The Summer-Fall Slump: Seasonal Variation in Average Daily Milk Production in Prince Edward Island, Canada

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ABSTRACT

Average test-day milk production in Prince Edward Island, Canada, was observed to follow a pronounced and consistent seasonal pattern, with peak and nadir production occurring in June and November, respectively. It was also observed that there was substantial herd-to-herd variation in the seasonal patterns of milk production, with some herds maintaining seasonally consistent average milk yields and others exhibiting a decline in average test-day milk yield of approximately fifty percent during the summer and fall months. There was also controversy surrounding the association of economic performance with seasonal variation in average test-day milk yield.

During the years 1990 to 1994, the average test-day production in November was 74.5 % of that observed in June for all Prince Edward Island dairy herds. The intra-herd correlation coefficient was calculated to be .537, indicating that herds tended to show similar patterns of milk production from one year to the next.

A large, cross-sectional, analytical observational study was used to determine which herd factors were significantly associated with the seasonal pattern of milk production exhibited by a herd. Four data collection herd visits were carried out during 1993 and 1994, with most analyses using the 1994 data.

An income-over-feed-cost (IOFC) analysis was used to determine the relationship between seasonal variation in milk production and economic performance. A positive, linear relationship was found between seasonal patterns of production and IOFC, with seasonally consistent herds demonstrating higher IOFC than herds with marked seasonal variability in production. On average, for

every 10 percent reduction in average test-day milk yield from June to November, IOFC of $ 215.32 per cow per annum was forfeited.

Delphi and conjoint analysis techniques were used to obtain estimates of the expected increase in pasture dry matter yield resulting from the use of various pasture management techniques. These two methods yielded results that were highly correlated when combined at the field level ($R^2 = .89$) and that demonstrated good agreement with the appropriate data in the literature.

In-depth examinations of the relationship between nutrition, body condition score, internal parasite exposure and the seasonal pattern of milk production were completed before using multivariable modeling techniques to explain the inter-herd variability in seasonal variation in average test-day milk production in PEI. In addition to the key nutrition, body energy reserve, and parasitism variables identified, information on herd reproductive performance and herd management data were included in the multivariable models. The models explained a significant proportion of the between-herd variability in the seasonal patterns of milk production ($R^2 = .594$ to .755), and were found to be robust and reliable after thorough examination. A number of factors were found to be statistically associated with the seasonality of herd average test-day milk production. In the most parsimonious model these included herd level factors that measured the reproductive performance (seasonal difference in days-in-milk, $\beta = -.001$), the internal parasite exposure levels (bulk tank milk *Ostertagia ostertagi* optical density values, $\beta = -.28$) and the nutritional management during the summer (kilograms of supplementary, non-forage DM cow^{-1} day^{-1}, $\beta = .019$). To rank the variables as to their relative importance, the regression coefficients were multiplied by the interquartile range of the observed values. Using this technique, reproductive performance and *Ostertagia ostertagi* optical density values were shown to have a similar impact on the seasonal pattern of milk production in a herd ($\beta \times IQR = -.055$), whereas in absolute terms the daily amount of non-forage dry matter per cow had a marginally lesser effect ($\beta \times IQR = .048$).

Acknowledgments

With the penning of these lines a long, and at times arduous task, has finally been completed. While this, the first completed Ph.D. dissertation at the University of Prince Edward Island, is identified as the work of a single author, it is in reality the culmination of the collaborative effort of numerous people and organizations. A short acknowledgment of these contributions is therefore in order.

I would like to thank the dairy producers of Prince Edward Island for their participation in this research. Without their cooperation, this work would not have been possible and their willingness and helpfulness has been greatly appreciated. I also consider myself fortunate to have gained some new friends in the process of visiting their farms and enjoying their hospitality!

My supervisory committee members; Ian Dohoo, Sean Hennessey, Ken Leslie, Mary McNiven, Lisa Miller, Tim Ogilive and Liz Spangler, also deserve a big "Thanks!" for their efforts. Committee meetings were generally a pleasant experience, and your contributions were appreciated. Because of their enthusiasm, special efforts, and seemingly endless energy (and patience!), I'll be brave and single out Ian and Ken for an extra "Thanks!!". It has been a pleasure working with you in this endeavour, and I hope we'll get another chance to collaborate 'down the road' somewhere.

Not to be forgotten are the many others who have in various and sundry ways assisted me over the last number of years. The Department of Health Management, the Atlantic Veterinary College at the University of Prince Edward Island, and Dean Larry Heider are thanked for their support (financial and otherwise!). The generous tuition scholarship provided by the Hagerman family was also greatly appreciated. "Many thanks!" are also due to Kirk Brown and the Industrial Research Assistance Program; Barry Russell, Ron Coles and the Atlantic Dairy Livestock Improvement Corporation (ADLIC); the Primary Resources Development Agreement; John Scales and Island Fertilizers Ltd.; Murray Myles and the P.E.I. Dairy Producers Association; Judy Clinton, Mary-Beth MacDonald and the Animal Productivity and Health Information Network; and Tapani Kunelius from Agriculture and Agri-Food Canada. Rosemary McIver also deserves an honourable mention here. Whew...quite a list!

But above all (humanly speaking, of course!) I want to acknowledge and thank Malinda, Rebecca, Jessica (and now Mark) for their patience and perseverance. I know it hasn't always been easy or fun...and though I won't make any firm promises ☺, I *think* this is the end of my (our) student life...

Of course, it is risky to undertake a detailed enumeration of gratitude such as this, since the probability of omitting someone (a Type II error) always exists. Therefore I will include an extra, "Thanks a lot ____________________!!" here, so that anyone who (justifiably or otherwise) feels slighted by not seeing their name mentioned, can fill their own name in the blank. It's a D-I-Y thanks!

Ernest

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INTRODUCTION

Identification and definition of seasonality of production

The Animal Productivity and Health Information Network was established in 1987 at the Atlantic Veterinary College, in Prince Edward Island, Canada (10). Among other data, it contains measures of individual animal and herd level performance measures for dairy herds utilizing the production recording services of the Atlantic Dairy Livestock Improvement Corporation. One of the monthly summary parameters recorded in the database is the herd average, test-day milk production.

When the overall provincial average test-day milk production is plotted by month, a consistent, prominent, and predictable seasonal pattern is evident (Figure 1). A brief description of this seasonal pattern has previously been given by researchers at the Atlantic Veterinary College (12), who identified a regular, 12 month cycle in the data by means of a periodogram.

There are, however, marked differences among individual herds as to the amount of seasonal variation in monthly average test-day milk yield. Some herds demonstrate almost no seasonal fluctuations in herd average test-day milk production during the course of a year, whereas other herds exhibit seasonal variation that is much more dramatic than the provincial average. Data from two herds demonstrating very divergent seasonal patterns of production can be found in Figure 2.

The observed seasonality of the provincial average production, as well as the wide range in seasonal patterns between herds, evoked the question of causality. Concurrently, there was marked divergence of opinions amongst producers regarding the economic consequences of seasonal variation in test-day milk production.

Potential economic consequences of seasonality in average test-day milk yield

At the time of the data collection, dairy producers in Prince Edward Island were operating under an annual quota system. Various constraints and conditions, put in place by the milk marketing agency, were intended to minimize seasonal fluctuations in the volume of milk shipped and encourage an even distribution of the total annual herd milk allotment. These regulations were, at best, only partially successful, as evidenced by Figure 3, which presents the monthly average (total) daily milk production for all Prince Edward Island herds. Similar seasonal fluctuations in bulk milk shipments have been reported in other regions, including the province of Ontario and New York State (4,28).

As in many parts of Canada, a daily quota system was introduced in Prince Edward Island (9), subsequent to the data collection phase of this study, in a further attempt to stabilize milk shipments. Under this system, producers purchase the right to ship a specified amount of milk per day (calculated on a monthly basis) at the current domestic price. A credit of up to 30 days' production can be carried forward to be filled at a later date. However, if under-quota production continues beyond this limit, any further credit (potential) to sell milk at the domestic price is forfeited. Similarly, producers are paid domestic price for production that exceeds their daily allowance, but only to a maximum of 20 days' production equivalent. Milk shipped that exceeds this limit is paid at world price, which is markedly lower than the domestic price. It is the intention that over time the flexibility in over-production and under-production limits will be reduced (9).

Alongside the economic consequences of various pricing policies at the herd level, the association of the seasonal pattern of test-day milk yield with the economic efficiency of production at the cow level also warranted examination. While it was the expressed opinion of some dairy producers that a reduction in milk yield was counterbalanced by the reduction in feed costs at pasture during the summer months, the scientific literature suggests that, in North America, marginal returns generally exceed marginal costs as production per cow increases (2,14,34).

Complex and multi-factorial nature of milk production and seasonality

Individual cow milk yield is the result of a complex and inter-related set of factors, both internal and external to the cow. Numerous studies have examined the effect of calving season on lactational milk yield (18,22,26,31) and various authors have reported or proposed that farm-to-farm variation in management and nutrition were responsible for variation in milk production patterns (1,6,12,19,33). However, there have apparently been no studies reported in the literature that address directly the factors associated with seasonality of herd average test-day milk yield.

Primarily due to the expected multi-factorial nature of seasonality of milk production, it was decided that this phenomenon was not amenable to study in a controlled experimental system, and that an analytical observational study, utilizing a reasonable number of dairy herds, was the preferred approach (25).

Based on the scant literature available, as well as postulated, biologically plausible relationships, the following individual cow- and herd-level factors were identified for investigation:

- the ration fed to the lactating cattle, including the management of pastures;
- the reproductive management and performance of the herd,
- the energy reserves of the lactating cattle,
- the level of exposure to internal parasites,
- general herd management variables, and,
- various other health parameters.

Climatic conditions were also considered, since factors such as high temperatures have been shown to affect milk production (6,18). However, since Papadopoulos et. al. (29) have suggested that summer temperatures in Atlantic Canada could seldom be considered a forage growth-limiting factor, it was deemed unlikely that heat stress could be considered to significantly affect animal performance. It was also hypothesized that there would not be significant farm-to-farm variation in temperature and rainfall amounts, and that the time and effort expended in collecting these data would not be justified.

THE CHALLENGES

The mathematical definition of seasonality

One of the first challenges faced was to numerically capture the seasonal pattern of average test-day milk yield in order to permit statistical analysis. Average test-day milk production data for approximately 200 dairy herds were plotted by month to examine the seasonal patterns. It was observed that seasonal changes in production generally occurred in a smooth and gradual manner, rather than frequently and abruptly. It was also observed that herds that showed marked seasonal variation in average test-day milk yield almost exclusively experienced the nadir production at some point during the months of October, November, and December and the peak production during the months of May, June and July. For these reasons it was decided to summarize the seasonality of production for each herd (i) according to the following formula:

$$MINMAX_i = \frac{\text{minimum}((\text{October, November, or December})\ \text{average kg/cow/day}_i)}{\text{maximum}((\text{May, June, or July})\ \text{average kg/cow/day}_i)} \quad \textbf{(Eq. 1)}$$

Thus, a MINMAX value of 1.0 would indicate a seasonally stable herd average test-day milk production, whereas a MINMAX value of .5 would indicate that the minimum herd average test-day milk production during the fall was one half of the maximum level realized during the late spring and early summer. A similar method was utilized by Oltenacu et. al. to summarize seasonal patterns of bulk milk shipments (28), and by Hoden et. al., over a much shorter time-frame, to monitor milk production after moving cows to a new pasture paddock (16).

Data collection

Numerous challenges were also encountered in the data collection phase of the study. Since it was postulated that the ration fed to the lactating cattle would significantly affect the milk production, a method was required to assess the ration on a large number of farms. Various approaches have been used in calculating or predicting intake in dairy cattle (5,13,27,32), and some large scale epidemiological studies, such as that carried out by Sargeant (33), have used detailed questionnaires to obtain herd level estimates of the amount of feedstuffs given to the lactating herd. In this study it was decided to collect detailed ration information, including actual measured quantities and quality analysis of all feedstuffs, for each of the study herds.

A detailed pasture assessment was also an integral component of this large-scale observational study, since it was postulated that pasture forage contributed significantly to the ration in many of the herds. While numerous techniques have been used and recommended for estimating pasture forage production (8,17,36), it was concluded that the large number of fields and the large number of herds precluded these intensive and repetitive methods of data collection. Instead, conjoint analysis (15), and the Delphi technique (37), were identified as potential methods for obtaining estimates of the effect of various pasture management techniques on pasture forage yield. Subsequently, this would permit the calculation of an average pasture forage dry matter allotment per cow per day based on the knowledge of the pasture management practices utilized on each farm.

An additional challenge encountered was finding a technique to determine, at the herd level, the exposure of the lactating dairy cows to gastrointestinal parasites. Repeated fecal egg counts, regular pasture larval counts or the use of tracer animals were some of the methods that could have been used to estimate parasite exposure levels (7,30,38). However, these methods were ruled out due to the time and expense involved in utilizing these methods in a large-scale observational study . An enyme-linked immunosorbent assay, initially developed to determine serological titres to gastrointestinal nematodes (3,20,23), and subsequently evaluated for its ability to detect antibodies in milk (21), was chosen for use with bulk milk samples obtained from all study herds.

MODELING STRATEGY

A large amount of data were collected during the course of the "Summer-Fall Slump Study", and a structured, statistically sound, method was required for gleaning the important and relevant elements therefrom. Various techniques for dealing with large numbers of independent variables in epidemiologic studies (11) and approaches for developing valid and useful multivariable regression models (24) have been presented. Two approaches were considered for reducing the number of variables and developing a sensible regression model from the data collected in this study. Using the first approach, all the variables would have been included in a large, multivariable model. The independent variables that demonstrated a statistically significant, conditional association with the dependent variable would have been retained in a final model. However, given the large number of independent variables, and the difficulty in elucidating in detail some of the relationships in the data, it was decided to utilize a second method, which involved prior screening or evaluation of the associations between a group of biologically related variables and the dependent variable (MINMAX). This process permitted the in-depth examination of a number of relationships and the selection of a subset of variables for inclusion in the final multivariable regression analysis.

Congruency of sampling strategy and analytic methodology

The sampling strategy used to select herds for the "Summer-Fall Slump Study" is outlined in Chapter 3 (p. 40). Basically, equal numbers of herds were selected from each extreme of the distribution of 1992 MINMAX values (Eqn. 1) connoting a case-control study. Figure 4 demonstrates the resulting biphasic nature of the distribution of 1992 MINMAX values for the study herds. Ordinary least squares (OLS) linear regression analysis techniques would not have been appropriate to use given this sampling strategy. However, the distribution of MINMAX values had normalized during the two years intervening the selection of herds and the collection of the data presented in these analyses, and the study herds were substantively equivalent to a random sample from the 1994 population. Figures 5 and 6 show the distribution of the 1994 MINMAX values for the population and the study herds. Figure 7 is a cumulative distribution graph depicting these distributions. The Kolmogorov-Smnirnov equality of distributions test (35) confirmed that there was no significant difference between the distributions (P = .99), and justified the use of OLS regression techniques.

SPECIFIC STUDY OBJECTIVES

The "Summer-Fall Slump Study" was designed to address a number of issues related to the seasonal variation observed in average test-day milk production in Prince Edward Island, Canada. Specifically, the objectives of this study were:

- to describe the seasonal patterns of milk production observed in Prince Edward Island dairy herds;
- to evaluate the relationship between the seasonal patterns of test-day milk production and dairy herd economic performance;
- to determine the herd level factors associated with seasonal

variation in milk production, and;

- to provide data and information to the regional dairy producers to enhance their ability to manage their herds in a viable and sustainable manner.

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Figure 1. Monthly herd average test-day milk production (kilogram cow^{-1} day^{-1}) for Prince Edward Island dairy herds from January 1990 to December 1994. Data source: Animal Productivity and Health Information Network (n̄ = 210).

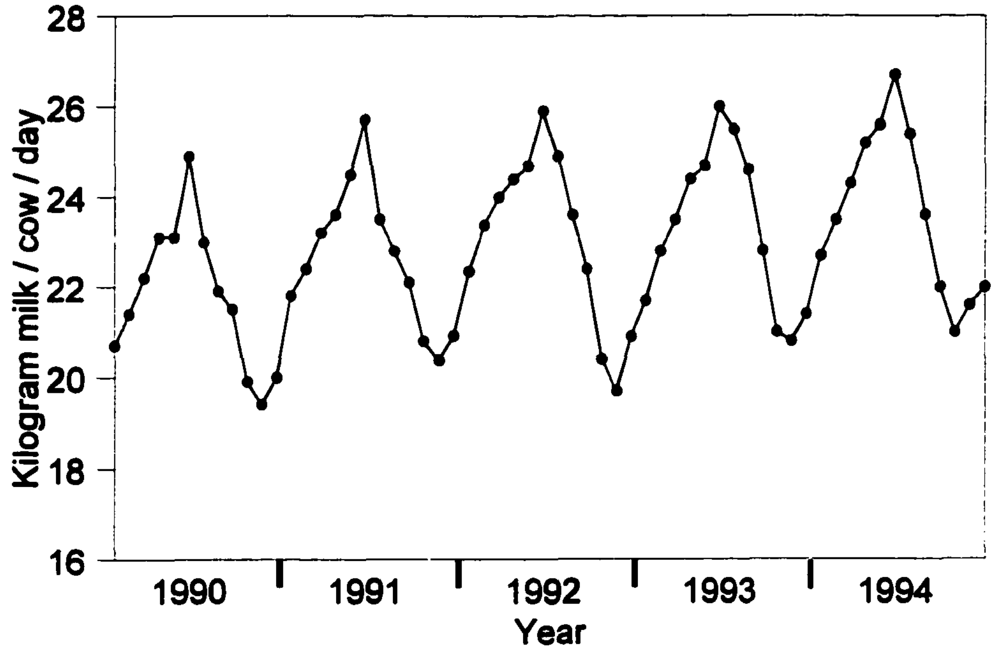


Figure 2. Monthly average test-day milk production (kilogram cow^{-1} day^{-1}) for two Prince Edward Island dairy herds (January 1993 to December 1994). Data source: Animal Productivity and Health Information Network.

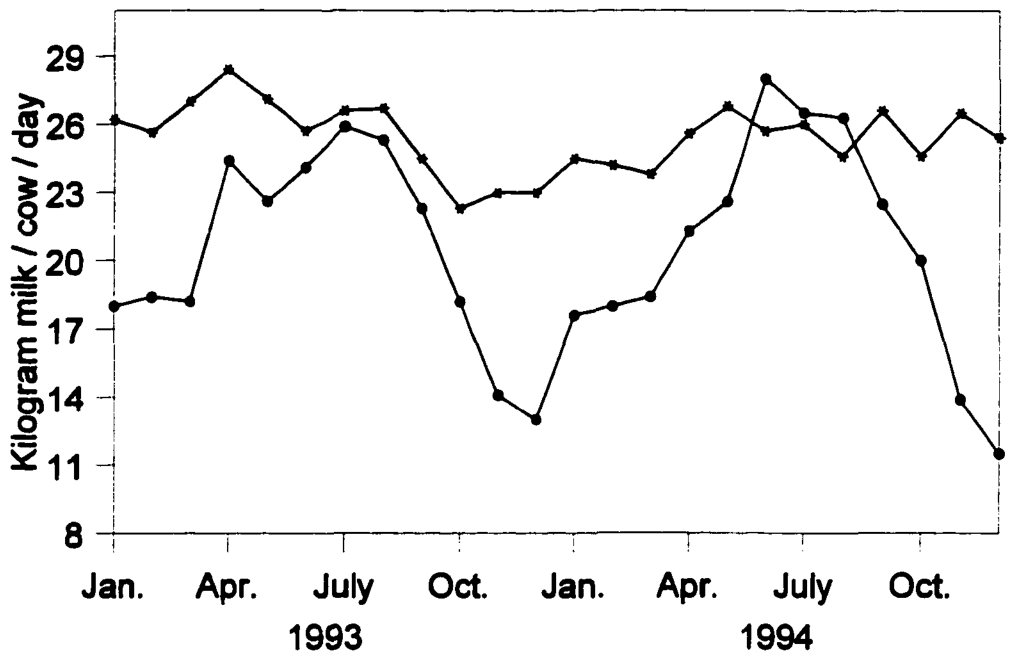
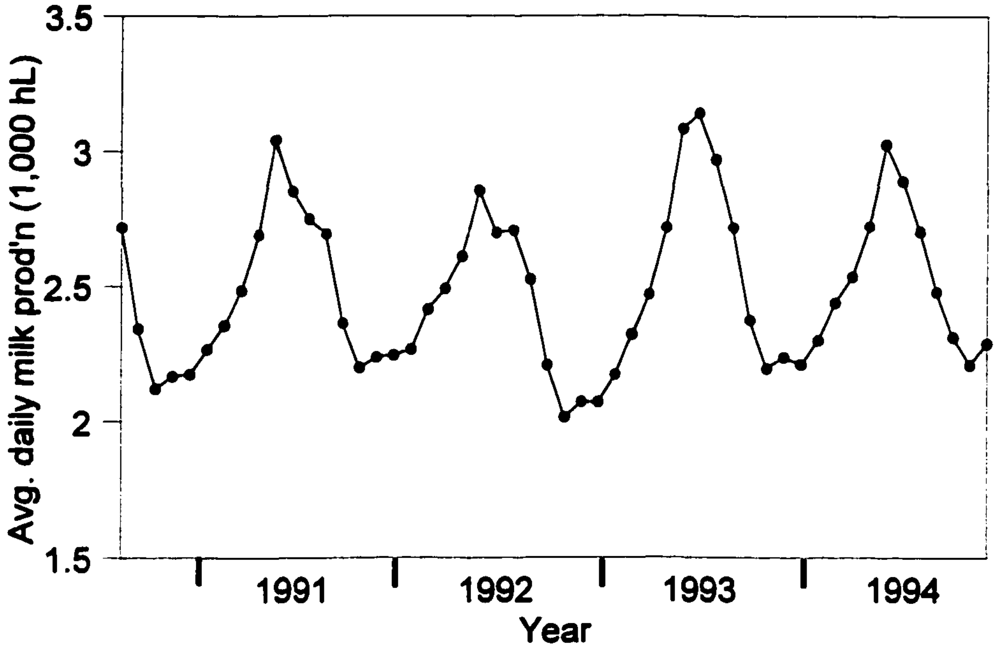


Figure 3. Average total daily milk production (X 1,000 hL) in Prince Edward Island from August 1990 to December 1994. Data source: Prince Edward Island Milk Marketing Board.



Chapter 2

Patterns of Seasonal Variation in Individual Cow Milk Production in Dairy Herds in Prince Edward Island, Canada

INTRODUCTION

Prince Edward Island (PEI) is the smallest , but most densely populated of the Canadian provinces. Most of it's landmass is arable and much of it is under cultivation. The dairy sector is a significant part of the agriculture industry in PEI accounting for 18.3 % of the total farm cash receipts in 1993 (5). In the 1993-1994 dairy year (August 1, 1993 to July 31, 1994) there were 490 milk and cream producers holding quota. Approximately half of these farms utilize the services of the Atlantic Dairy Livestock Improvement Corporation (ADLIC, Moncton, New Brunswick) to record various production and health parameters, and to provide management services and recommendations. Much of the data collected by ADLIC is also stored in the Animal Productivity and Health Information Network database (APHIN, Charlottetown, PEI) at the Atlantic Veterinary College, University of Prince Edward Island. This database, which has been described previously (6), is used by veterinarians and researchers to monitor production and health parameters for a number of different livestock species. One of the parameters that is recorded for the dairy herds included in APHIN is the average daily milk production per cow.

Dohoo and Ruegg (7) have previously demonstrated a seasonal pattern in raw and adjusted milk weights from the APHIN database using a periodogram, which showed that there was a 12 month cycle to the data during the years 1988 to 1991. A graph of the data for 1989 and 1990 showed that, in general, the peak in production occurred in June and the nadir occurred in November. Considerable farm-to-farm variation has been observed as indicated in Figure 1 which presents two years data from two dairy herds. However, the farm to farm variation and the consistency within a farm of seasonal production patterns has not been well described. Anecdotally, the wide variety of opinions from producers, scientists, and extension and industry personnel about the causes, costs and methods of preventing a "slump" also demonstrates that factors affecting seasonal production are not well understood. There is a need for identification of the causes and costs associated with different milk production patterns so that producers can make decisions that will allow their farms to remain as viable and profitable enterprises in the coming years.

The objectives of this paper are to describe in detail the seasonal pattern of milk production per cow per day on Prince Edward Island for the years 1990 through 1994, and to explore some of the associations between seasonal patterns of production and winter baseline milk production per cow, herd average genetic index, and milking herd size. Between herd and within herd variation of milk production patterns will also be described.

Materials & Methods

Source of Data

Data for the years 1990 through 1994 from all dairy herds enrolled with ADLIC were extracted from the APHIN database. These included, among other variables, monthly measures of the numbers of cows milked, the average amount of milk produced per cow per day, and the average adjusted corrected milk per cow, which adjusts the test day production at the herd level based on the percent of heifers in the herd, the average days in milk for the herd, and the average percent fat in the monthly bulk tank milk samples (6). Average herd level genetic indices were obtained directly from ADLIC in an electronic spreadsheet format. These are measures of the average deviation of the cows in a herd from the national average of all cows calving 2 years prior to the calculation of the indices (19,20). Unique identification numbers identified the herd of origin for all data (Table 1). Total monthly milk production for Prince Edward Island farms was obtained from the PEI Milk Marketing Board. Average milk per cow per day for Ontario dairy herds was available from a recent investigation into factors affecting milk protein yield (21). Weather data for Prince Edward Island and Ontario was obtained from records kept by the federal government's Environment Canada weather service.

Data Management

All data, except the weather data and Ontario production data, were merged into STATA (STATACorp., College Station, TX), a data management and statistical analysis software package, using ADLIC's unique herd identification number. From the original data a number of variables were calculated (Table 1). An annual "slump" parameter (MINMAX), relating a herd's minimum test-day average milk production in the fall to its maximum spring production, was calculated for each herd using the formula found in Chapter 1 (Eqn. 1; Chapter 1, p. 5).

This parameter, MINMAX, was used to summarize the amount of decline during the summer and fall months in average test day milk production per cow. A baseline figure for average daily milk production per cow during the winter (WINTMILK) was calculated by averaging the production for the months of February and March, weighted by the number of cows on each test day. The average number of cows milking in the herd (NUMCOWS) was derived by averaging the number of cows milking on each test day over a whole year.

Descriptive statistics for all variables were obtained. Measures of variation between and within herds were obtained for MINMAX by decomposing the variation into between-herd, and within-herd components. In addition, oneway analysis of variance was performed using herd as the independent variable and the intraherd correlation coefficient ($\hat{\rho}$) was calculated using the following formula (8):

$$\hat{\rho} = \frac{(MSB - MSW)}{(MSB + (m-1) \times MSW)} \qquad \textbf{(Eq. 1)}$$

where: MSB is the between herd mean square,

MSW is the within herd mean square, and

m is the average number of yearly measures of MINMAX per herd.

In order to assess the unconditional associations between herd size and the slump, the herds were divided into three equally sized groups based on the average number of cows milking in 1993. An ANOVA was then used to determine if herd size was a significant predictor of the slump and a Bonferonni test was performed to compare the group specific averages. This procedure was repeated using the average winter production and the average genetic index for milk production as stratification factors.

RESULTS

Two hundred and fifty-eight herds contributed 1051 measures of MINMAX for the 5 year period from 1990 to 1994. The Holstein breed accounted for about 90 percent of the population with the Guernsey and Ayrshire breeds accounting for the majority of the remaining 10 percent. Table 2 presents in detail more information about the slump parameter MINMAX for the years 1990 to 1994. The average slump (MINMAX) for all PEI herds, over all 5 years, was .745, indicating that on average, the minimum daily production per cow in the fall (October, November, December) was 25.5 % less then the maximum in the spring and early summer (May, June, July). It can be seen that the average slump was very consistent from year to year, ranging from a low of .721 in 1992 to a high of .762 in 1991. The standard deviation was also very stable from year to year. The skewness and kurtosis values of the distribution were -.29 and 3.6 respectively.

