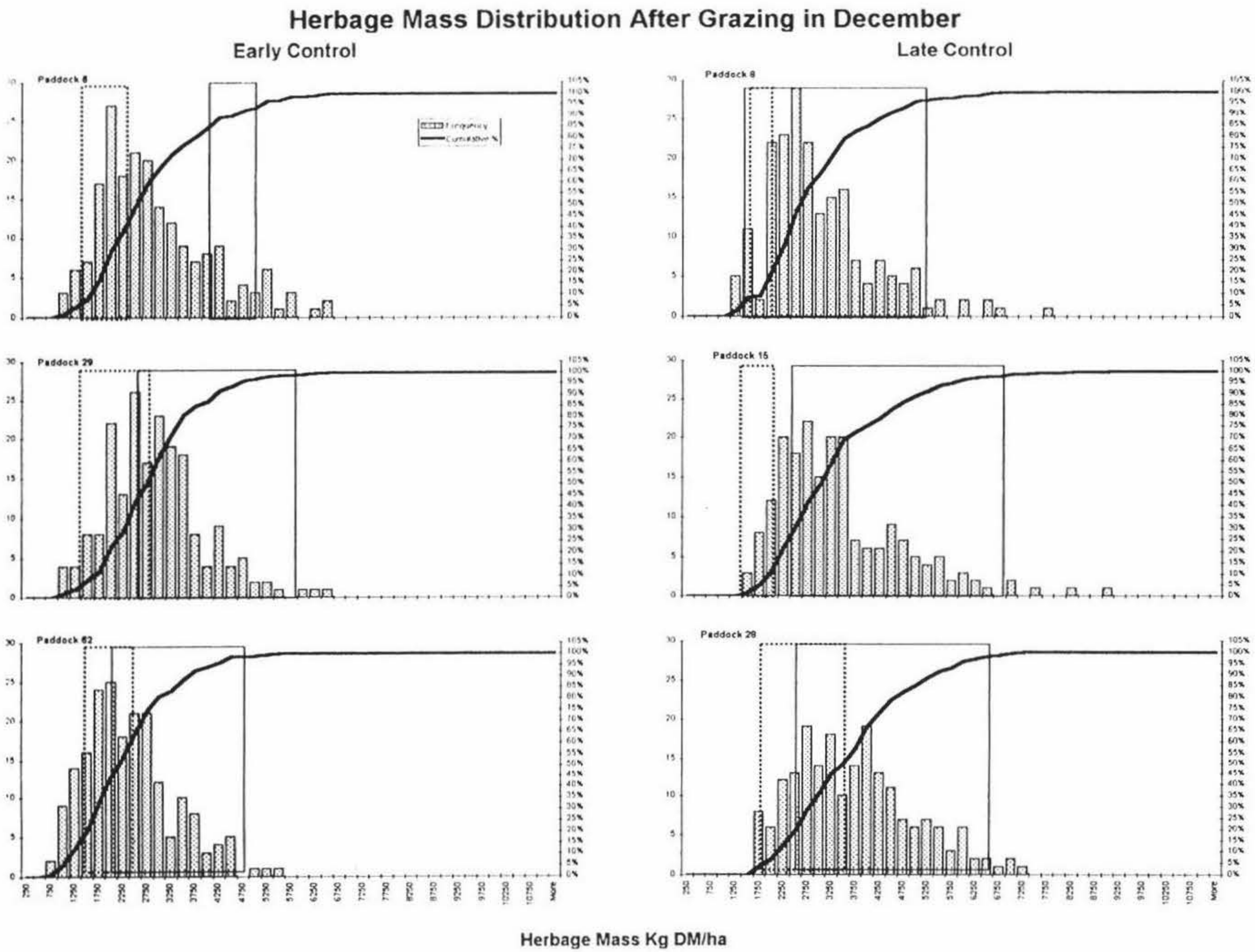


Figure 2. Herbage mass frequency and cumulative distribution in Early and Late control after grazing during December. The dotted box represents the location in the distribution of the sampled short patches. The line box represents the location in the distribution of sampled tall patches.

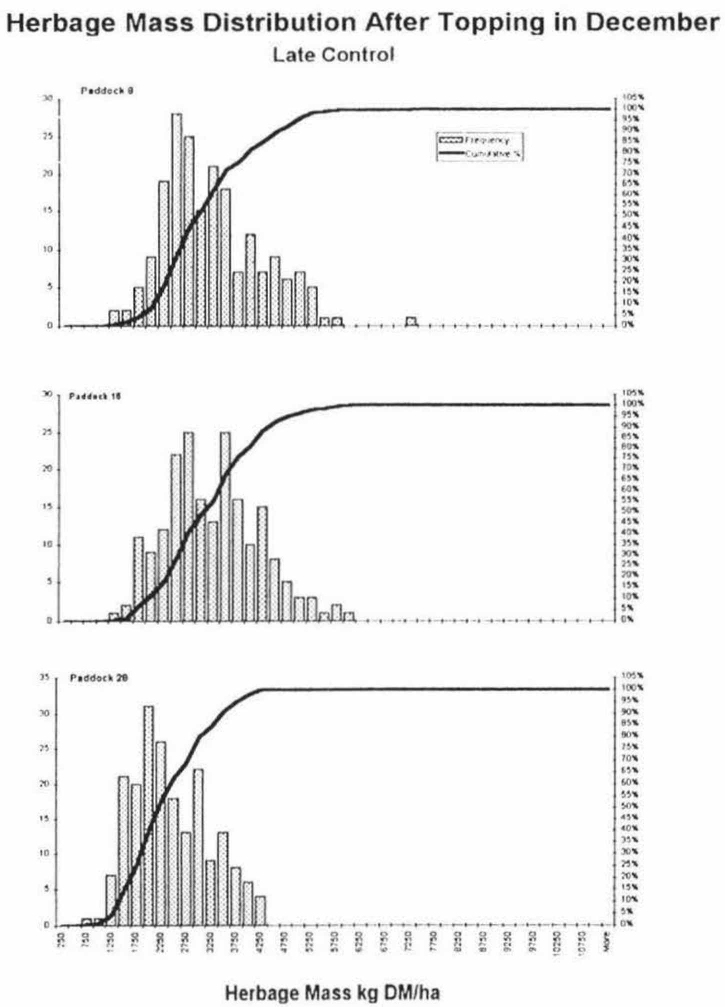


Figure 3. Herbage mass frequency and cumulative distribution in Late control after topping during December.

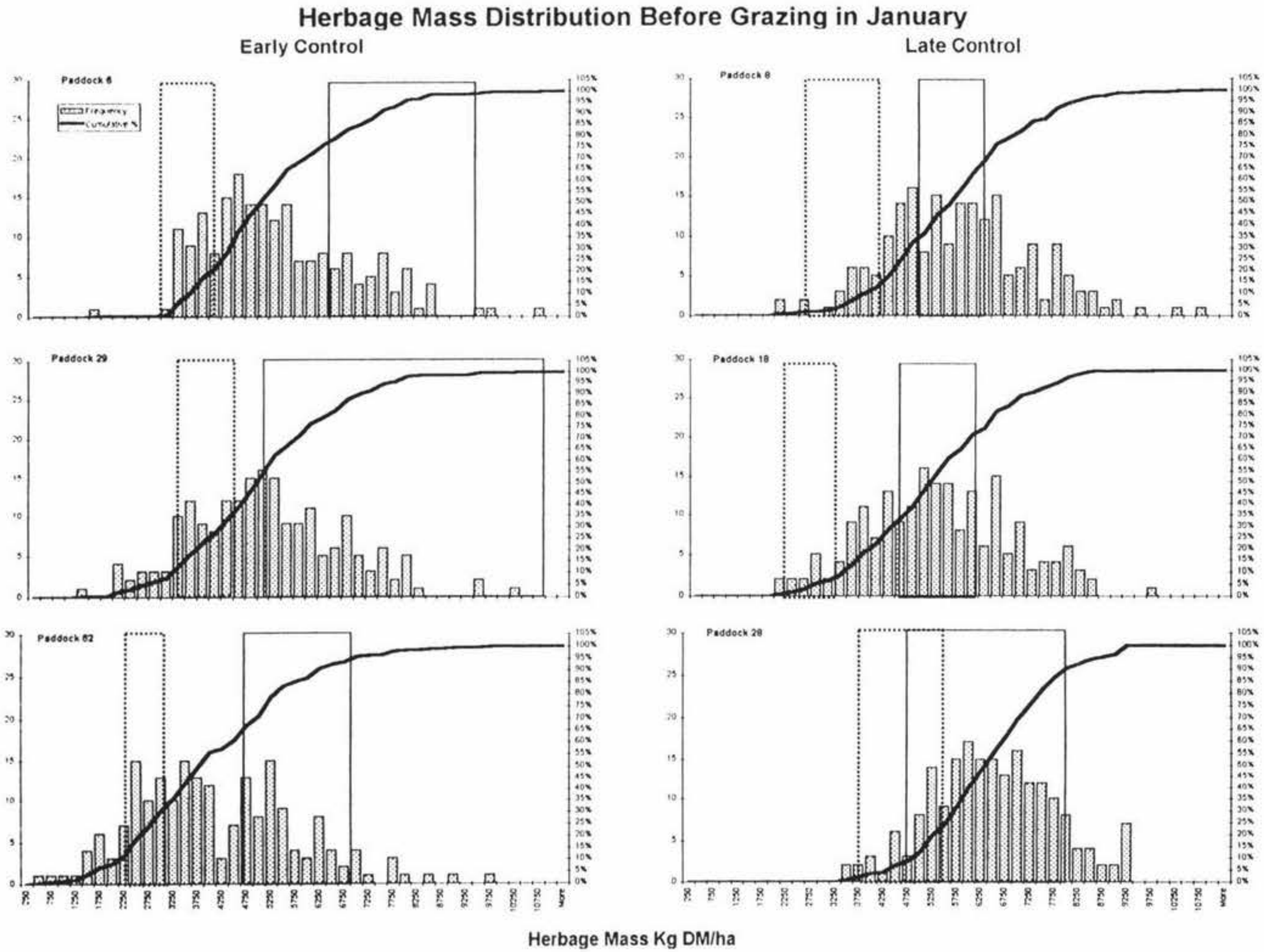


Figure 4. Herbage mass frequency and cumulative distribution in Early and Late control before grazing during January. The dotted box represents the location in the distribution of the sampled short patches. The line box represents the location in the distribution of sampled tall patches.

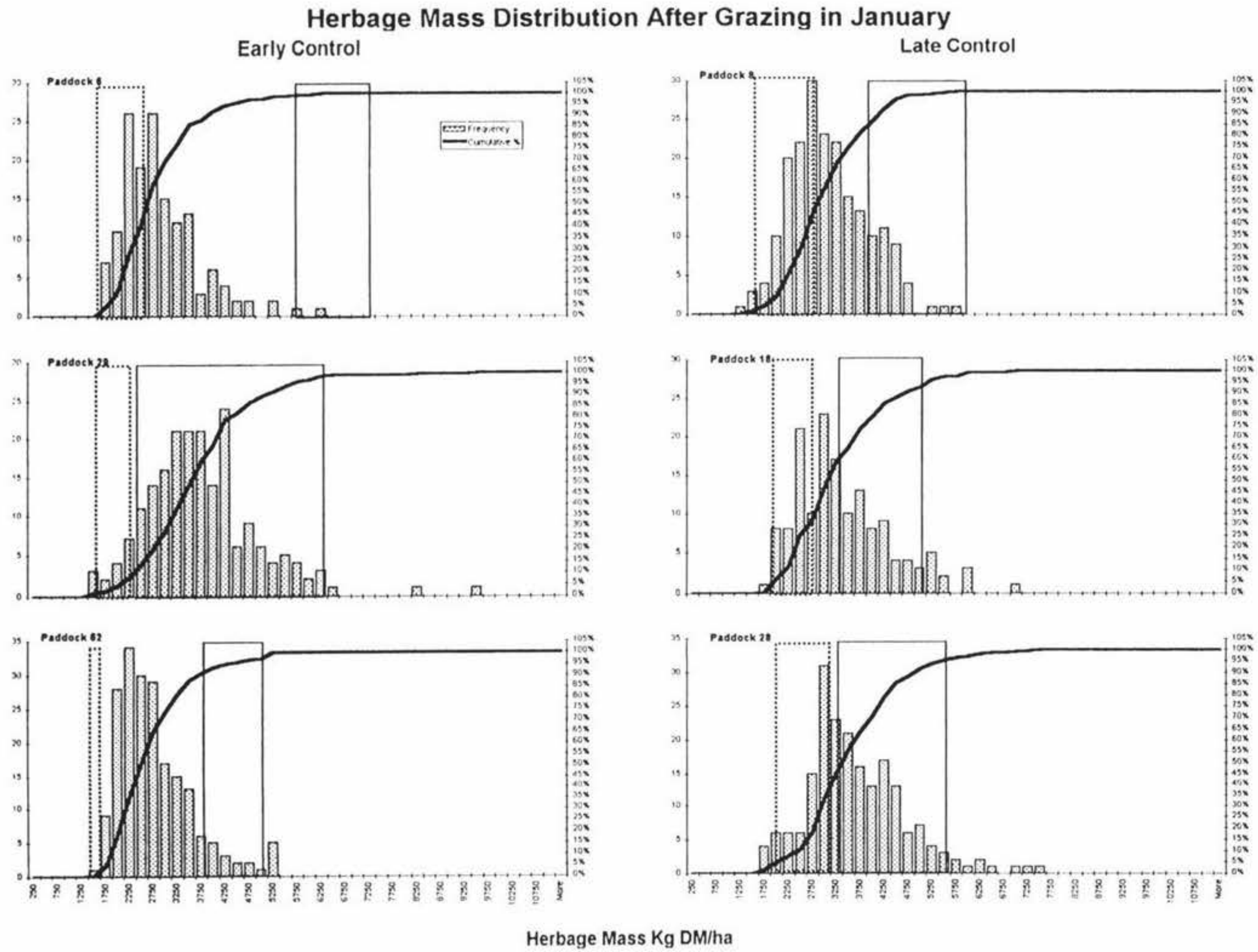


Figure 5. Herbage mass frequency and cumulative distribution in Early and Late control after grazing during January. The dotted box represents the location in the distribution of the sampled short patches. The line box represents the location in the distribution of sampled tall patches.

4.3. Tall and Short patches

There was no general relation of sampled patches to the paddock herbage mass distribution among paddocks within each treatment. The sampled tall and short patches relation with the paddock herbage mass distribution was associated more with the individual paddock characteristics of mean herbage mass and the total range of herbage mass values. As a generalisation, short patches herbage mass was below the paddock herbage mass distribution median, and the tall patches herbage mass were above the median. The range of herbage mass sampled by short and tall patches relative to herbage mass distribution in individual paddocks is shown in Figures 1,2,4,and 5.

4.3.1. Herbage mass

Herbage mass before grazing (kg DM/ha) (Table 6) was greater in tall patches than short patches (6100 v 3400, s.e.110), and greater in January than in December (5000 v 4400, s.e.120). There were no significant differences between Early and Late control (4800 s.e.110 v 4700, s.e.120). These treatment averages do not have any relation to the paddock level herbage mass average presented in Section 4.2.1 because they were obtained from the sampled tall and short patches, which do not represent the paddock average. All interactions, month by patch, patch by treatment and month by treatment were significant. Short patches had similar herbage mass before grazing in both December an January (3200 v 3500 s.e.160, $p>0.20$), but herbage mass before grazing in tall patches increased from December to January (5700 v 6500 s.e.160, $p<0.0005$). Tall patches herbage mass before grazing was greater in Early control than in Late control (6400 s.e.150 v 5800 s.e.160, $p<0.0005$) but means for short patches were similar (3200 s.e.150 v 3500 s.e.160, $p>0.10$). The interaction patch by month by treatment was significant ($p<0.05$). There were significant differences between paddocks within treatment.

Table 6. Herbage mass before grazing (kg DM/ha) of sampled tall and short patches, for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	3100	5700	3300	7100	220
Late Control	3400	5700	3700	5900	240

Significance Pr > F

Treatment	Month	Patch	Patch*Tx	Month*Tx	Month*Patch	Padd(tx)
0.789	0.0013	0.0001	0.0024	0.0991	0.0649	0.0001

Herbage mass after grazing (kg DM/ha) (Table 7) was greater in tall patches than short patches (4500 v 2000 s.e.110), and greater in January than in December

(3500 v 3000 s.e.120). There were no significant differences between Early and Late control herbage mass after grazing (3300 s.e.110 v 3200 s.e.120). The month by patch and patch by treatment interactions were significant. Herbage mass after grazing was greater in January than in December in tall patches (5000 v 4000 s.e.160, $p<0.0005$), but means for short patches were again similar (2100 v 2000 s.e.170, $p>0.60$). Tall patches herbage mass after grazing was greater in Early control than in Late control (4700 v 4300 s.e.160, $p<0.06$) but similar in the short patches (1900 v 2000 s.e.160, $p>0.15$). The treatment by month interaction was not significant. There were significant differences between paddocks within treatment.

Table 7. Herbage mass after grazing (kg DM/ha) of sampled tall and short patches, for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	1900	4000	1900	5400	220
Late Control	2100	4000	2300	4600	240

Significance Pr > F

Treatment	Month	Patch	Patch*Tx	Month*Tx	Month*Patch	Padd(tx)
0.8362	0.0026	0.0001	0.0216	0.5084	0.0056	0.0132

4.3.2. Botanical composition

Botanical composition results are presented for the proportion of live material, proportion of legume within the live fraction, proportion of ryegrass on the grass fraction, and proportion of leaf in the ryegrass fraction in Tables 8 to 11. Live material is complementary to dead matter content, and live and dead material represent 100% of the herbage mass. The proportion of legume is complemented by the grass component within the live fraction; weeds were present at less than 1% of the live fraction. The proportion of ryegrass is complemented by the proportion of other grasses for the grass fraction within the live proportion. Proportion of leaf is complemented by stem on the ryegrass fraction; stem includes sheath, vegetative stem and reproductive stem.

