MONITORING DAIRY COW ACTIVITY WITH GPS-TRACKING AND SUPPORTING TECHNOLOGIES

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ABSTRACT

Most animals have distinctive activity patterns. Factors such as topography, pasture mass, available shelter can all affect nutrient distribution through their effect of the behaviour of individual animals or groups. Sensor technologies are used at farm level and are employed in the study of animal behaviour. This study used sensor technologies to investigate the patterns of behaviour and excreta distribution in dairy cows under commercial conditions. Seventeen cross-bred dairy cows in late lactation, in a herd of 180, were fitted with global positioning system (GPS) collars, IceTag3D® activity sensors and urine sensors for seven consecutive days. The herd was milked twice a day and rotationally grazed, without supplements. Animals were at pasture from 06:00 h to 14:00 h (AM grazing) and from 15:00 h to 05:00 h (PM grazing). Cows were rotated through 12 paddocks of ~1.1 ha. Urination events followed a non-random distribution pattern. Cows spent more time grazing and less time lying down during the AM than PM grazing period. As the frequency of grazing decreased, the frequency of lying increased within AM and PM grazing periods. Activity patterns were consistent within and between grazing periods. Understanding activity patterns and subsequent excreta distribution may have application in farm management strategies aimed at managing loss of nutrients and pasture utilisation.

Keywords: dairy cows; activity patterns; sensor technology; farm management; GPS; urination

INTRODUCTION

Most animal species have distinct activity patterns and for the dairy cow some of the more common behaviours performed include grazing, ruminating and maintaining social structure with conspecifics (Phillips, 1993).

Global positioning system (GPS) technology is increasingly applied in livestock science and it is central to precision farming and resource management. GPS monitoring can provide efficient and accurate information on different aspects of animal behaviour (e.g. Rutter *et al.,* 1997; Rempel and Rodgers, 1997; Ganskopp, 2001; Schwager *et al.,* 2007; Trotter and Lamb, 2008). By using GPS recordings and data from other animal sensors within a geographic information system (GIS), animal distribution and behaviour can be related to landscape features, management practices and diurnal trends. Understanding the effect of spatial and temporal variability on foraging and other behavioural activities provides potential to modify pasture management and improve efficiency of utilisation.

Several factors might influence how dairy cows allocate their time to different behavioural activities and thus significantly impact on how cows utilise resources and redistribute nutrients within paddocks. These factors can be grouped into three broad categories, environmental factors (Hardison *et al.*, 1956; Phillip, 1993; Orr *et al.,* 2001; Gibb *et al.,* 2002), management factors (Orr *et al.*, 2001; Trevaskis *et al.*, 2004; Oudshoorn *et al.*, 2007) and animal factors (Rind and Phillips, 1999; Ganskopp, 2001; Botheras, 2006). This paper describes a base-line study of temporal patterns of behaviour of dairy cows under commercial conditions and suggests possible implications of changed management.

MATERIALS AND METHODS

The study took place on an intensively managed dairy farm at Massey University, Palmerston North, New Zealand. The herd comprised 180 cross-bred dairy cows in late lactation (210 days ± 30 days). Cows were milked twice a day and were rotationally grazed without supplementary feed. Animals were at pasture from 06:00 h to 14:00 h (AM grazing) and from 15:00 h to 05:00 h (PM grazing). Cows were grazed through 12 paddocks of 1.1 ha (±0.31). The animals were monitored for seven consecutive days during March 2009. This corresponded to available data for a total of six AM grazing and six PM grazing periods. All animal experimentation was carried out following approval by the Massey University Animal Ethics Committee.

Seventeen cows were fitted with GPS collars and IceTag3D® motion sensors (IceRobotics, Scotland). Fifteen cows were also fitted with urine sensors (Betteridge *et al.*, in press) which measured frequency and timing of urination over the trial period. The selected cows were balanced for age, milking order, condition score and milk yield. GPS provided a spatio-temporal matrix of individual cow positions across the farm, while IceTag3D® sensors provided frequencies for grazing, lying, resting and walking for each cow. The GPS receivers recorded data when the cow moved >4 m or every 1 min if the cow did not move during that time. IceTag3D® sensors recorded data once every minute for the duration of the trial. Data output from the IceTag3D® and urine sensors were associated with a geographical position to add to the existing spatio-temporal matrix.

Group mean frequencies of each behaviour category per hour and mean number of urinations per hour for AM and PM periods were calculated using MINITAB 15 for Windows (Minitab Inc., State College, Pennsylvania). Differences between means of each behavioural activity, in relation to temporal factors, were tested by ANOVA (Minitab Inc., State College, Pennsylvania). Urine spot density and distribution was investigated using R 2.10.1 for Windows (R Development Core Team, New Zealand). Urine spot intensity per unit area was examined using Kernel Density Estimator (R Development Core Team, New Zealand).