These coefficients indicate that the slump parameter was approximately normally distributed. If the data were completely normally distributed, these values would be 0 and 3 respectively (23). Skewness is a measure of the relationship of the median to the mean. If the median is greater than the mean, the resulting value is negative indicating a left skew to the data. Conversely, a right skew to the data means that the median is less than the mean. Kurtosis is an indicator of the peakedness of the distribution. A value greater than 3 indicates that the data are concentrated about the mean more closely than would be expected with normally distributed data, whereas a lower value indicates a 'flatter' distribution of the data. Measures of skewness and kurtosis of 0 and 3 are considered necessary, though not sufficient, conditions of normality (23). The minimum value for adjusted corrected milk in the fall (October, November, December) was 12.36 % less than the maximum value in the spring and early summer (May, June, July). Figure 2 presents the PEI and Ontario monthly mean milk production data, as well as the average total daily milk shipments (1,000's of hectolitres) for PEI for the same time period.

The average number of cows milking for all herds in Prince Edward Island enrolled on ADLIC during the years 1990 to 1994 was 30.6 cows (standard deviation (SD = 14.29). The average winter milk (February and March) production level for all herds during the same time period was 23.05 kilograms of milk per cow per day (SD = 4.32), with an upward trend of 2.0 percent per year. The average genetic index for milk for the herds for 1994 was -1.00 (equivalent to -106 kg EBV milk) with a standard deviation of 2.02.

The results of the decomposition of the variance in MINMAX into within and between herds components are presented in Table 3. A greater amount of the variability over the 5 years arose from inter-herd variation in the slump parameter (SD = .115) than from the intra-herd variation (SD = .078). An ANOVA demonstrated that "herd" was a significant predictor of slump ($P < .001$). The intraherd correlation coefficient was calculated as .537.

The results of the stratification based on herd size (NUMCOWS), winter milk production (WINTMILK) and genetic levels (AMILKNDX), are found in Table 4. While the smaller herds demonstrated a statistically greater slump than either the medium or large herds ($P < .05$), there was a large range of values of MINMAX found within each stratum. There was a significant difference with respect to MINMAX between all three groups when stratified on the basis of WINTMILK, the average of the February and March production per cow ($P < .05$). The group of herds with the lowest average genetic index for milk (AMILKNDX = -3.00) showed a significantly greater decline in milk production over the summer and fall months than the herds with the highest average herd genetic index for milk (AMILKNDX = 1.17, $P < .05$). Neither of these groups was statistically different from the medium group (AMILKNDX = -1.02). Once again, a wide range of values for MINMAX was found in each stratum.

Figure 3 presents, on a monthly basis, the average daily mean temperature for Prince Edward Island and Ontario from 1990 to 1994.

DISCUSSION

Two components to the seasonal variation seen in milk production have been described in the literature. The month of calving affects the total milk production in that lactation for an individual cow (cohort effect), whereas the "test date" effects are those factors which affect all cows in the herd on a specific day (current effects) (22,24).

There is considerable evidence that the cohort effect is substantive and that the month of calving will affect the total lactation milk production (10,12,14,18). However, Wood (25) demonstrated that the variation in total yield associated with the month of calving could be explained almost completely by other factors. A test day model developed by Stanton et al (22), which absorbed the herd level test date effects in the model, also found that there were only slight differences between the lactation curves for the different seasons of calving. These studies suggest that most seasonal patterns of production are due to current effects and that the cohort effects are minimal.

Several studies have investigated the relationship between economics and seasonality of bulk milk shipments from dairy farms (2,3,16). While there may be a direct association between low levels of daily milk production at the cow level and decreased bulk milk shipments from the farm, this has apparently not been documented. Producers who are shipping less milk at certain times of the year may be milking fewer cows while maintaining a high level of production per cow. Likewise, it may be that producers milk more cows during times of the year when production per cow is lower in order to maintain relatively consistent bulk milk shipments. Though it is impossible to draw conclusions about factors that affect individual cow production from studies which focus on the seasonality of bulk milk shipments, the similarity in the patterns of production at the cow level and total daily milk shipments at the provincial level on Prince Edward Island (Figure 2) appears too strong to be coincidental.

Average daily milk production per cow in PEI dairy herds follows a predictable temporal trend (Figure 2). The average amount of seasonal variation is quite consistent from year to year, as is the distribution of herds about the mean (Table 2). A relatively normal distribution about the mean, rather than a biphasic distribution, implies that seasonal variation in production occurs as a continuum among farms rather than as a dichotomous situation.

The intraclass (intraherd) correlation coefficient ($\hat{\rho}$) is the proportion of the total variance in the population which can be attributed to the variation between the herds (8). McDermott and Schukken (13), in their review of methods used to adjust for cluster effects in epidemiologic studies, rank an intraclass correlation coefficient as 'high' if it is in the range of .1 to .2. In our study, $\hat{\rho}_{MINMAX}$ was computed at .537, indicating that 53.7 percent of the variance in MINMAX from 1990 to 1994 can be attributed to the variation between herds, and that the remaining 46.3 percent of the variation occurs within a herd from year to year. The high degree of clustering within herds over the five years, as well as the consistency of the slump parameter (MINMAX), strongly suggest that there may be important herd management factors that consistently affect summer and fall milk production on farms in PEI.

The results from the stratification analysis (Table 4) indicate that there are small but significant relationships between the amount a herd declines in production over the summer and fall and the herd size, winter production, and average genetic index. However, it is also obvious that there is much more variability in the slump parameter (MINMAX) than can be explained by these factors alone, and collinearity likely exists among these variables. In all strata there are herds that experience a significant slump in milk production and herds that maintain consistent production. This implies that there is a large influence on summer and fall milk production from other factors such as management and nutrition, which have been proposed as being causes of farm to farm variation in milk production patterns (1,4,7,11,21).

The seasonal variation observed in average daily milk production could also be attributed to the normal decline in production that is observed as cows pass peak lactation, if most cows in a herd calved in the spring. Similarly, another factor that must be considered is the proportion of the herd in first lactation. Heifers tend to have lower peak milk production than mature cows, but also have a slower rate of decline after peak production (22). Thus, a herd that has a large number of mature cows past peak lactation during the summer and fall months could expect to demonstrate a greater amount of seasonal decline in milk production than a herd that had a large number of heifers with the same average days in milk. These normal physiological processes are the basis of the parameter "adjusted corrected milk" that has been described by Nordlund (15), and modified in the APHIN database (6). On average, PEI values for adjusted corrected milk tend to decline only half as much as the values for test day milk production per cow. This indicates that the stage of lactation, parity profile and bulk tank fat percentage do contribute a significant component of the seasonal variation in average daily milk production observed in Prince Edward Island.

The phenomenon of seasonality in test day milk production is not restricted to PEI. Adjusted corrected milk (9) and test day milk production data (21) from Ontario demonstrate an obvious seasonal pattern. The zenith and nadir in Ontario occur exactly one month before those in Prince Edward Island. This corresponds very closely with the lag in the spring rise in temperature in PEI when compared to Ontario (Figure 4).

Heat stress has also been implicated as one of the possible causes of seasonality of production at the individual cow level (4,10). Although there may occasionally be a short period of weather during July and August that is hot enough to affect feed intake, Papadopoulos et. al. (17) suggest that, in general, the summer temperatures in Atlantic Canada are not severe enough to limit pasture growth. It seems very unlikely, therefore, that heat stress is a significant component of the summer and fall slump observed in PEI.

CONCLUSIONS

The average decline in test day milk production across Prince Edward Island is very stable from year to year and production patterns are quite consistent within a herd. The phenomenon of seasonality is not limited to Prince Edward Island and, though well recognized, it does not appear to be well understood. Herds of all milk production levels, all sizes, and all levels of genetic potential can experience a significant slump or can remain seasonally consistent with respect to the average daily milk production per cow. The specific impact of these and other factors on the seasonality of production, as well as the economics of summer and fall milk production, is being investigated in a detailed longitudinal study involving a subset of the herds reported on in this chapter.

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Table 1. Monthly and annual variables downloaded from the Animal Health and Information Network (APHIN) database and variables computed on an annual basis.

Variable	Description
Monthly herd level data obtained from APHIN (1990 - 1994)	
HERDID	Unique Atlantic Dairy Livestock Improvement Corporation (ADLIC) herd identification number
YRMNTH	Numeric representation of the year and month (combined) in which milk test was done
AVGMILK	Average test day milk production (kilogram per cow/day)
ADJMILK	Adjusted corrected milk production (kilogram per cow/day)
AVGFAT	Average percent fat from bulk tank milk sample
NUMMILK	Number of cows milking
NUMTEST	Number of cows tested
Herd level data from ADLIC	
AMILKNDX	Herd average genetic index for milk (1994)
Parameters computed on an annual basis (1990-1994)	
MINMAX	Minimum production per cow/day in fall expressed as a percentage of maximum production per cow/day in the spring
WINTMILK	Weighted average of February and March production per cow/day
NUMCOWS	Average number of cows in milk

Table 2. Slump parameter (MINMAX) measures over a 5 year period, 1990-1994, for all Prince Edward Island dairy herds utilizing the Atlantic Dairy Livestock Improvement Corporation's milk recording services.

	YEAR (# herdtests)					
Slump (MINMAX[1])	1990 (224)	1991 (211)	1992 (205)	1993 (212)	1994 (199)	'90-'94 (1051)
mean	.744	.762	.721	.750	.748	.745
standard deviation	.132	.129	.131	.133	.131	.132
minimum	.289	.336	.285	.247	.296	.247
1st quartile	.654	.675	.642	.680	.683	.663
3rd quartile	.833	.856	.811	.840	.833	.833
maximum	1.082	1.208	1.013	1.127	1.161	1.208
skewness	-.319	-.009	-.368	-.378	-.364	-.288
kurtosis	3.251	3.392	3.192	3.901	3.966	3.564

[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. (See Chapter 1 for details.)

Table 3. Partitioning of variance in slump parameter (MINMAX[1]) into between- and within-herd components over a five year period, 1990-1994.

Slump (MINMAX[1])	Observations	Mean	Standard Deviation	Minimum	Maximum
overall	1051	.7451	.1316	.2469	1.208
between	258		.1151	.2894	1.028
within	4.07		.0780	.5143	1.095

[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. (See Chapter 1 for details.)

Table 4. Slump parameter (MINMAX[1]) descriptive statistics for 1993 with data stratified based on herd size, winter milk production and herd average milk genetic index.

Parameter	Group (# herds)	Group average	Slump (MINMAX[1]) average	st. dev.	minimum	maximum
Herd size[2] (# cows)	Small (69)	19.3	.688[a]	0.137	0.415	1.011
	Medium (69)	30	.764[b]	0.123	0.247	1.105
	Large (69)	48.2	.796[b]	0.116	0.45	1.126
Winter milk production (kg)[3]	Low (69)	18.12	.688[a]	0.125	0.415	1.011
	Medium (69)	23.52	.753[b]	0.123	0.247	1.022
	High (69)	28	.818[c]	0.115	0.45	1.126
Genetic index (milk)[4]	Low (52)	-3	.752[a]	0.122	0.491	1.105
	Medium (51)	-1.02	.774[a,b]	0.093	0.554	0.928
	High (51)	1.17	.813[b]	0.124	0.482	1.126

a,b,c Average slump (MINMAX) between groups with different superscripts (within each parameter) differ ($P < .05$).

1 Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. (See Chapter 2 for details.)

2 Herd size = Average number of cows in herd 1993.

3 Winter milk production = Average daily milk production (kilogram per cow/day) of February and March 1993.

4 Genetic index (milk) = Herd average genetic index for milk as of April 1994 as calculated by Agriculture and Agri-Food Canada.

Figure 1. Monthly average test-day milk production (kilogram cow^{-1} day^{-1}) for 2 Prince Edward Island dairy herds (January 1993 to December 1994). Data source: Animal Productivity and Health Information Network.

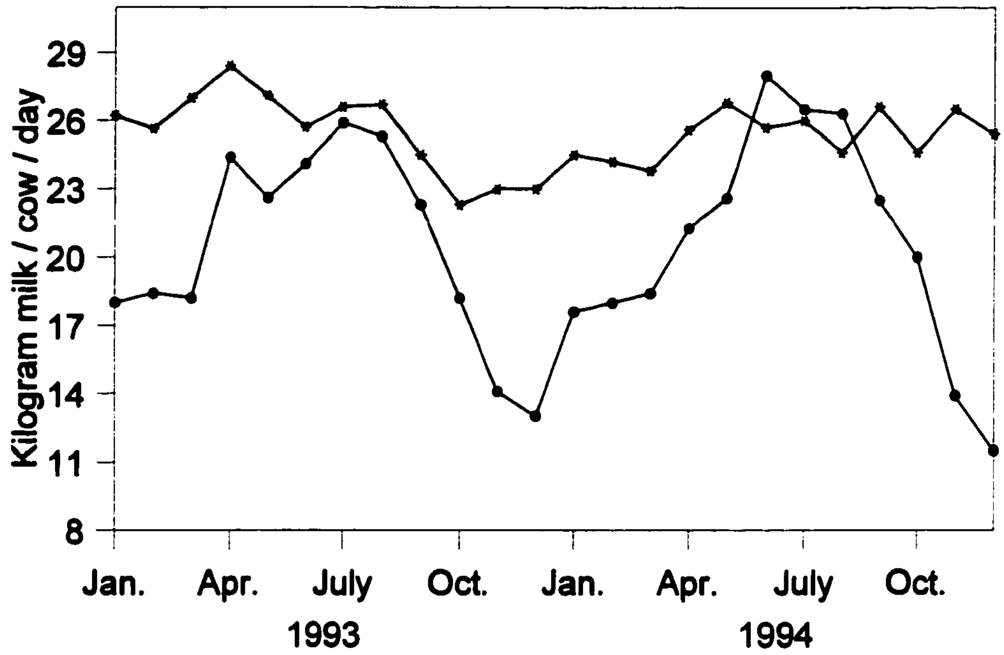


Figure 2. Average test day milk production per cow for Prince Edward Island (PEI) (•) (January 1990 to December 1994), Ontario (✱) (January 1990 to September 1994) and PEI average total daily milk production (▶) (August 1990 to December 1994).

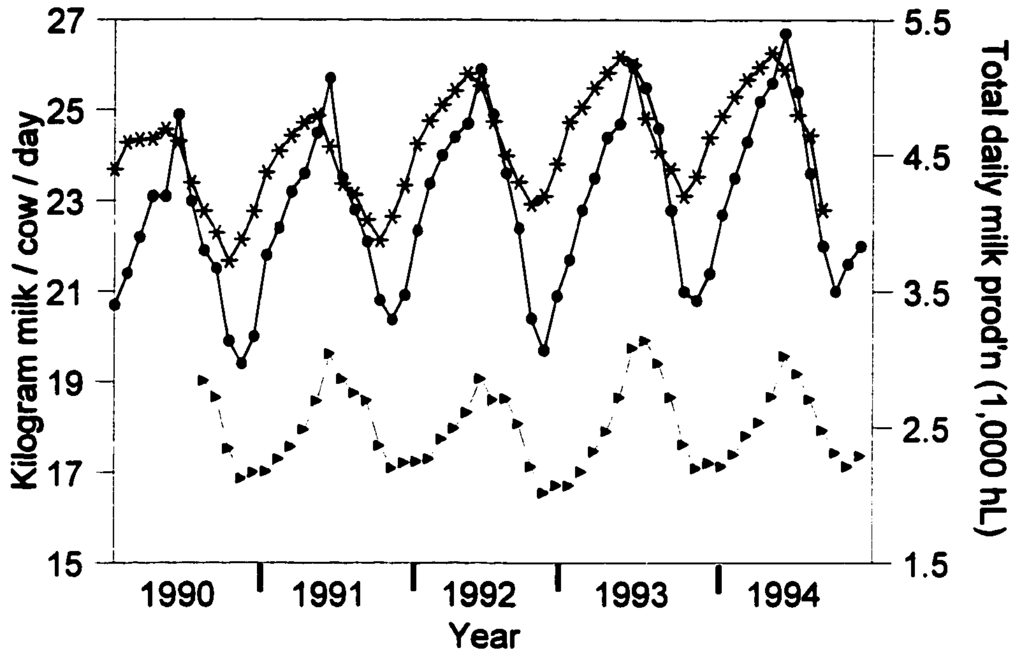
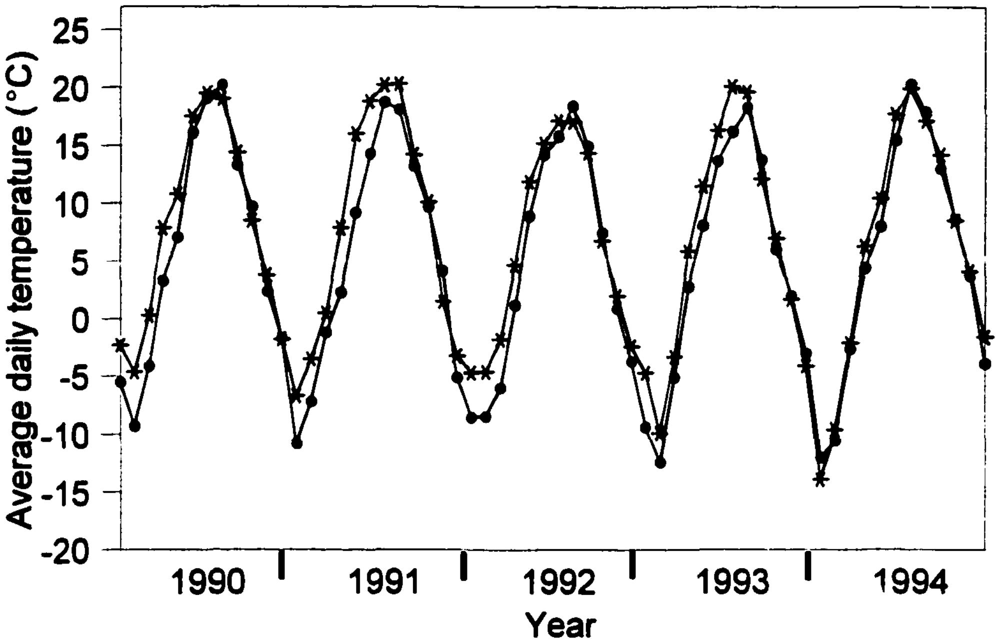


Figure 3. Average monthly mean daily temperature for Prince Edward Island (•) and Ontario (✳) Canada from January 1990 to December 1994. Data from Weather Service, Environment Canada.



Chapter 3

Contribution Margin and Seasonal Variation in Individual Cow Milk Production in Dairy Herds in Prince Edward Island, Canada

INTRODUCTION

In the previous chapter (Chapter 2), the seasonal variation of average daily milk production per cow in Prince Edward Island (PEI), Canada, was described. It was shown that many herds experience a significant decline in individual cow milk production during the summer and fall months of the year irrespective of herd size, genetic index, and level of milk production during the winter months, but that there were also herds that maintained very consistent levels of production throughout the year.

Kelton (11), in a study investigating the productivity and profitability of Ontario dairy herds, found that annual income over feed cost per cow (IOFC) was not related to the amount of seasonal variation in adjusted corrected milk production. Adkinson et al. (1) found, however, that the 10 percent of herds in Louisiana with the highest IOFC had less seasonal variation in daily milk yield per cow than all herds.

The primary objective of this study was to explore the relationship between the amount of seasonal variation in daily milk production per cow in PEI during 1994 and the contribution margin per cow (CM_C), and per hectolitre (CM_H), where the CM is defined as the income in excess of the feed costs, in accordance with the definition provided by the Farm Accounting Standardization Review Committee (6). In addition, the relationship between the daily summer and winter feeding costs and the seasonal variation in production was examined, as was the relationship of herd factors with the CM_C. The relationship of these factors to the CM_H was also briefly explored.

MATERIALS AND METHODS

Selection of Study Herds

The Animal Productivity and Health Information Network (APHIN) is an electronic database containing production and health data for various agricultural commodities in PEI (8). All dairy herds that had individual cow milk production information in the APHIN database for the calendar year 1992 were included in the initial sampling pool. Monthly figures for average milk production per cow on test day during 1992 were electronically downloaded along with a unique herd identification number. A parameter that represented the amount of decline in test-day milk production from the maximum observed during May, June and July to the minimum during October, November and December was calculated for each herd. This variable, MINMAX, was defined in Chapter 1 (Equation 1; Chapter 1, pg. 5).

The data were then sorted by MINMAX, so that herds were ranked according to the amount of decline in milk production they experienced during the summer and fall of 1992. The 45 herds that experienced the most significant decline in production and the 45 herds that experienced the least amount of decline were enrolled in the study. Due to the time period intervening the sample selection and the data collection, the distribution of the MINMAX values in the study sample was compared with the distribution of the population values. Distribution histograms and cumulative distribution plots were used to graphically compare the groups. The Kolmogorov-Smirnov Equality of Distributions Test (19) was used to formally assess the equality of the distributions.

Site Visits

Each farm selected for the study was visited twice in 1993 and twice in 1994, once near the end of the stabling period (April) and once during the latter part of August. The principal investigator and a single research assistant carried out all the site visits. Only the data collected in 1994 were used in this analysis.

Stored Feeds Fed to Lactating Cows - the Data

The daily quantity of each feed that was fed to the lactating cows was recorded on a per cow basis. This was recorded by production group (high, average, and low groups) if the amount fed was proportional to the milk production level. In these instances the farm specific cut points dividing the production groups were ascertained. Data from the APHIN database were used to determine the percentage of milk tests occurring within each range during February, March and April. A herd average amount fed per cow for each feedstuff was calculated using these group percentages as a weighting factor. The summer stored ration was recorded in a similar manner, using the milk production records for July, August and September to weight the group specific data.

Samples of all available forages, grains and concentrates were taken to determine the dry matter, protein and energy content, except where a commercially prepared product with a known composition was being fed. In this case, enough details about the product were recorded so that the dry matter, energy and protein levels could be ascertained from other sources at a later time. In most instances, the actual weight of the feedstuffs fed to the cows was also measured and recorded.

In the case of forages fed *ad libitum* or where total mixed rations were fed, the total dry matter intake was calculated based on the average dry matter intake expressed as a percent of body weight of cows of similar breed and size that were also included in the study and had complete feed data available.

Stored Feeds Fed to Lactating Cows - the Costs

Prices for hay and silage were obtained from the 1994 PEI Dairy Cost of Production Study (15). These were used to determine the cost of stored forages fed to the cows. Prices for commercially prepared pelletized and mixed rations, and other supplements, were obtained from the suppliers of the products. Grain prices were available from the local grain elevator. Where rations had been prepared on farm, the price was calculated based on the protein concentration of the completed mix. Using barley grain as a base, the amount of a commercially available 38 percent protein concentrate needed to reach the measured protein level was determined and the price of the resulting ration calculated. Cull potato prices were obtained by surveying a number of producers who utilized this feed. Where total mixed rations or partially mixed rations were fed the cost per tonne was calculated on the basis of the components included in the mix.

The winter daily feed cost per cow was calculated by adding all the costs from the winter ration components. The summer daily feeding costs included the costs of the stored feeds that were fed during the summer as well as the pasture costs per cow per day.

Pasture Forage for Lactating Cows - the Data and Costs

Information regarding pasture management was collected by means of a questionnaire that listed all the pasture fields utilized on a farm. It included information regarding the field size, the method of access to the fields and the details of any fertilizer, lime or reseeding utilized. A detailed list of information collected can be found in Appendix A.

Total pasture costs were calculated based on the information collected and this was divided by the average number of cows being fed on pasture during the months of May to September. This figure was then divided by a constant 153 grazing days across all farms to arrive at the total pasture cost per cow per day. Details of the calculation of pasture costs can be found in Appendix A.

Production and Income Data

Records of individual cow milk production were available from the APHIN database for all study herds. Herds, and animals within herds, were identified by unique identification numbers. These data were used to calculate monthly summary statistics for the average daily production and the number of animals milking. Total monthly milk shipments for each herd were available from the PEI Milk Marketing Board, as were the pricing formulas required to calculate the total milk revenue for each farm for each month during 1994.

Calculation of Contribution Margin

The Farm Accounting Standardization Manual (6) defines "contribution margin" (CM) as "...the excess of total revenue minus the variable costs that directly relate to the business enterprise." Since purchased and farm-grown feed costs account for approximately forty-five percent of the variable and fixed costs of milk production in Atlantic Canada (13,15), the CM was defined, for the purposes of this study, as the total annual milk revenue in excess of the total annual feed costs, including both stored feeds and pasture, for the lactating cows.

Revenue from milk sales was calculated for each herd on a monthly basis from total milk shipments and the pricing formulas provided by the PEI Milk Marketing Board.

The total daily feed costs per cow were derived as explained above and used to calculate the total monthly feeding cost for a lactating cow. Daily summer feed costs (pasture plus stored feed) were used in the calculation of costs for the months of May to September, and the remaining months were based on the daily winter feed costs (stored feed). The total monthly cost per cow was multiplied by the number of cows milking in each month as reported in the APHIN database. In the case of missing data in the event of a missed monthly test, the number of cows milking was calculated as the average of the number milking during the previous and following months. The total milk revenue in excess of feed costs for each month was then calculated. These monthly totals were summed to arrive at the annual CM.

In order to remove the effect of herd size on the CM, the annual CM was divided by the average number of cows milking during 1994 to arrive at the annual contribution margin per cow (CM_C). The CM was also expressed per hectolitre of milk shipped from the farm during 1994 (CM_H) since this is the income limiting factor in quota based production systems.

Two-way scatter plots were used to examine the relationships in the data. Simple linear regression was used to determine the coefficient (β) of the independent variable, the percentage of the variation in the dependent variable accounted for by the independent variable (R^2) and the significance level of the relationship (P). Regression diagnostics included examination of the residual scatterplots for heteroscedasticity, and examination of the leverage values for points of high leverage. The presence of heteroscedasticity was formally tested for using the Cook-Weisberg test (4,10), which models the variance as a function of the fitted values. Evidence of omitted power terms (x_i^2, x_i^3 and x_i^4, and $\hat{y}^2$, $\hat{y}^3$ and $\hat{y}^4$) was assessed by the Ramsey test, which incorporates power terms of each variable into the model and evaluates their statistical significance (9,16). The DFBETA statistic (19), which is a measure of the impact of an observation on the individual regression coefficients, was calculated for each observation. The difference between the coefficient estimates obtained with an observation included in and omitted from the model is scaled by the standard error of the coefficient. The resulting value is a measure of how many standard error units the observation changes the coefficient estimate.

All data manipulation and statistical analyses were carried out using STATA (20).

RESULTS

Loss and removal of herds from study

Six producers exited the dairy industry during the data collection phase of the study, and three did not have adequate milk production data to calculate a seasonality value (MINMAX). One herd underwent a physical relocation and substantial expansion during the summer of 1994, and it was decided that the milk production in this herd was affected sufficiently by these factors to justify their removal from the study. These 10 herds were thus removed permanently from the "Summer-Fall Slump Study."

A number of herds were removed from the economic analyses presented in this chapter for other reasons: two "cream-shippers" were judged to have sufficiently different enterprise dynamics to warrant their exclusion, and six herds were not included in the economic analysis due to incomplete ration information or an inability to accurately calculate daily feed costs.

Congruency of sample and population distributions

Figures 1 and 2 depict the distribution of MINMAX values for the study herds for 1992 and 1994, respectively. Figure 3 is a cumulative distribution graph depicting the distribution of 1994 MINMAX values for the study herds and for the population. The Kolmogorov-Smimov Equality of Distributions Test showed that no significant difference (P = .99) could be detected between these two distributions.

Table 1 summarizes the MINMAX parameter, as well as the 1994 daily feeding costs for the winter (stabling) period, the total daily summer feed costs per cow, and the average pasture costs per cow per day. In 1994, the minimum test-day milk production per cow during the fall was at 75 percent of the maximum test-day milk production per cow in the late spring and early summer, when averaged across all herds. It can be seen that there is a wide range of daily feed costs, both during the summer and during the winter. Of the 72 herds with complete economic data, only four did not utilize any pasture as a feed source.