For all the botanical composition analyses, the averages for treatment effects were obtained from sampled tall and short patches. The treatment averages may not represent the paddock level because the proportion of the two microsite types are not necessarily equal and their characteristics may also differ from intermediate patches (that were not sampled). Transformation for the analysis of variance was not necessary.

The overall pregrazing live component mean was 70%. There were no significant differences between Early control and Late control (69 s.e.2.3 v 71 s.e.2.5 %), December and January (70 v 70, s.e. 2.5 %) or their interaction (Table 8). The live proportion was greater in the Short patches than the Tall Patches (73 v 67, s.e. 2.4 %). There were no significant differences between paddocks within each treatment.

Table 8. Live proportion (%) on tall and short patches before grazing for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	70	67	76	64	4.7
Late Control	72	70	75	66	5.1

Significance Pr > F					
Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.9518	0.7238	0.0795	0.7168	0.2239	0.2738

The overall mean for the legume proportion in the live component was 28 % (Table 9). The legume proportion was similar between Early control and Late control (24 s.e.4.2 v 29 s.e.4.4 %). The legume proportion was higher in January than in December (30 v 23, s.e.4.5 %), and higher in short patches than in tall patches (31 v 23, s.e.4.2 %), but these differences were not significant. There was large variability (coefficient of variation = 51%). The month by patch interaction was significant. During December, legume content was not different between short patches and tall patches (20 v 25, s.e.6.1 %, $p>0.50$), but in January the short patches had significantly more legume content than the tall patches (41 v 20, s.e.6.1 %, $p<0.05$). There were significant effects between paddocks within treatment ($p<0.08$).

Table 9. Legume proportion (% live fraction) on tall and short patches before grazing for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	18	21	40	18	8.3
Late Control	23	30	42	22	8.9

Significance Pr > F					
Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.282	0.616	0.1961	0.7704	0.0472	0.0777

The overall mean for the proportion of ryegrass in the grass component was 64% (Table 10). The proportion of ryegrass in the grass component was significantly higher in December than January (71 v 53, s.e.4.2 %). There was more ryegrass in Late control than in Early control (67 s.e.4.1 v 57 s.e.3.9 %) but the difference was not significant. The proportion of ryegrass in the grass component was similar on short and tall patches (60 v 64, s.e.4.0 %). The proportion of ryegrass in the grass component in the short patches was greater during December than in January (74 v 47, s.e.5.8 %, $p<0.01$), but in the tall patches it was similar (68 v 60, s.e.5.8 %, $p>0.30$). In December, Early control and Late control had similar ryegrass proportion in the grass component (72 s.e.5.5 v 70 s.e.6.4 %, $p>0.80$), but in January Early control had less ryegrass proportion in the grass component than Late control (43 s.e.5.5 v 63 s.e.6.4 %, $p<0.05$).

Table 10. Ryegrass proportion of grasses (live fraction) on tall and short patches before grazing for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	75	68	40	46	7.9
Late Control	74	67	54	73	8.4

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.0158	0.2123	0.5708	0.1157	0.1077	0.3257

The overall mean of the leaf proportion of ryegrass was 67% (Table 11). There were no significant differences on the leafiness of ryegrass between Early control and Late control (65 s.e.2.6 v 66 s.e.2.8 %) and between December and January (63 v 68, s.e.2.8 %). The interaction of treatment and month was significant. During December the leaf proportion of ryegrass was greater in Early control than in Late control (68 s.e.3.7 v 58 s.e.4.2 %, $p<0.12$), but in January leaf proportion of ryegrass was greater in Late control than in Early control (74 s.e.4.2 v 63 s.e.3.7 %, $p<0.10$). The leaf proportion of ryegrass was higher in short patches than tall patches (68 v 63, s.e.2.7 %), but the difference was not significant. There were significant effects between paddocks within treatment ($p<0.08$).

Table 11. Ryegrass leaf proportion in the ryegrass component on tall and short patches before grazing for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	71	64	67	59	5.3
Late Control	56	60	80	67	5.7

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.1891	0.9217	0.1374	0.0322	0.2805	0.0798

4.3.3. Tiller numbers

For all tiller numbers and stolon weight analyses, the average for treatment effects were obtained from sampled tall and short patches. The treatment averages may not represent the paddock level because the proportion of the two microsite types are not necessarily equal and their characteristics may also differ from intermediate patches (that were not sampled). Transformation of tiller numbers was not necessary for the analysis of variance.

The overall mean of total tiller numbers per m^2 was 9300 (C.V. 22%)(Table 12). Total tiller numbers were significantly higher on short than tall patches (10600 v 8400, s.e.430). The total tiller numbers in Early Control and Late Control (10400 s.e.420 v 8600 s.e.450) and December and January (8900 v10000, s.e.450) were not significantly different. Paddocks within treatments differed significantly.

Table 12. Total tiller numbers (m^2) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	10800	9100	12700	8900	840
Late Control	9000	6700	9800	8700	910

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.117	0.1361	0.0009	0.7382	0.6937	0.0369

Ryegrass tiller numbers per m^2 overall mean was 4400 (C.V. 32%)(Table 13). The ryegrass tiller numbers were greater in the tall than in the short patches (4600 v 4000, s.e.300), but the difference was not significant. There were no significant effects between December and January (4300 v 4200, s.e.300). Ryegrass tillers numbers were greater in Early control than in Late control (4600 s.e.280 v 4000 s.e.300), though the difference was not significant. There was a significant month and treatment interaction. The ryegrass tiller numbers in Early control were greater in December than in January (5100 v 4100, s.e.400, $p<0.07$), but in the Late control ryegrass tiller numbers were similar between December and January (3500 v 4400, s.e.460, $p>0.50$). The month and treatment interaction was greater in tall patches than in short patches. There was no significant patch by month interaction. There was a significant difference between paddocks within treatment.

Table 13. Ryegrass tiller numbers (m^2) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	4400	5900	4200	3900	570
Late Control	3300	3600	3900	4900	610

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.8473	0.5185	0.1234	0.0311	0.5279	0.0012

Other grasses tiller numbers per m^2 overall mean was 4900 (C.V. 33%)(Table 14). Other grasses tiller numbers were greater in the short patches than in the tall patches (6600 v 3800, s.e.340). Other grasses tiller numbers were greater in January than in December (5800 v 4600, s.e.360). Other grasses tiller numbers were greater in Early control than in Late control (5800 s.e.330 v 4600 s.e350) but not statistically different. During December other grasses tiller numbers were similar between Early and Late control (4800 s.e.470 v 4400 s.e.540, $p>0.60$), but in January other grasses tiller numbers were greater in Early control than in Late control (6700 s.e.470 v 4800 s.e.540, $p<0.05$), although the treatment by month interaction was not significant. No other interactions were significant. There was a significant difference between paddocks within treatment.

Table 14. Other grasses tiller numbers (m^2) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	6400	3200	8500	5000	670
Late Control	5700	3200	5800	3800	720

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.0350	0.3311	0.0001	0.1479	0.9689	0.0021

The overall mean of the proportion of ryegrass tillers in the total grass tiller numbers was 48%(Table 15). The proportion of ryegrass tillers in the total grass tiller numbers was greater in tall patches than in short patches (55 v 39, s.e.2.3 %), and greater in December than in January (51 v 43, s.e.2.4 %). There was no significant difference between Early control and Late control (46 s.e.2.3 v 48 s.e.2.4 %). There were no significant interactions. There were significant differences between paddocks within treatment.

Table 15. Proportion of ryegrass tillers in the total grass tiller numbers (%) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	41	64	33	45	4.5
Late Control	43	57	37	55	4.9

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.0203	0.8316	0.0001	0.2157	0.5515	0.0001

The weights (g/m^2) of the white clover stolon obtained from the tiller cores are presented in Table 16. The average white clover stolon weight was 30g per m^2. The weight of white clover stolon was greater in January than in December (35.3 v 24.4, s.e.2.23) and the weight of stolon was greater in the short than in the tall patches (33.7 v 25.9, s.e.2.11). The weight of stolon was greater in Late control than in Early control (32.0 s.e.2.20 v 27.6 s.e.2.07), but the difference was not significant. During December the white clover stolon weight was similar between short and tall patches (26.1 v 22.7, s.e.3.04, p>0.40), but in January white clover stolon weight was greater in the short patches than in the tall patches (41.4 v 29.2, s.e.3.04, $p<0.01$), but the interaction was not significant. No other interactions were significant.

Table 16. White clover stolon (g/m^2) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	22.1	20.1	41.0	27.2	4.15
Late Control	30.0	25.4	41.7	31.1	4.46

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.0021	0.2536	0.0118	0.5158	0.1383	0.2932

4.3.4. Tiller Dry Weight.

The results of the analysis of variance on the untransformed tiller weight are presented. Logarithmic transformation fitted the data better but the conclusions were similar to those obtained with the untransformed data.

The average ryegrass tiller dry weight was 33 mg (C.V. 44%)(Table 17). There were no significant differences between Early Control and Late Control (30 s.e. 4 v 39 s.e. 5 mg), or between December and January (38 v 31 s.e. 5 mg), and no significant treatment by month and treatment by patch interactions. The ryegrass tiller dry weight was significantly greater in the tall patches than in the short patches (41 v 27 s.e. 4 mg). The ryegrass tiller dry weight was similar in short and tall patches during December (36 v 40 s.e.6 mg, $p>0.50$), but in January, the ryegrass tiller dry weight was less in the short than in the tall patches (19 v 43 s.e.6 mg, $p<0.02$), but the month by patch interaction was not significant.

The average tiller dry weight of the other grasses was 19 mg (C.V. 51%)(Table 18). There was no significant differences between Early Control and Late Control (20 s.e.3 v 18 s.e.3 mg), or between December and January (18 v 20 s.e.3 mg). The tiller dry weight of the other grasses was significantly higher in the tall patches than in the short patches (29 v 9 s.e.3 mg). There were no significant treatment by month, treatment by patch and month by patch interactions.

Ryegrass tillers were significantly heavier than other grasses tillers (33 v 19 s.e.2.4 mg, $p<0.0005$).

Table 17. Ryegrass tiller dry weight (mg) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	32	33	14	40	8.7
Late Control	39	46	24	45	9.3

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.3406	0.2444	0.0419	0.8516	0.1396	0.4056

Table 18. Other grasses tiller dry weight (mg) on tall and short patches for early and late control treatments in December and January.

	December		January		
	Short patch	Tall patch	Short patch	Tall patch	SEM
Early Control	7	29	9	36	5.6
Late Control	5	31	13	22	6.0

Significance Pr > F

Month	Treatment	Patch	Month*Tx	Month*Patch	Padd(tx)
0.5927	0.5307	0.0003	0.5407	0.4723	0.5442

4.4. Herbage mass, Utilisation and Accumulation Variability within paddocks.

Analysis of the utilisation and accumulation of herbage were based on the herbage mass change on the sequence of individual sites every 25 cm along the 30 m transects before and after grazing during December and January. The herbage mass was estimated using the pasture probe using the equations calibrated from cut quadrats (Section 4.1). Herbage mass utilisation at each site was calculated as the predicted herbage mass before grazing minus the predicted herbage mass after grazing. Herbage accumulation at each site was calculated as the predicted herbage mass before grazing in January less the predicted herbage mass after grazing in December. Herbage utilisation and herbage accumulation were analysed using regression and frequency analyses.

4.4.1. Spatial pattern of herbage mass

The pattern analysis (TTQLV) did not yield useful information on patch size and it was not further investigated. There was no consistent pattern within paddocks and between paddocks within each treatment. In the profile plots (Appendix 1) a pattern between 1 to 2 m is apparent, but this pattern was not detected by the pattern analysis.

4.4.2. Relationships

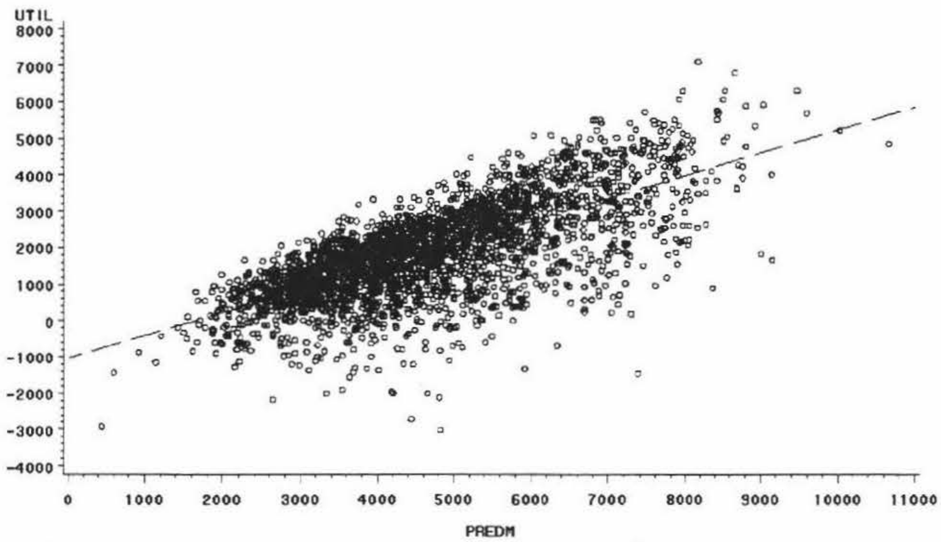
Regression analysis was used to describe the relationships between herbage mass before grazing and utilisation (in kg DM/ha and as a proportion). Regression analysis was also used to describe the relation between accumulation (from December to January) and herbage mass after grazing, and the relation between accumulation and the proportion of herbage mass utilised during December.

4.4.2.1. Herbage mass before grazing and herbage utilisation

There was evidence that an increase in herbage mass before grazing was associated linearly with an increase in the expected value of utilisation of herbage mass (kg DM/ha) (Figure 6). The herbage mass before grazing-utilisation linear model for the entire data set explained 49% of the overall variation. The fitted model and variation explained varied among paddocks and months, but all with the same trend. Test statistics comparing several sets of linear models using paddocks, treatment and month as classes, determined that the statistical fit of data decreased in the following order, paddocks per month > paddock > treatment per month > month > treatment. Slopes of the fitted line varied between 0.53 to 0.75, with different negative intercepts. The variation explained on individual paddocks varied between 16% to 57%. The set of scatter plots for the relation between herbage mass utilisation for all paddocks in December is in Figure 8, and for all paddocks in January in Figure 9.

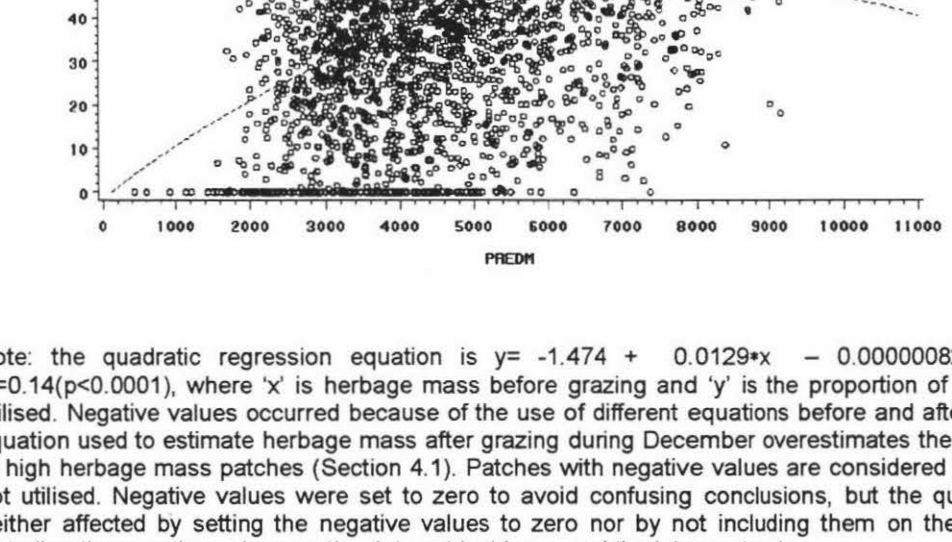
There was evidence that an increase in herbage mass before grazing was associated curvilinearly with the expected proportion of utilisation of herbage mass (Figure 7). Using all data, the quadratic model gave a better fit than the linear model. The herbage mass before grazing-proportion utilised quadratic model explained 14% of the variation. Test statistics comparing different set of linear models determined that the statistical fit of data decreased in the following order, paddocks per month > paddock > treatment per month > month > treatment. Slopes of the fitted line varied between -0.002 to 0.10, with intercepts ranging from –5 to 43. The variation explained on individual paddocks varied between 0% to 33%. The proportion of utilisation can be seen for individual paddocks in December and January in Figures 8 and 9 by taking the dotted line at 50% utilisation as a guideline.

Figure 6. Relationship between herbage mass before grazing (PREDM, kg DM/ha) and herbage mass utilisation (UTIL, kg DM/ha) for the combined data of all paddocks on both Early control and Late control, during December and January.



Note: the linear regression equation is y=0.63 x -1051, adjusted r^2=0.49 (p<0.0001), where 'y' is utilisation and 'x' is herbage mass before grazing. Negative values were the result of different calibrated equations for herbage mass before and after grazing (Section 4.1), and they were considered to be patches that were poorly or not utilised.

Figure 7. Relationship between herbage mass before grazing (PREDM, kg DM/ha) and proportion of herbage mass utilised (PROPUTIL, %) for the combined data of all paddocks on both Early control and Late control, during December and January.



Note: the quadratic regression equation is y= -1.474 + 0.0129∗x − 0.00000082∗x^2, adjusted r^2=0.14(p<0.0001), where 'x' is herbage mass before grazing and 'y' is the proportion of herbage mass utilised. Negative values occurred because of the use of different equations before and after grazing. The equation used to estimate herbage mass after grazing during December overestimates the herbage mass of high herbage mass patches (Section 4.1). Patches with negative values are considered to be poorly or not utilised. Negative values were set to zero to avoid confusing conclusions, but the quadratic fit was neither affected by setting the negative values to zero nor by not including them on the data set. Not including the negative values on the data set just increased the intercept value.