RESULTS

Cows spent significantly more time grazing during the AM than the PM periods (P<0.01; Table 1). In contrast, cows spent significantly greater time lying down during the PM than the AM period (P<0.001; Table 1). There were no significant differences between AM and PM periods in the time spend standing (P=0.1) and walking (P=0.1), during time at pasture.

Table 1. Average time spent in each behavioural activity (± standard error) during six AM and six PM periods.

Behaviour	Grazing Period	
	AM (%)	PM (%)
Grazing	51 (±4)	34 (±4)
Lying	28 (±4)	50 (±4)
Standing	15 (±2)	12 (±1)
Walking	5 (±1)	4 (±1)

Time of day had a significant effect on all behavioural activities within grazing periods (AM, P<0.001 for all behaviours except Standing where P<0.01; PM, P<0.001 for all activities; Fig. 1). Grazing peaked between 06:00 and 08:00 in the morning and then again between 16:00 and 18:00 in the afternoon, times when cows first entered newly allocated pasture following milking. There were two more grazing peaks at 10:00 and again around 23:00. The afternoon decrease in grazing activity coincided with sunset. In general, as the time spent grazing decreased, the time spent lying increased. Although cows spent a large proportion of their time lying during both grazing periods, most lying occurred after 20:00 at night. Standing at pasture peaked between 11:00 and 12:00 and again between 18:00 and 19:00, but was a small proportion of the animal's daily activities. Walking occurred throughout the day, with increased frequencies recorded prior to leaving paddocks for milking. These behaviour patterns were consistent within each of the paddocks whether in AM or PM grazing periods, with no significant differences in behaviour frequencies between paddocks (AM, P=0.05 for all behaviour; PM, P=0.05 for all behaviour).

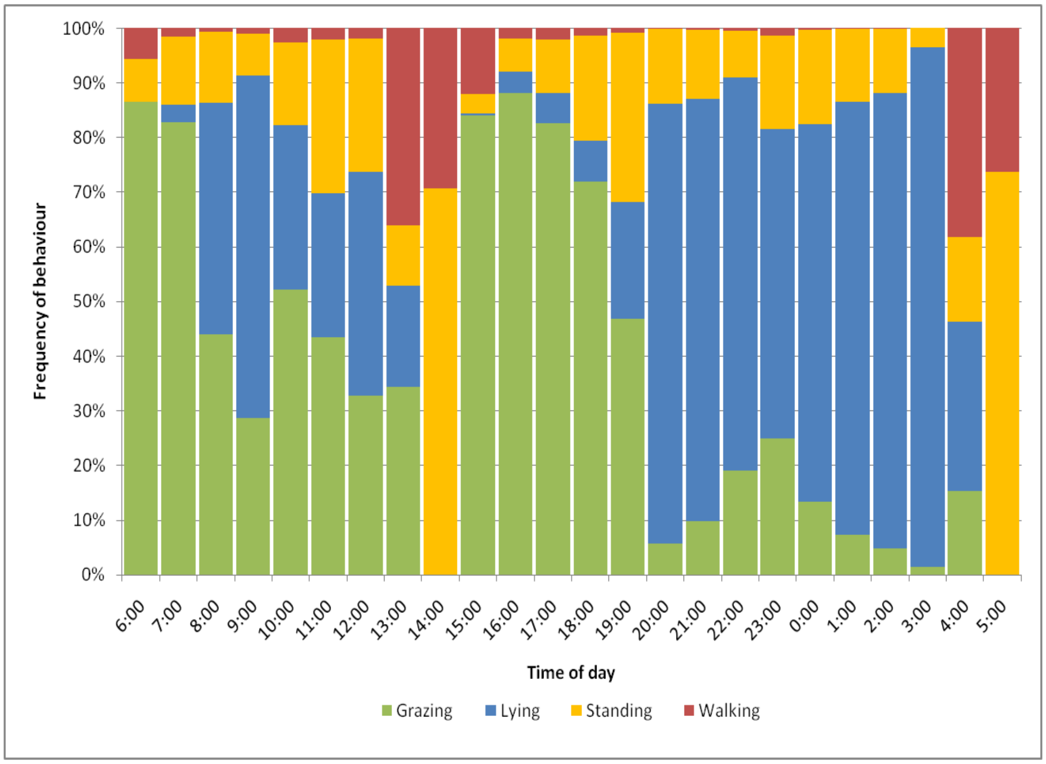

Figure 1. Proportion of time spent in each activity by 17 cows in late lactation, over seven consecutive days. Data plotted against time of day.