The CM_C ranged from $1453.57 (Cdn.) to $4753.64 with a mean of $3238.74

and a standard deviation of \$664.12. Skewness and kurtosis values of -.092 and 2.061 respectively, and a Shapiro-Wilk W value of .990 reflect a normal distribution of this variable (19). The MINMAX parameter was also normally distributed with skewness, kurtosis and Shapiro-Wilk W values of -.53, 2.93, and .97 respectively.

Figure 4 depicts the relationship between CM_C and the seasonal pattern of average test-day milk production (MINMAX). There was a general upward trend in CM_C as the seasonal variability in production declined. On average, as the seasonal variability decreased by .01 there was an increase of \$21.53 (Cdn.) per cow per year. Figure 5 shows the positive relationship between the average daily feed costs per cow in the summer and the MINMAX parameter. As summer daily feed costs increased there was less decline in production during the summer and fall months. There was no significant relationship between winter daily feed costs and MINMAX.

The positive relationships between the CM_C, average daily production per cow and herd size are shown in Figures 3 and 4. There was a positive relationship between average genetic index for protein and CM_C ($\beta = 138.77$, $R^2 = .18$, $P < .01$).

There was a very weak positive relationship between the average daily summer feed costs and the CM_C ($\beta = 144.63$, $R^2 = .03$, $P = .11$), while there was no relationship between the average daily winter feed costs and the CM_C ($\beta = 14.34$, $R^2 = .00$, $P = .88$).

Although there was a high degree of correlation between the CM_C and the CM_H (Figure 8), there was no significant relationship between CM_H and MINMAX

($\beta = 3.32$, $R^2 = .01$, $P = .36$). As average daily summer feed cost increased there was a slight decrease in the CM_H ($\beta = -.99$, $R^2 = .07$, $P < .05$), although there was a strong negative relationship between the average daily winter feed cost and the CM_H ($\beta = -1.90$, $R^2 = .21$, $P < .01$).

DISCUSSION

Congruency of sample and population distributions

The sampling strategy initially used to select herds was indicative of a case-control study, and Figure 1 demonstrates the biphasic nature of the values in the study population. Given this selection process, and the resulting distribution of MINMAX values, herds could have been dichotomized based on their MINMAX values and logistic regression techniques used in the analysis of the data. Although it was previously shown that there was a trend for MINMAX values to cluster within herds across years (Chapter 2), Figures 2 demonstrates that the distribution of MINMAX values in the study herds had normalized during the two years intervening the sample selection and the collection of the data which was analyzed in this thesis. Figure 3 demonstrates that these two distributions were virtually identical, and this was formally confirmed by the Kolmogorov-Smirnov Equality of Distributions Test. This congruency between the study sample and the population, with the respect to the outcome of interest (MINMAX), presented justification for treating the study herds as a random sample from the population, notwithstanding the initial selection process. The dependent variable was therefore treated as a continuous variable, supporting the use of ordinary least squares linear regression techniques.

In order to be able to calculate the CM_C, values are needed for feed cost and milk revenue. There have been various methods used to calculate the amount of feed utilized by lactating cows, as well as the costs of those feeds.

In developing a model to estimate the economics of various production and pricing situations, van Arendonk (22) calculated the amount of forage consumed based on the energy requirements of the cows. Parker et al. (14) used a similar approach in developing a model consisting of a series of linked spreadsheets, which was used to compare the economics of grazing and confinement feeding systems. Producer estimates for the Ontario Farm Monitoring and Analysis Program (OFMAP) of start-of-year and end-of-year feed inventories and transfers in and out of the system were used to calculate total feed costs in a study investigating the profitability of Ontario dairy herds (11). A follow up study is being conducted to investigate the reliability of these data (D. Kelton, personal communication). Producer estimates of total daily feed consumption recorded through a DHI program served as the source for daily feed intake per cow in a study investigating IOFC and feeding practices in Louisiana (1).

There are also various approaches to the calculation of pasture dry matter intake. McClelland (12) deducted the energy derived from stored feeds from the requirements of the cows to arrive at the amount of energy supplied by pasture forage. Another method that has been used to calculate average daily pasture forage intake is to measure the tonnage of dry matter in a field before and after it has been grazed and to divide the amount consumed by the number of "cow-days" on the field (5).

While the calculation of intake based on energy requirements has a sound theoretical basis, it was decided to avoid this approach since a measure of production was being used as an outcome variable. Using production based energy requirements to predict intake would have resulted in milk production levels contributing to both the dependent variable and an independent variable in the analysis. Producer estimates of total annual or daily feed usage were expected to be less precise than recording actual measures of daily feed utilization per cow, and an estimates of total annual usage would also not allow comparison of summer and winter feeding regimes.

It was deemed not to be feasible to take repeated measures throughout the grazing season of the available pasture forage on 90 farms. Instead, the farm specific costs of producing and maintaining pasture were determined and these costs were assigned to the number of "cow-days" spent on pasture. While this approach avoided calculating the amount of forage intake per cow, the resulting daily cost per cow was thought to be more reflective of the actual feeding cost than the alternate approach of estimating forage intake and multiplying this by an estimated cost per tonne.

There have also been different approaches to calculating daily feed costs.

One method uses a constant cost per unit of energy or protein. This is multiplied by the estimated number of units required by the animal to arrive at the feed cost per cow (2,22). Another method uses forages and concentrates with a set price per tonne to meet the calculated energy requirements of the cow (21).

Pasture cost estimates also vary considerably. McClelland (12) recorded actual costs incurred over a 5 year period for 10 dairy farms in Quebec, Canada. These costs ranged from $108.00 to $211.00 per hectare. They were found to be highly influenced by the value assigned to the land. In the OFMAP data utilized by Kelton (11) a fixed cost across farms of $123.50 per hectare of pasture was assigned as a dairy enterprise feed cost. In the current study, average pasture costs per hectare amounted to $159.26 with a standard deviation of $40.60. (See Appendix A for details.)

The actual amount of stored feed used per lactating cow was measured on all farms in the present study. Farm specific feed costs were determined as accurately as possible, although calculating the farm specific costs of production for hay, silage and grain was beyond the scope of this study. Such calculations would have required performing an enterprise analysis for all farms. The use of farm specific costs associated with pasture utilization allowed for an accurate overall estimate of the average daily cost per cow for the summer period. It would be expected that the method used to calculate feed costs should approximate very closely the actual overall cost, since the calculations account for farm-to-farm differences in feed quality, utilization efficiency and wastage.

The relationship between MINMAX and the CM_C (Figure 4) suggests that the CM_C was reduced in herds that experienced significant seasonal variation in milk production. The positive association of average daily summer feed cost and the MINMAX parameter (Figure 5) demonstrates that less seasonal variability in production should result in response to an increase in summer feeding costs.

There was a strong positive relationship between average daily production per cow and the CM_C (Figure 6). This is consistent with the literature that suggests that in most situations it is economically advantageous to increase milk production per cow even though feed costs are increased (3,18). As milking herd size (Figure 7) and genetic index for protein increased there was also an upward trend in the CM_C. It seems unlikely that these factors have a direct effect on the CM_C, and their effect is likely modulated through other means. Veerkamp et. al. (23) also observed a similar positive correlation between the pedigree index (fat and protein yield) of an individual cow and her margin over feed costs. These relationships will be explored in more detail in subsequent analyses.

Although there was a positive relationship between summer daily feed costs and MINMAX and between MINMAX and CM_C, it appears that there was enough variability in the data so that there was not a significant relationship between summer daily feeding costs and CM_C. Adkinson et. al. (1), in a model controlling for the amount of silage and hay fed, demonstrated a positive response in milk production and a negative response in IOFC when concentrate feeding was increased. However, when concentrate feeding was controlled for, there was a positive response in milk production and IOFC in response to an increased level of silage feeding. These opposing results could be part of the reason for not observing a more significant relationship between CM_C and the daily summer feeding costs per cow in the present study. Further investigation into these relationships is warranted. It must also be remembered that the CM as defined in the present study does not account for all of the variable costs of production, and as such, care must be taken in interpreting the results.

The CM_H used in this study is similar to the gross margin per 100 kg of milk that was used by Rougoor et al. (17). In the quota-based production systems that exist in Canada and the Netherlands it may be of more benefit to maximize production efficiency per unit of milk sold, since the amount of milk that can be produced in a given period of time is restricted (17). The absence of a relationship between MINMAX and the CM_H, given the relationship between MINMAX and CM_C, was likely due to the confounding factors such as herd size and milk production per cow. The negative relationships found in this study between the CM_H and the daily summer and winter cost of feeding is, however, consistent with the results of Rougoor et al. (17), where an increased level of concentrates and silage purchased per cow per year had an overall negative effect on the gross margin per 100 kg of milk. It was speculated that these higher feed costs per cow outweigh the benefit of decreased maintenance costs that should be associated with an increased production per cow and a decreased herd size. Further investigation into the relationship of the CM_H to CM_C, to farm profitability, and to economic efficiency is warranted.

While this paper has examined the relationship between the CM_C and the seasonal variation in average test-day milk yield in 1994, there have recently been changes in the milk quota system throughout much of Canada which will affect the influence that seasonality of production will have on farm profitability. Rather than having a yearly production quota, producers in many provinces now have a daily milk production quota that they must meet (7). The flexibility allowed in the current system will be restricted over the coming years, resulting in decreased income for those producers with significant seasonal variation in milk shipments. There is a high degree of correlation between the average daily production per cow and the total monthly milk shipments in Prince Edward Island (E. Hovingh, unpublished data). Producers will therefore need to reduce the amount of variability in average daily production per cow in order to avoid the negative consequences of having significant seasonal variation in milk shipments.

CONCLUSIONS

Seasonal variation in average daily production per cow occurs in a predictable pattern in many Prince Edward Island dairy herds. The contribution margin per cow was higher in herds that did not experience significant seasonal variation in production as compared to those herds that did experience significant variation. Increased summer feed cost per cow was associated with reduced seasonal variation in production. Further investigation into the relationship between feeding levels of concentrates, forages, and pasture costs and the contribution margin per cow is warranted. The positive association between herd size and genetic index for protein likely points to a relationship between management factors and the contribution margin per cow. Thus, there is a need to further identify significant causes of seasonal variation in production. The use of income in excess of feed costs per unit of milk shipped, or quota owned, is an economic measure of performance that needs to be assessed. The profitability and efficiency of dairy farms also needs to be investigated in light of the regional pricing and payment schemes.

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Table 1. Summary statistics for the 1994 seasonal pattern of milk production (MINMAX[1]), the average daily feed cost per cow, and the daily pasture costs per cow for 72 Prince Edward Island dairy herds.

Variable	Mean	Std. Dev.	Minimum	Maximum
MINMAX[1]	0.75	0.11	0.45	0.97
Total winter feed cost/cow/day[2]	$ 4.06	0.83	1.76	6.9
Total summer feed cost/cow/day[2,3]	$ 3.24	0.88	1.61	6.92
Pasture cost/cow/day[2,4]	$ 0.50	0.28	0.15	1.43

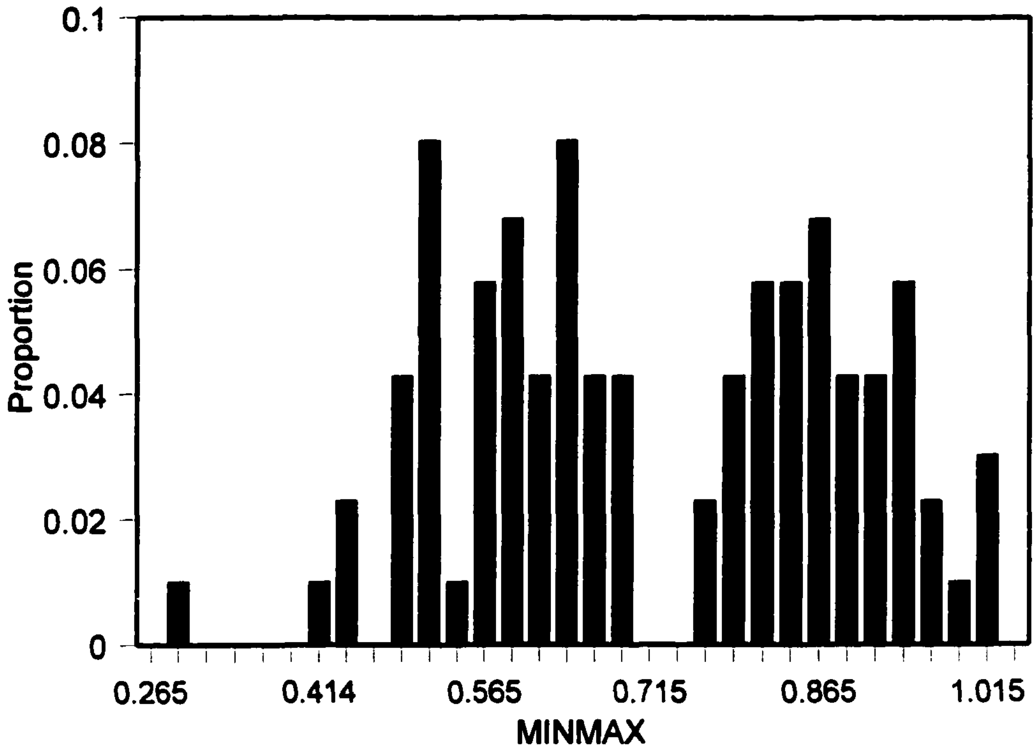
1 Seasonal pattern of milk production: minimum test-day milk production during Oct-Nov-Dec expressed as a percentage of the maximum test-day production during May-June-July. (See Equation 1, pg. 5, for details.)

2 All prices expressed in 1994 Canadian funds.

3 Includes pasture cost/cow/day.

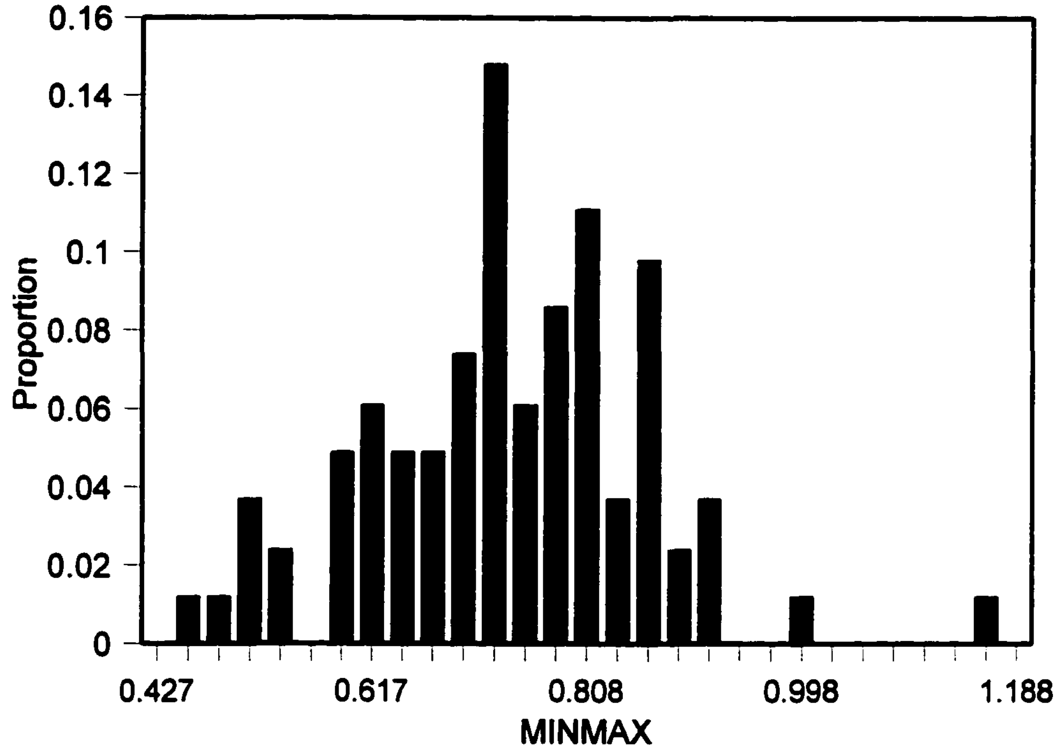
4 Only includes herds that utilized pasture as a feed source during 1994 (n=68).

Figure 1. Distribution histogram of the 1992 MINMAX[1] values for the Prince Edward Island dairy herds selected for the "Summer-Fall Slump Study."



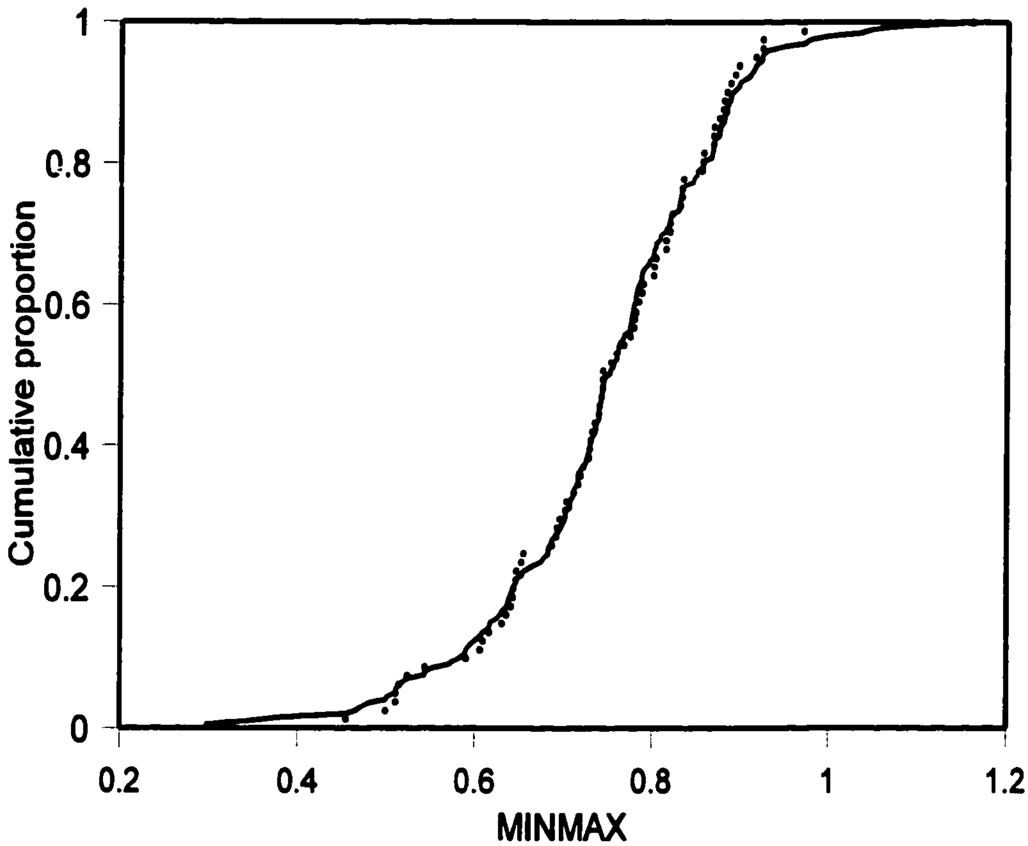
[1] Seasonal pattern of milk production: minimum test-day milk production during Oct-Nov-Dec expressed as a percentage of the maximum test-day milk production during May-June-July. (See Equation 1, pg. 5, for details.)

Figure 2. Distribution histogram of the 1994 MINMAX[1] values for the Prince Edward Island dairy herds selected for the "Summer-Fall Slump Study."



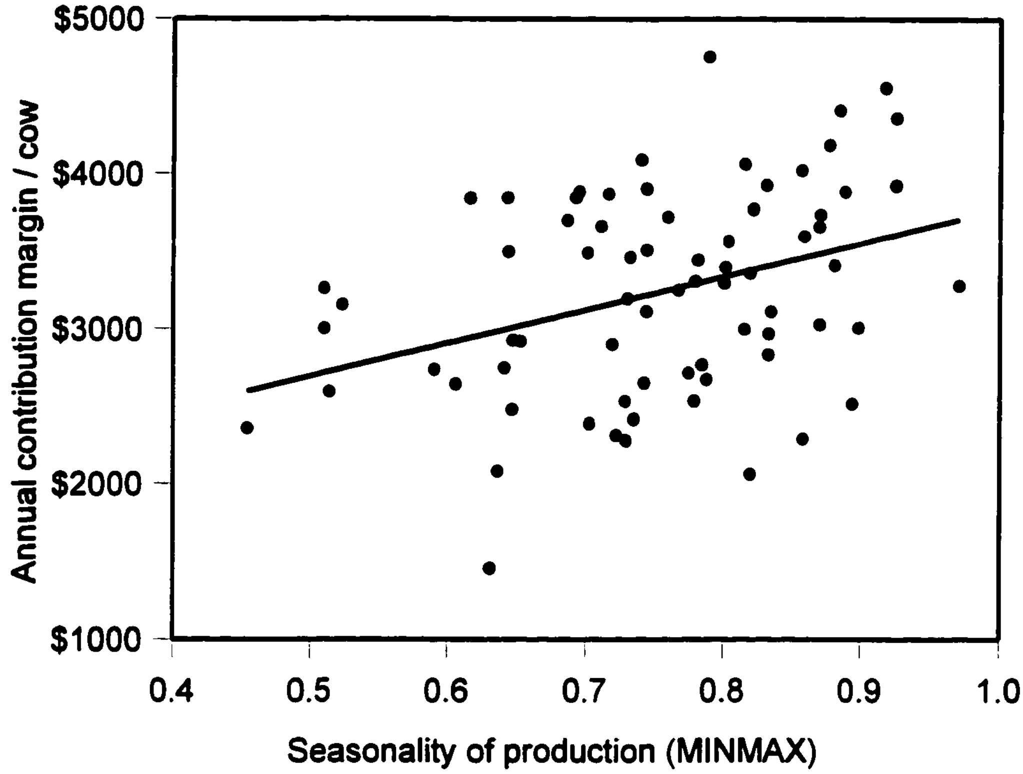
[1] Seasonal pattern of milk production: minimum test-day milk production during Oct-Nov-Dec expressed as a percentage of the maximum test-day milk production during May-June-July. (See Equation 1, pg. 5, for details.)

Figure 3. Cumulative distribution plot of 1994 MINMAX[1] values for all Prince Edward Island dairy herds using the Atlantic Dairy Livestock Improvement Corporation's milk recording services (– solid line) and the "Summer-Fall Slump Study" subset of herds (•dotted line).



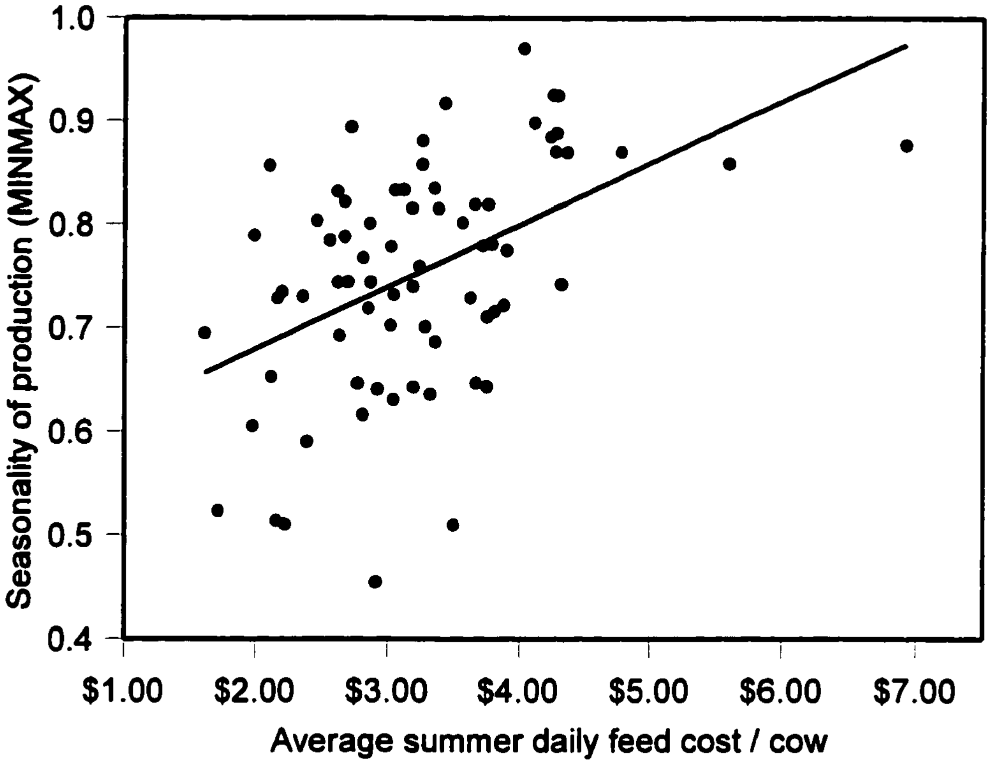
[1] Seasonal pattern of milk production: minimum test-day milk production during Oct-Nov-Dec expressed as a percentage of the maximum test-day milk production during May-June-July. (See Equation 1, pg. 5, for details.)

Figure 4. Scatterplot of annual contribution margin ($ Cdn.) per milking cow versus MINMAX[1] parameter for 72 Prince Edward Island dairy herds during 1994. $\beta = 2153.20$ $R^2 = 0.13$ $P < 0.01$.



[1] Seasonal pattern of milk production: minimum test-day milk production during Oct-Nov-Dec expressed as a percentage of the maximum test-day milk production during May-June-July. (See Equation 1, pg. 5, for details.)

Figure 5. Scatter plot of seaonality of average test-day milk yield (MINMAX[1]) versus average summer daily feed cost per cow ($Cdn.) for 72 Prince Edward Island diary herds during 1994. $\beta = 0.06$ $R^2 = 0.22$ $P < 0.01$.



[1] Seasonal pattern of milk production: minimum test-day milk production during Oct-Nov-Dec expressed as a percentage of the maximum test-day milk production during May-June-July. (See Equation 1, pg. 5, for details.)

Figure 6. Scatterplot of annual contribution margin ($Cdn.) per milking cow versus average test-day milk yield (kg) per cow for 72 Prince Edward Island dairy herds during 1994. $\beta = 148.79$, $R^2 = 0.68$, $P < 0.01$.

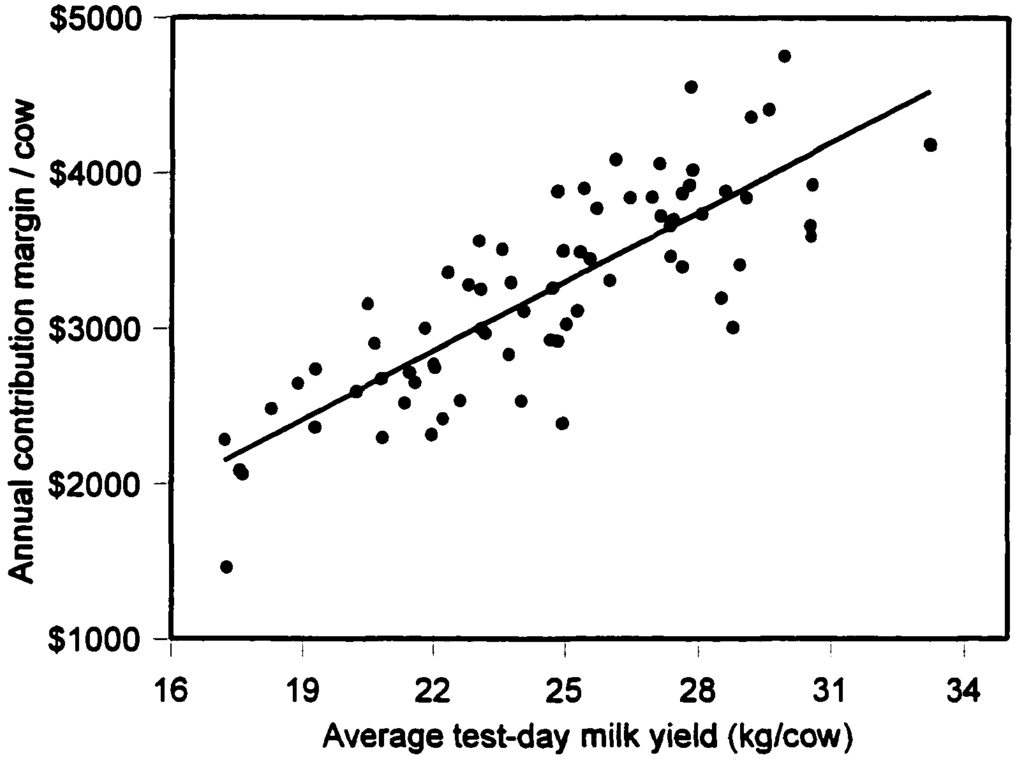


Figure 7. Scatterplot of annual contribution margin ($ Cdn.) per milking cow versus herd size (average number of lactating cows) for 72 Prince Edward Island dairy herds during 1994. $\beta = 13.72$, $R^2 = 0.08$, $P < 0.05$.