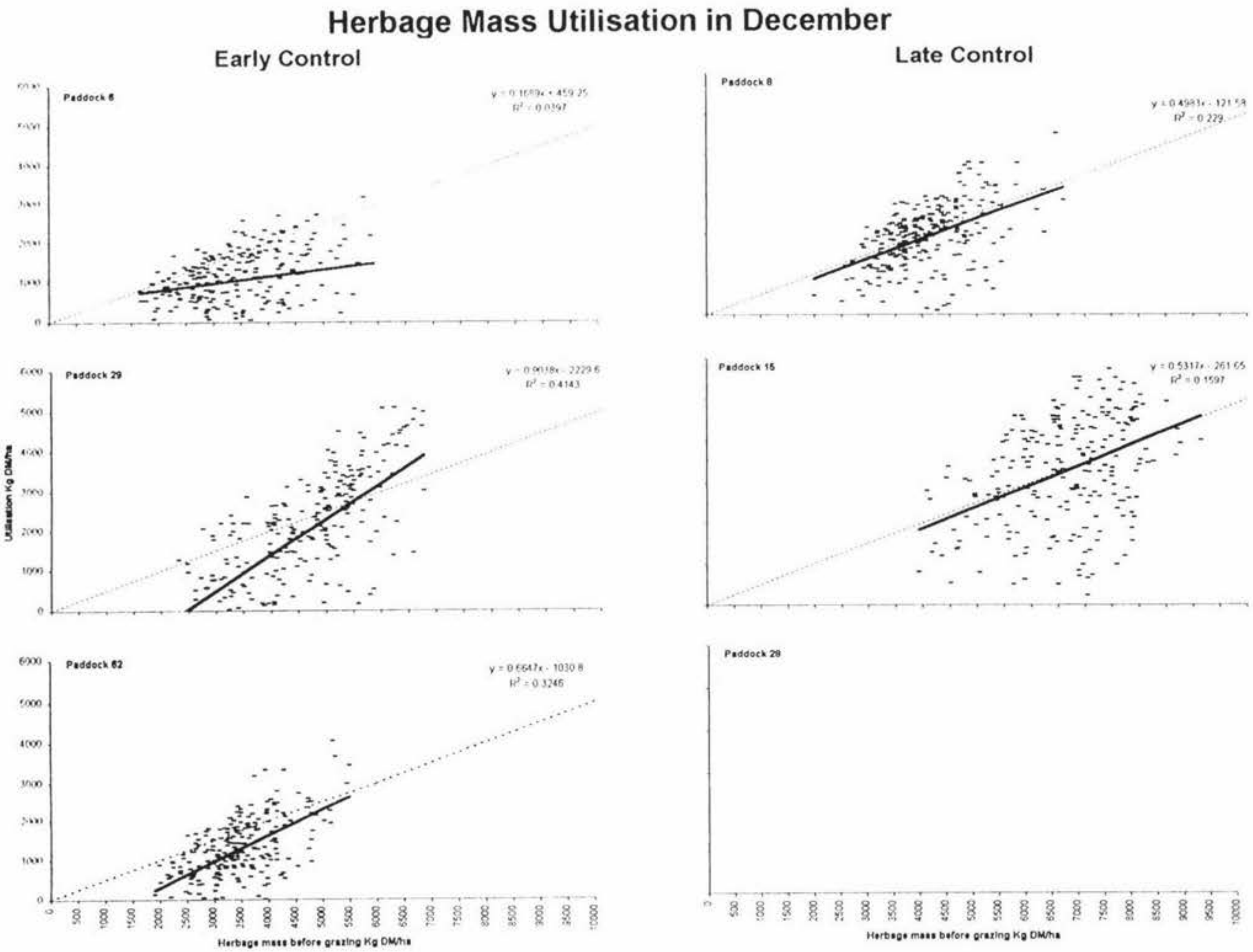


Figure 8. Herbage utilisation in relation to the level of herbage mass in Early control and Late control paddocks during December. The solid line is the regression fitted line showing the average relationship between utilisation and herbage mass. The dashed line represents 50% utilisation at any herbage mass level.

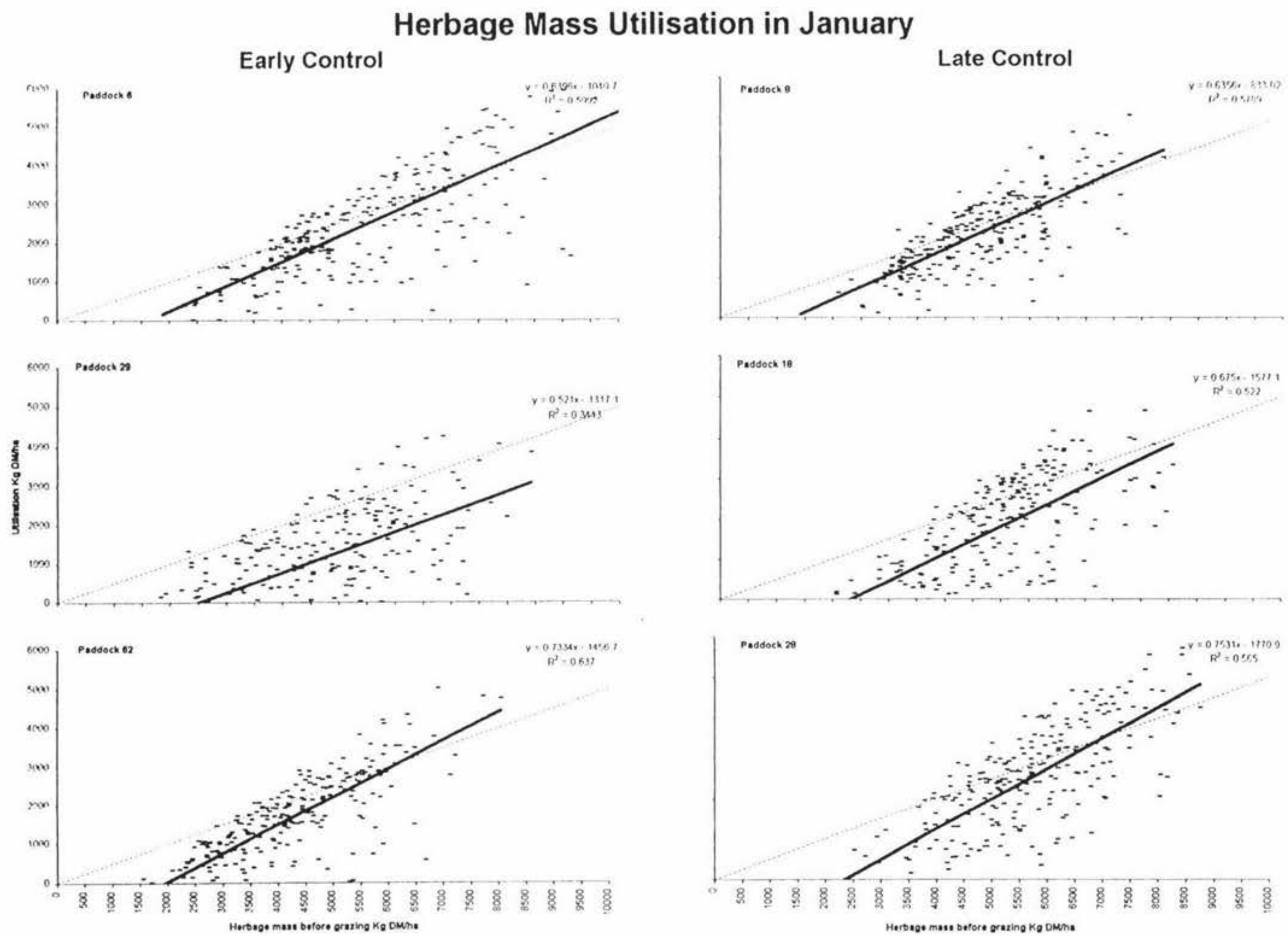
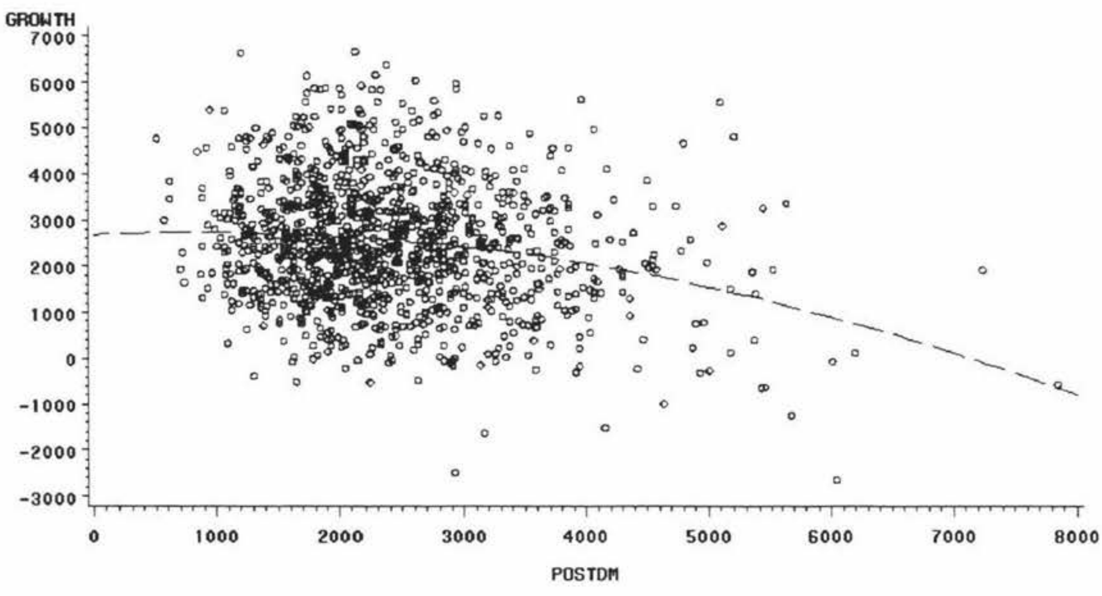


Figure 9. Herbage utilisation in relation to the level of herbage mass in Early control and Late control paddocks during January. The solid line is the regression fitted line showing the average relationship between utilisation and herbage mass. The dashed line represents 50% utilisation at any herbage mass level.

4.4.2.2. Herbage mass residual and herbage accumulation

There was evidence that an increase in herbage mass after grazing was associated with a curvilinear decrease in the expected value of accumulation of herbage mass (total kg DM/ha) (Figure 10). The quadratic model gave a better fit than the linear model. The herbage mass after grazing-accumulation quadratic model for the entire data set explained only 4.3% of the overall variation. Regression lines for individual paddocks gave a better statistical fit. The variation explained on individual paddocks varied between 0% to 14%. The set of scatter plots for individual paddocks is in Figure 12.

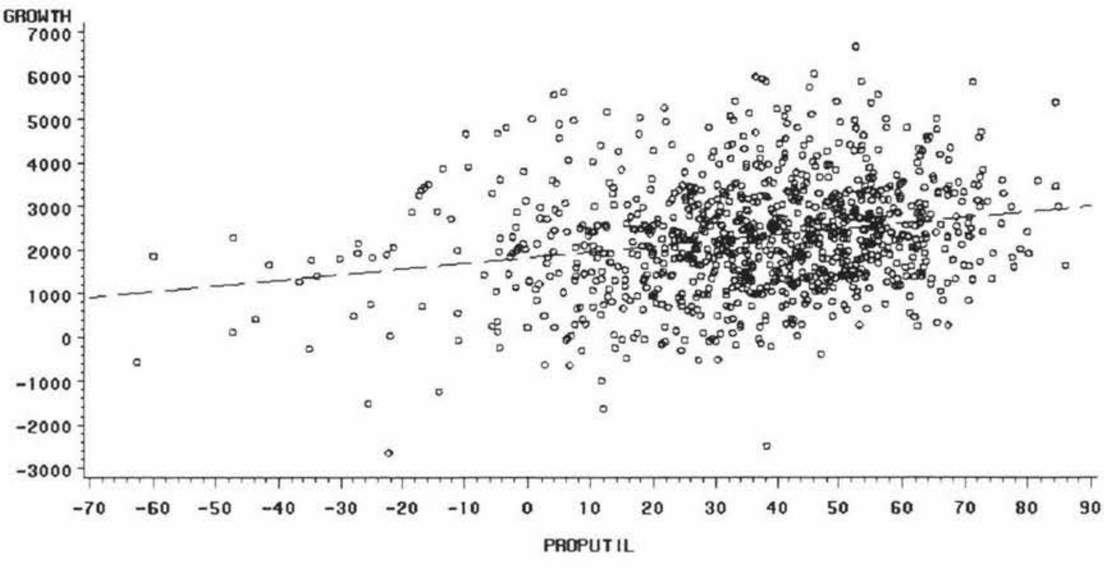
Figure 10. Relationship between herbage mass after grazing (POSTDM, kg DM/ha) and total herbage mass accumulation between grazing periods (GROWTH, kg DM/ha) for the combined data of all paddocks on both Early control and Late control, from December to January.



Note: the quadratic regression equation is $y = 2678 + 0.122*x - 0.00007*x^2$, adjusted $r^2=0.0416$ ($p<0.0001$), where 'x' is the herbage mass after grazing in December and 'y' is the total herbage mass accumulation between grazing periods.

There was evidence that an increase in the proportion of herbage mass utilised (kg DM/ha) was associated with a linear increase in the expected value of subsequent accumulation of herbage mass (total kg DM/ha) (Figure 11). The proportion of herbage mass utilised-total accumulation linear model for the entire data set explained only 5% of the overall variation. Regression lines for individual paddocks gave a better statistical fit. Slopes of the fitted regression lines for individual paddocks varied from 10 to 20 (kg DM/ha per one percentage unit increase), with intercepts ranging between 1200 and 2800 (kg DM/ha). The variation explained on individual paddocks varied between 2% to 15%.

Figure 11. Relationship between the total herbage mass accumulation (GROWTH, kg DM/ha) in response to the proportion of herbage mass utilised (PROPUTIL, %) and for the combined data of all paddocks on both Early control and Late control, from December to January.



Note: the linear regression equation is y=1830 + 13x, adjusted r^2=0.05 ($p<0.0001$), where 'y' is the total herbage mass accumulation and 'x' the proportion of herbage mass utilised. The points on the negative side of the proportion of herbage utilised were not considered influential or outliers and were included in the data set.

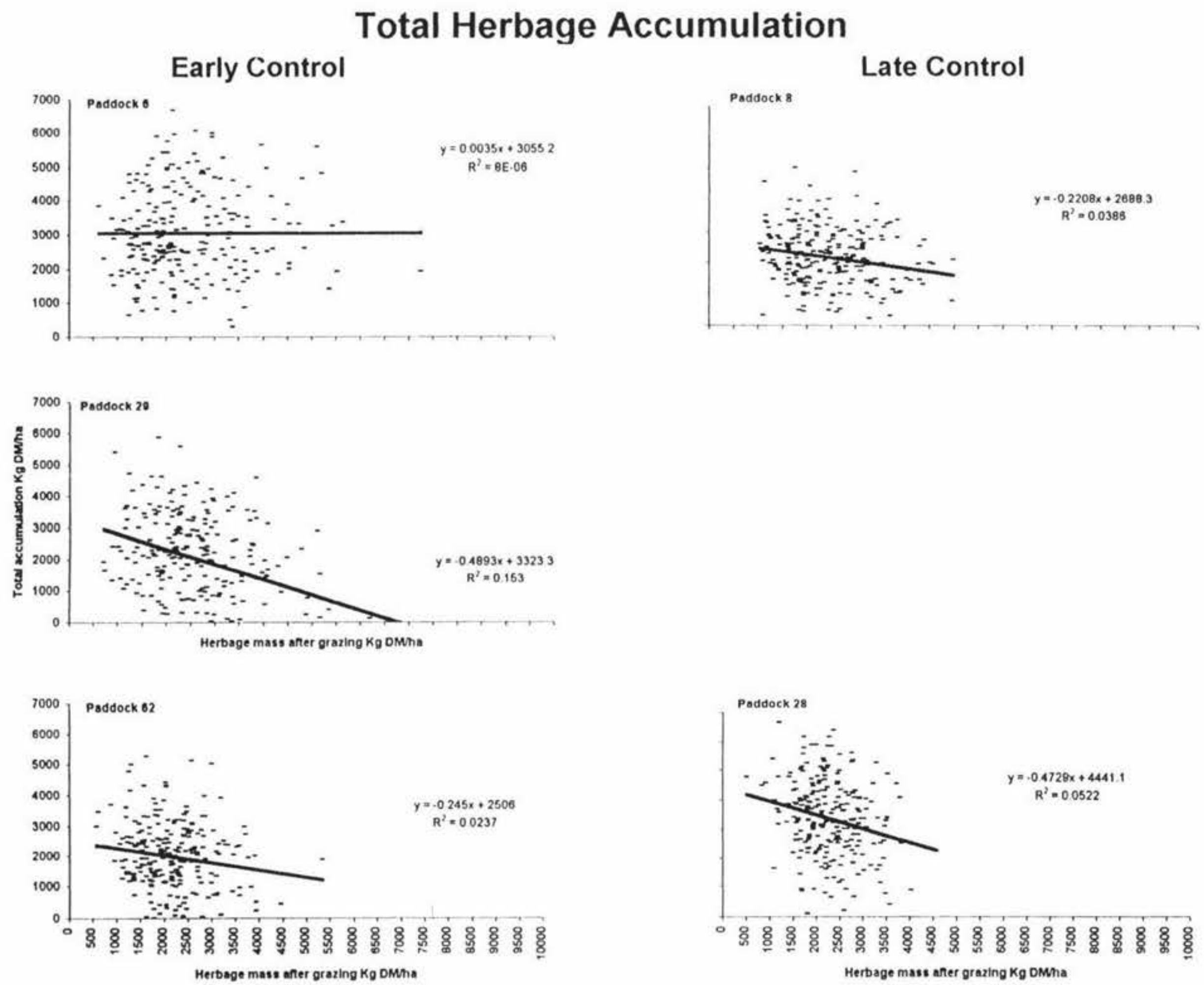


Figure 12. Total herbage accumulation with residual herbage mass in Late and Early control from December to January.