Time of day had a significant effect on the frequency of urination during PM grazing ($P<0.001$), but not during AM grazing ($P=0.5$). Urination activity peaked at 7:00 in the morning and again between 15:00 and 19:00 in the afternoon (Fig. 2). Urination patterns appeared to follow grazing activity with most urinations recorded during grazing bouts and following prolonged periods of lying behaviour. These urination patterns were consistent within each of the paddocks whether in AM or PM grazing periods, with no significant differences in urination frequencies between paddocks (AM, $P=0.2$; PM, $P=0.5$).

Kernel density estimation indicated a non-homogeneous intensity of urination events within paddocks (Fig. 3 gives an example of results for one paddock). Intensity patterns were more pronounced during PM grazing than AM grazing.

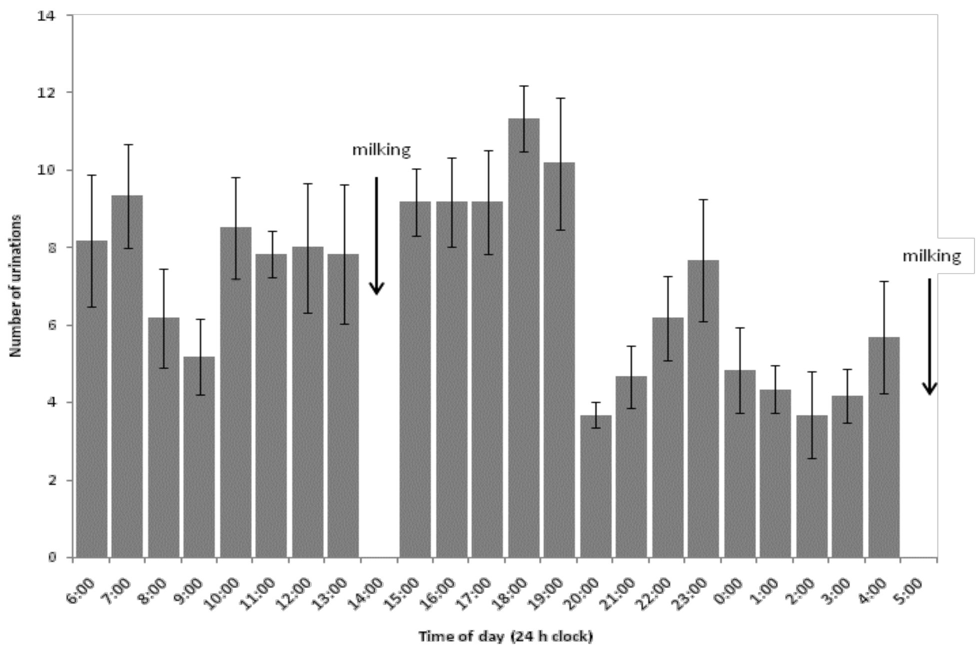

Figure 2. Mean number of urination per hour for 15 cows in late lactation, over seven consecutive days. Data plotted against time of day (±standard error).