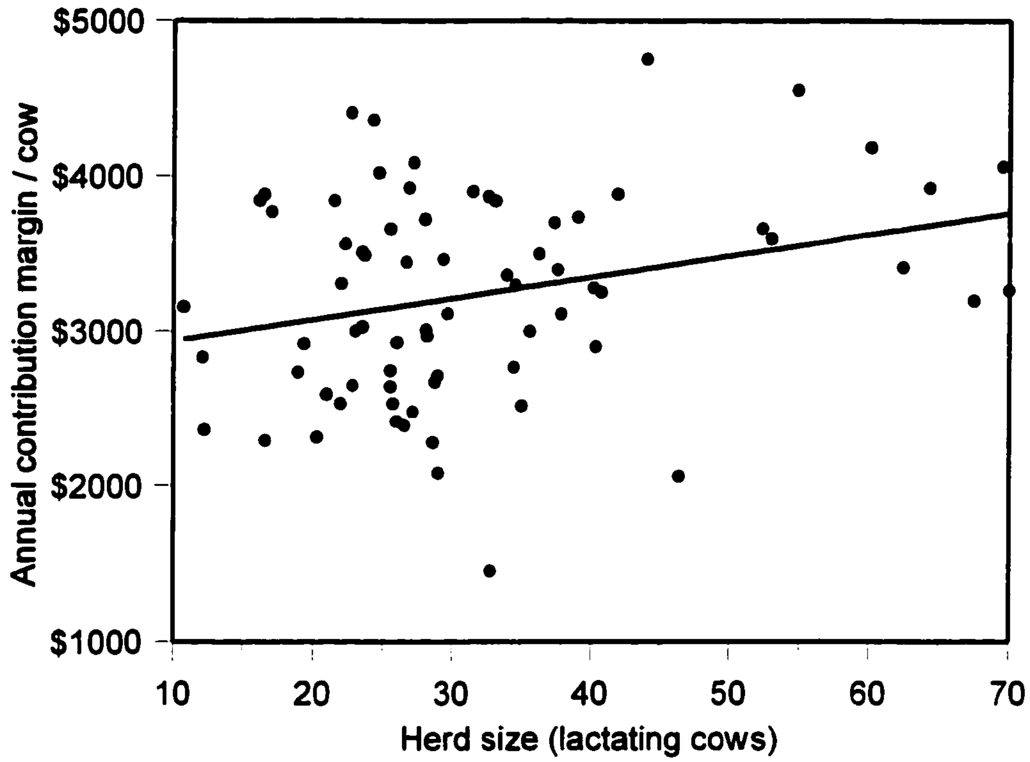
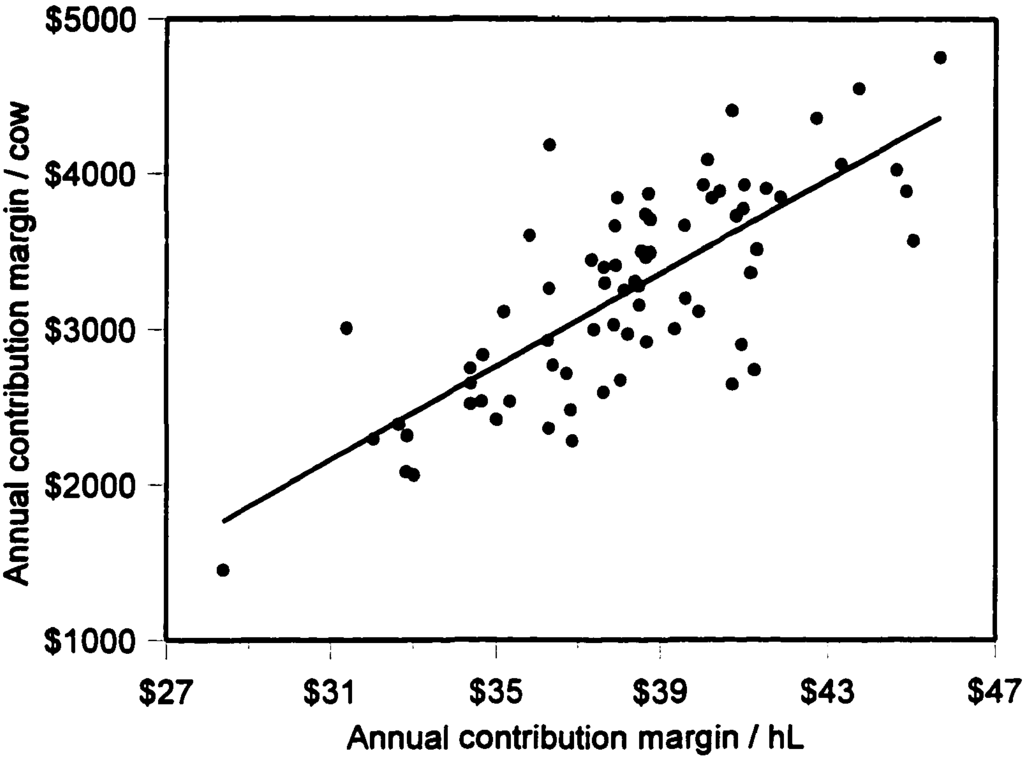


Figure 8. Scatterplot of annual contribution margin ($ Cdn.) per milking cow versus annual contribution margin ($ Cdn.) per hectolitre of milk shipped for 72 Prince Edward Island dairy herds during 1994. $\beta = 150.0$, $R^2 = 0.58$, $P < 0.01$.



Chapter 4

Predicting pasture forage dry matter yield in large scale observational studies

INTRODUCTION

Large-scale observational studies are frequently utilized in veterinary research and epidemiologic investigations. The "Summer-Fall Slump Study" is one such study which investigated the variation in seasonal patterns of average test-day milk production observed in dairy herds in Prince Edward Island, Canada. For the purposes of this study, an estimate of pasture forage dry matter (DM) yield was required for a large number of dairy herds.

Three techniques for obtaining estimates of pasture forage DM yield were considered; the 'metabolic equivalent' model, the 'change-in-forage-inventory' method and an approach involving the calculation of the predicted yield based on field-specific pasture characteristics.

In using the 'metabolic equivalent' model, as discussed by Baker (1) and Leaver (21), the milk production and physiologic status of the individual cows in a herd would be used to calculate their energy and protein requirements. The energy and protein supplied by grazed forage would be equivalent to the difference between the amount of energy and protein in the "stored feeds" and the requirements of the cattle. Based on the remaining metabolic needs of the cattle, and the composition of the pastures, the amount of pasture consumed could be calculated. This method would require an exact estimate of the daily metabolic requirements of the cow and an accurate estimate of the amount of stored feed consumed, as well as the protein and energy concentration thereof.

Researchers and dairy producers frequently employ the "change in forage inventory" method for determining the amount of grazed forage consumed by cattle (7,14,18). Employing this method would involve frequent and repeated measurement of pasture forage DM, utilizing various devices and techniques that have been developed to provide these estimates expediently and reliably. The amount of DM consumed by the whole group of cattle could be estimated by subtracting the "post-grazing" forage inventory from the "pre-grazing" inventory. Dividing this by the number of cattle on pasture and the number of days on the field would result in an estimate of the amount of pasture DM consumed per cow per day. This method requires the frequent observation of the pastures and a reliable method to estimate pasture DM inventory.

Another approach, seemingly undocumented in the literature, would involve predicting annual DM production from each pasture field based on its size, forage type, and the various management techniques applied to it, such as the application of synthetic fertilizer, or alkalizing materials. This methodology would require detailed information on all pasture fields utilized by the lactating cattle, and reliable estimates of the impact of pasture management techniques on pasture productivity. It would provide an estimate of the pasture forage DM availability, rather than a direct measure of the DM consumed by the cattle.

Since the "Summer-Fall Slump Study" was designed to investigate factors affecting milk production during the summer and fall, it was deemed inappropriate to utilize actual milk production data to predict intake from pasture. To do so would involve the use of a key component of the 'dependent variable' in this study to predict the level of one of the 'independent variables', resulting in a circular argument, and removing the independence that should exist between the outcome and predictor variables. Given the large number of herds involved in the study, physical and financial constraints precluded the possibility of collecting repeated measures of pasture inventory. It was decided therefore, to estimate total annual DM production from pasture by collecting field specific information for all pasture fields utilized in the study herds. This information was used to calculate the percentage increase in herbage production expected due to the use of pasture management practices and, in conjunction with an estimate of the "baseline" DM yield per acre, provided an estimate of the total annual herbage production for each pasture field.

Predicting pasture DM yields from field management data requires reliable information about the effects of various pasture management techniques on yields. Since this information was not available in the literature for a significant proportion of the management techniques in use, two methods of obtaining and summarizing 'expert opinion' were considered.

The Delphi method is an iterative method for obtaining a consensus from a panel of experts in situations where objective scientific information is lacking, and where the personal opinion of a single expert could be biassed (31). It is used to obtain estimates or rankings for a series of individual factors. A panel of experts relevant to the subject under investigation is selected and each participant is asked to independently provide estimates for a list of factors. These estimates, and any accompanying comments, are tabulated and returned to the participants, usually without associating the specific responses with the identity of the respondent. This anonymity serves to minimize the impact that any one individual might have if identities were revealed. The participants are given the opportunity to modify their responses based on those provided by the remainder of the panel. This process is reiterated until a consensus is reached or an insignificant amount of change occurs in the responses.

The Delphi technique, in assessing factors individually, does not address the synergism or antagonism that may occur when multiple factors occur together. This observation was also made by Papadopoulos et al. (27), in a review paper summarizing various controlled research trials that had investigated the effects of commonly utilized pasture management techniques on pasture productivity. They concluded that "...further studies should be attempted with commercial livestock operations to assess the combined effects of these factors..." (27).

Conjoint analysis is a research method used to determine the importance or ranking of groups of characteristics or factors (11). Profiles are constructed containing different subsets of the characteristics or factors that are being investigated. The participants are then given a single opportunity to rank, or assign an actual value to each profile, in order of preference. The profiles are then 'decomposed' through the use of linear regression analysis with "dummy variables" to arrive at the relative importance of each factor. Conjoint analysis therefore permits the investigator to evaluate the impact of a factor when a decision-making process is multi-factorial in nature, or when the effect of one factor can be modified by the presence of other factors.

The specific objectives of this study were fivefold:

1. to compare the estimates of the effect of pasture management techniques on expected increase in pasture yield as obtained by the Delphi technique with the estimates obtained by the conjoint analysis exercise,
2. to compare the estimates derived from the Delphi technique and the conjoint analysis method to values found in the literature,
3. to predict farm level total annual DM yield from pasture based on detailed field specific management data and the estimates obtained by means of the Delphi technique and the conjoint analysis exercise,
4. to evaluate the relationship between the annual DM yield predicted using the conjoint analysis estimates and an assessment of pasture feed inventory performed using sward height measurements during a single, late summer herd visit, and

5. to select a single method for estimating the total annual forage available and the amount of DM available per cow from pasture for the lactating cows of each herd involved in the Summer-Fall Slump study.

MATERIALS & METHODS

Two survey methods, the Delphi method and the conjoint analysis method, were used to estimate the effects of management techniques on annual pasture forage DM yield. The estimates obtained were used to calculate the total annual forage yield on a field-by-field basis for all herds involved in the study. A single point pasture feed inventory was also calculated based on sward height measurements recorded for each field on each farm during a data acquisition visit in the late summer period.

To obtain estimates for the effect of the most commonly employed pasture management techniques on the productivity of dairy pastures in Prince Edward Island, Canada, 14 researchers and extension workers in Atlantic Canada were asked about their willingness to participate in a Delphi exercise. Twelve experts agreed to participate, and were sent a form on which they were asked to estimate the percentage increase in herbage yield from the use of various pasture management techniques, as compared to the yields obtained from native, 'unimproved' pastures. Each management technique was assessed in isolation.

The respondents were also asked to provide the basis on which they had formulated their estimates. "Personal research" indicated that the respondent had conducted or was involved with colleagues who were performing research in this area. "Scientific literature" indicated that the participant had formulated their response, at least in part, on data published in the scientific literature. "Experience" was defined as any non-scientific, non-documented evidence that the expert was familiar with. (The Delphi exercise forms can be found in Appendix B.) The responses were tabulated by the moderator and all the estimates were returned to the participants, preserving the anonymity of the other members of the group. The participants were then given the opportunity to modify their original estimate based on the responses from the other members of the group. Comments were also solicited and returned with each round. This process was repeated until the results were deemed to be stable, as assessed by a lack of substantive change in the mean and standard deviation of the estimates.

Various 'profiles', or combinations of pasture management techniques, were constructed using a software module designed for that purpose (SPSS ORTHOPLAN, SPSS Inc., Chicago, IL). The profiles, which were used in the conjoint analysis exercise, were combinations of a subset of the pasture management techniques assessed using the Delphi exercise, and were designed to be mutually orthogonal.

Not all of the pasture management techniques from the Delphi exercise were included in the conjoint analysis due to the large number of profiles that would have been required to assess all the combinations and the limited number of qualified experts available to participate in the research. Greater than 100 profiles would have been generated using the full set of management techniques, but only 12 mutually orthogonal ones (including the null, or baseline set) were required to assess the subset of techniques chosen. Estimates for techniques that were not included were interpolated from the conjoint results using the ratios of estimates derived from the Delphi exercise.

The profiles that were generated were assessed by a subset of the panel of experts that had participated in the Delphi exercise. (The conjoint analysis material sent to the participants is included in Appendix C.) In the time that intervened between the Delphi exercise and the conjoint analysis, a number of the original participants had relocated from the region and were not available to participate. Each participant ranked the profiles according to the expected increase in total annual herbage yield beyond that expected from a native, unimproved pasture. The participants also provided a point estimate of the expected percentage increase in yield for each profile.

The estimates provided by the participants in the conjoint analysis were assessed and the responses from two participants were eliminated before the final analysis of the results. These responses were eliminated due to their extreme departure from the estimates provided by all of the other participants.

The profiles were 'decomposed' using random effects linear regression analysis with dummy and categorical variables, to arrive at the effect of individual management techniques on pasture yield. Clustering of responses within an individual was accounted for statistically by treating the participants unique identification number as a random variable.

One of the components of the late summer herd visits in 1994 was a detailed enumeration of all pasture fields that had been utilized for the lactating herd, that were currently in use, or were expected to be used during the remainder of the growing season. These were listed and assigned a farm specific identification number.

A number of characteristics were recorded for each field. The size was recorded in acres, as was the date that the pasture was last reseeded. The fields were also classified as annual or perennial, based on the predominant forage cultivar in the field.

Detailed information was also collected regarding the management techniques applied to each field. Appendix D contains the pasture data collection form that was used to record the following information:

- The cows' access pattern for each field was recorded as a categorical variable. "Continuous" use indicated that the cows had constant access to the field throughout the period it was in use. "Rotational" was characterized by a period of grazing followed by a period of rest of at least 10 days. "True strip" grazing was defined as the daily or every other day movement of the cows into a fresh area of pasture, with no access to a previously grazed portion for at least 10 days. "Forward strip" grazing was also defined by daily or every other day access to a fresh area of pasture, though access to previously grazed areas of the field was not restricted.

- The first day of access for the lactating cows was recorded for each field. The last day of access was also recorded for all fields that were not utilized for the lactating cows through to the end of the pasture season.
- A dichotomous variable was used to record whether or not a cut of hay or silage had been removed from each field.
- Detailed information regarding synthetic fertilizer use in the current grazing season was recorded for each field. The number of applications was recorded, as well as the amount applied per acre in each application. The nitrogen, phosphorus, and potassium concentration in the applied fertilizer was also recorded for each application.
- A categorical variable was used to record the application of manure to the pasture fields in the current or previous year. The application rates were broadly defined as "none", "light", "medium", and "heavy".
- The application of lime or other alkalizing materials within the previous 5 years was recorded on a field-by-field basis by means of a

dichotomous variable.

- The "top clipping" of pastures one or more times during the current grazing season was recorded by means of a dichotomous variable.

The experts who participated in the Delphi exercise and the conjoint analysis were also asked to provide an estimate of the total annual DM production from an acre of native, unimproved pasture. The mean of these values was utilized as an estimate of the baseline annual forage production from an acre of unimproved pasture when grazed by a lactating cow.

Two estimates of the total percentage increase in yield above the baseline production (from an unimproved pasture) were calculated for each pasture field. These were calculated as a simple summation of the estimates for the individual pasture management techniques used, based on the results obtained from the Delphi exercise and the conjoint analysis. For example, two estimates of the total percentage increase above baseline yield would have been calculated for a pasture field that had been limed and was rotationally grazed; one calculated as the sum of the Delphi exercise estimates of the effect of rotational grazing and liming, and one based on the conjoint analysis estimates of the same management techniques.

A native, unimproved pasture was defined as one: which had not had any applications of alkalizing materials or fertilizer in the past 5 years, except that deposited by the animals in the course of their grazing, that had not been reseeded or clipped in the previous 10 years, and, to which the cattle had continuous access throughout the grazing season. The annual baseline yield (tonnes DM) for an acre of this unimproved pasture was multiplied by the expected increase in yield for each field as predicted by the Delphi technique and conjoint analysis. This was multiplied by the field size to arrive at a final estimate for the total annual predicted herbage yield for each field. For fields which had a cut of hay or silage removed prior to grazing the annual total yield was adjusted by deducting the expected yield of hay or silage in order to arrive at an estimate of the total amount of forage available for grazing. The estimate of the forage DM removed as hay or silage was based on the work of Kunelius et al. (20) and took into account the number of applications of fertilizer applied to the field.

The field level estimates were combined within farm to calculate the total annual herbage yield available for grazing from pasture for the whole farm.

Since it was hypothesized that pasture forage availability would be a predictor of milk production during the summer and fall, the total pasture feed inventory was calculated based on sward height data collected during the late summer herd visit in 1994. These data were recorded on a field-by-field basis using the recording forms found in Appendix D. To minimize the effect of time as a confounding variable, the herd visits were carried out as expediently as possible, with all visits being conducted within a 12-day time frame.

Systematic random measurements were taken from each pasture field that was used for the lactating cattle. A "W" pattern was walked through each field with measurements of average sward height and legume density taken at systematic intervals so that the required number of measurements was attained. Fields that were no longer in the rotation for the milking herd were not walked.

Average sward height was determined at each interval in the 250 square centimetre quadrant directly in front of the toe of the investigator, using a metre stick placed on the soil surface. This measurement was recorded on a data collection sheet designed for that purpose, which listed each field with its identification number and size.

Generally, two sward height measurements were taken per acre, although a minimum of twelve measurements were recorded for fields of six acres or less. In fields larger than six acres, greater than two measures per acre were recorded in situations where the whole field had not been walked before the calculated number of measurements was obtained.

Sward height measurements were converted to herbage DM estimates using a second order polynomial fitted to experimental data from Johnson et al. (17). The zero to five centimetre horizon was considered as unavailable to the cow and therefore the field average sward height above five centimetres was used to determine the amount of available herbage per acre. This was then multiplied by the field size to obtain an estimate of the herbage available to the cows in each field on the day of the herd visit. The feed inventory for all fields was summed to arrive at a total pasture feed inventory for the farm. This was divided by the total acreage to arrive at an estimate of the DM available per acre, and by the average number of lactating cows in the months of July, August and September to arrive at an estimate of the average pasture DM inventory per cow.

All data manipulation and statistical analysis was performed in STATA (StataCorp, College Station, Tx.).

RESULTS

It was observed that many of the estimates of the percentage increase in pasture DM yield converged through consecutive iterations of the Delphi exercise. After four rounds the exercise was concluded since the responses from the participants demonstrated little evidence of change. Figure 1 demonstrates the sequential changes in the mean and standard deviation for two of the pasture management techniques assessed by the panel of experts. The mean of the estimates for true strip grazing increased and the variation of the responses decreased with subsequent iterations. A decrease in the standard deviation was the only significant change seen in the estimates for the effect of an application of manure on the productivity of pasture. Table 1 provides the final point estimates and standard deviations of the expected effect of the commonly employed pasture management techniques in Prince Edward Island.

Of the original twelve experts in the Delphi exercise, nine participated in the conjoint analysis, which was carried out approximately 15 months after the Delphi exercise was concluded. Two of the remaining three participants had relocated and could not be contacted whereas the third elected not to participate.

The mean and standard deviation for all profiles are contained in Table 1, as are the results of the decomposition of the conjoint analysis profiles, and the interpolated values. While not all of the components of the profiles were statistically significant at the P=.10 level, all point estimates were used as calculated.

The Delphi estimates of the effect of pasture management practices on herbage yield were compared to those obtained from the conjoint analysis at the individual participant level using two methods. The individual Delphi estimates from each respondent were combined to form similar profiles as those used in the conjoint analysis. Figure 2 shows the relationship between the conjoint analysis estimates and the composite Delphi estimates for each profile for each participant, with the exception of the "baseline" profile which, *a priori*, was set to zero. A 'line of equality' is also plotted on Figure 2. It can be seen that with very few exceptions, the conjoint analysis resulted in lower estimates than the combined Delphi estimates (β=.73, P<.001, R^2=.29), indicating that most of the respondents felt the effect of combinations of pasture management techniques was less than the sum of the effect of the individual ones.

Of the 80 herds in the "Summer-Fall Slump Study" a total of 272 fields, comprising 2936 acres, were used on the 74 farms that utilized pastures as a feed source for the lactating herd in 1994. The average fixed field size (not including intemal subdivisions for rotational grazing) was 10.8 acres (S.D. = 9.6).

Two herds utilized only a single continuously grazed field for their lactating herd over the course of the whole grazing season, and these herds fed substantive amounts of stored feeds throughout the pasture period. The remainder of the herds utilized multiple fields to graze their cattle.

Table 2 presents a list of management practices enumerated during the investigation and the proportion of the pasture fields and total pasture acreage across all farms that was managed with each practice.

The mean of the conjoint analysis participants estimates of the annual herbage DM production from an acre of native, unimproved pasture was 1.7 tonnes (S.D. = .46).

Two estimates of the total predicted percent increase in yield were calculated for each pasture field based on the management practices applied to that field. Figure 3 is a scatterplot of the total predicted increase in yield for each pasture field using the Delphi method and the conjoint analysis estimates. It can be seen that there is a high degree of correlation between the estimates when combined at the field level (β=1.4, $P<.001$, R^2=.89).

Average field height followed a relatively normal distribution, with a mean of 10.4 centimetres. There was evidence of slight paleokurtosis, with the distribution being more concentrated around the mean than expected. Five percent of all fields had an average height below five centimetres, and were thus considered not to have any herbage available for grazing. Approximately seven percent of study farms did not utilize pasture, although all provided an outside exercise for the lactating cattle.

A second-order polynomial approximated the data from Johnson et al. (17) very well, with an R^2 of .99. (Details of these calculations are found in Appendix E.) Using the height-biomass relationship based on this equation, the herds that utilized pasture as a feed source were estimated to have an average of 312.0 kilograms per acre (S.D. = 167.2) and an average of 429.6 kilograms of pasture DM per lactating cow (S.D. = 331.7) available at the time of the herd visit.

The predicted total annual forage production using the conjoint analysis estimates and the total inventory present at the 1994 summer herd visit were expressed on a "per acre" basis to eliminate the effect of farm size. Figure 4 is a scatterplot of the average predicted annual forage production per acre based on the conjoint analysis estimates and the average pasture inventory per acre at the time of the herd visit. It can be seen that although there is a statistically significant relationship (β=178.5, P = .01) between the estimates of annual pasture forage production per acre and the late summer pasture forage inventory per acre, there is a substantial amount of variation in forage inventory not explained by the predicted annual production (R^2=.09).

Discussion

A large proportion of the dairy producers in Prince Edward Island graze their lactating cattle, and various combinations of pasture management techniques are used by producers to optimize forage production. To overcome the acidity and lack of nutrients, especially nitrogen, phosphorus, and potassium in many soils (27), many producers apply synthetic or natural fertilizers and alkalizing agents. To coordinate forage availability with animal requirements, some form of managed grazing is often utilized. Other pasture management techniques commonly employed to optimize and manage pasture forage production include top clipping, reseeding and the removal of hay from pasture fields prior to grazing.

While the effect of these pasture management practices has been studied in a number of controlled research trials, there is a dearth of information regarding the effect of the management practices when multiple techniques are used simultaneously.

A Delphi study involves a panel of experts ranking or scoring single factors or product attributes as to their relative importance. It is an iterative procedure in that it allows participants to modify their opinions based on the responses of the other panel members. The Delphi method has been used in marketing and consumer preference studies (10) as well as in medical (19) and agricultural (12) research. The use of the Delphi method has been infrequently reported in the veterinary literature. A Delphi study was used to identify and prioritize areas of concern within veterinary medical education (30). Dewey et al. (6) sought to consolidate the opinions of a panel of swine veterinarians, pork producers and animal scientists on the causes of variation in litter size by means of the Delphi method. Miller et al. (24) consulted a panel of experts by means of the Delphi technique to determine the productivity effects of pseudorabies in swine enterprises.

In the current study, the Delphi exercise was carried out with a panel of regional scientists possessing expertise in pasture management and research. Although a list of the participants was made available to the panel, the responses were not linked to a specific name to preserve the anonymity of the responses. This was done to avoid peer pressure and the introduction of bias into the results by the influence of any of the participants.

The participants in the Delphi technique exhibited some willingness to change their responses based on the responses of the other participants. However, for some pasture management techniques there was little change in the average of the estimates throughout the process, as indicated by a relatively stable mean and standard deviation. Most of the change that took place in the responses occurred between the first and second iterations. Subjectively, it was observed that substantially less change occurred in the third and fourth iterations, and the Delphi method was concluded for this reason.

There were fewer comments from the Delphi participants included with the responses than had been expected. This lack of exchange of ideas and opinions was perhaps one of the drawbacks associated with the use of the Delphi method, especially since the responses remained anonymous. The experts were not challenged or forced to defend their responses. This may have resulted in some of the panellists having little motivation to reevaluate or alter their initial response.

One of the pasture management techniques investigated with the Delphi exercise was the removal of a cut of hay prior to grazing. There appeared to be some confusion regarding the definition of this technique. Most of the participants felt that removing a cut of hay prior to grazing would have a net negative effect on the annual amount of forage available. Some participants, however, predicted that this would have no effect or even a positive impact on the 'grazeable' forage, possibly considering only the impact on the forage regrowth after the removal of a crop of hay. Although the moderator of the Delphi exercise attempted to clarify the situation, the responses remained erratic and it was decided not to use the final estimate in the calculations.

Conjoint analysis has been utilized in many disciplines. It is commonly employed in marketing research investigating consumer preferences (11,13). It has also been used in the medical field for such purposes as evaluating and designing health care unit programs (9), and to assess treatment decisions made by patients with laryngeal cancer (23). Conjoint analysis has also been utilized to examine opinions on animal welfare issues (5) and to determine the importance of various risk factors for a number of contagious diseases (16).

Conjoint analysis was used in the study reported on in this paper to further evaluate the reliability of the results from the Delphi exercise and to evaluate the influence of pasture management techniques when multiple techniques were used simultaneously rather than in isolation of one another. It could not be reliably determined from the literature whether the simultaneous use of pasture management techniques would demonstrate a synergistic or antagonistic response or if the application of one technique would have no influence on the effect of other techniques.