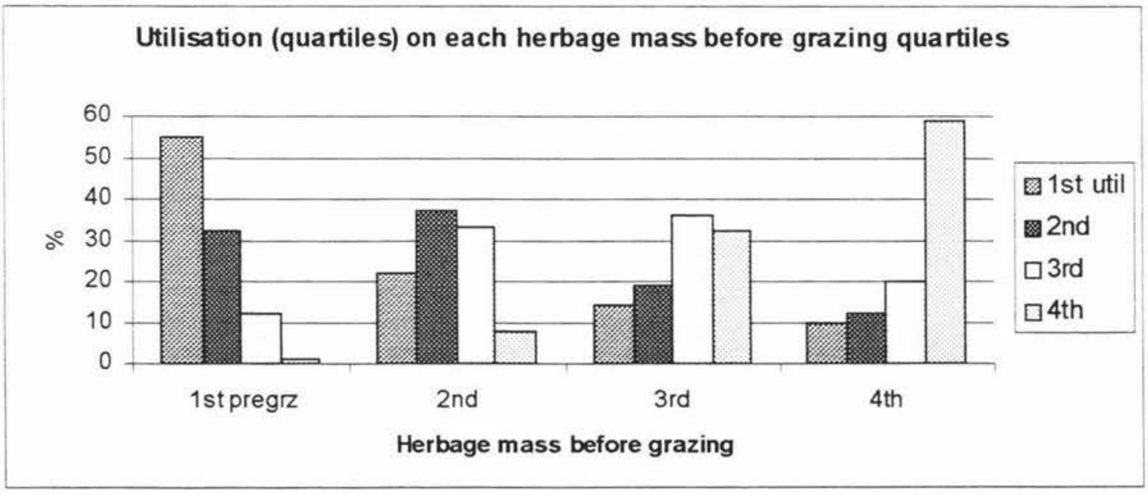
4.4.3. Frequency analysis results

Frequency analysis was performed on the relation between herbage mass before grazing and after grazing, herbage mass before grazing and utilisation (kg DM/ha and proportion), and stability of herbage mass patches from December to January. In the frequency Tables, herbage mass and utilisation distributions (observations from the transects) were grouped into quartiles (1st, 2nd, 3rd and 4th). The quartiles for herbage mass, utilisation or accumulation were determined based on the distribution of estimated values from the 30 m transects on each paddock, on December and January. The frequency analyses presented represent the average of within paddock relations, rather than comparing paddocks under one set of quartile thresholds.

4.4.3.1. Frequency of utilisation levels in relation to herbage mass

The probabilities of four levels of utilisation on herbage mass quartiles are presented in Figure 13. Greater levels of utilisation (kg DM /ha) occur in the top 25% herbage mass patches, and the lowest levels of utilisation occur in the bottom 25% herbage mass patches. The probability of high utilisation declines and the probability of low utilisation increases, as herbage mass decreases.

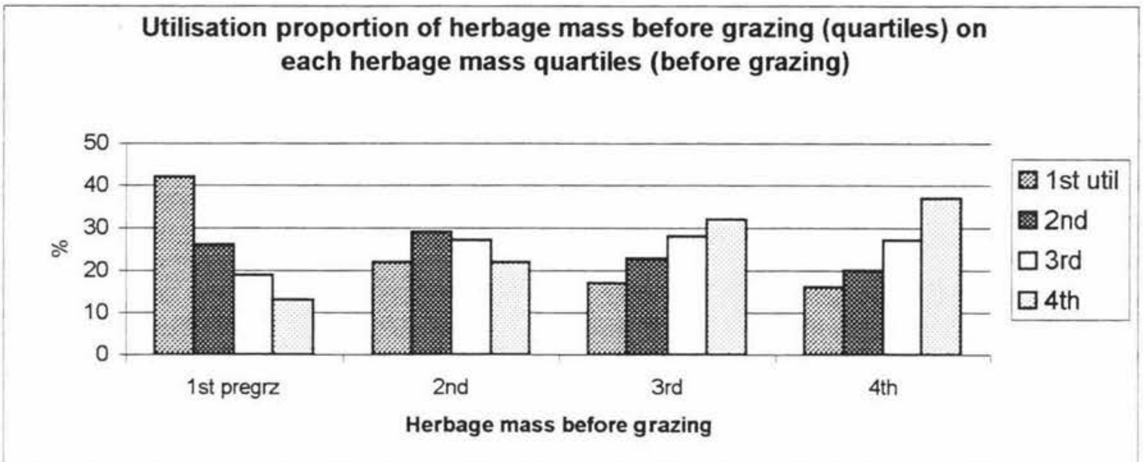
Figure 13. Probabilities of level of utilisation (kg DM/ha) in relation to herbage mass before grazing (kg DM/ha).



Note: in the horizontal axis is the average (between paddocks and months) herbage mass before grazing quartiles (1st=2458-3560, 2nd=3561-4575, 3rd=4576-5745 and 4th=5746-7559 kg DM/ha) and the columns represent the averaged (between paddocks and months) herbage mass utilisation quartiles (1st=0-950, 2nd=951-1800, 3rd=1801-2700 and 4th=2701-4316 kg DM/ha). In the vertical axis is the probability of the herbage utilisation quartiles to occur in each quartile of herbage mass before grazing.

The probabilities of four levels of the proportion of herbage mass utilised on herbage mass quartiles are presented in Figure 14. Higher levels on the proportion of herbage mass utilised (%) occur in the top 25% herbage mass patches, and the lowest levels occur in the bottom 25% herbage mass patches. The probability of high proportion of utilisation declines and the probability of low proportion of utilisation increases, as herbage mass decreases.

Figure 14. Probabilities of the level of utilisation (proportion) in relation to herbage mass before grazing (kg DM/ha).



Note: in the horizontal axis is the averaged (between paddocks and months) herbage mass before grazing quartiles (1st=2458-3560, 2nd=3561-4575, 3rd=4576-5745 and 4th=5746-7559 kg DM/ha) and the columns represent the average (between paddocks and months) proportion of herbage mass utilised quartiles (1st=0-25, 2nd=26-42, 3rd=43-54 and 4th=55-70 %). In the vertical axis is the probability of each one of the proportion of herbage utilisation quartiles to occur in each quartile of herbage mass before grazing.

In Table 19 is presented a summary of each herbage mass quartile, its average herbage contributed (kg DM/ha) and its proportional contribution to the total herbage mass, as well as the average herbage utilised in each herbage mass quartile and its proportional contribution to total utilisation. Also presented is the average proportion of herbage utilised in each herbage mass quartile. The top 50% herbage mass areas contributed 60% of total herbage mass, but the herbage utilisation from this area accounted for 65%. There is a greater contrast between the top 25% and bottom 25 quartiles. The bottom 25% herbage mass quartile contributed 17% of the total herbage mass but only 13% of the herbage total herbage utilised, whereas the top 25% herbage mass quartile contributed 33% of the total herbage mass but 37% of the herbage total herbage utilised. A similar trend is observed for the proportion of herbage utilised in each quartile. It is likely that these proportional contributions of total herbage mass and total utilisation will differ according to the herbage mass distribution characteristics (mean, skewness, standard deviation, and the range between the first and third quartiles, as well as the range of the bottom and top 25% in the distribution).

Table 19. Herbage mass before grazing quartile contribution to the total herbage mass on offer and its utilisation (kg DM/ha and percentage).

Herbage mass before grazing quartiles	Average herbage mass kg DM/ha	Proportional contribution to total herbage mass	Average utilisation kg DM/ha	Proportional contribution to total utilisation	Proportion of herbage utilised in each quartile
1st	3235	17%	966	13%	30%
2nd	4287	23%	1659	22%	38%
3rd	5055	27%	2137	28%	42%
4th	6175	33%	2803	37%	45%
Mean	4734	100%	1894	100%	39%

4.4.3.2. Stability of herbage mass patches from before to after grazing

The frequency of the herbage mass before grazing on each of the herbage mass quartiles after grazing is presented in Figure 15. The bottom and top 25% herbage mass patches before grazing are more likely to remain in the same quartile after grazing, but about half migrates to other quartiles in decreasing proportions on the opposite direction. For those patches in which herbage mass before grazing is in the middle 50% range, they have almost the same probability to migrate to any quartile after grazing.

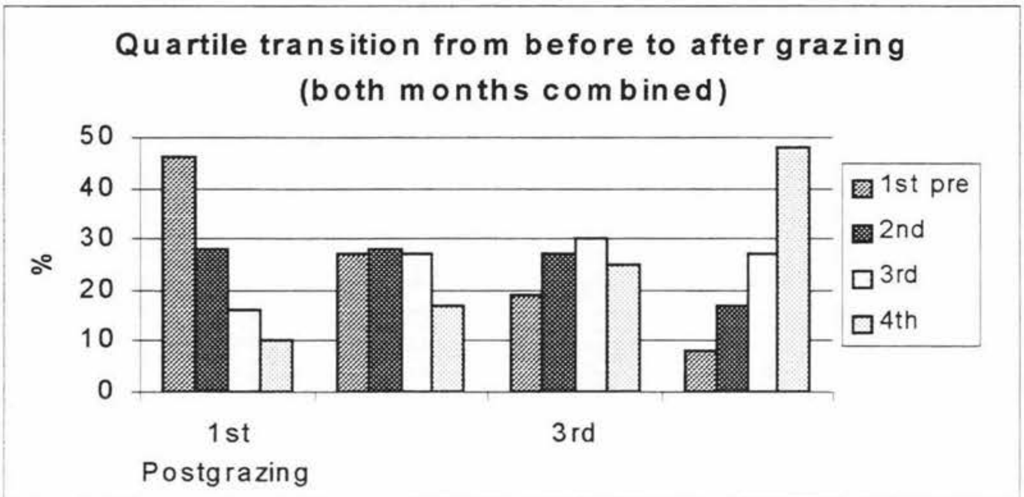
4.4.3.3. Stability of residual herbage mass patches to the next grazing period

The likelihood of a patch to remain in the same herbage mass quartile (according to the sampled population) after one regrowth period was greater in the top and bottom 25% herbage mass patches (Figure 16). The patches in the 25-50% range of the herbage mass distribution were more likely to shift between quartiles, but the majority remained on their same side from the median.

4.4.3.4. Stability of herbage mass patches before grazing from one grazing period to the next

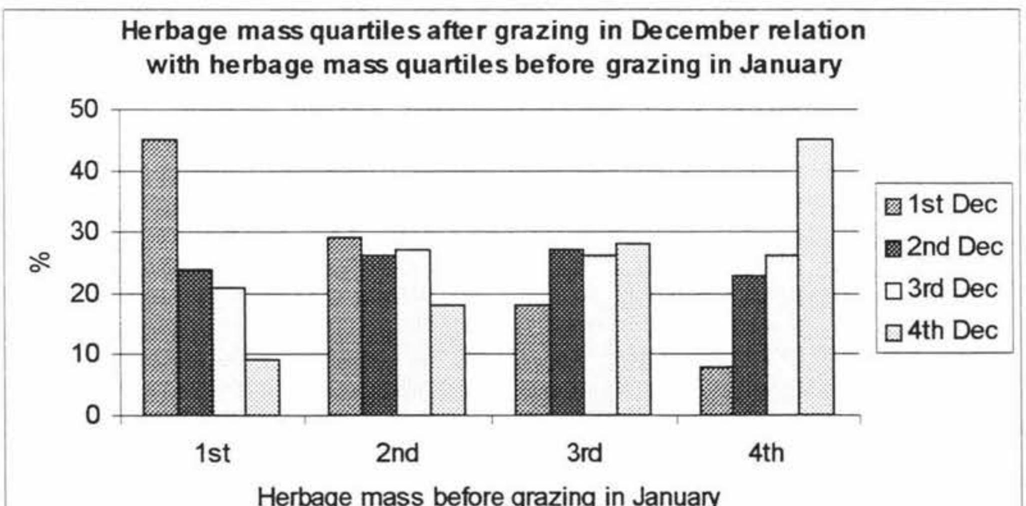
The stability of patches (herbage mass) before grazing from December to January is shown in Figure 17. In the top and bottom 25% herbage mass patches, 45-50% of the number of measured sites stayed in the same quartile, and decreasing proportions of sites migrated to the opposite direction. In the 50% middle range, close to 55% remain within the two middle quartiles, while the rest distributed similarly between the rest of the quartiles.

Figure 15. Stability of patches during one grazing period, from before grazing to after grazing.



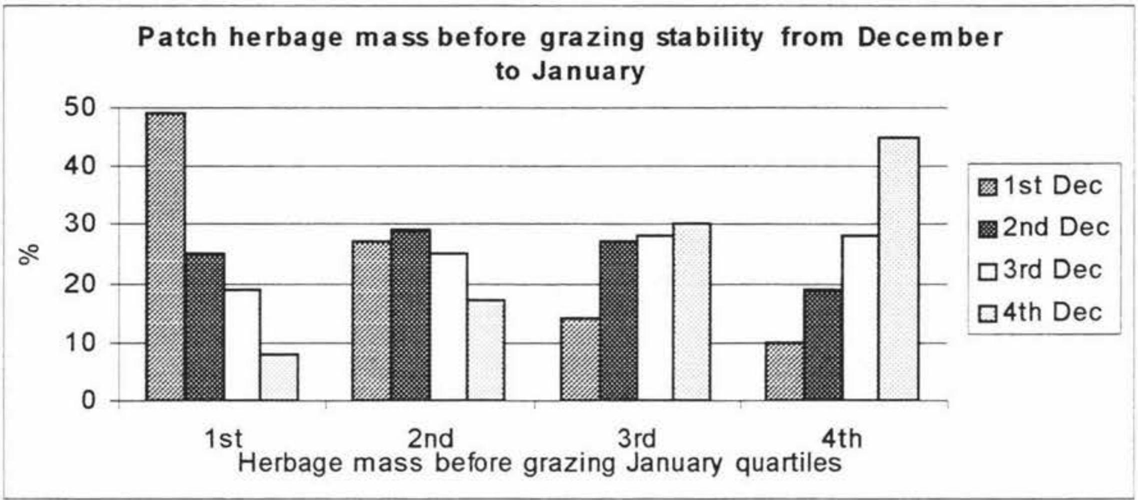
Note: the chart shows the probabilities of a patch in one quartile of herbage mass before grazing to stay in the same quartile after grazing or to move into another quartile. In the horizontal axis are the averaged (between paddocks and months) quartiles of herbage mass after grazing (1st=1454-2117, 2nd=2118-2741, 3rd=2742-3558 and 4th=3559-7559 kg DM/ha). The columns represent the averaged (between paddocks and months) quartiles of herbage mass before grazing (1st=2458-3560, 2nd=3561-4575, 3rd=4576-5745 and 4th=5746-10665 kg DM/ha). In the vertical axis is the probability of quartiles of herbage mass before grazing to occur in each quartile of herbage mass after grazing after one grazing period.

Figure 16. Stability of patches after one regrowth period from after grazing in December to before grazing in January.



Note: the chart shows the probabilities of a patch in one herbage mass quartile to stay in the same quartile after one regrowth period or to move into another quartile. In the horizontal axis are the averaged (between paddocks) herbage mass before grazing quartiles in January (1st=2500-3900, 2nd=3901-5000, 3rd=5001-6000 and 4th=6001-7800 kg DM/ha). The columns represent the averaged (between paddocks) herbage mass after grazing quartiles in December (1st=1200-1940, 2nd=1941-2570, 3rd=2571-3500 and 4th=3501-5600 kg DM/ha). In the vertical axis is the probability of quartiles of herbage mass after grazing to occur in each quartile of herbage mass before grazing after one regrowth period.

Figure 17. Stability of patches from December before grazing to January before grazing.



Note: the chart shows the probabilities of a patch in one quartile of herbage mass before grazing to stay in the same quartile from one grazing period to another (from December and January). In the horizontal axis are the averaged (between paddocks) quartiles of herbage mass before grazing in January (1st=2500-3900, 2nd=3901-5000, 3rd=5001-6000 and 4th=6001-7800 kg DM/ha). The columns represent the averaged (between paddocks) quartiles of herbage mass before grazing in December (1st=2400-3300, 2nd=3301-4200, 3rd=4201-5200 and 4th=5201-7300 kg DM/ha). In the vertical axis is the probability of quartiles of herbage mass before grazing during December to occur in each quartile of herbage mass before grazing During January.

Chapter 5. Discussion

5.1. Experimental Techniques

The use of the Pasture Probe capacitance meter for estimating herbage mass was preferred over other methods because of the ease of recording individual readings and downloading to a computer. The pasture probe had good accuracy in the estimation of herbage mass on individual paddock measurements and on tall reproductive pastures. The pasture probe had some problems to estimate herbage mass accurately between patches of extremely different dead matter content, but this occurred occasionally within paddocks, and did not have major effects on the results.

The expected problem in describing tall and short patches by their herbage mass was a potential overlapping of herbage mass values between the two populations, depending on the extent of plant size-density compensation, but this happened only occasionally, and the distinction of herbage mass between tall and short patches was very clear (Tables 6 and 7). Tall and short patches were selected visually for sampling (Section 3.3) and they represented the shortest and tallest patches within a paddock. Mid height patches were not sampled and were assumed to be a transition between short and tall sites. Herbage mass overlapping between short and mid height patches, and tall and mid height patches must have occurred, but to an extent related to within-paddock variability (Section 4.3). This probably happened because plant weight or herbage mass can have more variability than plant height within the same plant population (Hara, 1993).