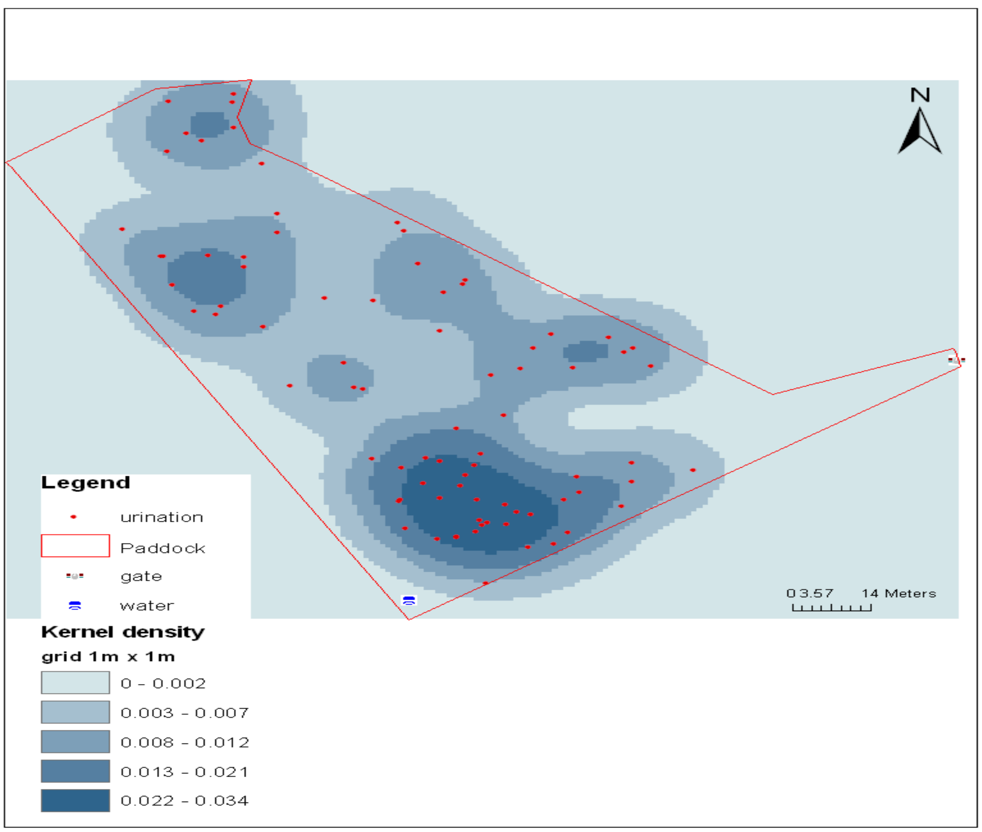

Figure 3. Kernel density estimation of urination events per 1 m^2 in one paddock during PM grazing.

DISCUSSION AND CONCLUSIONS

The behaviour patterns of dairy cows in late lactation showed constancies within and between grazing periods. Cows spent longer grazing following afternoon milking than morning milking. Similarly, Gibb *et al.* (1998, 2002), Orr *et al.* (2001) and Trevaskis *et al.* (2004) reported that the longest meals of the day were the grazing periods immediately between conclusion of afternoon milking and dusk. Cows in this study decreased grazing frequency with the approach of sunset. Trevaskis *et al.* (2004) concluded that removal for milking and the arrival of dawn have the greatest effect on determining beginning and ending of grazing in the dairy cow. Betteridge *et al.* (in press) found that beef cows and sheep on hill country pasture, increased their hourly average bite rate during the day, having the highest bite rate in the hour before sunset. Penning *et al.* (1991), reported that sheep grazed the longest in the four hours before sunset.

Dairy cows have four major rest periods (lying down and standing), after the morning grazing period and again before afternoon milking and between sunset to sunrise, broken by a minor grazing bout peaking at 23:00 h. These results were similar to findings by Hardison *et al.* (1956) and O'Connell *et al.* (1989). Hardison *et al.* (1956) reported four to five major rumination periods in the 24-hour period of the dairy cow. The largest proportion of rumination was observed during darkness (Hardison *et al.*, 1956; Gibb *et al.*, 2002). Although rumination activity patterns were not specifically studied in our trial, rumination has been found to be highly correlated with lying down (Hardison *et al.*, 1956; O'Connel *et al.*, 1989) and in this study the longest lying down period was observed during PM grazing and after sunset.

It appears that cows are more likely to be affected by temporal factors during PM grazing than AM grazing where cows are likely to be influenced by management factors (e.g. removal for milking) and the need to balance grazing and ruminating requirements during the much shorter AM grazing interval than the PM interval . These findings may have possible management applications. Phillips (1993) found that pattern of defecation over the day was mainly determined by the grazing pattern, with cows most likely to defecate during grazing or after prolonged periods of lying down. Betteridge *et al.* (2007, in press) reported a higher density of urine patches near stock camps in sheep and cattle pastures. Betteridge *et al.* (in press) also showed that urination frequency increased as grazing intensity increased during the afternoon, for sheep but not for beef cows. Our study found that urination frequencies were affected by time of day and urination patterns followed similar patterns to grazing activities. More urinations were recorded during times when grazing frequency was high, as was reported by Phillips (1993) where urinations occurred most during feeding periods. Although urination frequency decreased as the time spent lying increased, urination events were recorded during extended periods of lying down, although cows would have stood up to urinate. Further, White *et al.* (2001) reported that the number of excretions that occur in a location is highly correlated to the time spent in that location and concluded that because of the correlation between excreta frequency and time spent in a location, the deposition of manure can be effectively managed by changing grazing practices. Therefore, cows can be kept off pasture when it is known that they are most likely to stand or lie down and thus reduce uneven nutrient returns to pasture associated with these

behaviours, especially during times of low plant N uptake and/or wet conditions when nutrient leaching is most likely to occur (McGechan and Topp, 2004). Cows can also be removed from pasture at times of day when they are most likely to stop grazing, particularly during months with high precipitation rates. This in turn may help reduce the pugging and treading damage of pasture by livestock and thus improve pasture production and utilisation.
Understanding patterns of activities like grazing, lying and standing may have possible application in restricted grazing practices or in managing deposition of nutrients by livestock.