The estimates derived from the Delphi technique and the conjoint analysis demonstrated a high degree of correlation. The high correlation between the estimates and rankings of the two techniques, notwithstanding the time lapse between the two exercises, confers a measure of internal validity or consistency to the results. The lower estimates obtained for the predicted effect of pasture management techniques after decomposition of the conjoint analysis profiles indicates that it is believed that the effect of a specific management technique is generally reduced when used in combination with other techniques.

There was a marked reduction between the Delphi exercise estimate (17.9 % increase) and the conjoint analysis estimate (3.8 % increase) of the effect of manure application on pasture productivity. This indicates that the conjoint analysis study participants believed the effect of manure application, when performed in combination with other pasture management techniques, was almost inconsequential. It is impossible to determine the reasons for this change in effect between the two studies. The paucity of literature dealing with the effect of manure application on the productivity of pastures prohibits the validation of either result.

Black (2) investigated the effects of irrigation and nitrogen on the productivity of naturalized pasture. He found that on average, across both irrigated and non-irrigated pastures, multiple applications of nitrogen increased the DM yield by 27.8 percent. This is very similar to the Delphi and conjoint analysis estimates for multiple applications of 30-0-0 which are 27.5 and 21.7 percent, respectively. Calder and Nicholson (3) carried out a study examining pasture productivity and the interaction of botanical composition of the sward and nitrogen fertilization. They found that mixed grass/legume swards that had a single application of nitrogen fertilizer produced on average 16.4 percent more total annual DM per hectare than unfertilized fields. On average, the pure grass, pure legume and mixed swards yielded 21.9 percent more annual DM per hectare when fertilized with a single application of nitrogen fertilizer. The Delphi method estimate for a single application of 30-0-0 fertilizer was 18.3 percent, whereas the conjoint method estimate was 20.2 percent. These estimates closely approximate the results of Calder and Nicholson (3), and lend credence to the estimates derived by these surveys.

Annual herbage DM yields of 6000 kg ha^{-1} were found in a study investigating productivity of beef cattle that rotationally grazed native pasture in Atlantic Canada, that had been fertilized with a single application of nitrogen (26). Based on these management practices and the baseline yield estimates for unimproved, 'unmanaged' pasture, the Delphi method and conjoint analysis estimates would predict annual yields of 6550 kg ha^{-1} and 6030 kg ha^{-1}, respectively. In a study by Kanneganti et al. (18), which described the seasonal distribution of forage yield, the investigators reported total annual pasture yields from natural pasture of 8580 kg DM ha^{-1} and 6160 kg DM ha^{-1} in two consecutive years. The pastures were grazed by lactating dairy cows in a rotational manner, with a period of stay of only one day in any particular paddock. Nitrogen fertilizer was also applied on two separate occasions. Based on the conjoint analysis for strip grazing (defined as daily or twice daily access to fresh pasture) and two applications of 30-0-0, and the baseline pasture production estimates from this study, a yield of 6370.8 kg ha^{-1} would have been predicted, whereas the Delphi method estimates would predict an annual DM yield of 7403.5 kg ha^{-1}. Despite regional or climactic differences, the agreement observed between these yields lends credence to the estimates derived by the use of conjoint analysis and Delphi exercises.

Various methods have been utilized by researchers and producers to estimate pasture feed inventory (4,22). Visual assessment of forage DM $hectare^{-1}$, as utilized by Stockdale (28), is the simplest of these, though it is the most subjective. Accurate measures of forage biomass can be made by mechanical clipping, drying and weighing of pasture samples from randomly selected areas of known size (17). Devices to measure electronic capacitance of the sward and the compressed sward height have been developed to overcome some of the vagaries inherent in visual assessment of pastures as well as to ameliorate the effort associated with obtaining multiple clipping samples (8,29). Average sward height, as measured above the soil surface using a measuring stick, can also show linear or quadratic relationships with forage biomass estimates made from quadrant clipping samples (8,17,28). However, it is usually noted by the investigators that the validity of these relationships beyond the specific sward being studied is questionable. Variation in such factors as season (25), botanical composition (8), grazing management (17), fertilization practices, and animal species can significantly affect the mathematical relationships found under a specific set of conditions (4,15,22,28).

In the present study, a low correlation was found between the predicted yield per acre based on the conjoint analysis estimates and the sward height based estimate of average pasture inventory per acre. This poor level of correspondence indicates that the feed inventory present per unit of area at the end of August was not directly related to the predicted annual herbage production per unit of area. The complex interactions that occur between producer-regulated management practices, sward and soil characteristics, the microclimate, supplemental feeding, and animal factors likely obscured the relationship that intuitively should be present between annual predicted yield per acre and the actual pasture feed inventory per acre at a specific time during the grazing season. One of the main factors expected to be responsible for the lack of an observed relationship is the seasonal distribution of forage yield from pasture, which is influenced by, among other factors, the botanical composition of the pastures (27) and the timing of the fertilization applications (20). In native, unimproved pastures, growth normally commences in early May, with peak DM production per day occurring in June. A steady decline in the growth rate then occurs through to mid-August, when a small increase in growth is observed which lasts about 6 weeks. This biphasic pattern can be 'smoothed' by such pasture management techniques as the application of fertilizer after the peak growth is observed, or by the planting of pasture species that are more drought and heat tolerant than many of the native species. The use of annual ryegrass and kale species can also be used to extend the grazing season and provide pasture DM at times when native pasture species are reducing their growth rate (27).

CONCLUSION

The estimates derived by the Delphi technique and the conjoint analysis demonstrated a high degree of correspondence. There was also a high level of agreement between these estimates and values found in the literature for the effect of various pasture management practices on DM yields. While there needs to be some caution in utilizing these estimates across farms, seasons, and regions, they appear to be quite suitable for providing a means to predict pasture DM in the current large scale observational study. The estimates obtained from the conjoint analysis will be used to calculate the annual DM production per cow to permit further examination of the relationship between pasture DM availability and milk production. While a poor correlation existed between a point estimate of pasture DM inventory and the annual predicted yield, the relationship of pasture inventory per cow and milk production will be further investigated.

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Figure 1. Mean and standard deviation for estimates of percentage increase in herbage yield obtained for 2 pasture management techniques in each iteration of the Delphi technique.

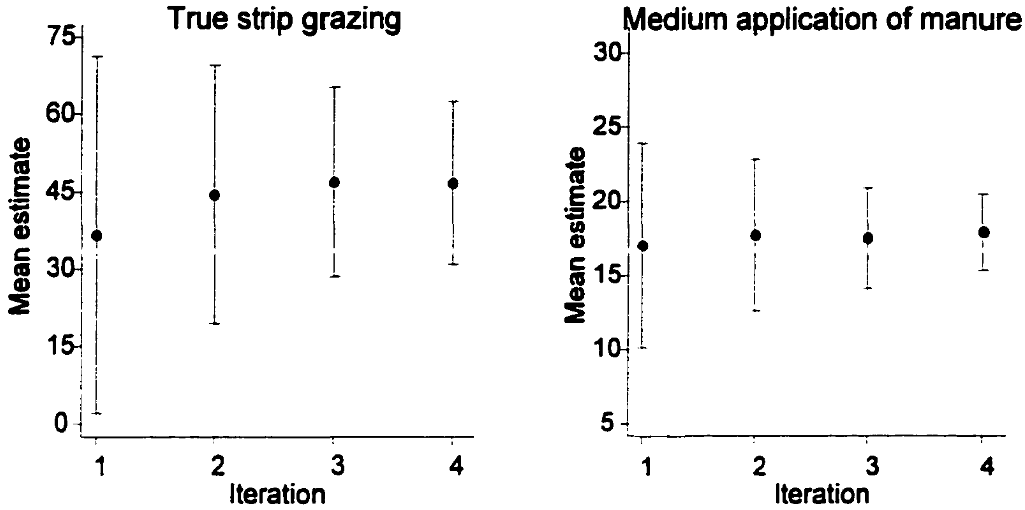
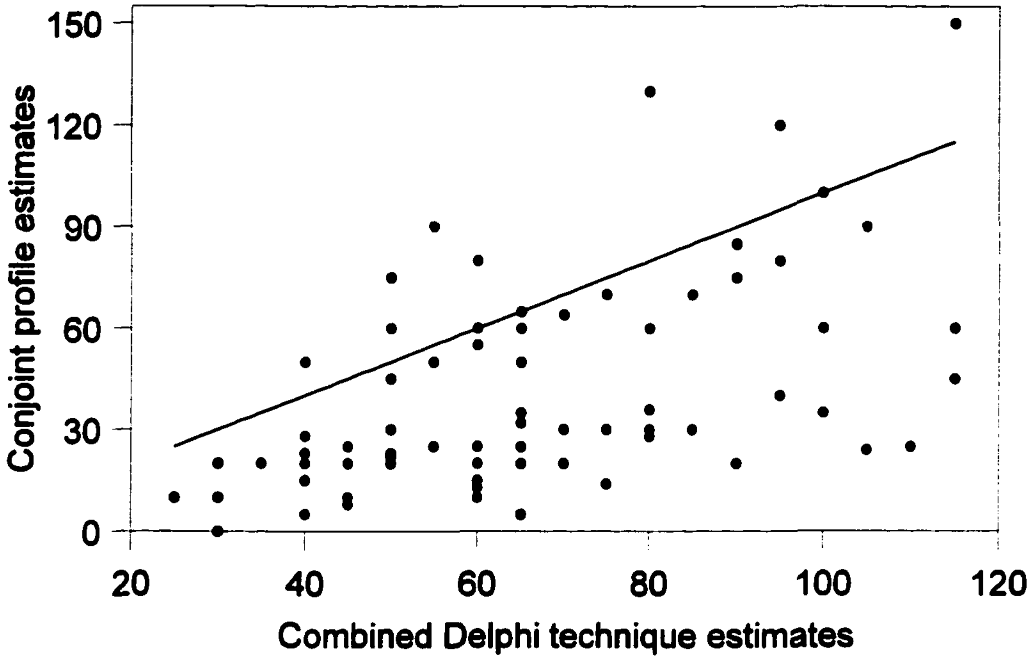


Figure 2. Scatterplot of conjoint analysis profile estimates versus the equivalent combined Delphi technique estimates[1]. A 'line of equality' (where $\beta = 1$) is also plotted.



1 Estimates of the expected annual percentage increase in pasture herbage yield resulting from the use of various pasture management techniques.

Figure 3. Scatterplot of percentage increase in predicted annual yield for all pasture fields using estimates derived from conjoint analysis vs. estimates derived from the Delphi technique. (β=1.4, P<.001, R^2=.90)

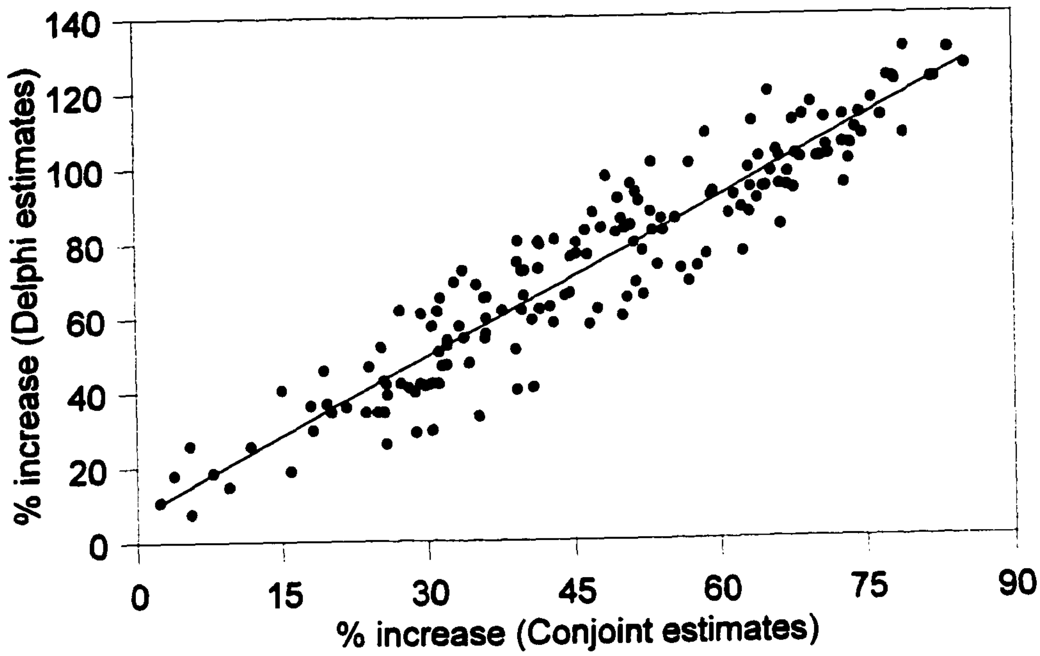


Figure 4. Scatterplot of 'conjoint analysis based' predicted annual dry matter yield (tonnes) per acre vs. late summer forage dry matter inventory (kilogram) per acre. (β=178.5, P=.01, R^2=.09)

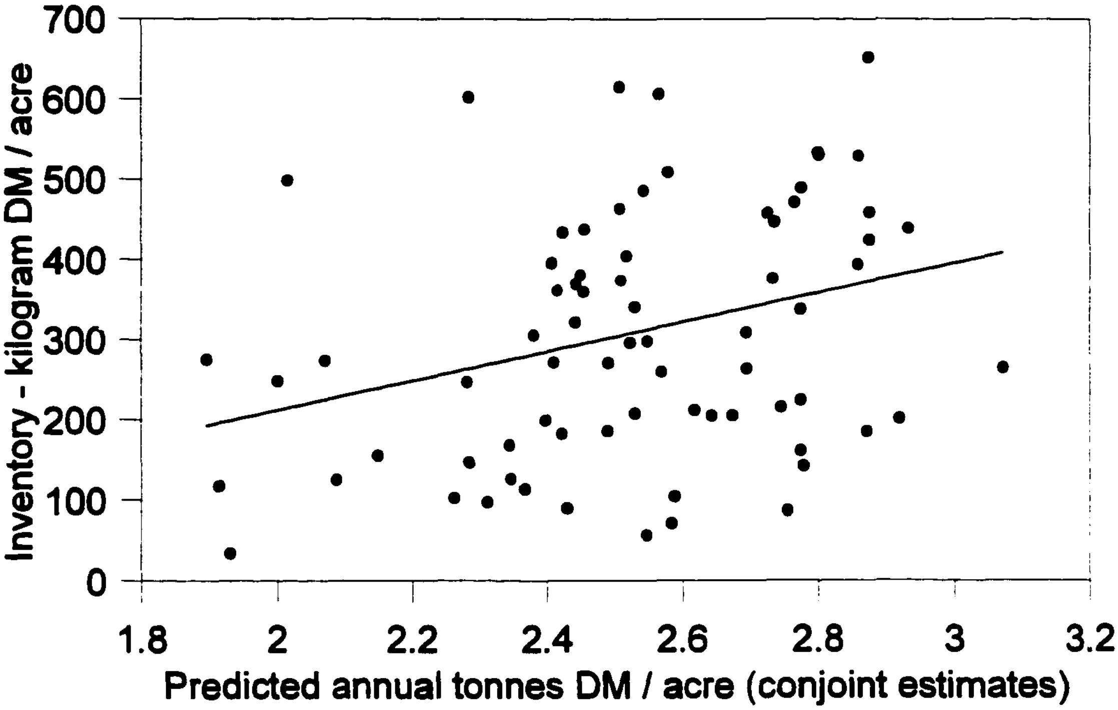


Table 1. Final point estimates, and interpolated values, of percentage increase in herbage dry matter yield expected from the use of various pasture management techniques, as obtained via the Delphi technique and Conjoint Analysis.

Pasture Management Technique	Delphi technique point estimate[1] (S.D.)	Conjoint Analysis													
		Profile Number & Composition												Point estimates (P)	Interpolated values[2]
		1	2	3	4	5	6	7	8	9	1	1	1		
Rotational grazing	35.8 (11.3)	X	X			X				X		X	X	21.7 (.04)	
Forward strip grazing	22.7 (8.1)														13.9
True strip grazing	46.7 (16.3)														28.2
Lime (within 5 yrs.)	11.3 (3.1)	X		X			X		X				X	10.3 (.01)	
Manure - light application	10.8 (1.9)														2.3
Manure - medium application	17.9 (2.6)	X	X		X						X	X		3.8 (.51)	
Manure - heavy application	25.8 (4.2)														5.5
Fertilizer (15-15-15) - one appl'n	21.2 (4.1)				X				X		X			24.9 (.01)	
Fertilizer (30-0-0) - one appl'n	18.3 (2.5)														21.5
Fertilizer (15-15-15) - two[+] appl'n	32.5 (7.8)														25.6
Fertilizer (30-0-0) - two[+] appl'n	27.5 (5.0)					X	X			X		X	X	21.7 (.02)	
Top clipping	7.7 (4.5)														5.6
Reseeded in the past year	27.9 (7.2)	X		X	X	X						X		15.6 (.07)	
Reseeded in last 1-5 years	7.1 (5.8)														3.9

[1] Point estimate and standard deviation of expected percentage increase in annual pasture herbage yield resulting from the use of the pasture management technique.

[2] Interpolated values are based on the point estimate for a different level of the same technique, and the ratio of those two estimates obtained by the Delphi technique. For example, two applications of 15-15-15 were predicted by the Delphi technique to yield 18% more than 2 applications of 30-0-0 (32.5% vs 27.5%). Thus, the conjoint analysis derived estimate for 2 applications of 30-0-0 (21.7%) was increased by 18% to interpolate the value for 2 applications of 15-15-15 (25.6%).

Table 2. Percentage of fields and acreage managed using various management techniques, Prince Edward Island, Canada, 1994. (272 pasture fields, totalling 2936 acres, on 74 dairy farms.)

	Percentage of .... receiving management practice	
Management practice	..fields..	..total acreage..
Grazing management		
continuous grazing	15.4	17.6
rotational grazing	47.1	39
true strip grazing	26.5	33.7
forward strip grazing	11	9.7
Manure applied (previous 2 years)		
'light' application	13.2	16.2
'medium' application	30.1	33
'heavy' application	25	27
Fertilizer applied in current season		
single application of 15-15-15	27.2	27.8
single application of 30-0-0	6.6	5.8
two or more applications of 15-15-15	16.5	18.9
two or more applications of 30-0-0	0.4	0.3
Soil alkalizing material in previous 5 years	69.1	71.8
Sward age/type		
perennial pasture sown in current or previous year	10.8	11.3
pasture seeded in previous 2-5 years	32.3	33.4
annual ryegrass	9.4	7
Top-clipping in current grazing season	59.2	54.2

Chapter 5

Association of Ration Characteristics and Seasonal Patterns of Milk Production in Dairy Herds in Prince Edward Island, Canada

INTRODUCTION

Numerous complex and inter-related factors affect milk production in dairy cattle. Arguably, one of the most important of these is the ration consumed by the cows, including the dry matter intake, the quality and the balance of ration. Numerous publications in the literature report the results of studies which have investigated different aspects of the relationship between nutritional factors and milk yield. Most of these studies were carried out in controlled studies and feeding trials involving limited numbers of animals. Epidemiologic studies, such as Scholl (23) and Sargeant (22), have also been used to explore the relationship between nutritional factors and milk production at the herd level in large-scale studies.

The objectives of this study were; 1) to develop and evaluate a detailed method of assessing rations, including pasture usage, at the herd level in a large-scale observational study, 2) to summarize information pertaining to the use of stored feeds and reliance on pasture in Prince Edward Island (PEI), Canada, and 3) to explore the associations between the ration characteristics on 75 dairy herds in PEI and the seasonal pattern of milk production observed in those herds. Ration assessments were carried out twice during the year; at the end of the stabling period in mid-spring, and during the grazing period in late summer. The quantity and quality of the stored feed components were measured, and the contribution of the pasture forage to the ration was evaluated.

Materials and Methods

In order to explore the relationships between various ration characteristics and the seasonal patterns of milk production, an accurate and detailed assessment of the ration fed to the lactating cows was required for each of the study herds. This necessitated an evaluation of both the quantity and quality of the stored feeds fed as well as the dry matter available from pasture. From these evaluations, estimates of the average amount of dry matter (DM), digestible energy (DE), and crude protein (CP) consumed by each herd could be determined and compared to the requirements for each herd.

Calculation of average intake of stored feeds

An assessment of the ration fed to the lactating cows was carried out during both herd visits in 1994. The ration fed during the first visit was comprised solely of stored feeds in all herds, whereas the summer ration, assessed during the second visit, consisted of varying proportions of stored feeds and pasture forage.

During both visits detailed information was recorded regarding the quantity of each component of the ration fed per cow per day (Appendix F). The amount fed per cow per day for each ration component was determined as outlined below, using a calibrated, portable, hanging weighscale when required:

- grains, concentrates, prepared rations, and potatoes: a "feeding unit" (eg. a "scoop") was weighed, and the number of feeding units recorded
- rectangular bales of hay: approximately 10 bales were weighed to determine an average bale weight and the number of bales fed was recorded
- round bales of silage or hay: if actual (average) weights were not available from the producer, the height and diameter of bales was recorded, as well as the name-brand of the baler used. This information was used to determine an average bale weight using locally obtained data (15).
- chopped silage: where cows were fed in tie stalls, the amount of silage fed was weighed for 4 or 5 cows to estimate the average amount fed.
- feeds delivered by automated delivery systems: programmed weights were recorded from equipment that was regularly calibrated - in other instances the actual amount of feed delivered was measured.

In all instances, the amounts were recorded on an "amount offered" basis, unless a substantial proportion of the amount offered was discarded as orts[1]. In these situations, the amount offered was adjusted according to the estimated proportion not consumed.

The amounts fed were also recorded by production level or stage of lactation if these criteria were used as a basis for determining the amount fed. To arrive at

[1] feed offered to, but not consumed by, an animal

herd level estimates for all feedstuffs, the amount fed to each production group was weighted by the percentage of herd tests occurring in that group. The producers were asked to provide an estimate of the cut-points which were used to distinguish the low, average and high production groups. All individual cow test day production and stage-of-lactation information was obtained from the Animal Productivity and Health Information Network (APHIN) (4), for all herd tests occurring during the three month period centered about the day of the herd visit. The percentage of tests occurring in each production group was calculated, and these weighting factors were used to calculate the herd level average amount of each ration component fed at each herd visit. In situations where the stage of lactation was used as a feeding guide instead of actual milk production, the weighting factors were determined as the percentage of tests occurring within each stage of lactation group.

Ad lib feeds and herds feeding total mixed rations

Seven herds fed forages on an *ad libitum* basis at the time of the visit at the end of the stabling period and were not able to provide a reliable estimate of the amount fed per cow per day. In order to estimate the intake for those herds for the first visit, the average total amount of DM fed (based on the DM content of each feed stuff) was calculated for all herds for which estimates were available for all ration components and expressed as a percentage of the herd average body weight. The total DM intake for the herds feeding a portion of their ration *ad libitum* was then calculated as the product of the herd average cow weight and the overall

DM intake expressed as a percentage of body weight as described above. The amount of the *ad libitum* feed consumed on a dry matter basis was then calculated as the difference between the total estimated DM consumption and the actual DM intake from those ration components which had been measured.

Of the eighty study herds which were visited in 1994 (see Chapter 3, p. 46), a number were excluded from the analyses presented in this chapter for specific reasons. Three herds that were feeding silage *ad libitum*, with no estimate of intake available, were also utilizing pasture. These herds were not included in these analyses due to the inability to calculate in any meaningful way the forage intake from stored feeds. (Three herds that fed silage on an *ad libitum* basis during the summer visit did not utilize pasture as a source of forage and an estimate of intake could therefore be made as described above.)

Two herds which fed (total or partially) mixed rations were removed from the dataset for these analyses for two reasons. The amount of the individual components consumed could not be accurately determined, and one of the herds fed *ad libitum* supplemental hay or silage in addition to the mixed component of the ration. Secondly, the DM, DE, and CP analysis carried out on the feed sample presupposed a thorough and complete mixing of all ration components and that the sample obtained was a true composite sample of the ration. It was believed that there was a reasonable doubt that the mixed ration samples obtained could meet these criteria.

Calculation of dry matter, digestible energy, and crude protein intake

Samples were taken of each available feed by use of a probe (grain and grain mixture components), a core sampler (baled silage and hay), or grab samples (chopped silage). Multiple, random samples were obtained and thoroughly blended to maximize the likelihood of obtaining a representative sample of each ration component. These were sub-sampled if required and submitted to the Prince Edward Island provincial feed laboratory for standard analysis of the DM, DE, and CP content.

The DM, DE, and CP contents for commercially prepared concentrates and mixed grain rations were determined according to the "guaranteed analysis" available for each product, or in consultation with the supplier of the product. Published values for the DM, DE, and CP content of potatoes were utilized (16).

In situations where an insufficient quantity of a ration component was available for sampling, or where the supply of a specific feed had been very recently depleted, the analysis of a sample previously submitted by the owner was used. Where this was not available, current provincial average DM, DE, and CP values were used for a feed of similar description (e.g. 1994, second-cut, timothy hay).

Herd level estimates of the amount of all ration components were obtained on an "as-fed" basis as described above. These estimates were used, in conjunction with the feed analyses, to arrive at an estimate of the amount of DM, DE, and CP derived from each ration component. The grain, mixed grain ration, concentrate, and potato component values were combined to arrive at a single point estimate of the average amount of DM, DE, and CP fed per cow per day from all 'non-forage' sources. Similarly, a single point estimate was calculated for the daily average amount of DM, DE, and CP fed per cow from all forage sources.

Prediction of dry matter, protein and energy requirements

In order to assess the adequacy of the amount of DM, DE and CP fed per cow per day, daily requirements for these three 'components' were calculated. Formulas were derived from tabular data in the National Research Council's "*Nutrient Requirements of Dairy Cattle*" (16) which determined dry matter intake (DMI), and the DE and CP requirements based on 4 % fat corrected milk (FCM) production and body weight. A 15 % increase in maintenance energy requirements was included for herds which utilized pasture as a forage source during the summer months to account for the energy expended in grazing activities (16). Details of these calculations can be found in Appendix G.

Herd average body weight was available from data collected during the summer herd visit in 1994. Cow weights were regularly obtained, usually by means of a heart girth measurement, during herd visits by the Atlantic Dairy Livestock Improvement Corporation technician.

A variety of milk production figures were utilized along with the herd average body weight to calculate DM, DE, and CP requirements.

- The average test day milk production during March and April was corrected to a 4 % FCM basis using the average milk fat percentage in

March and April.

- The mean of the herd average adjusted, corrected milk (ACM) production figures (4) for March and April 1994. This value was used to represent an average production figure near the end of the stabling period.
- The maximum herd average ACM production during May, June, and July 1994. It was felt that this would represent an achievable target production, since this is the time of year during which herds generally achieve their maximum test day milk production.
- The herd average genetic index for milk production was also used to estimate the herd average potential production. This index was used to calculate the genetic potential 305-day milk production, which was subsequently divided by 305 to arrive at an average potential daily milk production. Details of these calculations can be found in Appendix G.

The use of these four milk production values resulted in three sets of estimates for daily DM, DE, and CP requirements. Based on a comparison of these sets of estimates, the DM, DE, and CP requirements calculated using the genetic indices were selected for use in all further analyses.

The actual amounts of DM, DE, and CP fed from stored feeds at the summer visit in 1994 were expressed as a percentage of the DM, DE, and CP requirements (as derived above, using the genetic indices) in order to arrive at estimates of the percentage of requirements provided by stored feed components of the ration. The amount of DM, DE, and CP fed at the late winter visit in 1994 was similarly calculated and expressed as a percentage of the daily requirements based on the herd average genetic index for milk.

Pasture dry matter availability

Total annual pasture dry matter production for each pasture field was calculated based on the management practices applied to the field and the expected increase in yield for each practice. Details of these calculations are available in chapter 4. The total annual pasture forage for each herd was divided by an average of 153 grazing days and by the average number of lactating cows, to arrive at an estimate of the average amount of pasture dry matter per day.