Microsite sampling rather than strict random sampling requires careful interpretation at the paddock level for main effects (Matthew et al., 1995) because the sampled microsites might not represent proportionally, the higher levels of plant communities organisation. Microsite sampling causes very well defined differences between the two sampled populations (Matthew et al., 1995). The general lack of statistical differences between treatments in botanical composition (Section 4.3.2) and tiller population (Section 4.3.3) is probably because of the similarity of sampled tall and short patches between treatments. When tall and short patches were averaged in the analysis of variance, the average did not represent the proportion of occurrence of tall and short patches within each treatment.

The comparison between treatments can be difficult in system trials if paddocks within the farm reflect inherent differences in soil characteristics or soil fertility, and associated differences in botanical composition and productivity. The sampled paddocks need to be balanced according to the farm situation (Section 3.2). Because in this experiment the sampled paddocks were not balanced, in the analysis of variance the error term to test treatment effects was specified to be paddocks within treatment. Conclusions drawn from the analysis of variance were therefore conservative for treatment effects on botanical composition and tiller population.

The quadrat variance pattern analysis (TTQLV) did not yield useful information. Small patterns on the spatial herbage mass distribution did not produce clear variance peaks. One possible reason for this may have been the presence of larger patches with a smaller scale of patches within them (Dale and MacIsaac, 1989). The great intensity of variance at larger scales of patchiness may smooth or nullify peaks of variance at smaller scales. This was apparent in the profile plots (Appendix 1), were there was great variability within 1 to 2 m, within a larger scale of 10 to 25 m. It is possible that greater variance at the smaller scale was amplified by the pasture probe capacitance meter in which the diameter of measurement is about 10 cm, and it is very sensitive to variability at that scale. As pasture probe measurements were taken every 25 cm, the error at that scale might have increased.

As a general rule transects must be about four times the length of the scale which is desired to be detected (Turner et al., 1991). To detect small scales of variance it would have been better to have at least four replicate transects. It is probable that the 30 m length transects used in this experiment were not long enough to determine if there was a pattern of herbage mass above 10 m due to low degrees of freedom. To detect a pattern at a smaller scale using the capacitance meter as the herbage mass predictor, it probably would have been better to have shorter and more transects, and have measurements done every 10 cm. Another problem was that in some paddocks conclusions drawn from the two transects were different. In those paddocks there was a large scale of herbage mass heterogeneity, and two 30 m length transects were not enough to detect a pattern at that scale.

For these two reasons it was decided not to continue the analysis of pattern in the transects. Among the analyses that were planned was the Patch-gap analysis which gives information on the size of patches (above a threshold) and gaps (below a threshold). It was also the intention to evaluate the evolution of patches, their location and their size across time, during a grazing period and from one grazing period to the next. In the profile plots (Appendix 1) it can be appreciated that the spatial pattern of herbage mass within the transects is in qualitative terms maintained after grazing, and from one month to another after one regrowth period.

5.2. Effectiveness of Management Strategies

Early spring was colder and wetter than average and the pasture growth rates were low, and the average pasture cover on Early and Late control treatments was similar until supplements were given in the Late control treatment from late October to November 1995. About 26 tons of extra DM as supplements of carrots or brewers grain (about 216 kg per cow) were added to the Late control farmlet. During this period, supplements constituted about half the cows dry matter intake requirement. As a consequence, average pasture cover increased in the Late control farmlet during that period. Weather conditions improved during November and pasture cover increased on the Early control farmlet as well, but not as much as on the Late control farmlet.

Swards in both treatments exceeded the pasture cover targets during December (Section 3.2). Greater mean herbage mass during December in Late control than in Early control was required to allow some reproductive development. Targets were established as average pasture cover on farm, and not in herbage mass before and after grazing on each paddock. The farmlet pasture cover was targeted at 2700 kg DM/ha in the Late control farmlet before the control phase, in contrast to 2000 kg DM/ha targeted for the Early control farmlet. Average pasture cover was not measured in this experiment, but it was estimated from the average between the mean herbage mass before grazing and the mean herbage mass after grazing during December on sample paddocks (Table 3), assuming that these averages before and after grazing were similar on the paddocks within each farmlet. The estimated average pasture cover in total DM in Late control in December was approximately 4050 kg DM/ha and in Early control it was 3100 kg DM/ha. Total herbage mass is often underestimated by visual assessment during the late spring-early summer period 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 to pasture targets (Butler, 1986). The live material proportion in December was 70% of the total herbage mass (Section 4.3.2), therefore the average green pasture cover in Late control in December was around 2800 kg green DM/ha and in Early control was around 2200 kg green DM/ha.

The control of reproductive growth was achieved effectively during December on the Late control treatment by a combination of grazing and then topping after the cows had grazed. Cows were not pushed to graze very low in the Late control treatment to avoid herbage intake limitations and a drop in milk production. Even though cows were not pushed to graze too low, the total herbage removal was greater in Late control than in Early control. Greater herbage removal in Late control was possible because of the greater herbage mass before grazing than in Early control. Pasture morphological and structural characteristics in herbage mass before grazing (Section 4.3) were in general not an impediment for efficient removal of herbage in Late control at the grazing pressure used. Increasing grazing pressure would have increased total herbage removal further, but possibly at the cost of a reduced intake at the end of the grazing period in each paddock which would have caused day to day variation in milk production and a decrease in total production. The consequences of not pushing the cows to harvest more pasture caused just a minor increase in the mean herbage mass after grazing compared to Early control (Table 3), but the standard deviation (Table 4) and the skewness were greater on Late control paddocks (Table 5 and Figure 2) reflecting a more variable distribution of herbage mass.

Pasture production was increased by Late control compared to Early control (Section 4.2.1). On average, herbage residual was similar after grazing in December in Early control and after topping in Late control, but herbage mass before grazing in January was 34% greater in Late control than in Early control (Table 3). The difference in accumulation was not significant but the trend found in this experiment agrees with previous reports on Late control (Matthew, 1991; Da Silva, 1994; Hernández-Garay, 1995)

During January, paddocks in both treatments were well above the pasture cover target of 2000 kg DM/ha (Section 3.2). The average pasture cover obtained from the average between the mean herbage mass before grazing and the mean herbage mass after grazing was 3850 kg DM/ha in Early control and 4800 kg DM/ha in Late control of total dry matter, but 2695 kg DM/ha in Early control and 3360 kg DM/ha in Late control of green dry matter after adjusting for 30% of dead material (Section 4.3.2*)*. Pasture growth rates during late December and January were presumably greater than average due to good soil moisture conditions (85 kg DM/ha per day in Early control and 120 kg DM/ha per day in Late control. This suggests that targets may have to be defined better.

Topping was effectively used in Late control paddocks to reduce the variability of herbage mass after grazing, and to guarantee full control of reproductive growth. The mean (Table 3), standard deviation (Table 4) and skewness (Table 5) of the herbage mass after grazing decreased after topping, even if topping was done relatively high (7-10 cm) and removed only 300 kg DM/ha by trimming just the tops of tall patches present after grazing and generally leaving short patches intact. After topping, mean herbage mass of Late control paddocks became similar to the mean herbage mass after grazing in Early control, and standard deviation and skewness became lower in Late control than in Early control (Section 4.2.1 and 4.2.2). High herbage mass patches that were trimmed after grazing were in general patches that were tall and of high herbage mass before grazing (Compare Figures 2 and 3, see Table 15), and likely to have higher dead matter content (Table 8), more stemmy grass (Table 11) and greater proportion of reproductive tillers. Topping removed the tops of these tall stemmy patches and reactivated their structure (Table 11), herbage quality and regrowth. The importance of topping to control tall stemmy patches is mainly because even at high grazing pressures animals will not defoliate them efficiently enough (Figure 14) to improve their structure and net growth. In Early control during this experiment, this type of tall stemmy patch was not controlled despite greater grazing pressures than in Late control. In contrast to Late control, topping was not used in Early control, and therefore efficiency of topping can be evaluated by comparing the fate of tall stemmy patches that were trimmed or not, on their effects on herbage mass distribution and on their structural and botanical composition (discussed in Section 5.3.2).

5.3. Pasture Differences between Management Strategies

A farm can be viewed as a set of paddocks, and a paddock is a conglomeration of patches. Patches within a paddock may be different in their structure and botanical composition in response to the history of defoliation and regrowth events that they have experienced. This section aims to compare the herbage mass distributions between Late control and Early control and identify their changes across time due to grazing management, and their relation with botanical composition and morphological and structural characteristics.

In theory, frequency distributions can change their characteristics through time when the population under study is subject to time dependent processes (Westoby, 1982; Hara, 1984). Under rotational grazing, herbage mass distribution and its variability within a sward at one point in time and its change through time, depends on the characteristics of utilisation and accumulation. The effects of Late and Early control on utilisation and accumulation are also discussed in this section.

5.3.1. Pasture Characteristics in December

Lax grazing before December in the Late control paddocks resulted in greater mean herbage mass than in Early control, but similar standard deviation. There were differences in the skewness of the herbage mass distribution between paddocks but not related to treatments (Figure 1 and Tables 3,4,5). No detailed pasture measurements were done before December but it is assumed that greater herbage mass in Late control was a combination of greater herbage residuals and longer rotation length for at least two grazing periods before December control (Section *3.2*). Because the standard deviation was similar between treatments (Table 4), it is assumed that herbage accumulation was occurring at greater rate in Late control than in Early control but with similar variability between patches of the same herbage mass and between patches of different herbage mass on each paddock. Differences in the herbage mass distribution before grazing in December were probably the result of these different pasture growth rates between Late control and Early control, plus the different residual herbage mass distribution characteristics that may have existed on past grazings.

There were no strong botanical composition (legume and grasses) differences attributable to Early or Late control (Tables 9 and 10), but there were differences between paddocks within treatments. The paddocks sampled in this experiment had been under Early or Late control for two previous seasons, and it can be questioned if management effects on the botanical composition prevail past the winter and early spring (Thórhallsdóttir, 1990a), or if botanical composition is more related to particular paddock characteristics (soil type, fertility, topography) (Matthew et al, 1988). Ryegrass content in December was 71 % (Table 10) in the grass fraction and 55% in the live material. The legume content averaged between short and tall patches was 23% (Table 9).

The different grazing intensity between management treatments before December control, caused pasture morphological differences between treatments. In the laxer grazing management of Late control there were less ryegrass tillers (Table 13) but heavier (Table 17) than in Early control. There were no differences between treatments on other grasses morphology (Table 14 and 18). Therefore there were signs of tiller size-density compensation in response to the intensity of defoliation before December.

The sampled short and tall patches had similar average herbage mass between treatments (Table 6), and no strong botanical composition differences (Table 9 and 10), but there were different morphological characteristics between patches (Table 13, 14, 17 and 18), reflecting the variability in the intensity of defoliation within a paddock on both treatments, and the stability of patches (Figures 15, 16 and 17). The greater tiller numbers in Early control applied for both tall and short patches between treatments. There were more total ryegrass tiller numbers in tall patches than in short patches, and the tiller weight was similar between patches in Early control, but in Late control the tiller weight was greater in tall patches than in short patches. Tall patches are often related to greater soil nutrient availability than average (Coughenour, 1991), and this may have improved tillering as well. Greater tiller numbers in tall patches than in short patches may have also been related to greater reproductive tiller development and increased production of daughter tillers (Matthew et al., 1989). Greater tiller weight in tall patches in Late control may be due to greater carbohydrate storage due to laxer defoliation or simply an effect of the average weight between heavier reproductive tillers and greater number of daughter tillers. Lax grazing during late spring increases the number of daughter tillers at the base of reproductive tillers (Matthew et al., 1989). Ryegrass tillers were in all cases heavier than other grasses tillers, probably showing that ryegrass was the dominant grass component. The 29% contribution of other grasses to the grasses herbage mass fraction (Table 10), was related to 58% of the total tiller numbers in short patches, while in tall patches other grasses tiller proportion was 40%. Other grasses tillers were not much lighter than ryegrass tillers in tall patches (Tables 17 and 18).

Also reflecting the different grazing intensity between treatments, the stem proportion in ryegrass tillers was greater in Late control than in Early control (Table 11). In Late control the stem content in ryegrass was not so different between short and tall patches, but in Early control the stem content in ryegrass was slightly greater in tall patches. The stem content of ryegrass was significantly greater in the short patches under Late control than in Early control. Stem content may also be the result of longer periods of regrowth in both tall and short patches in Late control and in tall patches in Early control, which resulted in greater height or herbage mass before grazing (Table 6). Stem content (pseudostem) in the short patches under Early control was 29% of the ryegrass content, compared to 36% in tall patches (Table 11). Considering also the greater tiller population in the short patches than in tall patches, we can assume that the grazing intensity in short patches was greater than in tall patches in Early control. Stem proportion on the ryegrass on Late control was 42%. Therefore, grazing intensity was laxer before December in Late control than in Early control, although in Early control tall patches are presumed to have not been grazed as hard as the short patches.

Dead matter content was not very different between patches and treatments during December, only 3 percentage units greater in tall patches than in short patches (Table 10). This may be an indication of a similar level of defoliation according to the herbage structure on both patch types under both treatments in the past (at least for the sampled patches). Lax grazing in Late control was probably not long enough to increase dead matter content over that in Early control before December, in part because length of the lax grazing was similar to the leaf life span (Parsons and Penning, 1988). Dead matter content was similar to that reported previously in similar pastures during the same season (Butler, 1986).

For December, there is no need to make inferences about average sward composition in Early and Late control from sampled tall and short patches because botanical composition was similar between patches. But for morphological differences and structural characteristics it is worthwhile to note that sampled tall and short patches represented different proportions of the sward on different paddocks (Figure 1). In general, during December sampled tall patches represented a greater area of the sward in Late control than in Early control (55% vs. 23% in average but variable between paddocks, see Figure 1). On the contrary, short patches represented in general a greater area in Early control than in Late control swards (55% vs. 28% in average but variable between paddocks, see Figure 1).

Average herbage mass utilisation (kg DM/ha) was greater in Late control than in Early control (Table 3), because of greater herbage mass before grazing and greater grazing pressure. But pasture herbage mass distribution and presumably botanical composition (Arnold, 1987) and sward structure characteristics, had an effect on the within paddock herbage mass relation with utilisation (Section 4.4.2.1 and Figures 6, 7 and 8), making the harvesting of herbage more efficient in the taller and less skewed Late control swards.

The relation between herbage mass and the level of utilisation (Figure 8) shows why harvesting was high in Late control. In Late control paddocks the average proportion of utilisation of patches at any herbage mass was close to 50%, reflecting the greater herbage mass before grazing, and less skewness in those paddocks (Figure 1). Whereas in Early control there was not a uniform relation in the utilisation of herbage mass between paddocks, reflecting pasture differences. In paddock 6 tall patches were utilised in less proportion than short patches, whereas in paddock 29 tall patches were utilised in greater proportion than short patches. Although both paddocks had similar herbage mass mean and skewness, paddock 29 had more area covered with less than 2500 kg DM/ha than paddock 6 (about 25 vs. 5%), and grazing pressure was less in paddock 29 because its paddock size was greater. Patch quality and botanical composition might also have affected the relationship as herbage mass mean and skewness were similar. In paddock 62 average proportion of utilisation was below 50% at any level of herbage mass, showing the effects of low herbage mass levels. The variability in utilisation in relation to herbage mass was not very different in Late control paddocks (except paddock 15) and Early control paddocks, and therefore this variability is assumed to have had the same effect on both treatments (Figure 1).

In absolute terms, cows generally obtained more herbage mass from tall patches than short patches in all paddocks (Figure 6 and 8). Cows were able to remove similar herbage mass from other lower herbage mass patches than from tall patches, although the probability of this happening was lower (Figure 13). The average contribution to utilisation by low herbage mass and high herbage mass areas of the sward is presented in Table 19. The top 25% herbage mass areas in a sward contributed two times more herbage mass than the bottom 25% herbage mass areas, but the top 25% herbage harvested was three times more than the bottom 25%.

More half-day grazings were needed in Late control than in Early control to efficiently harvest pasture (4.0 vs. 2.3 feeds)(Section 3.2), and bring herbage mass after grazing to a similar level (Table 3). As a consequence, herbage allowance was less in Late control than Early control during the control phase (51 vs. 67 kg DM per cow, but variable between paddocks) and the average herbage mass offered per feed in Early control was greater than in Late control. The average herbage mass available per feed in Early control was around 1565 kg DM/ha (3600 kg DM/ha mean herbage mass divided into 2.3 meals) whereas in Late control it was 1250 kg DM/ha (5000 kg DM/ha mean herbage mass divided into 4 meals) (Table 3). But herbage harvested was greater in Late Control than in Early control. In Early control paddocks an average of 434 kg DM/ha was removed per meal, whereas in Late control paddocks an average of 475 kg DM/ha was harvested in each meal, (calculated as [total herbage removed kg DM ha / No. meals]). This data shows how greater grazing pressures in Late control allowed for greater and more efficient herbage removal than in Early control, and resulted in similar herbage residual (Table 3). This may be the effect of higher herbage height (Laca et al., 1992) in Late control pastures, even if they were in reproductive growth stage.

The characteristics of herbage mass after grazing (Figure 2) were the result of the herbage mass characteristics before grazing and the type of relation between herbage mass and its utilisation. Greater skewness of the herbage mass distribution after grazing in Late control than in Early control and therefore greater patchiness, was caused by greater levels of herbage mass before grazing (Table 3, Figure 1), and because of variability of utilisation in relation to herbage mass (Figure 8). Even if Late control pastures had greater grazing pressure than in Early control, it was not enough to harvest more pasture (McCall et al., 1986) and herbage mass levels after grazing mass levels were greater than in Early control. But under the half-day grazing system exerted in this experiment and the fixed paddock size, it was not possible to have one more grazing without the risk of forcing the cows to eat too low and eat old material, with the risk of a drop in milk production. Those high herbage mass patches that were poorly utilised were likely to have been stable before December. The stability of tall patches (top 25%) from before to after grazing was estimated to be close to 50% of patches that remained in the same category (Figure 15).