On-going analyses will examine the effect of paddock and pasture characteristics on cow behaviour and nutrient redistribution.

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REFERENCES

Betteridge K, Costal D, Balladur S, Upsdell M, Umemura K. (in press). Urine distribution by female sheep and cattle grazing a steep New Zealand hill pasture. In 'Proceedings of the 28th Biennial Conference' (Australian Society of Animal Production: Armidale, NSW).

Betteridge K, Hoogendoorn C, Costall Des, Carter M, Griffiths W. (in press). Sensors for detecting and logging spatial distribution of urine from grazing female cattle and sheep. Computers and Electronics in Agriculture.

Betteridge K, Costall D, Hoogendoorn C, Carter M, Griffiths W. 2007. GPS and urine sensor for sheep and cattle to improve nitrogen models and identify sources areas for targeted mitigation management. In 'Proceedings of the 11th Annual Australasian Symposium on Precision Agriculture' p. 29.

Botheras N. 2006. The behaviour and welfare of grazing cows (*Bos taurus*): Effects of time away from pasture and position in the milking order. PhD thesis, University of Melbourne, Australia.

Ganskopp D. 2001. Manipulation cattle distribution with salt and water in large arid-land pasture: a GPS/GIS assessment. Applied Animal Behaviour Science 73: p. 251-262.

Gibb MJ, Huckle CA, Nuthall R. 2002. Effetcs of level of concentrate supplemenation on grazing behaviour and performance by lactationg dairy cows grazing continuosly stocked grass swards. Animal Science 74: p. 319-335.

Gibb MJ, Huckle CA, Nuthall R, Rook AJ. 1998. The effects of physiological state (laactating or dry) and sward height on grazing behaviour and intake by dairy cows. Applied Animal Behaviour Science 63: p. 269-287.

Hardison WA, Fisher HL, Graf GC, Thompson NR. 1956. Some observations on the behaviour of grazing lactating cows. Journal of Dairy Science 39: p. 1735-1741.

McGechan MB, Topp CFE. 2004. Modelling environmental imapct of deposition of excreted nitrogen by garzing dairy cows. Agriculture, Ecosystems and Environment 103: p. 149-164.

O'Connell J, Giller PS, Meaney W. 1989. A comparison of dairy cattle behaviour patterns at pasture and during confinement. Irish Journal of Agricultural Research 28: p. 65-72.

Orr RJ, Rutter SM, Pennning PD, Rook AJ. 2001. Matching grass supply to grazing patterns for dairy cows. Grass and Forage Science 56: p. 352-361.

Oudshoorn FW, Kristensen T, Nadimi ES. 2008. Dairy cow defecation and urination frequency and spatial distribution in relation to time-limited grazing. Livestock Science 113(1): p. 62-67.

Penning PD, Rook AJ, Orr RJ. 1991. Patterns of ingestive behavior of sheep continously stocked on monocultures of ryegrass or white clover. Applied Animal Behaviour Science 31: p. 237-250.

Phillips CJC. 1993 Cattle Behaviour. Farming Press Books (Ipswich, UK).

Rempel RS, Rodgers AR. 1997. Effects of differential correlation on accuracy of a GPS in animal location system. Journal of Wildlife Management 61: p. 525-530.

Rind MI, Phillips CJC. 1999. The effects of group size on the ingestive and social behaviour of grazing dairy cows. Animal Science 68: p. 589-596.

Rutter SM, Beresford NA, Roberts G, 1997. Use of GPS to identify the grazing areas of hill sheep. Computers and Electronics in Agriculture 17: p. 177-188.

Schwager M, Anderson DM, Butler Z, Rus D. 2007. Robust classification of animal tracking data. Computers and Electronics in Agriculture 56: p. 46-59.

Trevaskis LM, Fulkerson WJ, Nandra KS. 2004. Effect of time of feeding carbohydrate supplements and pasture on production of dairy cows. Livestock Production Science 85: p. 275-285.

Trotter M, Lamb DW. 2008. A low-cost GPS tracking device for monitoring animal, plant and soil interactions in livestock systems. In 'Proceedings of the 9th International Conference on Precision Agriculture' p. 29-35 (Denver ICPA, Colorado, USA).

White SL, Sheffield RE, Washburn SP, King LD, Green JT Jr. 2001. Spatial and time distribution of dairy cattle excreta in an intensive pasture system. Journal of Environmental Quality 30: p. 2180-2187.