The pasture dry matter allowance per day (PDMA) was calculated as the ratio of the amount of daily pasture forage DM available (kg per cow) to the daily amount of DM required based on the genetic potential for milk production (total DM required minus stored feed DM).

Pasture management index

A pasture management index was calculated for each farm. This index represented the average percentage increase in forage yield expected per unit of pasture, and was calculated as a weighted average of the sum of the conjoint analysis estimates for the management practices applied to each field. Details of the calculations and conjoint estimates can be found in chapter 4. The pasture management index for the farm was used to represent the overall level of pasture management, independent of the actual area of land committed to pasture.

Examination of relationship between ration & slump

Basic descriptive statistics and histograms were used to examine the variables and parameters calculated. The relationship between the seasonal pattern of milk production and various ration characteristics (including the PDMA and the pasture management index) were examined using scatterplots, simple linear regression and multiple linear regression. Details concerning the definition of the seasonality variable (MINMAX) can be found in Chapter 1 (p. 5).

RESULTS

Seventy-five study herds (69 Holstein, 6 other breeds) had reliable and complete information about the ration fed to the lactating cows for both data collection visits.

On average, herds fed 13.1 kg forage DM (S.D. = 3.1) and 8.7 kg of non-forage (grain, concentrate and potatoes) DM (S.D. = 2.2) during the stabling period. Total forage DM was fed at a rate of 2.2 % of body weight (SD = .51), whereas the total ration DM was fed at a rate of 3.7 % of body weight (SD = .58) in the stabling period.

At the time of the summer visit, 20 % of the herds (n = 15) were not feeding any stored forage to the lactating cows. In the herds where the cows were receiving a source of stored forage, cows were being fed, on average, 8.0 kg of forage DM (S.D. = 5.1). All herds were feeding at least some grain or concentrate, with an average of 7.0 kg of non-forage DM (S.D. = 1.8) being fed per cow per day. Total forage dry matter was fed at a rate of 1.1 % (SD = .94) of body weight, whereas the total ration dry matter was fed at a rate of 2.3 % (SD = .93) of body weight at the time of the summer herd visit.

Prediction of dry matter, protein and energy requirements

The herd average body weight for all herds was 586 kg (SD = 37.4). For the Holstein herds (n=69), the average body weight 593 kg (SD = 29.9). The six non-Holstein herds included in the dataset were predominantly Ayrshire.

The herd average genetic index for milk, for all herds with greater than 10 cows contributing to the average, was -.65 (n = 52, S.D. = 2.2). This is equivalent to a estimated breeding value (EBV) of -68.9 kg of milk (G. Jansen, personal communication).

Table 1 presents the summary descriptive statistics for the 4 % FCM average test day production in March-April, the March-April (average) and May-June-July (maximum) ACM (corrected to 3.5 % fat, 35 % heifers, and 150 DIM) as well as the daily production calculated using the herd average genetic index. Although the average values are quite similar, it can be seen that the daily production calculated using the genetic potential demonstrates a much narrower distribution than the two values which are calculated using actual test day milk production information.

Figure 1 is a histogram which shows the distribution of the ratio of DM supplied by the ration at the first herd visit in 1994 to the DM requirements (based on the average test day 4 % FCM production during March and April). These visits were carried out during late April and early May, when the ration consisted only of stored feeds. The mean percent of the DM requirements provided by the ration was 117.0, with a minimum of 77.8 and a maximum of 160.9 percent. Ninety-one percent of the herds were meeting at least 95 percent of their calculated dry matter requirements.

Figures 2 and 3 show the distribution of the proportion of the DM requirements met by stored feeds fed at the time of the winter and summer herd visits, calculated using the daily milk production estimates derived from the genetic indices, and the herd average cow weight. Table 2 presents a summary of the descriptive statistics for the percentage of the genetically determined DM, DE and CP requirements met by the stored feeds fed at the time of both visits.

Pasture dry matter availability

The herds that utilized pasture as a component of the ration had an average of 16.2 kg (S.D. = 5.4) of pasture DM available per cow per day. Four herds did not utilize pasture as a source of forage for the lactating cows.

The values for the PDMA, which expressed the daily pasture DM available per cow as a percentage of the DM required beyond that supplied by the stored feeds, was truncated at 450 percent, with values occurring above the truncation point being set to 450 percent. Values below 0, indicating that more than the required amount of dry matter was being fed from stored feeds, were set equal to the mean PDMA. The mean PDMA was 237 percent (S.D. = 102). Sixty-six percent of herds had a PDMA of 200 percent or greater.

Pasture management index

The pasture management indices (PMI) were normally distributed with a mean of 147 and a standard deviation of 14.7. The minimum and maximum PMI were 111 and 180, respectively.

Examination of relationship between ration and seasonal pattern of milk production

Figures 4 and 5 are scatterplots of the relationship between the herd average daily amount of non-forage DM and silage fed during the summer and the level of the summer-fall slump (MINMAX). This analysis was restricted to Holstein herds due to the statistically significant size differences between the breeds and the influence of body size on intake. It can be seen that there is a strong relationship between the amount of non-forage DM fed per cow per day during the summer (GRADM_S) and the seasonal pattern of production (β_{GRADM_S} = .03, R^2 = .26, P < .00), with herds that fed higher amounts of non-forage DM maintaining a more consistent pattern of milk production. Silage feeding (SILDM_S) had a small positive relationship with MINMAX (β_{SILDM_S} = .005, R^2 = .09, P = .01). However, when total forage (silage and hay) fed (FORDM_S) and grain fed per day were included in a multiple regression model (Table 3), both terms were highly significant ($P < .01$) and accounted for 38.4 percent of the variation observed in MINMAX ($\beta_{GRAIN} = .035$, $\beta_{FORAGE} = .007$, $P_{MODEL} < .00$). An interaction term was computed after centering the non-forage DM variable to reduce the correlation between the interaction term and FORDM_S. Since this term was not significant ($P = .51$) it was determined that the effect of non-forage DM feeding and silage feeding were statistically independent of one another.

The effect of various pasture parameters were also examined using multiple linear regression to control for the effect of grain and forage feeding. Neither the number of pasture acres per cow ($P = .75$), the PMI ($P = .96$) nor the PDMA ($P = .91$) were significant when included sequentially in the model with GRADM_S and FORDM_S. Two-way and three-way interaction terms for all variables were also examined and were not found to be statistically significant.

The relationship of the DE and CP from non-forage sources and stored forages with MINMAX were also assessed using linear regression. In both models, the amount of DE and CP from non-forage and from stored forage sources were significantly, positively related to MINMAX, although the R^2 was lower than that obtained using non-forage and stored forage DM as the independent variables.

The relationship between the adequacy of the stored feed ration and the seasonal pattern of production was also examined. Figures 6 is a scatterplot depicting the association between the level of the summer-fall slump (MINMAX) and the percentage of the DE requirements (based on the genetic index and average cow weight) met by the stored feed component of the ration ($\beta = .186$, $R^2 = .25$, $P < .05$). Similar patterns existed in the scatterplots of the percentage of DM and CP met by the stored feed ration and MINMAX, although a greater proportion of the variation in MINMAX was explained by the percentage of DE requirements ($R^2_{DM} = .20$, $R^2_{CP} = .21$). There was a slight upward trend in all plots, indicating that herds that fed a higher percentage of the daily requirements of DM, DE, and CP as stored feeds (rather than pasture) tended to maintain a more consistent level of milk production during the summer and fall. It is especially evident that very few herds experienced a significant seasonal decline in milk production while feeding a high percentage of requirements as stored feeds. While the general trend indicates that herds that relied substantially on pasture demonstrated greater seasonal variation in milk production, there were also a substantial number of herds that were able to maintain consistent production while relying heavily on pasture to meet daily DM, DE and CP requirements.

Linear regression analysis was used to elucidate the relationship between MINMAX and the percentage of the dry matter requirements met by the stored feed ration (PCTDM_S), the PDMA and the interaction of these two variables. No significant interaction was found between PDMA and PCTDM_S ($P = .35$). Also, when controlling for the percentage of the dry matter requirements met by stored feeds, the amount of pasture DM relative to that required (PDMA) was not significant ($P = .92$).

The relationship between MINMAX, the overall pasture management level

(PMI), and the percentage of the dry matter requirements met by stored feeds was also assessed. Neither the PMI, nor its interaction with the percentage of the dry matter requirements met by stored feeds, was found to have a significant relationship with MINMAX.

Routine residual diagnostics were carried for all linear regression models. Residual versus fitted value plots were examined for trends, and were assessed for homoscedasticity. Leverage and influence on the regression results were also assessed by calculating 'Cooks distance' residual, jackknife residuals, and by removing point(s) with high residual or leverage values and repeating the regression analysis. In no models did the removal of any points significantly influence the coefficients or standard error estimates of the independent variables. It was concluded that the results above were not unduly influenced by either a single or small group of highly influential observations (herds).

Discussion

Collecting reliable and accurate ration information is a challenge in large scale observational studies of dairy herds. In controlled studies the amount of feed offered to an individual animal and the amount rejected can be measured frequently and with a high degree of precision and accuracy. In studies involving many herds and thousands of cows however, it is usually impractical, and prohibitively expensive, to collect data in this manner.

Previous large scale studies involving dairy herds, including Scholl (23) and Sargeant (22), have utilized questionnaires to collect ration information. The potential for error has been reported in human nutritional surveys, where the accuracy of reporting is influenced by many factors, including estimation and computational errors, respondent bias, and under or over-reporting (6,7). The questionnaire or survey approach can potentially introduce error in a number of ways in livestock nutritional assessment as well. In herds where cows are individually fed, many producers use containers or scoops to apportion grains and concentrates to their cows, and the actual weight of feed delivered to the cow may be significantly different than is expected, due to, for example, variations in container size or feed density. This discordance was observed in many instances during the data collection phase of this study (E. Hovingh, unpublished observations). It also seems plausible that dairy producers could produce consciously or subconsciously biased estimates; for example, a producer might overestimate the amount his or her animals eat to make them appear 'better' or 'more aggressive', or may deliberately underestimate the amount of a certain ration component if it is being fed at a level exceeding that espoused by conventional wisdom. The process of arriving at an accurate, weighted estimate of the (herd) average amount of grain or concentrate fed may be mathematically or conceptually too difficult for some producers to comprehend. Lastly, using a 'paper' ration (a ration prepared by a nutritional consultant, for example) also has its disadvantages, since the ration that is actually consumed can be significantly different from that which is offered to the cow, which, in turn, can be substantially different from the ration prepared 'on paper' (5).

In this study an attempt was made to eliminate some of the most obvious sources of error in performing ration assessments in large scale observational studies, and to arrive at accurate herd level estimates for the amount of dry matter, digestible energy and crude protein that was fed per cow per day. Actual weights of the ration components delivered to the cows were obtained, and feed samples were taken to assess feed DM, DE, and CP. Where components were fed by production or stage of lactation, accurate herd level estimates were obtained by weighting the group values by the percentage of tests occurring within that group at the time the ration assessment was being performed.

The quality of the ration data collected in this study was evaluated in a number of ways. Good concordance was observed between the National Research Council estimates of the average percent of body weight consumed as dry matter and those calculated from the study data. Dry matter intakes (as a percentage of body weight) to fulfill maintenance, milk production and live weight change requirements for 600 kilogram cows producing 15 to 45 kg of 4 % FCM ranged from 2.6 % to 5.0 % (16). Data from Conrad (2) suggest that intakes (as a percentage of live weight) will range from 2.25 % to 4.32 % depending on the digestibility of the diet. In this study, the dry matter intake values as a percentage of body weight values were normally distributed with a mean of 3.7 %, and a range of 2.4 % to 4.8 %.

Adequate amounts of DM, DE and CP to meet the average production observed in March and April 1994 were supplied by 84, 91, and 83 percent of herds, respectively, at the time of the visit in late April to early May 1994. Given the concurrent changes in production, feed type and body condition score that would have occurred between the time of the herd visit and the average milk production recorded one to two months previously, a high percentage of the herds appear to be meeting the nutritional requirements.

Prediction of dry matter, protein and energy requirements

The herd average body weight measures, taken from the ADLIC report form, were generally recorded using heart girth tape measurements although weights were occasionally assessed visually on some farms (E. Hovingh, unpublished data). Although less accurate than actual scale weight measurements, these herd level estimates did provide a means to assess between-herd differences in cow size, in order to account for the subsequent differences in maintenance requirements.

Actual summer milk production values were not used to calculate the DM, DE, and CP requirements since summer and fall milk production values were used to calculate MINMAX, the dependent variable in many of the relationships being examined. To have utilized these values to calculate the requirements would have introduced a circularity in the analysis, since the milk production values used to calculate MINMAX (the dependent variable) would also have been used to calculate the value of the independent variables. Similar rationalization would suggest that it would not be appropriate to use the winter or early spring milk production values to calculate the nutritional requirements.

The herd average genetic index for milk demonstrated a relatively small degree of variability between herds. It is expected that this was due to the almost ubiquitous use of artificial insemination from commercially accessible sources of semen. From a visual examination of the available genetic data (herd minimum, mean, and maximum indices) it appeared that there was generally a greater range of genetic indices within many of the herds than between the herd average genetic indices of the herds. Formal statistical tests to compare the within-herd and between-herd variation could not be performed due to a lack of information on the dispersion of the indices within each herd.

The resulting 305-day milk yield and per diem predicted milk yield showed only a small degree of variation about the mean, due to the lack of significant interherd variability observed in the herd mean genetic indices. Since a typical 305-day lactation curve is not evenly distributed about 150 days, the calculated per diem production values would somewhat underestimate the actual 150 day value. However, for the purpose of inter-herd comparisons it was deemed to be an adequate measure of production.

The potential milk production, as calculated by means of the genetic indices, was ultimately chosen as the basis on which to calculate the nutritional requirements. This was due to its independence from the outcome variable, and from other herd level factors affecting milk production. The relationships between the requirements calculated using these production estimates, the ration characteristics and the seasonal pattern of production were examined, as discussed above. These variables were used in constructing a subsequent multivariable regression model predicting the seasonal pattern of milk production in PEI dairy herds (Chapter 8).

Pasture dry matter availability & allowance

Total annual pasture dry matter yield was calculated using the estimates derived from the conjoint analysis process as outlined in Chapter 4. The estimates of the expected increase in dry matter yield resulting from the use of various pasture management techniques demonstrated a high degree of agreement with values available in the literature. To calculate the daily dry matter availability, the total annual predicted yield was divided by the number of cows and an overall average number of grazing days. This was based on the simplifying assumption that the distribution of the forage availability throughout the grazing season would remain constant. While the temporal distribution of pasture forage growth and availability is affected by many natural and management factors (10,14), there was no accurate means to determine farm specific distribution patterns with the data available.

Since the efficiency of pasture forage utilization could not be expected to approach 100 percent, a method to assess the relative availability of pasture forage was needed. All but one herd had a total predicted pasture forage dry matter yield per day which would meet or exceed their calculated dry matter deficit after accounting for the amount of stored feeds fed. The relative availability of pasture forage was therefore calculated as the PDMA, which expresses the pasture forage dry matter available per day as a percentage of the daily dry matter deficit after accounting for the stored feeds being fed. Rayburn and Fox (19) suggest that a PDMA of at least 200 % is required to enable cows to maximize their dry matter intake at pasture. Using these criteria, 34 % of the study herds did not have adequate pasture forage dry matter to meet their daily requirements.

Examination of relationship between ration & slump

Numerous controlled research studies have looked at the effects of supplemental feeding of forages and concentrates on dry matter intake and milk production of grazing ruminants. Holden et al. (9) found no effect on total dry matter intake or milk production when feeding 20 to 25 % of the total ration dry matter as corn silage, as compared to cows receiving no supplemental forage source. In some earlier work however, Bryant and Donnelly (1) found that milk production was decreased when pasture dry matter was substituted at a high rate by corn silage dry matter. Dhiman et al. (3), used rations containing three proportions (100:0, 66:33, and 33:66) of pasture and supplement to investigate the impact of supplemental feed on milk yield. The supplement used was a mixture of corn or alfalfa silage, grains and other additives. They found an increased production response to increasing levels of supplementation, although the pattern and distribution of the additional milk was not supplied in their paper. Similarly, Phillips (17) demonstrated an increase in milk production, though with a concurrent decrease in milk fat percentage, when offering silage to animals with inadequate pasture forage available.

Rearte et al. (20) observed a statistically significant increase in milk production, although not in fat corrected milk yield, when supplementing dairy cows with a small amount of hay and concentrate as compared to the concentrate supplement only. Pasture forage was of high quality and present in adequate quantity. Stockdale et al. (24) and King and Stockdale (11) demonstrated a positive effect on milk production when hay was offered to cows grazing pastures that had insufficient dry matter to meet nutritional requirements. Although Phillips and Leaver (18) also demonstrated an increase in milk production as a result of hay supplementation of grazing dairy cows, the graphical representation of the data appeared to demonstrate similar rates of seasonal decline in both groups of cows.

Mayne et al. (12) compared time-restricted supplemental forage feeding and a 'leader/follower' grazing system to a 'conventional' rotational grazing system control group. The preferential treatment within each group (supplemental silage and 'leader' grazing) was accorded the highest yielding cows. A small, non-significant increase in milk production was observed in the high-yielding cows in the modified grazing system as compared to the control group. Although not formally evaluated in the paper, the rate of decline appears graphically to be similar between groups, with a possible exception of a slightly slower rate of decline in the low-yielding group receiving supplemental forage, suggesting a sparing effect of supplemental forage on low-yielding cows.

Meijs (13), in a trial investigating the effect of high starch and high fibre concentrates on milk production of grazing dairy cows, found that the high fibre supplement produced higher milk yields and higher fat corrected production. Similar daily herbage allowances existed between the groups.

Hoden et al. (8) examined the effects of stocking rate and concentrate feeding on milk production. The moderate and high stocking rates were 115 % and 130 % respectively of the control stocking rate, and two levels of concentrate feeding were used. Concentrates were fed at either a constant low rate or were adjusted for milk production. All cattle were moved to fresh paddocks when the daily milk yield of the control group was at 90 % of the maximum production attained during that stay in the paddock. The maximum production occurred an average of 3.6 days after entering the paddock, and the mean length of stay in a paddock using this management system was 10 days. The average intra-paddock ratio between the minimum and maximum production in the moderate and high stocking groups was .89 and .87 respectively, which was not significantly different from the controls. Cows receiving supplements at the higher level had statistically higher milk yields, and a persistence of 89 % per month as compared to a persistence of 85 % for cows receiving the low level of supplementation.

Rook et al. (21), in a trial examining the effects of concentrate supplementation and sward height, found that concentrate supplementation increased milk production at all sward heights. However, pasture forage intake was marginally decreased by supplementation in animals that were maintained on swards of inadequate heights.

The apparently contradictory results that are evident in the literature suggest that complex interactions occur between pasture quality and pasture utilization, supplemental feeding of grains and various forages, and milk production. Pasture utilization can be influenced by such factors as sward composition, sward height, and forage digestibility, while the intake of supplemental feed can be affected by the quality of the feed, the ease of access to the feed as well as various sward characteristics.

In this study, the total kilograms of forage and non-forage ration components fed in the late summer period showed a strong positive relationship with the consistency of milk production during the summer and fall months (Figures 4 - 6). When the amount of grains and conserved forages fed was controlled for, the pasture dry matter availability (as assessed using the PDMA) was not found to be a significant predictor of the seasonal pattern of production. Also, there were a substantial number of herds that relied on pasture to provide a significant percent of the daily dry matter requirements that maintained consistent production throughout the summer and fall, even though it was found that herds feeding higher percentages of the total required dry matter, energy and crude protein from stored feed showed less decline in milk production on a seasonal basis.

CONCLUSIONS

This large scale observational study investigated nutritional factors affecting the rate of decline of milk production in PEI dairy herds, rather than the absolute levels of milk production. The results suggest that at increased levels of supplemental feeding of grains, concentrates, and silage, a decrease in the rate of decline of milk production will be observed during the mid to late pasturing period. A similar effect is observed when assessing the percentage of the nutritional requirements met by the stored ration. When the amount of non-pasture dry matter being fed is controlled for, the amount of pasture dry matter relative to that required, and the overall pasture management level, is of little or no significance to the seasonal decline in milk production.

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Table 1. Summary statistics for 3 milk production variables used to calculate dry matter, digestible energy, and crude protein requirements.

	N (herds)	Mean (kg)	S. D.	Minimum (10th percentile)	Maximum (90th percentile)
Average of March/April 4% FCM[1]	75	25.3	4.2	15.9 (20.1)	35.1 (30.7)
Average of March/April ACM[2]	72	26.5	4.4	17.4 (21.0)	38.9 (32.2)
Maximum of May/June/July ACM[2]	70	28.6	4.3	19.5 (23.1)	39.9 (34.1)
Genetic potential - milk production / day	52	28.8	.75	26.9 (27.8)	30.6 (29.5)

1 Average test day production during March and April corrected to 4 % fat - based on average fat content of milk during March and April (source: Animal Productivity and Health Information Network (APHIN) (4))

2 Adjusted Corrected Milk values from APHIN; adjusted to 3.5 % fat, 35 % heifers, and 150 DIM

Table 2. Summary statistics for daily dry matter, digestible energy, and crude protein requirements, and percentage of requirements met by stored feeds, based on herd average body weight, and daily milk production, calculated from herd average genetic index[1].

		Mean	S. D.	Minimum (10th percentile)	Maximum (90th percentile)
Calculated daily requirements					
Dry Matter (kg)		19.3	.55	18.15 (18.52)	20.46 (19.97)
Digestible Energy (Mcal)		56.7	1.44	54.16 (54.56)	60.08 (58.66)
Total Crude Protein (kg)		2.8	.07	2.66 (2.73)	3.00 (2.91)
Proportion of daily requirements from stored feeds					
Dry Matter	Winter	1.11	.17	(.91)	(1.4)
	Summer	.69	.28	(.35)	(1.10)
Energy	Winter	1.20	.20	(.90)	(1.56)
	Summer	.77	.28	(.44)	(1.18)
Crude Protein	Winter	1.19	.37	(.81)	(1.65)
	Summer	.78	.39	(.41)	(1.25)

[1] Daily requirements calculated from NRC requirement tables (16).

Table 3. Regression coefficients (β), confidence intervals and significance values for independent variables kilogram non-forage DM[1], and kilogram forage DM[2] when regressed on MINMAX[3]. Model $R^2 = .384$, $P < .00$.

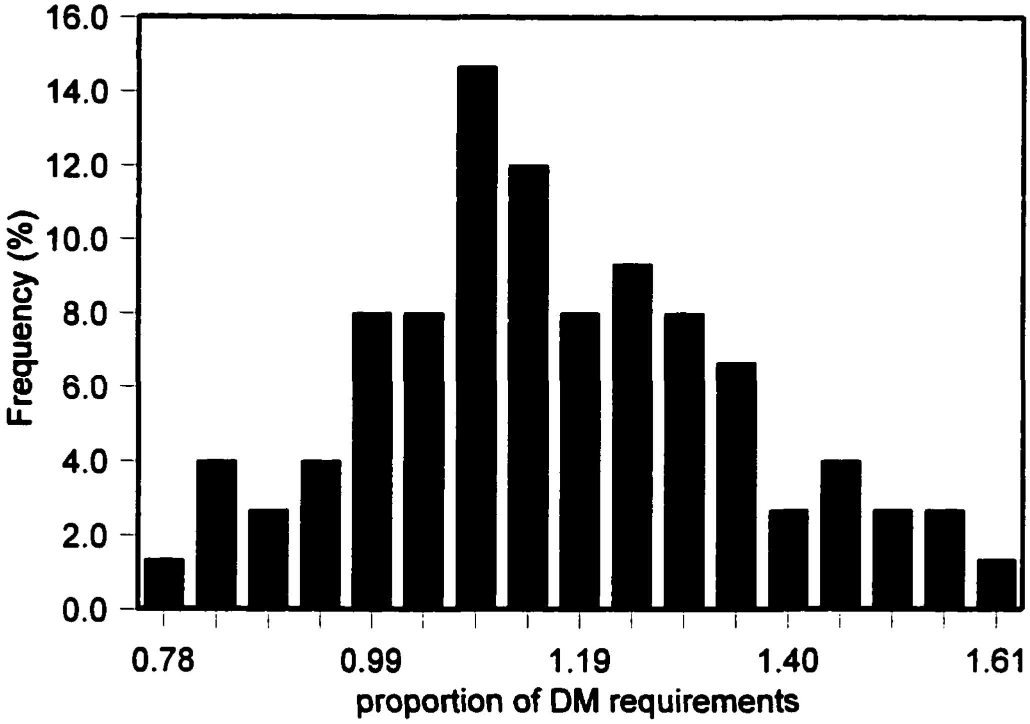
	β	Standard error	95 % confidence interval	P value
kg non-forage DM -late summer[1]	.035	.006	(.023, .047)	.00
Kg forage DM - late summer[2]	.007	.002	(.003, .011)	.00
Intercept	.462	.048	(.367, .557)	.00

[1] total kilogram of grains, concentrates and potatoes (DM basis) fed per cow per day in late summer 1994

[2] total kilogram of hay and silage (DM basis) fed per cow per day in late summer 1994

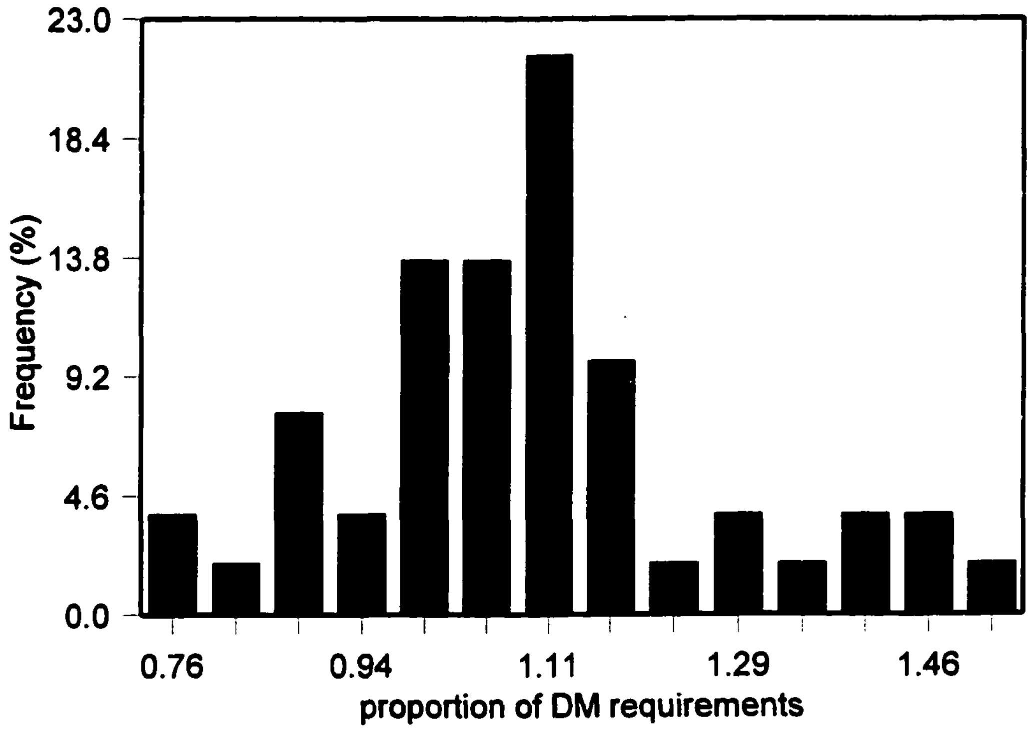
[3] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Figure 1. Histogram of herd average proportion of dry matter (DM) requirements provided by ration fed in late April 1994. DM requirements[1] based on herd average body weight and average, daily, 4 % fat corrected milk yield during March and April 1994.