Pasture accumulation was in absolute terms greater in Late control paddocks than in Early control paddocks (Section 4.2.1), but there was variation between paddocks within treatments (Section 4.4.2.2). Differences between paddocks may have been the result of variation in herbage mass after grazing (Figure 2) and the date when they were last grazed (Table 1) and its interaction with environment. Within paddock variation of herbage accumulation was great, and poorly correlated to residual herbage mass (Figure 10) or the proportion of herbage utilised (Figure 11). This was not surprising because the proportion of utilisation in relation to herbage before grazing was variable (Figure 14). This might have caused very different residual leaf area index between patches of similar herbage mass level, depending on their herbage mass level before grazing and their proportion of utilisation. Individual patches regrowth might have been further altered by dominant species and their response to environment and defoliation, nutrient availability and/or carbohydrate storage, and increased tillering and leaf elongation in some patches over others.

5.3.2. Pasture Characteristics in January

Pasture characteristics during January were different to those during December in both treatments. Characteristics of herbage mass distribution, botanical composition, sward morphology and structure were influenced by those in December, plus the characteristics of defoliation and accumulation. There were differences in pasture characteristics between Late and Early control during January.

Greater herbage residuals (Figure 2, paddock 8) or greater accumulation rate in Late control (Figure 12, paddock 28) than in Early control, resulted in a greater herbage mass mean in Late control than in Early control paddocks during January (Table 3 and Figure 4). The standard deviation increased from December to January (Table 4). The standard deviation in January was similar between Late and Early control (Table 4), because the high variability of herbage accumulation within paddocks was similar between paddocks in both treatments (Figure 10, 11 and 12), and independent of the rate of growth (Figure 12).

In January, skewness of the herbage mass distribution before grazing was less in Late control than in Early control paddocks. Skewness of the herbage mass distribution before grazing decreased in Late control from December to January (Figures 1 and 4), reflecting the effects of decreasing the skewness of herbage mass after grazing in December by topping pastures after grazing (Table 3 and Figure 3). Skewness of the herbage mass distribution before grazing was similar in Early control between December and January (Table 5, Figures 1 and 4). Therefore, It was observed that skewness of herbage mass after grazing can affect the skewness of herbage mass before grazing in the next grazing period, although positive skewness can decrease depending on the accumulation relation with herbage mass.

Despite the great variability within paddocks in herbage accumulation (Section 4.4.2.2), about 45% of tall patches (top 25%) and short patches (Bottom 25%) before grazing in December, remained as tall or short patches before grazing in January (Figure 17), after one defoliation event (Figure 15) and one regrowth period (Figure 16). These are results obtained from sites measured independently every 25 cm, but they are related with neighbour patches to form patches on a greater scale, and those patches are likely to be even more stable in the short term (see Appendix 1).

There were changes in botanical composition, pasture morphology and sward structure in response to Late and Early control, which occurred during the regrowth period from December to January. In January, the sampled short patches in Early control represented the bottom 20 to 40% herbage mass patches covering the sward area, and sampled tall patches represented the top 45 to 25%. The sampled short patches in Late control represented the 10 to 20% lowest herbage mass patches in the herbage mass distribution, while tall patches represented the area of herbage mass patches in the middle of the range of the distribution, generally between above 30% and below 70% of the herbage mass values (Figure 4). Tall patches to be sampled in January were chosen among the tallest patches after grazing in December (Section 3.3), and were probably trimmed at topping of pastures in Late control. The highest herbage mass patches in January must have been primarily patches that were little or not affected after topping and kept higher leaf area index than those trimmed patches. Consequently, they grew faster, and changed their position in the herbage mass distribution from the middle range in December to the top 25% in January (Figure 16 and 17). These patches are assumed to have had similar botanical composition and morphological changes to trimmed tall patches after grazing in December. Therefore it can be inferred that average botanical composition in Early control during January is the average of sampled tall and short patches, while in Late control the average composition is represented by 1/3 short patches and 2/3 tall patches (see Figure 4). Herbage mass of sampled short patches was similar between treatments, but herbage mass of sampled tall patches was greater in Early control than in Late control (which were trimmed) (Table 6).

Legume content (vs. grasses in live material) increased from December to January in short patches caused by a season effect. In contrast, legumes content decreased during January in tall patches under both treatments in proportion (Table 9) and absolute terms associated with an increase in grass content. Then short patches had more legume content than tall patches in both treatments. Stolon weight (g/m^2) increased in both short and tall patches (Table 16), but more in short patches.

In tall patches there was an increment in the grasses proportion, but in Late control it was associated with an increase in ryegrass content and a decrease in the other grasses content, while the opposite occurred in Early control (Table 10). The increment in ryegrass content in Late control tall patches was associated with an increase in ryegrass tiller numbers (Table 13) but with similar tiller weight to that in December (Table 17). In Early control, decrease in ryegrass content in tall patches was associated with a decrease in tiller numbers although their weight was slightly greater than in December (Tables 13 and 17).

In short patches of both treatments ryegrass content decreased and other grasses content increased from December to January, but the change was greater in Early than in Late control. The net result was a decrease in the total grass content in short patches (Table 10).In Late control short patches, ryegrass tiller numbers increased but their weight decreased, while in Early control short patches ryegrass tiller numbers were similar in January to December, but their weight decreased (Table 13 and 17).

The increase in other grasses content was associated with other grasses tiller numbers increase from December to January, but the effect was greater in Early control than in Late control. Other grasses tillers increased in weight, except in tall patches in Late control where a decrease in other grasses content was associated with their tiller weight decrease (Table 14 and 18).

Topping pastures in Late control after grazing in December might have caused the stem content in the ryegrass to decrease from December to January, while in Early control stem content increased. Within treatments, tall patches had more ryegrass stem content than short patches (Table 11). However, topping did not cause a decrease in dead matter content in tall patches during January (Table 8), but this may have been the effect of dead reproductive stems rather than senescence of unutilised leaves and/or little dead matter degradation. Dead matter content in tall patches during January was still greater than in short patches, because while in tall patches dead material increased in short patches it decreased (Table 8).

During January more herbage was removed in Late control than in Early control (Table 3). Considering that herbage mass before grazing was greater in Late than Early control, herbage mass after grazing was not much greater in Late control than in Early control, and the number of half-day grazings used to harvest the pasture were similar between treatments (Section 3.2). Herbage allowance was not much greater in Late control than in Early control (78 vs. 69 kg DM per cow). The average herbage available per meal in Late control was around 1754 kg DM/ha (5700 kg DM/ha mean herbage mass divided into 3.25 meals) whereas in the Early control it was 1566 kg DM/ha (4700 kg DM/ha mean herbage mass divided into 3 meals). In Late control paddocks an average of 759 kg DM/ha was harvested in each meal, whereas in Early control paddocks an average of 567 kg DM/ha was removed per meal (calculated as [total herbage removed kg DM ha / No. meals]). Herbage removed represented 43% in Late control and 36% in Early control of herbage offered.

More herbage was harvested more easily in Late control than in Early control, probably because pasture quality was better in Late control. For example, the content of ryegrass (Table 10) and its leafiness (Table 11) were greater in Late control than in Early control. Another possible reason is the greater proportion of low herbage mass patches in Early control than in Late control which were less utilised than tall patches (Figure 9 and 14). Topping in a way cleaned the pasture from old material while this did not happened in Early control, where it was likely that a proportion of the sward was covered by material less accessible or palatable to the animal.

The utilisation relation with herbage mass was not so different between paddocks as in December (Figure 9), probably because the level of herbage mass was greater in all paddocks (Table 3), and the range of herbage mass values was very similar between Late and Early control. However the herbage mass mean was greater in Late control because skewness was less in Late control than in Early control (Figure 4), which can explain in part the greater removal from late control paddocks during January (Table 3).

The variability of utilisation with respect to herbage mass was less during January than in December (Figures 8 and 9), which caused the decrease of standard deviation of herbage mass from before grazing to after grazing (Table 4, Figures 4 and 5). The characteristics of herbage mass after grazing were also different in part because the characteristics of the herbage mass before grazing were different between paddocks. Paddocks in Early control were more skewed before grazing (Table 5), and low herbage mass patches were less utilised (Figures 7 and 9). Consequently, paddocks after grazing were more skewed in Early control than in Late control (Figure 5).

5.4. General Approach to Patchiness

Development of patchiness with Late control management during late spring has been a concern for researchers (Matthew, 1991; Hernandez-Garay, 1995; Da Silva, 1994) and farmers. In research, patchiness has been associated with variability in tiller population dynamics and white clover content. In practice the questions often asked have been about pasture quality, herbage utilisation and intake, but also the feasibility to meet efficient reproductive growth control and conversion of extra pasture growth into milk. Late control is a management option that appeals more to farmers who are interested in decreasing stocking rates, increasing pasture cover and feeding supplements to improve feed intake of high genetic merit dairy cows to achieve high per hectare output, rather than to farmers aiming to achieve high production per hectare through higher stocking rates (Matthews et al., 1996). Farmers see the advantages of Late control 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 (Matthew et al., 1996).

Tiller dynamics on grazed pastures have great spatial variability because of variability in the availability of nutrients and mix of pasture species, and temporal and spatial variability in defoliation and regrowth. In terms of tiller population dynamics, the present experiment showed both short and tall patches are affected by late control management. In general, Late control increased ryegrass tiller population (Table 13) and ryegrass leafiness (Table 11) as compared to Early control (Hernández-Garay, 1995), and increased the competitive advantage of ryegrass over other grasses within the grass fraction in both short and tall patches (Table 10). These results show how Late control management has an effect on the entire sward area provided that any prevailing level of patchiness is at a high level of herbage mass, as occurred in this experiment (Figure 1). If pastures are managed laxly and with long grazing rotations as in this experiment, it is likely that the intensity of patchiness will be low, because a substantial proportion of the area is close to or at ceiling herbage mass.

Improved pasture production after Late control has been found before in experimental plots and farm conditions (Hernández-Garay, 1995; Da Silva, 1994). The improved pasture production has not always been attributed only to increase in ryegrass production but also to improved white clover growth (Da Silva, 1994). In the present experiment, it was observed that after December control, white clover had the competitive advantage in short patches (Table 9), whereas ryegrass had the competitive advantage in tall patches (Table 10).

The present experiment showed that tall reproductive pastures like those in Late control during December can be efficiently harvested (Table 3). The duration of the lax grazing period to increase pasture cover and reproductive growth development was relatively short (November to Mid-December), and the interval between grazings was long enough to produce high herbage mass and tall pastures with little positive skewness (Figure 1). The key points that allowed an efficient grazing may have been the small contrast in patch quality (Table 8 and 10) and the high levels of herbage mass (Table 3 and Figure 1). A rather homogeneous pattern of defoliation may happen when there is little contrast between patches (Laca and Demment, 1991), and cows are not so reluctant to eat from mature patches (Dumont et al., 1994). Herbage mass distributions after grazing during December in Late control paddocks were positively skewed because grazing pressure was not great enough to limit cows herbage intake. Patchiness after grazing in Late control may also be attributed to an excess of pasture (Ring et al., 1985) rather than just to a heterogeneous pattern of defoliation. Topping of pastures was planned to remove what cows did not eat.

The better sward structure in Late control than in Early control during January (Table 8 and 11) can be attributed not just to lax grazing in late spring, but also to the effective control of reproductive growth, and removal of dead reproductive stems from the grazed horizon in December. The point is that paddocks in Early control should have been benefited by topping as well. Although tall unutilised patches were in lower proportion in Early control than in Late control before topping, they had detrimental effects on the efficiency of defoliation during January (Figures 3 and 8, Section 5.3.2).

Before grazing, heterogeneity of herbage mass was greater in Early control than in Late control (Figure 1). Lower grazing pressure in Early control than in Late control paddocks was combined with a lower herbage mass mean and a greater area covered by low herbage mass (Figure 1), which caused on average less utilisation of low patches (Figure 8). In Early control there was also some degree of patchiness after grazing, but its origin was a different cause than in Late control. Patchiness after grazing in Early control was the reflection of greater heterogeneity before grazing and heterogeneous pattern of defoliation, not excess of herbage.

The importance of considering the pattern and intensity of patchiness even when there is no great contrast in pasture quality within the sward is the potential difference in utilisation and probably regrowth between contrasting herbage mass patches as exemplified in Table 19. Grazing management should prevent great intensity in patchiness, and therefore it is necessary to develop practical guidelines to achieve this goal under laxer grazing methods such as those described by Matthews and Phillips (1994).

Late control is associated with a slower rotation than Early control during December and January. In January the greater rotation length in Late control is due to increased pasture accumulation (Section 4.2.1). Greater rotation length during periods of low soil moisture as in the summer are beneficial for the ryegrass persistence and regrowth , which can result in an extra advantage of using Late control in Late spring.

In general, patchiness will have no repercussions if it is controlled before pasture quality declines. In Late control during late spring, this means to control reproductive growth before anthesis. Different patches will be likely to be at different stages of reproductive growth, and it is important to determine what percentage of the sward area should be allowed to reach anthesis before being controlled. By grazing paddocks according to the tallest patches quality characteristics, efficient utilisation of the sward may be achieved, and will have no negative repercussions on herbage regrowth provided the shortest patches are not overgrazed. It is important to determine as precisely as possible the grazing pressure according to the herbage mass present in the paddock. This can be more complicated in patchy conditions. An evaluation of herbage removed from patches of different herbage mass and/or height in relation to the pattern and intensity of patchiness would be useful.

5.4.1. Management Implications

Because Late control showed advantages in the ryegrass performance in tall patches that were effectively controlled, pastures managed under late control should be aimed to have a greater proportion of that kind of tall patches, with rather homogeneous distribution of height and herbage mass, and ready to be harvested before anthesis. From the experience of this experiment, it is likely that one long regrowth period before control will provide the required conditions, because this will allow reproductive growth to occur in a greater proportion of the sward, and animals will not be reluctant to graze swards in the pre-anthesis stage. In this experiment greater rotation length was possible by adding supplements during that period. Key strategies that should accompany the Late control system to meet these conditions are higher pasture cover targets, strategic supplementation and lower stocking rate than usually recommended.

Strategic supplementation in Late control should be used to buffer seasonal and year to year variation in pasture growth, and to maintain swards in a state that permits fast regrowth. The critical periods where supplements should be given in Late control are late winter-early spring, and late spring. In late winter-early spring feed requirements exceed herbage growth, and defoliation has to be balanced between growth rate and rotation length, so pastures can accumulate herbage to meet the pasture targets before grazing by the time pasture growth starts to exceed feed demand. If pasture growth greatly exceeds feed demand, it would be necessary to drop paddocks out of the rotation to maintain pasture targets, to keep low levels of patchiness otherwise associated with excess of herbage allowance, and to maintain feed quality. The second critical period in Late control could be when pastures have to be prepared before control by allowing reproductive growth to occur. It would be necessary to increase rotation length to allow a greater proportion of the sward to express reproductive growth. If paddocks were closed previously due to increased pasture growth, they can be included in the rotation again which will increase the rotation length, but supplements may also be used if necessary. If environmental conditions were not favourable for pasture growth during the spring and no paddocks could be taken out from the grazing rotation, then the system will rely more on the use of supplements. However it is necessary to determine the maximum amount of supplements that can be economically used considering the extra pasture growth that can be obtained post-control.

Traditionally, high stocking rates are used to graze pastures hard throughout the spring to harvest herbage grown efficiently and to control reproductive growth. Pasture utilisation per hectare increases but intake per animal decreases. In Late control, stocking rate may be reduced but still maintains a balance between adequate pasture utilisation, high intake per animal and higher pasture residuals. Late control pastures can be prepared more easily at lower stocking rates than at higher stocking rates because reduced feed requirements in early spring will allow for higher herbage residuals. To decrease stocking rate without decreasing milk production per hectare means that individual cows will have to produce more milk. This is possible provided increased herbage intakes occur when higher herbage mass residuals are obtained. Pasture quality will not deteriorate if pregrazing mass is maintained at adequate levels. This highlights the importance to define pasture targets and the strategies used to achieve them.

Pasture targets define sward state conditions where pasture quality and animal intake may be optimised while maintaining a good regrowth capacity. It is important to determine pasture targets that will meet these requirements (Hodgson, 1990; Matthews and Phillips, 1994), but at the same time minimise the intensity of patchiness on the swards. As shown in Table 19, the lowest herbage mass areas contribute much less to total herbage utilisation than the high herbage mass areas. This means that pasture targets have to be determined and met within a target herbage mass and/or height standard deviation as well.

The management modifications to reduce patchiness are based on the homogeneously distributed defoliation over the sward surface. This can be achieved with precise estimation of feed requirements, sward characteristics and grazing behaviour. Pasture targets play a very important role in such system. If herbage mass characteristics will influence bite depth, then the herbage mass characteristics after grazing can be estimated. Therefore it is a matter of setting targets before grazing that will allow attainment of the desired characteristics of herbage mass after grazing. It is very important that the area offered is correctly assigned, to force an homogeneous animal distribution over the sward, and prevent poorly grazed areas occurring because of an excess of herbage offered, or overgrazing of some areas because herbage allowance was under-estimated. The factors that can be manipulated in rotational grazing are herbage mass before grazing, herbage mass after grazing, paddock size, number of animals, intake requirements. These factors may achieve the goal of "homogeneity" of defoliation with many combinations.

Minimising patchiness in Late control is important because the more homogeneous pastures can be when controlled, the better the results on pasture production and ryegrass persistence through summer that can be obtained. But after the control phase patchiness may arise because of high herbage allowance when cows are not pushed to graze too low. If herbage intake is not to decrease in the control phase, topping of pastures is necessary to efficiently restore sward structure. It is necessary to evaluate the cost of tractor hours against the expected loss in milk production, in the case that cows control pastures by grazing hard.