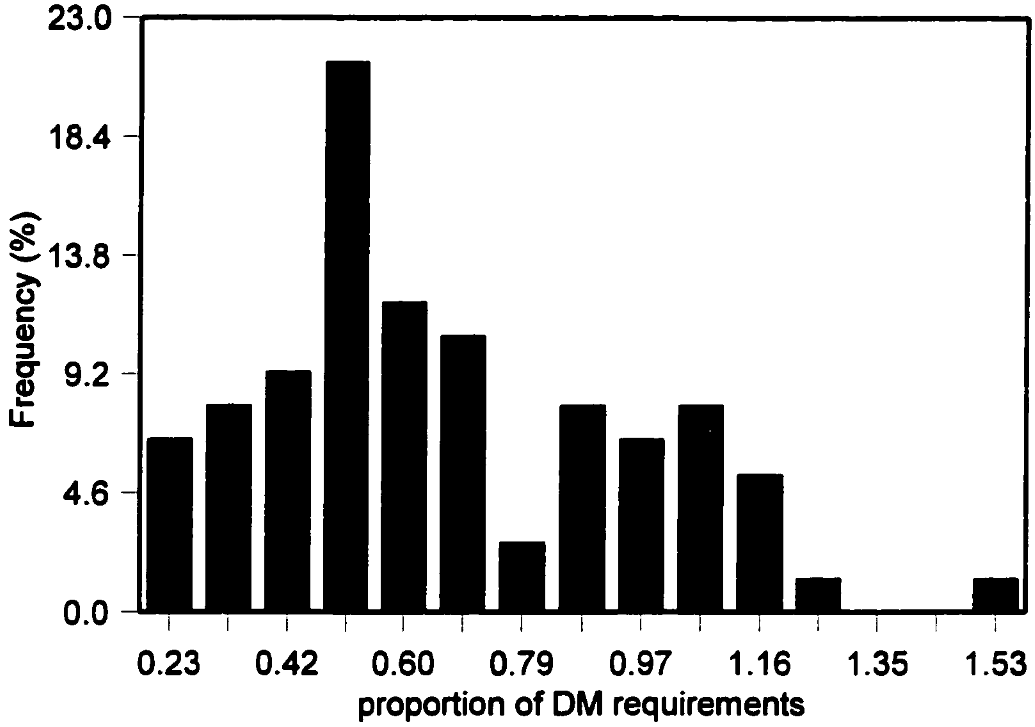
[1] Daily requirements calculated from NRC requirement tables (16).

Figure 2. Histogram of herd average proportion of dry matter (DM) requirements provided by ration fed in late April 1994. DM requirements[1] based on herd average body weight and average daily milk production calculated from the herd average genetic index.



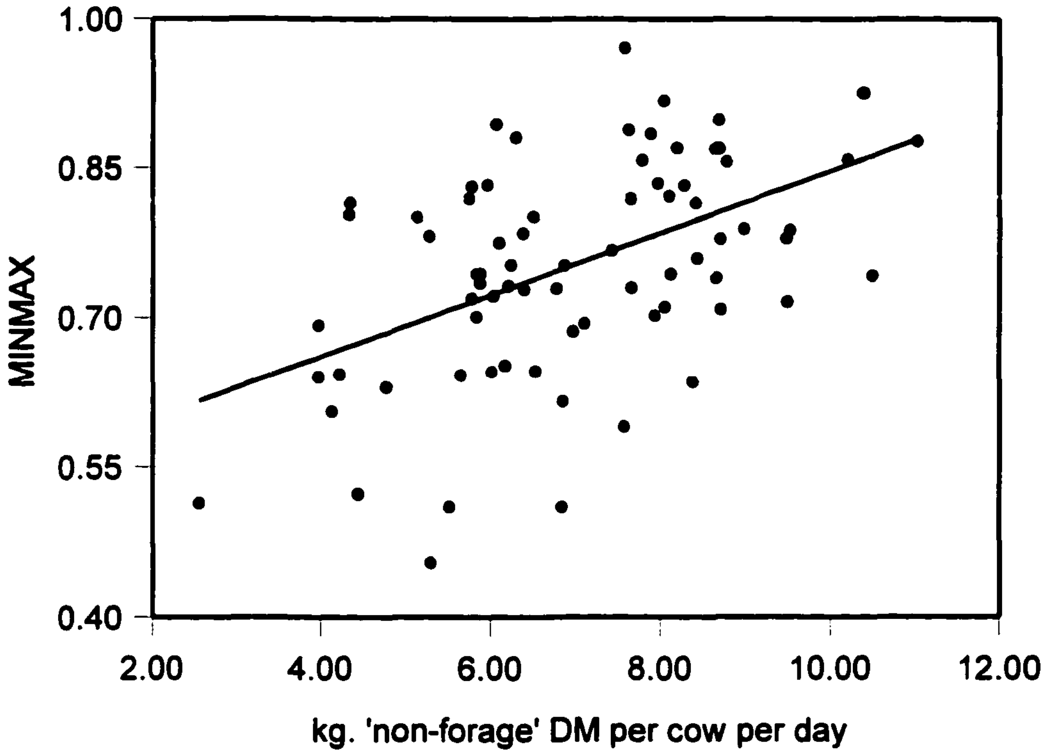
[1] Daily requirements calculated from NRC requirement tables (16).

Figure 3. Histogram of herd average proportion of dry matter (DM) requirements provided by stored feed ration fed in late summer 1994. DM requirements[1] based on herd average body weight and average daily milk production calculated from the herd average genetic index.



1 Daily requirements calculated from NRC requirement tables (16).

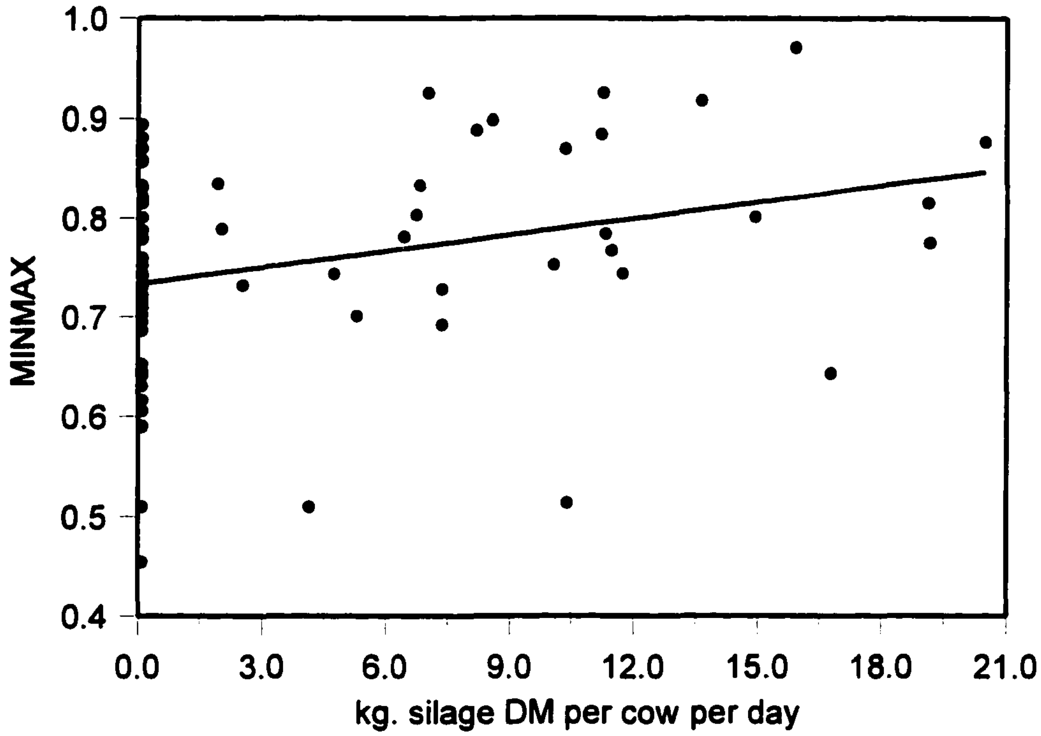
Figure 4. Scatterplot, with regression line, of total kilogram of non-forage DM[1] fed per cow per day in late summer 1994 versus the seasonal pattern of milk production (MINMAX[2]). Data from 69 Holstein dairy herds in Prince Edward Island, Canada. $\beta = .03$, $R^2 = .26$, $P < .00$.



[1] total kilogram of grains, concentrates and potatoes (DM basis) fed per cow per day in late summer 1994

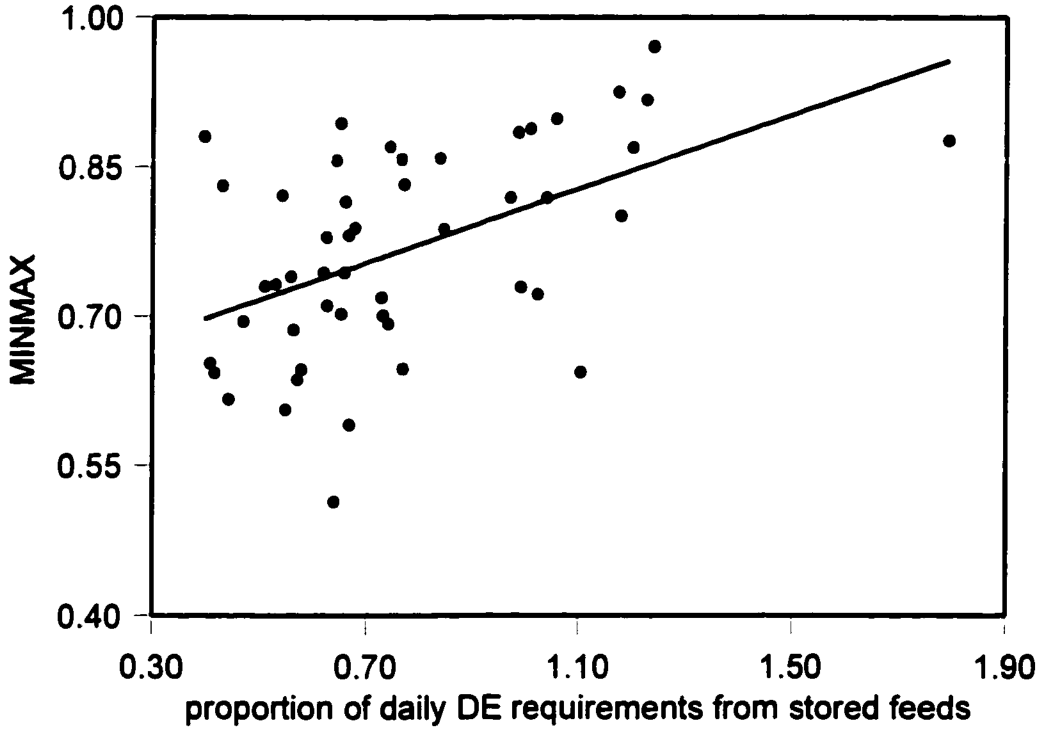
[2] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Figure 5. Scatterplot, with regression line, of total kilograms of silage dry matter (DM) fed per cow per day in late summer 1994 vs. the seasonal pattern of milk production (MINMAX[1]). Data from 69 Holstein dairy herds in Prince Edward Island, Canada. $\beta = .005$, $R^2 = .09$, $P = .01$.



[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Figure 6. Scatterplot of the proportion of daily digestible energy (DE) requirements[1] met by stored feeds in late summer 1994 vs. the seasonal pattern of milk production (MINMAX[2]). DE requirements based on herd average body weight and average daily milk production calculated from herd average genetic index. Data from 69 Holstein dairy herds in Prince Edward Island, Canada. $\beta = .19$, $R^2 = .25$, $P < .00$.



[1] Daily requirements calculated from NRC requirement tables (16).
[2] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Chapter 6

Association Between Adjusted Herd Average Body Condition Score and Seasonal Patterns of Milk Production in Dairy Herds in Prince Edward Island, Canada

INTRODUCTION

Body condition scoring is a subjective technique for assessing the body energy reserves of dairy cows, independent of body size (6,12,19). Bauman and Currie (1), in a review of homeostatic and homeorhetic mechanisms, state that greater than thirty percent of the milk yield in the first month of lactation is supported by body energy reserves, and that body reserves are utilized to support milk production until daily milk yield has decreased to below eighty percent of the peak milk yield achieved. The body condition score (BCS) of an animal can, therefore, be viewed as a 'record' of the historical energy balance of the animal, as well as a measure of the body reserves available for mobilization in the future.

Numerous studies have investigated the relationship between BCS at calving and change in BCS and parity (8,13,16), milk yield (8,9,13,16), health (10,13) and reproductive performance (13,19). The relationship of body condition score to genetic merit has also been examined (8,15,19). Although some of these studies involved multiple herds (8,10,13), the analyses of the relationship of BCS, milk yield, health and reproductive performance were performed at the individual animal level.

The objectives of this study were; 1) to develop a statistically and physiologically sound method of summarizing BCS at the herd level, and, 2) to explore the associations between the seasonal pattern of milk production in Prince Edward Island dairy herds, the herd average adjusted BCS near the end of the stabling period and during the mid- to late grazing period, and the change in the herd average adjusted BCS during the late spring and summer.

MATERIALS AND METHODS

All study herds were visited at the end of the stabling period in late April and early May 1994 (VISIT1) and again in the mid to late summer period of late August and early September (VISIT2). Two investigators carried out the herd visits and assigned body condition scores to all cows utilizing the 5 point system (with quarter point increments) developed by Edmondson et al. (6). All scores were assigned with the aid of a chart which provided the scoring criteria.

After some initial training, ninety-nine cows from three herds were scored by both investigators to measure the agreement in condition scores. A weighted kappa (4) was computed using the weighting matrix found in Appendix H. A weight of 1 was used when both investigators assigned the same condition score to an animal. Quarter and half point differences were assigned weights of .66 and .33 respectively, whereas differences beyond a half point were assessed as being 'not in agreement' and assigned a weight of zero.

A body condition score (BCS) was recorded for each cow, along with her barn name. The days-in-milk (DIM) was recorded for cows that had calved in the preceding 14 days and for any cows that were not included in the official Atlantic Dairy Livestock Improvement Corporation (ADLIC) records. Cows that were not lactating were also scored if they were accessible to the investigator, and the breed of each cow was recorded. The BCS was assigned primarily through visualization of the cow from the posterior and lateral-posterior positions, though tactile assessment or visualization from other angles was occasionally used. Most condition scoring took place during or close to regular milking times and all data were recorded on paper forms designed specifically for that purpose. Cow identification (barn name), breed, BCS, and lactation status (dry / lactating) were entered into a Paradox (2) database, which was subsequently converted to a STATA (14) data file for further manipulation and analysis.

A data file containing all 1994 ADLIC individual cow test day information including calving date and parity, along with a unique cow identification number, was obtained from the Animal Productivity and Health Information Network (APHIN) (5). This file was merged with the file containing the BCS information by means of separate file which associated each unique cow identification number with the barn name or number. Parity, and DIM at the time of BCS were thus available for each cow at each visit.

Records with DIM values above 370 (n=204) were eliminated due to the large range of DIM values greater than 370, and the small number of BCS within each 10 day interval beyond 370 DIM. Four parity groups were formed (1st, 2nd, 3rd, and 4^{+}

parity). The average BCS for each parity group was summarized in 10 day intervals and the relationship between DIM and BCS was examined using quadratic linear regression. Graphical assessment included the use of lowess (locally weighted scatterplot smoothing) curves (3). Subsequent to this preliminary data analysis the number of parity groups was reduced to two, one for the primiparous animals (PARITY = 0) and a second for multiparous animals (PARITY = 1).

In order to summarize the BCS at the herd level, individual cow scores were adjusted to a standard parity and stage of lactation. A regression equation was developed for this purpose using BCS as the dependent variable and DIM and parity as independent variables. The addition of a logarithmic transformation of the DIM variable was used to improve the fit of the regression curve. Dummy variables were also included in the model to assess if the relationship between DIM, parity and BCS was dependent on the season (VISIT). Two-way and three-way interaction terms were generated and assessed for significance.

A final regression equation relating parity, season and DIM to BCS (across all herds) was generated. This equation was used to produce predicted BCS values for all cows, based on their DIM, their parity and the season at the time of the observed BCS. A predicted BCS value for a 'standard cow' - a multiparous cow at 150 DIM in the spring - was also calculated. This standard BCS was multiplied by the ratio of the observed BCS to the predicted BCS for each cow to arrive at an adjusted (standardized) BCS (aBCS) for each cow. A herd average aBCS at each of the two visits was then calculated as the mean of the individual cow aBCS values. The difference between the herd average aBCS in the late summer and early spring was computed and referred to as delta aBCS (daBCS). Negative daBCS values indicated a loss of condition between the early spring and late summer visits.

Basic descriptive statistics were generated for the observed BCS, predicted BCS, and the aBCS for VISIT1 and VISIT2, as well as the daBCS. The relationship between herd average aBCS at VISIT1, aBCS at VISIT2, daBCS, and the seasonal pattern of milk production, as summarized by MINMAX, was examined using scatterplots and simple linear regression. (Details on the calculation of MINMAX can be found in Chapter 1.)

All data manipulation and statistical analysis were carried out using STATA (14), except as indicated above.

RESULTS & DISCUSSION

Edmonson et al. (6) and Ferguson et al. (7) have previously demonstrated a high degree of inter-rater agreement using the body condition scoring system utilized in the current study. Table 1 presents the results of the calculations of the un-weighted and weighted kappa-statistics which were used to measure inter-rater agreement. Both kappa-statistics showed a high degree of agreement beyond that expected by chance. The observed agreement using the weighting matrix was 78.8 percent, with an expected agreement of 34.4 percent, resulting in a kappa value of .68 ($z = 13.3$, $P < .000$). This high degree of agreement provides assurance that the two investigators assigned condition scores in a similar manner and that the data can be legitimately pooled and inter-herd comparisons justifiably made.

The weighted kappa is a more appropriate measure of inter-rater agreement than the unweighted kappa for the BCS system used in this study. Differences of a quarter point and half point between investigators should not be viewed as outright disagreement, but rather as some of the vagary inherent in a subjective scoring system. Also, a difference of a quarter point is not likely of any biological significance, and agreement within a half point still represents a closer approximation of body energy reserves than BCS differences of 1 or 2 points. Weights of .66 and .33 represent the relative agreement of these quarter and half point differences in scores, with a weight of 1 assigned to inter-rater scores that were in complete agreement.

Figure 1 is a frequency distribution histogram of all the cow BCS (n = 4939) assigned at both herd visits for which parity and DIM information was available. The BCS, although demonstrating a slight right skew, follows an approximately normal distribution, with an overall mean of 2.78 and a standard deviation of .515. Non-lactating cow records were removed from the dataset due to the missing data, and the low number of dry cows on many farms. A similar frequency distribution of BCS was reported in a large study by Gallo et al. (8) involving 5851 BCS records on 1395 cows.

Lowess is a technique that generates weighted regression equations, and predicted values ($\hat{y}_i$) for each x_i, using a subset of symmetrically adjacent x_i values.

Weights are assigned based on the absolute distance from x_i, with the highest weighting given to x_i. The number of adjacent values used is computed as the number of observations in the dataset multiplied by the bandwidth. Thus, bandwidths utilizing fewer values approximate the original x_i values more closely than do larger bandwidths. Figure 2 is a lowess curve plot of the average BCS for all cows against DIM (from 1 to 370) in 10 day increments, for VISIT1 and VISIT2. The nadir point of the curves occurred at day 65 and day 84, at the time of the spring and summer visits respectively, whereas the observed minimum average BCS occurred at day 44.5 and day 74.8 respectively (data not presented). This agrees with the data presented by Ruegg and Milton (13) who found that minimum BCS occurred at about 50 and 80 DIM, dependent upon the BCS at calving. Gallo et al. (8) observed minimum BCS occurring somewhat later, at approximately 100 DIM, although this was dependent on the class of mature equivalent milk yield (ME) of the cows, with cows in lower classes reaching minimum BCS sooner than cows in higher ME classes. The mean ME of herds in that study (9037 kg) was higher than for herds in this study (7171 kg), and this may account for the differences observed.

The BCS in the first 10 day interval was lower than that observed after 234 and 324 DIM during VISIT1 and VISIT2 respectively, which could indicate a loss of condition during the dry or periparturient period, especially at the time of VISIT1. Ruegg and Milton (13) suggested that about .25 BCS points were lost between day 20 prepartum and day 7 postpartum. Gearhart et al. (10) also observed that some cows lost condition during the dry period and that those that lost the most condition were at increased risk of culling in the subsequent lactation. Caution must be used however, when interpreting the observations in the current study, since the data were obtained as a cross-sectional sample of all lactating cows at each visit, and the possibility of a cohort effect must be considered. The cohort of cows in early lactation in the spring may have started their lactation with a lower BCS than cows in late lactation, with the resulting appearance of greater loss in BCS during the dry period or early lactation than actually occurred. BCS in cows in late lactation at VISIT2 were more similar to those observed in early lactation cows at the same visit, suggesting that cows were regaining body condition to the level observed in early lactation. Although perhaps more readily explicable than the pattern observed in the spring, caution must be taken in drawing conclusions since cohort effects may also be confounding this relationship.

The relationship of parity, DIM and BCS is depicted in figures 3 and 4. Primiparous animals attained nadir BCS and also began regaining condition earlier than multiparous animals at both visits, although the relationship between the groups was not so clearly defined towards the end of lactation. This agrees with Gallo et. al. (8) and Waltner et. al. (16) who demonstrated that the fat reserves of primiparous cows were completely restored during mid to late lactation, whereas multiparous cows often required a longer period of time to recover the lost condition. Similarly, Ruegg and Milton (13) found that primiparous cows had a lower amount of loss in BCS and a slower rate of gain than did mulitparious cows, though this was not significant (P = .07) when including herd effects and 305-day milk yields in the model. Gallo et al. (8) demonstrated a tendency for multiparous cows close to the end of lactation to have slightly higher BCS than primiparous cows, and suggest that there may be risk of overconditioning mature cows at later stages of lactation. In this study, there is a notable difference between the parity groups in the early lactation BCS in the late summer that is not evident in the spring. Gallo et al. (8) noted a very small difference in mean BCS between parity groups, with first lactation animals having the higher average scores. The reasons for the observed discrepancy in this study are not known, although the extensive use of pasture for heifer rearing (E. Hovingh, unpublished data) may contribute to the higher BCS at calving in the summer as compared to the spring. Compensatory weight gain at pasture may occur in situations where feed availability to heifers is restricted during the stabling period.

The regression coefficients for the terms included in the model used to predict individual cow BCS are listed in Table 2. Terms were included in the model at $P \leq .05$. The VISIT term, though not statistically significant in the final model, was left in since its interaction with DIM and PARITY was significant. A robust estimator of variance, as developed by White (17,18), was used rather than the conventional estimator of variance. The robust estimator of variance allows for inter-dependence (correlation) among the observations, and, while not affecting the point estimates, will usually modify the standard error estimates. Because BCS within herd were presumed to be more similar than between herds (that is, herd level factors other than DIM would affect BCS within a herd), "herd" was included as a clustering term.

Only 15 % of the variation observed in the BCS was explained by the model. The interaction of DIM and PARITY, and the 3-way interaction of DIM, PARITY and VISIT, were found to be statistically significant and were thus included in the final model. Gallo et al. (8) also observed multiple significant 2-way and 3-way interactions between parity, DIM and ME, although no statistically significant interaction terms included season, which was a significant term by itself. Although the nutritional management of these herds was not specified it was speculated that, given the high yield (mean ME = 9037 kg) of these herds, the reliance on pasture was less than observed in Prince Edward Island (see Chapter 5 for details). If true, this lack of reliance on pasture could have accounted for the lack of interaction of season with other terms in the model. The multiple significant interaction terms observed in this and other studies (8,13) point to the complex relationship existent among BCS, DIM, parity, season, and milk yield.

The observed BCS for each cow was expressed as a percentage of the predicted BCS (OBSPRED). Thus, a cow with an observed BCS of 3.50 and a predicted BCS of 3.0 - given her parity, DIM and the season - would have an OBSPRED value of 1.167. This value was multiplied by the predicted BCS for the standard cow to arrive at an adjusted BCS (aBCS) for each cow. Basic descriptive statistics for the observed BCS, predicted BCS, aBCS and the herd average aBCS for both visits can be found in Table 3, along with the change in herd average aBCS (daBCS) between the early spring and late summer visits.

To assist with within cow, between cow, within herd and between herd comparison of milk production values test day milk production is often adjusted to standard values for DIM, age and milk fat content (5,11). The above described method of adjusting the individual cow BCS to account for parity, season, and DIM is similar in concept to the adjustment procedure utilized in calculating 'adjusted corrected milk' values. Whereas most of the BCS research reported in the literature has utilized such measures as 'days to minimum BCS', 'BCS at calving', or 'relative loss of BCS' to capture information regarding BCS and changes in BCS, the methodology outlined in this study allows BCS comparisons within and between herds. The assumption that a cow's BCS will follow a predictable pattern given her stage of lactation, parity and the season seems reasonable, given the results of many of the studies referenced above. Further evaluation of this method of adjusting BCS is warranted.

The relationship between the spring and summer herd average aBCS, the dBCS, and the seasonal pattern of milk production, as summarized by MINMAX (see Chapter 1, p. 5) was examined using scatterplots and simple linear regression. One highly influential outlier was omitted from the analyses - this 13 cow herd was comprised primarily of highly conditioned Milking Shorthorns. Table 4 contains the results of the regression analyses. No significant relationship was found between MINMAX and the herd average aBCS at the time of the spring visit (β = -.004, P = .95, R^2 = .00). The herd average aBCS at the time of the summer visit showed a weak positive relationship with the seasonal pattern of milk production (β = .16, P

= .05, R^2 = .05), indicating that herds with higher summer herd average adjusted BCS maintained more consistent levels of milk production during the summer and fall. No statistically significant relationship could be detected between MINMAX and the change in herd average aBCS (daBCS) (β = .00, P = .15, R^2 = .03). However, with the omission of one additional herd which demonstrated a significant loss in herd average aBCS and only a moderate decline in milk production during the summer and fall, the relationship between MINMAX and daBCS was statistically significant (β = .20, P = .05, R^2 = .05), with increasing values of daBCS (less condition loss or condition gain) being associated with more consistent milk production.

The low R^2 values for all models indicate that only a small proportion of the total variation observed in seasonal patterns of milk production in Prince Edward Island can be explained directly by the herd average body condition score during the summer, or by the changes in condition during the late spring and summer.

CONCLUSIONS

The calculation of an individual cow and herd average, adjusted BCS permitted comparisons between cows and herds across parity, seasonal, and stage of lactation differences. This paper has outlined a method to adjust BCS values based on season, parity and DIM. Further evaluation of this technique is warranted.

Statistically significant associations were found between the herd average adjusted body condition score in the summer and the seasonal pattern of milk production, suggesting that herds that had greater body reserves of energy in the mid to late summer were able to maintain more consistent milk production. Similarly, contingent upon the removal of one herd from the analyses, reduced losses or net gain of body condition during the early to mid grazing season relative to the end of the stabling period were also associated with more a consistent pattern of milk production in the summer and fall. Conversely, body condition at the end of the stabling period and beginning of the grazing season did not appear to influence the pattern of milk production during the summer and fall months.

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Table 1. Results of unweighted and weighted kappa calculations to assess agreement in body condition scores assigned to 99 lactating dairy cows by 2 investigators.

	Observed agreement	Expected agreement	Kappa	Z	Pr > Z
Un-weighted Kappa	43.43	12.25	.3553	9.67	0.00
Weighted Kappa	78.77	34.43	.6762	13.30	0.00

[1] Weighting matrix can be found in Appendix H.

Table 2. Regression coefficients, standard errors, 95 % confidence intervals and P values for multiple regression model with individual cow body condition score as the dependent variable. Model $R^2 = .15$, $P < .001$.