Nitrogen fertiliser may help to reduce patchiness. During spring, environmental conditions are optimum for pasture growth, and those patches with more available nutrients will grow faster. Herbage around dung grows at a higher rate than other patches because of the access to nutrients (Fitzgerald and Crosse, 1989). The application of fertiliser may help to reduce differences in growth rate between patches (Lantinga et al., 1987) and defoliation may be more homogeneous.

Factors that can increase the standard deviation of herbage mass within a paddock should be identified, and management strategies should be developed to control them. Standard deviation of herbage mass can increase in situations such as those given in Late control during January, which did not have a negative effect on pasture utilisation as it did in Early control (Section 5.3.2). Simple methods to evaluate the source and consequences of within sward variability should be developed. Combining herbage mass estimates with estimates of pasture height can be useful because together they give an indication of sward structure. The use of permanent transects to evaluate changes in herbage mass and or height can give, first the opportunity to evaluate management and seasonal effects on the variability of herbage mass and /or height, secondly to identify management strategies that may control variability in pasture, and third, monitor pasture changes through time and take appropriate management action. In combination with the historical data obtained with transects, visual cues may also be determined to apply management decisions. The time and labour requirements needed when assessing herbage mass in a paddock should be evaluated against it benefits. Because herbage dissections to obtain botanical composition may not be feasible, if the interest is to obtain an indication of variability according to management and variability in herbage mass and/or height, photographic records can be an option. Computer programs may be developed to process the information easily.

Finally, modelling procedures should be used to evaluate stocking rate, feasible supplementation, and pasture targets under various environmental conditions, and evaluate their consequences in milk production and farm revenue.

CONCLUSION

The level and characteristics of patchiness presented in paddocks under Late control management before the control phase, did not adversely affect herbage utilisation. However, in both Late and Early control, short patches were on average less utilised than tall patches. Topping of pastures was an effective strategy that fully controlled tall patches and improved sward structure.

Pasture accumulation increased in Late control swards compared to Early control swards. Pasture accumulation in Late control was related to high tillering activity and great tiller weight in tall patches, but in short patches the accumulation was due to high white clover growth. However, in this experiment Late control did not seem to increase white clover content as compared to Early control

In general, Late control increased leafiness of ryegrass. Late control increased the ryegrass content in tall patches by increasing tiller numbers and maintaining tiller weight. Late control also caused an increase of ryegrass tiller numbers in short patches, although their weight decreased. Tall patches in Early control increased other grasses and stem content compared to trimmed tall patches in Late control.

Patchiness was not exclusive to Late control, as Early control paddocks presented patchiness as well. Because herbage utilisation was greater in tall patches than in short patches, it seems that high pasture cover may increase herbage intake even if patchiness is an issue. However, tall patches must be defoliated regularly to avoid a decrease in herbage quality.

Because Late control had greater responses in tall patches the objective should be to modify management to a longer rotation length before controlling reproductive growth in late spring, to allow a greater proportion of the sward to achieve high herbage mass. Herbage utilisation was effective in late control tall pastures, but if intake is not to be limited, cows should not be used to clean pasture completely and grazing should be followed by topping to effectively control ryegrass reproductive growth. Rotation length can also be increased during the summer in Late control due to increased pasture accumulation, which may benefit further ryegrass tillering.

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Appendix 1

The appendix contains the herbage mass profile plots for individual paddocks under Early control and Late control. These graphs complement the comments made in section 4.4. For the majority of paddocks, the herbage mass profile is compared before and after grazing during both December and January, Herbage mass after grazing in December is compared to herbage mass after grazing in January to show the stability of patches after one regrowth period, and herbage mass before grazing is compared between December and January to show the stability of patches from one grazing period to the next. Where not all these profile plots are shown is because there were missing transects. Four blocks (25 cm each) is equal to one meter. On each graph, the first transect is presented from block 1 to block 120, and the second transect is presented from block 121 to block 240.

Following the profile plots are the variance-block size plots obtained from the pattern analysis (Dale and MacIsaac, 1989). One block size is equal to 50 cm (2 times 25 cm, distance between pasture probe readings). For interpretation and discussion see Sections 3.3.1 and 5.1, and for more details see the paper of Dale and MacIsaac (1989). The transects within one paddock did not yield the same results, as peaks of variance occur at different block sizes. In general, the variance peak was greater during January before grazing, but is more evident in some paddocks than others (compare figures 1 to 5 and A1 to A5). In many paddocks, the variance-block size plots show peaks at the same block sizes before and after grazing during December and January, though at different intensity. This may be a reflection of the stability of patches across time, but the intensity of difference between high and low herbage mass patches can differ depending on the regrowth and utilisation characteristics.

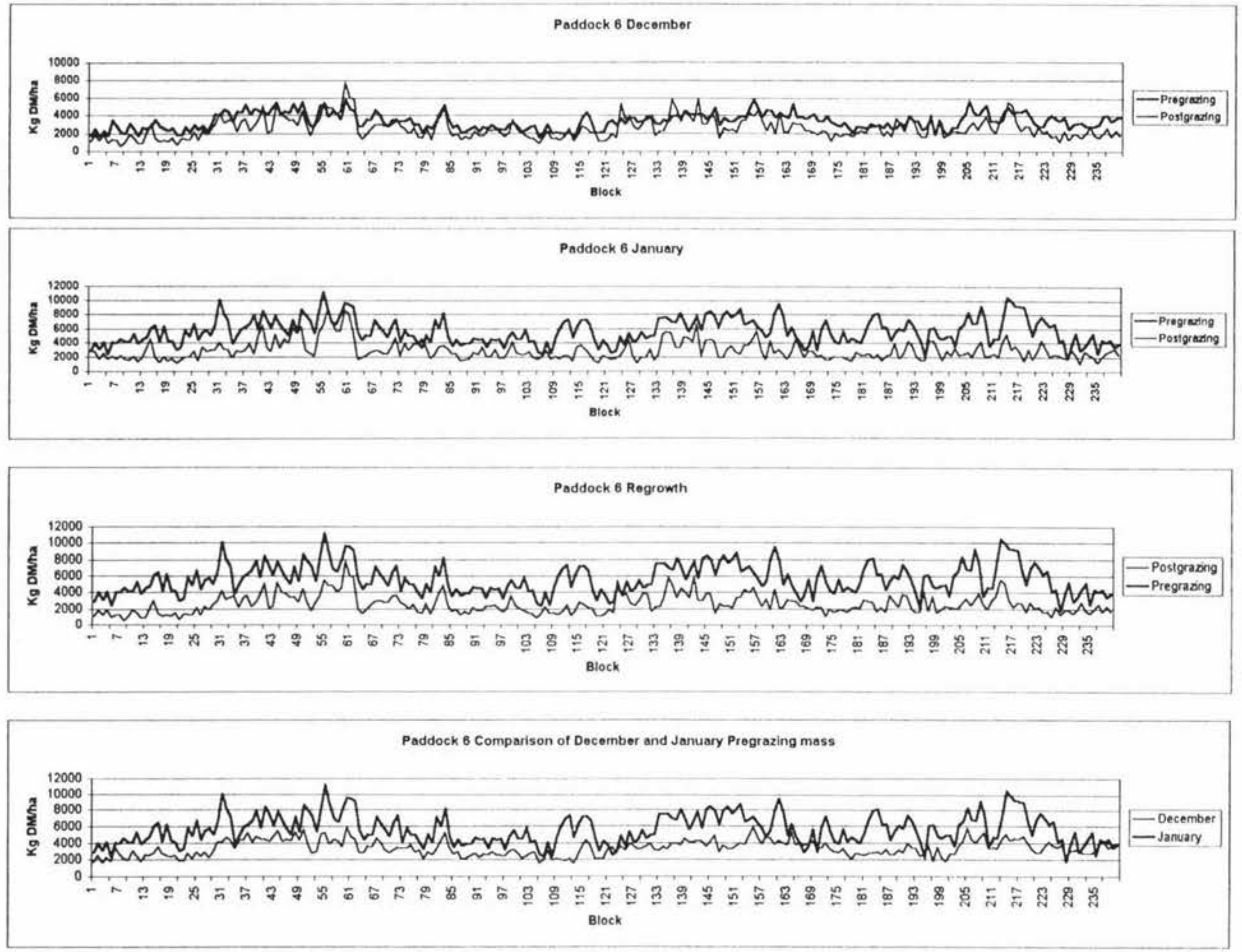


Figure A1. Transects herbage mass profiles in paddock 6 (Early control), before and after grazing in December and January, regrowth from after grazing in December to before grazing in January, and comparison of herbage mass before grazing between December and January to visualize stability of patches.

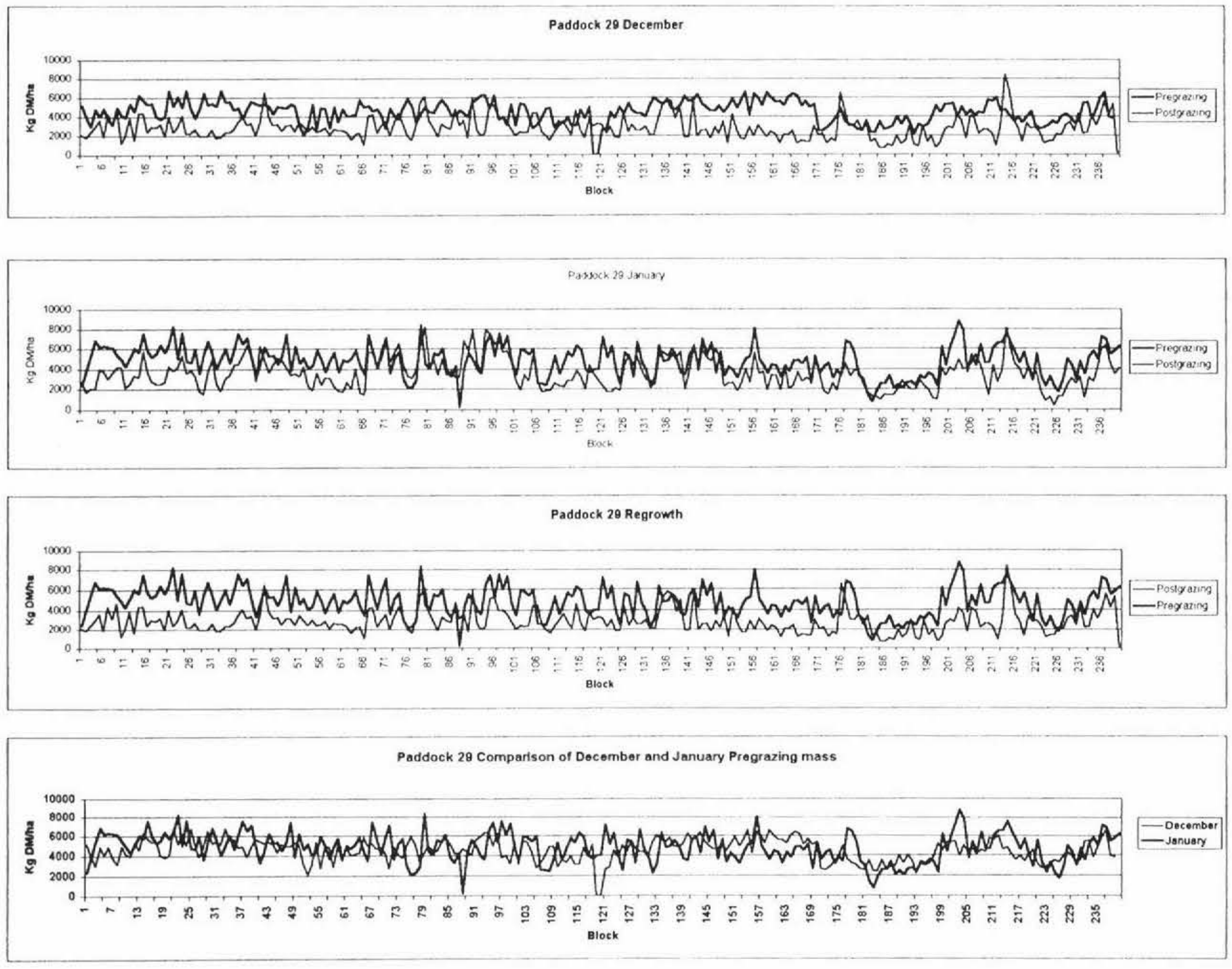


Figure A2. Transects herbage mass profiles in paddock 29 (Early control), before and after grazing in December and January, regrowth from after grazing in December to before grazing in January, and comparison of herbage mass before grazing between December and January to visualize stability of patches.

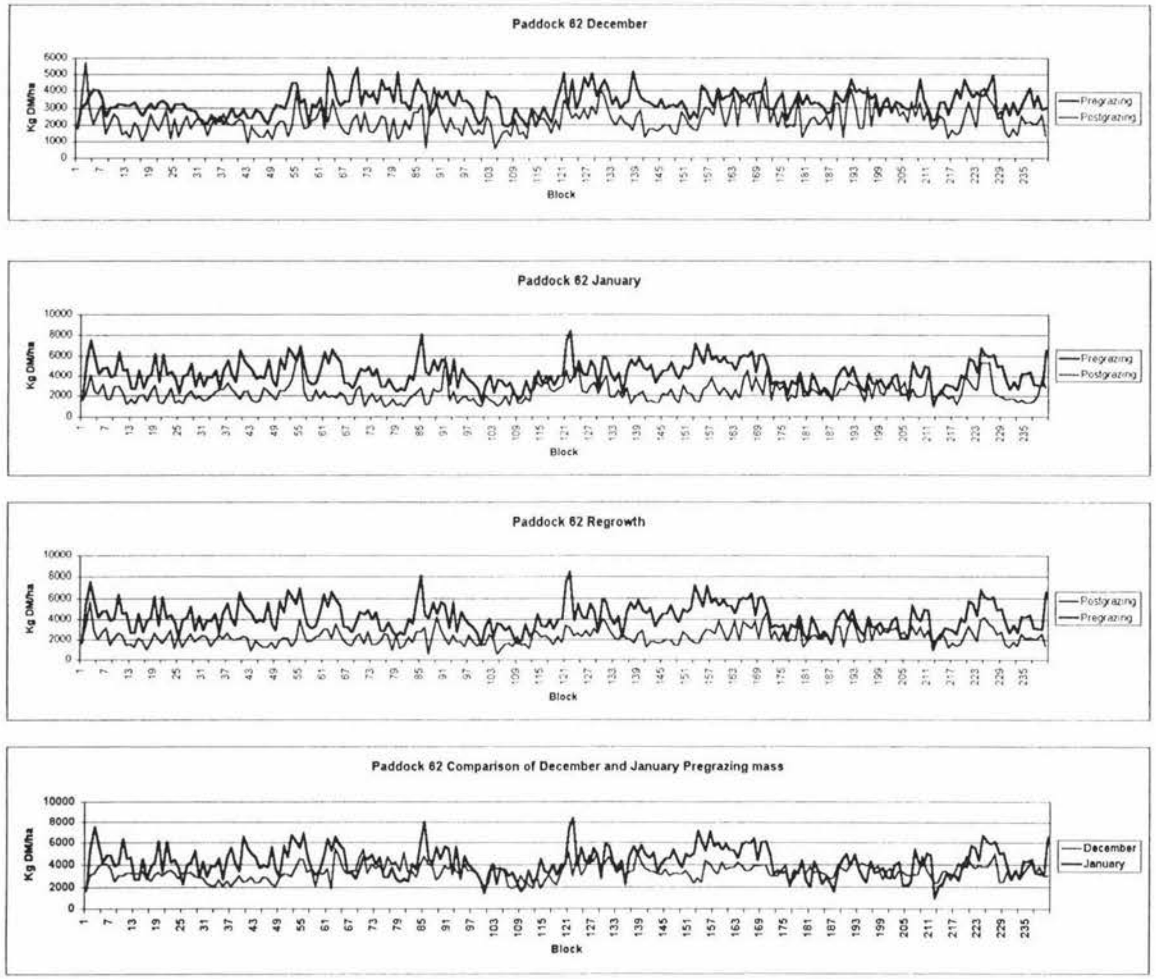


Figure A3. Transects herbage mass profiles in paddock 62 (Early control), before and after grazing in December and January, regrowth from after grazing in December to before grazing in January, and comparison of herbage mass before grazing between December and January to visualize stability of patches.

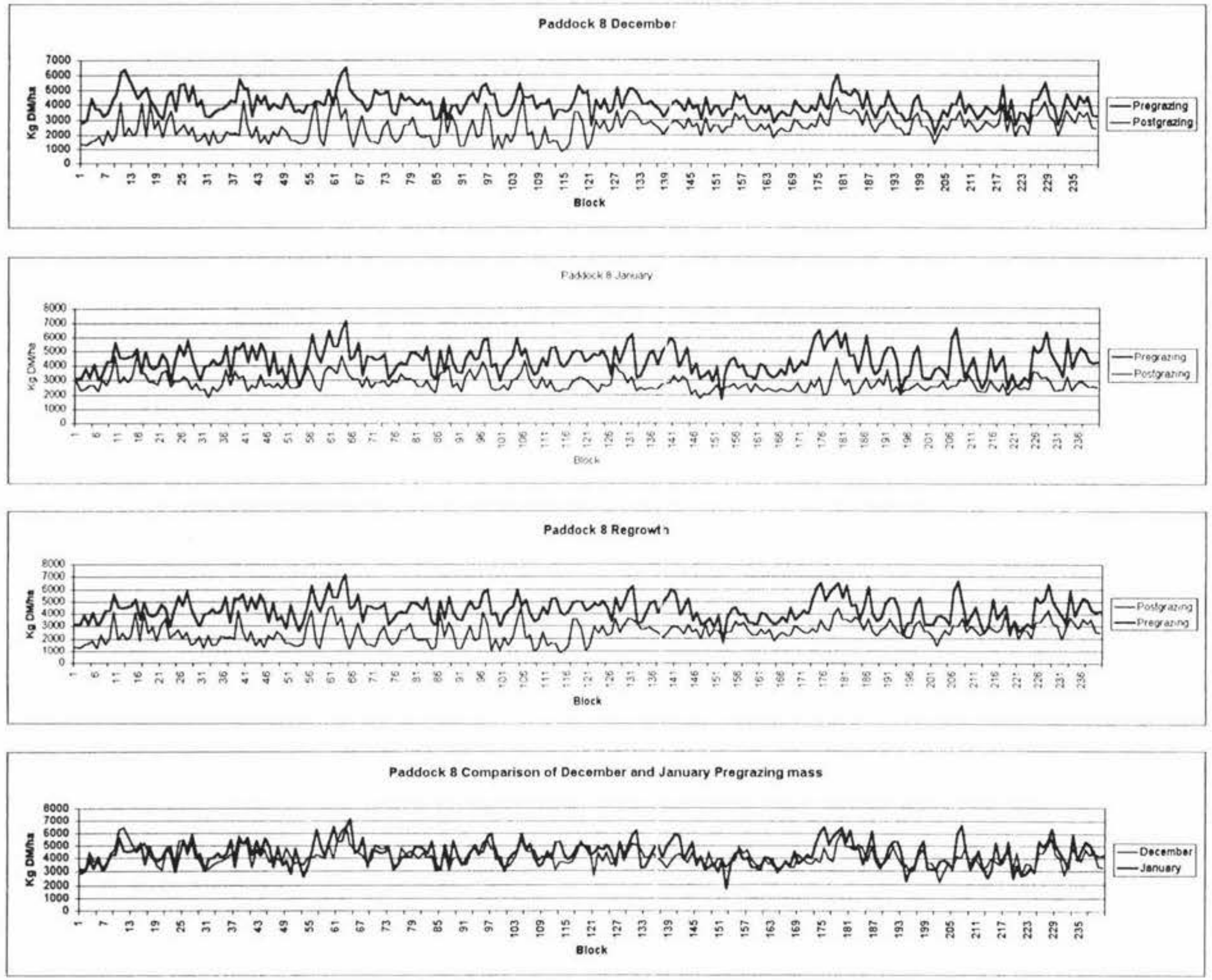


Figure A4. Transects herbage mass profiles in paddock 8 (Late control), before and after grazing in December and January, regrowth from after grazing in December to before grazing in January, and comparison of herbage mass before grazing between December and January to visualize stability of patches.

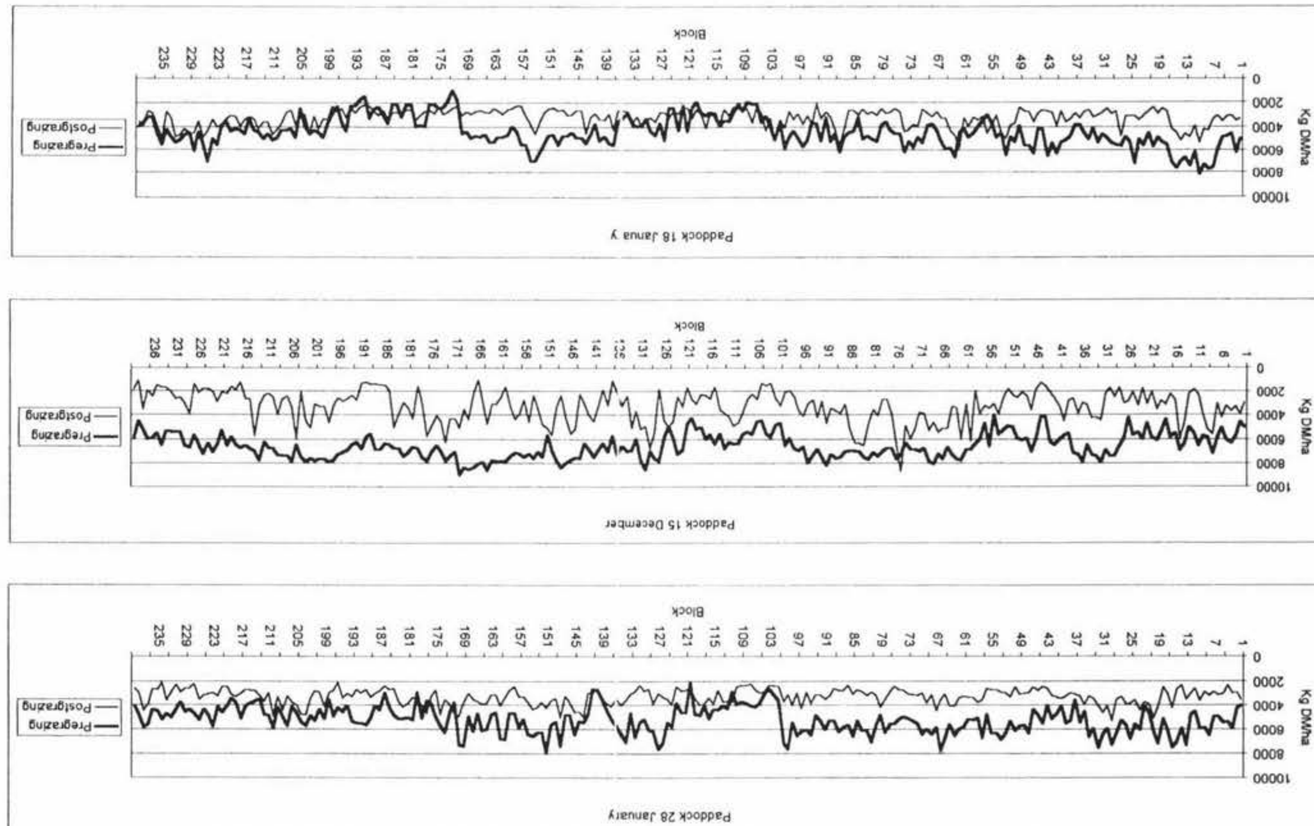


Figure A5. Transects herbage mass profiles, before and after grazing in January in Paddocks 28 and 18 (Late control), and December in paddock 15.

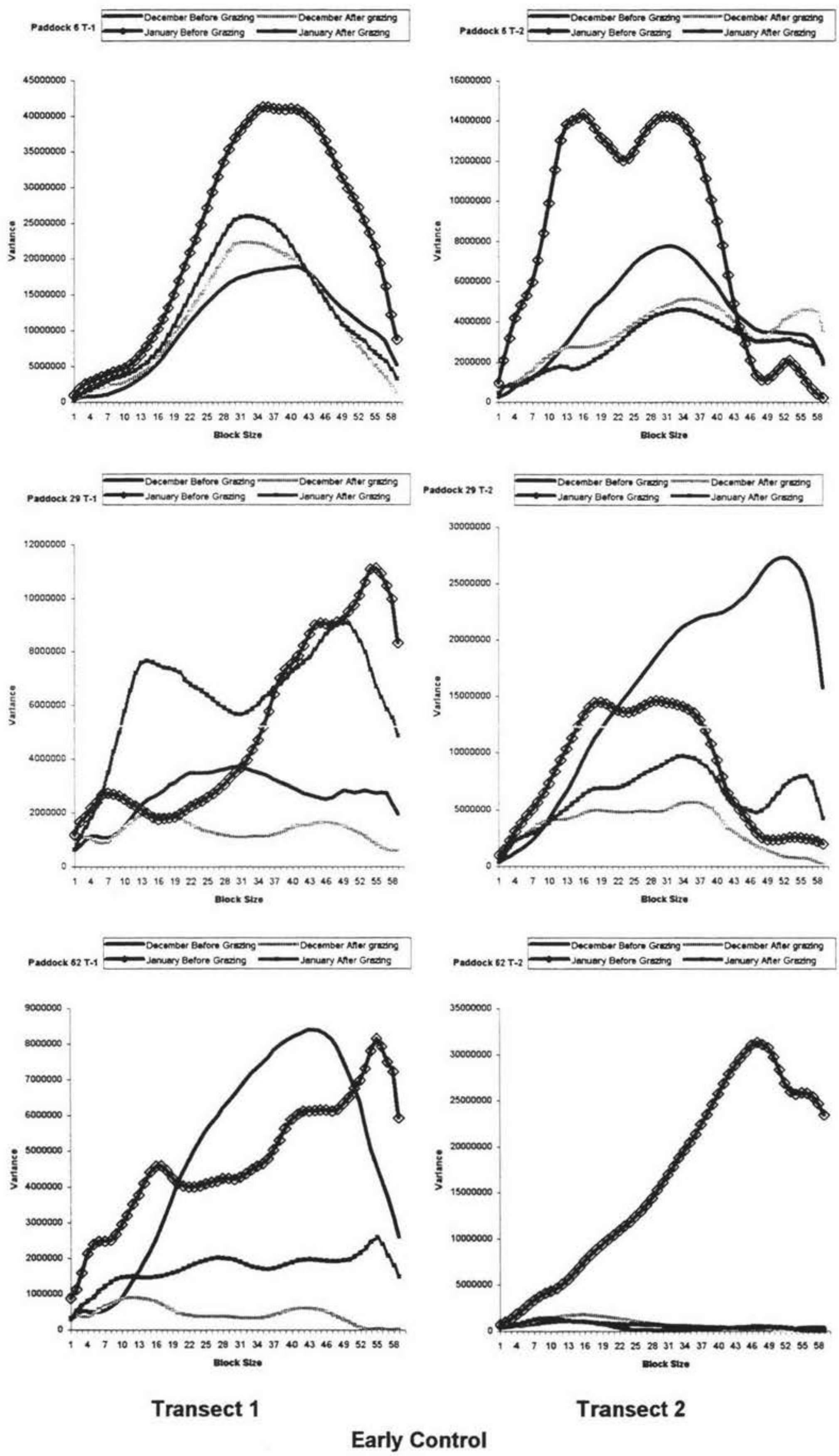
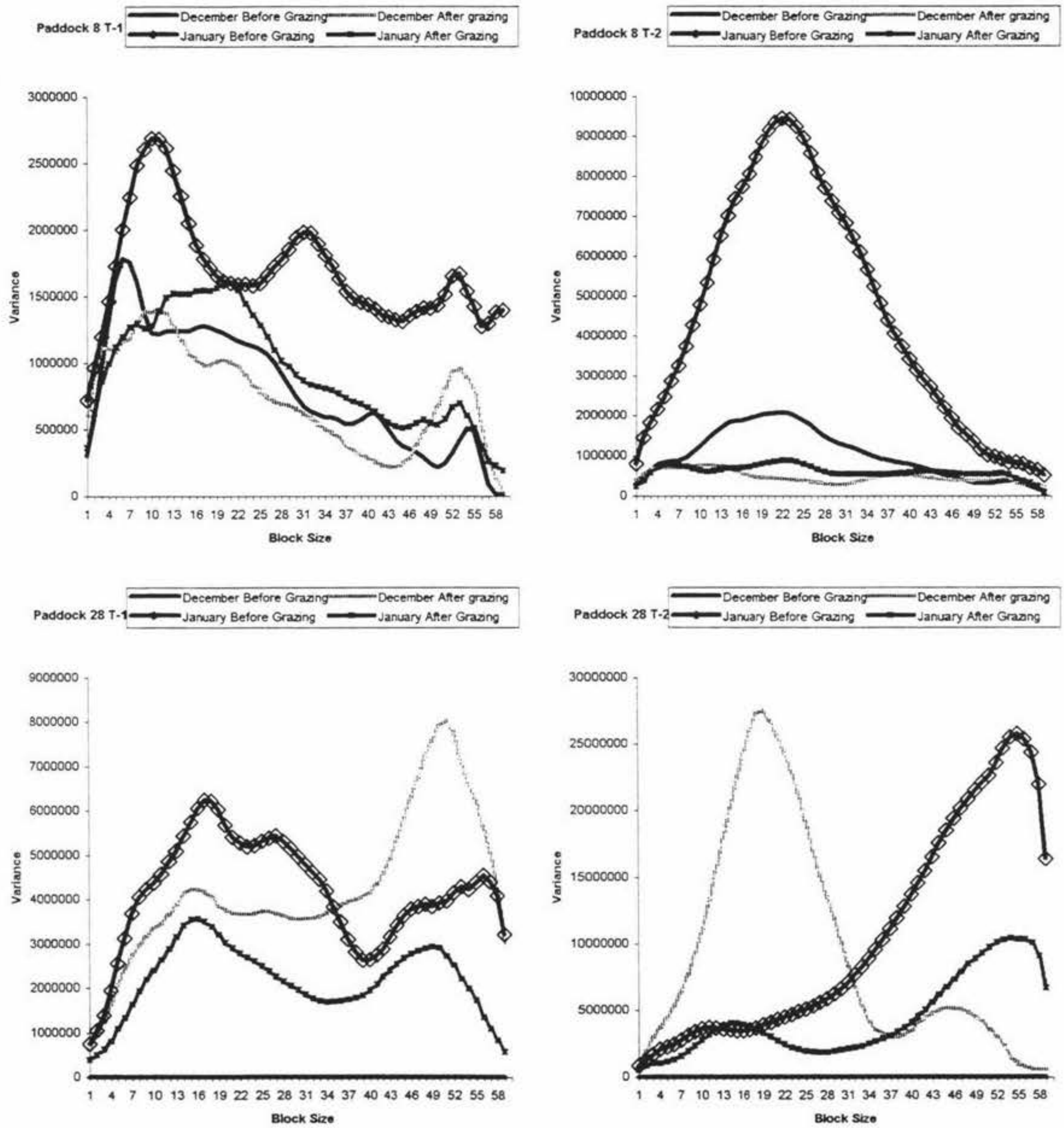


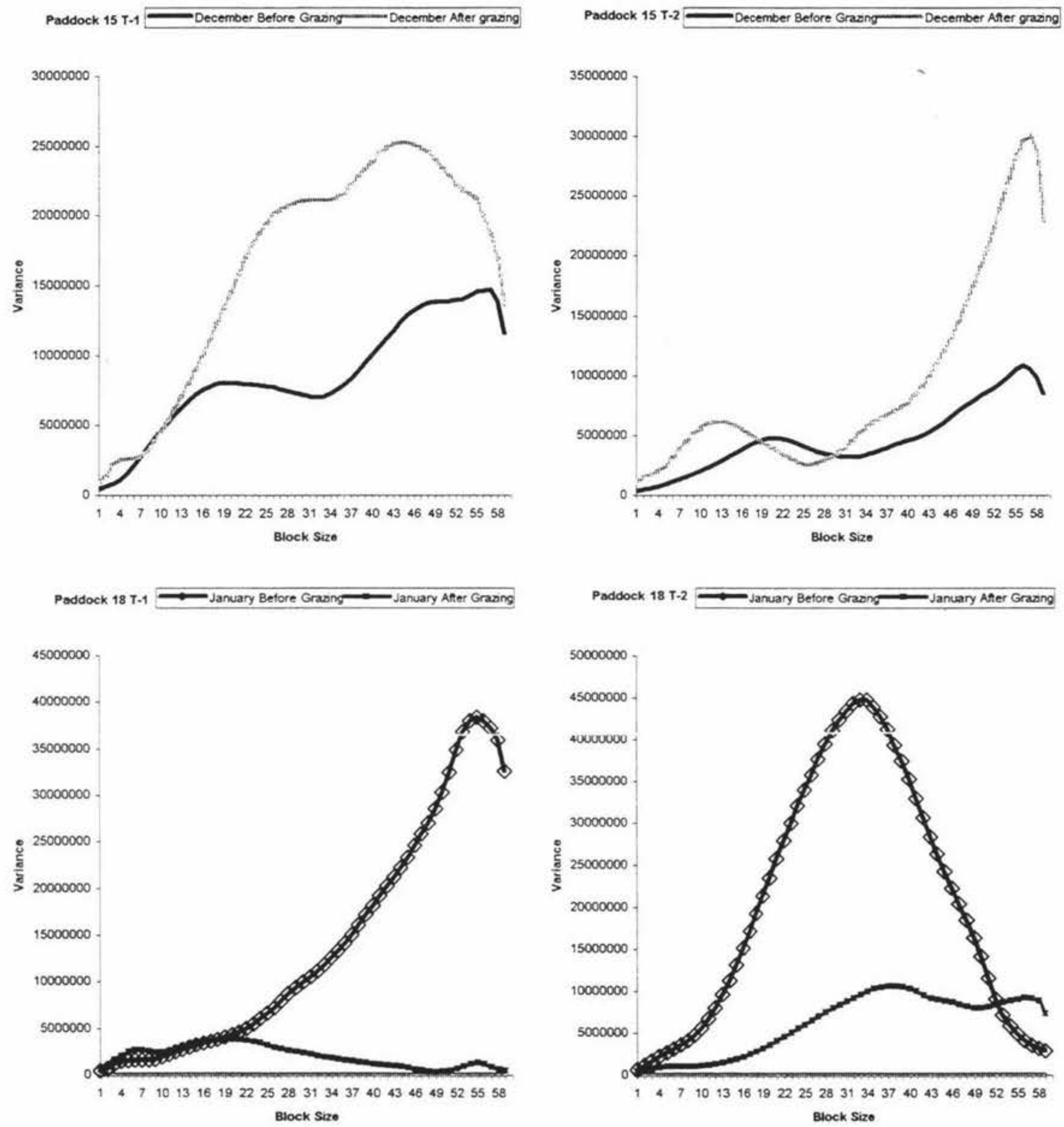
Figure A6. Plots of variance and block size before and after grazing during December and January, obtained from the pattern analysis for paddocks 6,29 and 62 under Early control.



Transect 1 **Transect 2**

Late Control

Figure A7. Plots of variance and block size before and after grazing during December and January obtained from the pattern analysis for paddocks 8 and 28 under Late control.



Transect 1 **Transect 2**

Late Control

Figure A8. Plots of variance and block size before grazing during December in paddock 15 and after grazing during January in paddock 18 (Late control), obtained from the pattern analysis.