	Coefficient	Standard error[1]	95 % confidence interval	P value
Number of days in milk[2]	.003	.0002	(.003, .004)	.00
Logarithm(days in milk)	-.235	.018	(-.272, -.198)	.00
Parity group[3]	-.147	.036	(-.218, -.076)	.00
Visit[4]	-.025	.026	(-.076, .026)	.33
dimXparity[5]	.001	.0002	(.0003, .0013)	.00
dimXparityXvisit[5]	-.0005	.0001	(-.0008, -.0002)	.00
Intercept	3.419	.079	(3.262, 3.576)	.00

1 White robust variance estimator (17,18) used to account for heteroscedasticity.

2 Number of days since beginning of current lactation at the time of condition scoring.

3 Parity group; 0 = primiparous cows, 1 = multiparous cows

4 Visit at which condition score was assigned; 0 = spring visit, 1 = summer visit

5 Interaction terms: where dimXparity is the interaction of "number of days in milk" with "parity group" and dimXparityXvisit the simultaneous interaction of "number of days in milk", "parity group", and "visit".

Table 3. Summary statistics for observed BCS, predicted BCS and aBCS[1] for both visits, as well as the change in herd average aBCS (daBCS[2]).

Visit / Variable	N	Mean	Standard deviation	10th percentile	90th percentile
Early spring					
BCS	2460	2.778	.535	2.25	3.50
predicted BCS	2460	2.743	.173	2.535	2.953
aBCS[1]	2460	2.754	.498	2.163	3.452
herd average aBCS	80	2.765	.231	2.537	3.041
Late summer					
BCS	2479	2.757	.478	2.25	3.50
predicted BCS	2479	2.792	.162	2.558	2.985
aBCS[1]	2479	2.687	.436	2.193	3.274
herd average aBCS	79	2.679	.195	2.421	2.907
daBCS[2]	76	-.094	.181	-.293	.076

[1] adjusted (standardized) BCS - standardized to a 150 "days-in-milk", multiparous cow, in the spring

[2] delta aBCS (daBCS) - the change in herd average aBCS from the early spring to the late summer visit - a negative number indicates a loss in herd average aBCS

Table 4. Linear regression coefficients for herd average aBCS[1] in early spring and in the late summer 1994, and the change in herd average aBCS during that time (daBCS[2]), when regressed individually against MINMAX[3].

Variable	Coefficient (P value)	Constant (intercept)	Model R^2
herd average aBCS[1] - early spring 1994	-.004 (.95)	.77	0.00
herd average aBCS[1] - late summer 1994	.16 (.05)	.33	0.05
dABCS[2]	.0 (.15)	.76	0.03
dABCS[2,4] (n = 75)	.20 (.05)	.76	0.05

1 aBCS - adjusted body condition score - standardized to a 150 days-in-milk, multiparous cow, in the spring

2 delta aBCS - the change in herd average aBCS from VISIT1 to VISIT2, a negative value indicates a loss in herd average aBCS

3 Seasonal pattern of milk production (MINMAX) - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

4 one influential outlier omitted from dataset (details in text)

Figure 1. Frequency distribution (% of total scores) of body condition scores (n = 4939) from early spring and late summer visits to 80 Prince Edward Island dairy herds, 1994.

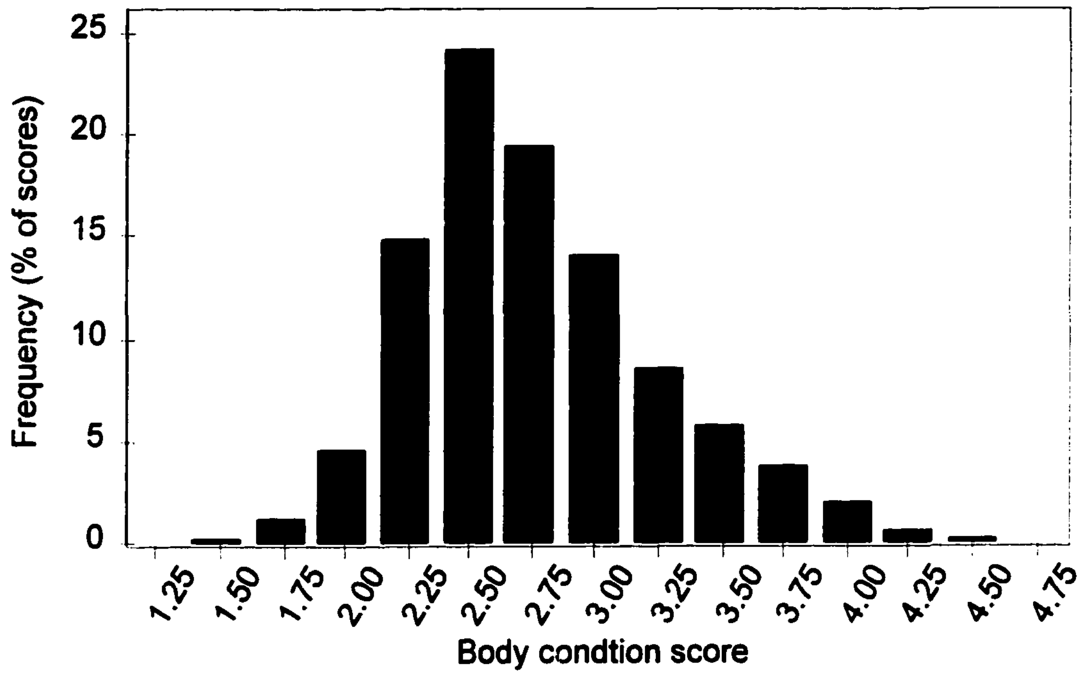


Figure 2. Lowess curves (bandwidth = .3) for early spring (O) and late summer (∇) visit of mean BCS vs. DIM (10 day intervals). 1994 BCS data, collected in 80 Prince Edward Island dairy herds.

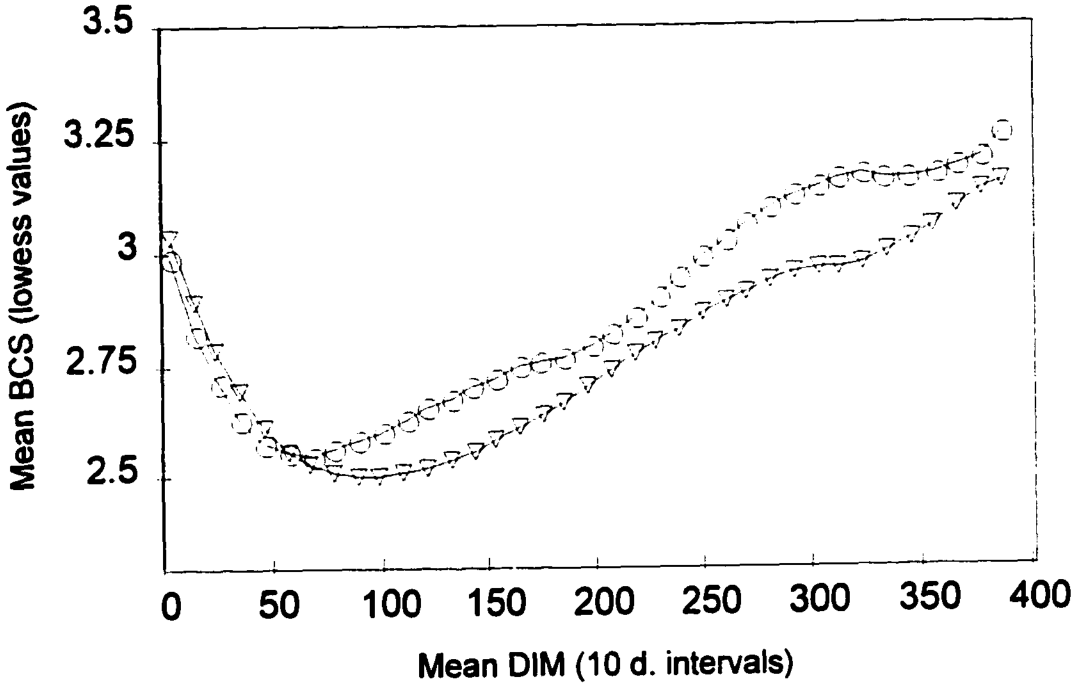


Figure 3. Lowess curves (bandwidth = .3) for primiparous (O) and mulitparous (∇) cows of mean BCS vs. DIM (10 day intervals). Early spring 1994 BCS data, collected in 80 Prince Edward Island dairy herds.

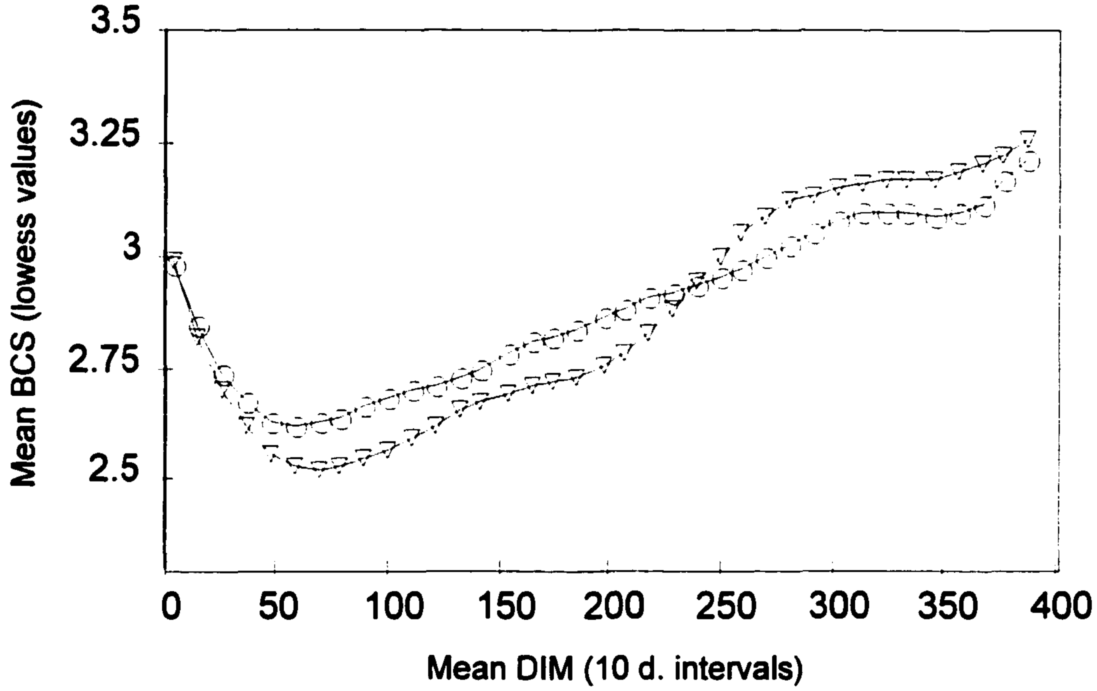
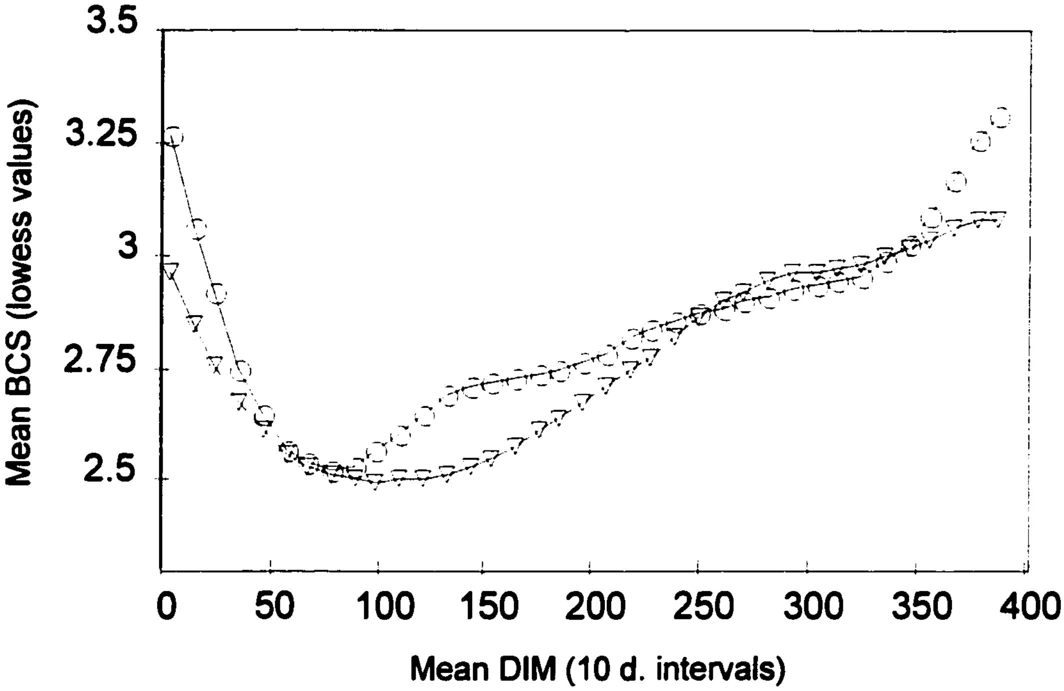


Figure 4. Lowess curves (bandwidth = .3) for primiparous (O) and mulitparous (∇) cows of mean BCS vs. DIM (10 day intervals). Late summer 1994 BCS data, collected in 80 Prince Edward Island dairy herds.



Chapter 7

Association Between Bulk Milk Titres to *Cooperia oncophora*, *Ostertagia ostertagi* and *Dictyocaulus viviparous*, Selected Herd Level Variables, and Seasonal Patterns of Milk Production in Prince Edward Island, Canada

INTRODUCTION

The impact and economic consequences of gastrointestinal nematode and lungworm (*Dictyocaulus viviparous*) infestation on performance has been a topic of much debate within the livestock industry. Numerous studies in dairy cattle have evaluated the effect of gastrointestinal nematodes in an indirect manner, by evaluating the milk yield response of lactating cattle after treatment with various anthelmintics. In a review of the scientific literature, Ploeger (20) concluded that many of the reported studies have been able to demonstrate an increase in milk yield after treatment, either over a 305 day lactation or a shorter period of time, although not all of these results were statistically significant. Kloosterman et. al. (15) properly point out that there might be a relative under-reporting of studies which demonstrated negative or non-significant positive results.

Enzyme-linked immunosorbent assay (ELISA) technology has been used in many areas of pure and applied research. A micro-titre ELISA test which had been developed to detect serum antibodies to *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi* (4,13,17), was subsequently used to measure milk antibody levels (16). Subsequent to the adaptation and use of the ELISA technique in Canada, as reported in this study, Dohoo et al. (8) carried out an evaluation of this test for monitoring parasite burdens in Quebec dairy herds. It has been suggested that this non-invasive, easy-to-use diagnostic modality may find use as a strategic herd health monitoring tool (10,20).

The objectives of this study were; 1) to adapt and apply the milk ELISA test for gastrointestinal nematodes and *Dictyocaulus viviparous* developed in the Netherlands to Canada, 2) to investigate the relationships between selected herd level variables and bulk milk optical density values for *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi* and, 3) to investigate the relationships between exposure to *C. oncophora*, *D. viviparous*, and *O. ostertagi*, (as reflected by the bulk tank optical density readings) and the seasonal variation in milk production.

Materials and Methods

Bulk tank milk samples for the "Summer-Fall Slump Study" herds were obtained from the PEI provincial milk quality laboratory. These milk samples were selected from among those that were routinely collected for regulatory purposes from all milk producers in PEI, by the bulk milk haulers. They had been obtained at the farm as dip samples from the bulk tank after thorough agitation and mixing of the milk, and were identified with a unique farm identification number. All available bulk tank milk samples collected over a three day period were obtained in the middle of October, and again at the end of October 1994, in order to increase the probability of having samples from all study herds. All milk samples were frozen and stored at -20 C until processed.

The ELISA test, which has been previously described (4,13,17), was used to determine optical density (OD) values for *Cooperia oncophora*, *Dictyocaulus viviparous* and *Ostertagia ostertagi* in the bulk tank milk samples. The antigens for this, the inaugural application of this technique in Canada, were supplied by colleagues in the Netherlands, and had been prepared from crude saline extracts of whole parasite antigens. All bulk milk samples were processed at the same time. The OD readings, obtained from the automated plate reader, were manually entered into a computer spreadsheet, and plate specific blank well OD values were subtracted from the sample OD value. The arithmetic mean of all samples from each herd was calculated to arrive at herd average OD values for *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi*.

A number of variables that were potentially associated with the herd level OD values were considered, and are listed in Table 1. Milk yield, stage of lactation, and parity information data were available from the Animal Productivity and Health Information Network (7). Pasture and nutritional information were collected during data collection visits to all herds, carried out during late August and early September, 1994. The percentage of total dry matter (DM) requirements provided by stored feeds (supplementary to pasture forage) was calculated as the ratio of the total kilograms of DM provided by the stored feeds - including all non-forage and all conserved forage components - to the total daily DM requirements. The daily DM requirements were calculated using herd specific cow weights, and herd level average milk yield potential based on the genetic potential of the herd. Details of these calculations, and more detailed information about the other variables can be found in Chapter 5. Information concerning the anthelmintic treatment of the herd was captured by means of a detailed management questionnaire administered at the time of the late summer data collection visit.

Relationships among herd average OD values, selected pasture management and ration variables, as well as milk production and the seasonal pattern of milk production were analyzed using correlation matrices, scatterplots and multiple linear regression techniques. Simple correlations between the independent variables were examined to check for collinearity. Correlation coefficients and scatterplots of the dependent variable with each independent variable were assessed in turn. Linear regression models with the bulk milk OD values as well as the seasonal pattern of milk production as dependent variables were considered in turn. A full model containing all independent variables of interest was fit, including all two-way and three-way interaction terms. These were evaluated for statistical significance and removed as appropriate. Subsequent to the evaluation of the interaction terms, the main effects were assessed for significance. Terms were sequentially eliminated based on their statistical significance, evaluating the remaining model at each step. When a final parsimonious model was selected, standard analysis of residuals was carried out to assess the fit of each model. Residual values were plotted against predicted values, and various residual values were calculated and examined for influential data points. A robust variance estimator (27,28) was used to estimate the standard error terms in place of the standard variance estimator, due to the heteroscedasticity observed in the residuals.

After preliminary examination of the correlation coefficients and partial correlations from multiple regression models, it was apparent that *Dictyocaulus viviparous* optical density values demonstrated very weak or non-significant relationships with the other variables considered. Therefore, only the results of the regression analyses involving *Ostertagia ostertagi* optical density values (OD_O) and *Cooperia oncophora* optical density values (OD_C) will be presented.

All data management and analyses were performed in STATA (STATACorp, College Stn., TX).

RESULTS & DISCUSSION

Bulk milk optical density values and between parasite correlations

Milk samples from the provincial laboratory were identified for 79 of the 80 study herds, with all but 1 herd having multiple samples available. Incomplete data resulted in the *a priori* omission of five additional herds. Briefly, for reasons discussed in Chapter 5 (p. 103), an accurate assessment of the proportion of the total daily dry matter requirements provided by stored feeds during the summer of 1994 was not available for these herds. This variable was one of the independent variables in a number of the analyses.

Summary statistics for the ELISA OD_O and OD_C values are found in Table 2. Correlations between *Cooperia oncophora* and *Dictyocaulus viviparous*, *Cooperia oncophora* and *Ostertagia ostertagi*, and *Dictyocaulus viviparous* and *Ostertagia ostertagi* were .78, .81, and .79, respectively. This is similar to the degree of correlation seen between antigens in other studies in both bulk milk and serum titres (8,16). The relatively high correlations between the gastrointestinal nematode and *D. viviparous* OD values could be indicative of simultaneous infections, or evidence of antigen cross-reactivity. While both explanations seem plausible, the possibility of cross-reactivity occurring is high, given the comparatively crude antigen preparation method (6,16). Given this cross-reactivity, Hale and Green (12) reported on a study in which they sought to identify antigens unique to *Dictyocaulus viviparous* that could be used to improve the performance of ELISA serum tests. Recent work, using recombinant antigens has shown minimal cross-reactivity and high levels of specificity for *Dictyocaulus viviparous* (24) and *Cooperia oncophora* (22).

The ELISA test developed by Poot et al. (22) has also recently been tested under field conditions and has shown promise as a monitoring tool for parasitic gastroenteritis in young cattle (10). The usefulness of the recombinant *C. oncophora* test in mature, lactating cattle, and the ability of this test to detect antibodies in milk still needs to be evaluated. The development of a similar test for *Ostertagia ostertagi* would be useful, especially given the relative importance of this parasite. Such work is ongoing in the Netherlands (10).

Factors associated with bulk tank C. oncophora and O. ostertagi OD values

Table 1 presents the independent variables which were assessed for their relationship with the herd bulk tank milk OD_C and OD_O values. The coefficients, standard errors, confidence intervals and associated significance values for the final linear regression models with OD_C and OD_O can be found in Table 3. Both models were highly significant ($P < 0.001$) and included the intercept, the average milk yield in October 1994, and the proportion of the DM requirements provided by the late summer stored feed ration. The OD_O model also included the use of anthelmintics in the mature cattle (as a dichotomous variable), and the proportion of the herd in the first lactation in October 1994. Twenty-two and thirty-eight percent of the variation in *Cooperia oncophora* and *Ostertagia ostertagi* optical density values were explained by the respective combinations of independent variables ($R_C^2 = .22$, $R_O^2 = .38$). No significant two-way or three-way interactions were found among the variables.

Increased levels of milk production in October 1994 were associated with decreased titres to *Cooperia oncophora* and *Ostertagia ostertagi*. A 5 kilogram increase in average milk yield in October 1994 was associated with a decrease of .06 units in OD_C and a decrease of .07 units in OD_O. This effect was not due to a high collinearity of high milk yield and increased feeding of stored feeds, since the correlation of these two variables was .14 and the removal of either term from the final model did not significantly affect the coefficient for the other term. A negative relationship was also observed by Kloosterman et al. (16), who noted that the mean milk yield of the herd was negatively related to the herd mean of the individual cow serum and milk titres, and the herd bulk tank titres.

Thirty-four percent of the study herds had administered anthelmintics to mature cows during 1993 or 1994, with a large majority of those indicating that they administered them on a continual (every lactation) basis (E. Hovingh, unpublished data). In this study, herds that administered anthelmintics to their lactating cattle had OD_O values .07 units lower than herds that did not utilize this class of products. Whether this association was a reflection of the direct effect of treatment on reducing parasite burdens and consequentially antibody titres, or a reflection of an indirect effect of other management practices not accounted for in this study, such as youngstock management practices, could not be determined from the data available. Ploeger (19,21) has also demonstrated a decline in *Ostertagia ostertagi* titres of individual cows that were treated with an anthelmintic, in 31 dairy herds in the Netherlands. The use of anthelmintic in the mature herd had no significant effect with the level of *Cooperia oncophora* antibodies in the October bulk milk samples (P = .55).

The negative relationship observed between the OD_O and OD_C and the percentage of dry matter requirements supplied by stored feeds appears intuitive. As cows consumed a greater percentage of their dry matter requirements from pasture, their potential exposure to nematode larvae, and consequentially their antibody titres, increased. A 20 percentage point increase (+ .2) in the proportion of the DM requirements provided by stored feeds was associated with a decrease in the OD_C and OD_O of .03 and .02 units, respectively. It appears that a similar quantitative relationship in lactating cattle has not been reported elsewhere. Schneider and co-workers (25), in a seroepidemiological study on *Dictyocaulus viviparous* in northern Germany, found that supplementary feeding of calves "significantly reduced the number of seropositive herds", although the association was not further quantified. These results are similar to those from an earlier study reported by Downey (9). Schneider et al. (25), also found, however, that supplementary feeding and daily observation of calves were highly collinear, and the authors noted that "it was not possible to differentiate the independent influence of both parameters." They speculate that frequent observation of the animals resulted in more expedient treatment of clinical signs of dictyocaulosis, and an ensuing decrease in the spread of disease.

It is interesting to note the negative relationship between the percentage of heifers in the lactating herd and the level of antibodies to *O. ostertagi* in the bulk tank milk sample. A 10 percentage point increase (+.1) in heifers was associated with a .03 unit decrease in OD_O values. This relationship was observed in spite of the fact that milk yield, which was negatively associated with OD_O titres, was positively related to age. It is possible that the observed relation is a reflection of superior parasite management in youngstock and preparturient nulliparous animals, possibly combined with an increased antibody response due to the continued stimulation of the immune system in mature cows as they age. However, while Kloosterman et al. (16) also found a similar relationship between milk titres and age at the cow level, the relationship between serum titres and age was in the opposite direction, indicating that older cows did not have a higher larval intake than younger cows. Based on their results, they speculated that older animals are able to transfer antibodies from the serum into the milk more readily than younger cows, possibly owing to a change in mammary physiology.

The proportion of the total pasture area mechanically harvested at least once before grazing exhibited a negative, although not statistically significant, relationship, with *Cooperia oncophora* (P = .13) and *Ostertagia ostertagi* (P = .12) OD values. A similar relationship in first and second year grazing calves has been documented elsewhere (1,19,25) and was already recognized by Oostendorp and Harmsen as a "...farm management approach [that] could be developed, guaranteeing a natural balance between parasite and host." (18).

Relationship between OD_C and OD_O values and seasonal pattern of production

MINMAX is a variable that was calculated to summarize the seasonal pattern of milk production in PEI dairy herds. Details concerning its calculation can be found in Chapter 1 (p.5). The correlation between MINMAX and the ELISA OD values for *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi* were -.35, -.22, and -.46, respectively. The low correlation observed between MINMAX and *Dictyocaulus viviparous* should not be related to a lack of persistence in titres, since it has been shown that titres to *D. viviparous* are quite persistent once established (6,26). The low correlation could have been due to a low infection level with *Dictyocaulus vivparous* in PEI dairy herds, or the inability of the test to accurately detect *Dictyocaulus viviparous* antibodies. On the other hand, *D. viviparous* infection may simply not have a significant impact on seasonal patterns of milk production in Prince Edward Island.

Figures 1 and 2 are scatterplots of MINMAX versus OD_C and OD_O, respectively. Thirteen percent of the variation in MINMAX was associated with variation in the bulk milk *Cooperia oncophora* OD values ($R^2 = .13$). The negative relationship between these two variables ($\beta = -.29$) was statistically significant ($P = 0.001$). As herd bulk tank OD_C values increased, reflecting increased levels of *Cooperia oncophora* infection, greater seasonal fluctuation in milk production was observed. A higher proportion (23 percent) of the variation in MINMAX was associated with variation in the bulk milk *Ostertagia ostertagi* OD values. The negative relationship between MINMAX and OD_O ($\beta = -.40$, $P < .001$) was stronger than the relationship with OD_C. Although a robust variance estimator (27,28) was used to estimate the standard error terms, a parallel analysis with the standard estimator of variance demonstrated that this did not affect the results or their interpretation.

The association between *Cooperia oncophora* infection and MINMAX was also assessed while controlling for the variables found to be significantly associated with OD_C (Table 3). However, one of the variables, the average milk yield in October 1994, was not independent of MINMAX since one of the terms used to calculate MINMAX was the average milk yield in the late fall. (Detailed information about the calculation of MINMAX can be found in Chapter 2). Thus, this term was highly correlated with MINMAX and was excluded from the model *a priori*. The only remaining term that was potentially associated with both the seasonal pattern of milk production and the bulk milk *Cooperia oncophora* optical density, was the proportion of DM requirements provided in the stored feed ration in late summer. These variables, along with the interaction term, constituted the full model that was regressed on MINMAX. Table 4 presents the regression coefficients and associated values of the final, reduced model, which explained 23 percent of the variation in seasonal patterns of milk production in Prince Edward Island ($R^2 = .23$, $P < .001$). The bulk milk *C. oncophora* optical density in October 1994 was negatively related to MINMAX, indicating that herds that had higher *Cooperia* infection levels exhibited a greater decline in average daily milk yield during the summer and fall. Conversely, herds that fed higher proportions of the total daily DM requirements from stored feeds during the summer maintained more consistent production. There was no significant interaction between these two variables (P = .82).

The relationship between *Ostertagia ostertagi* and MINMAX was similarly evaluated. Included in the full multiple regression model were the proportion of DM requirements provided in the stored feed ration in late summer, the use of anthelmintics in mature cattle, the proportion of cows in first lactation, and all two-way and three-way interaction terms. The interaction terms were assessed and discarded *en bloc* as not having a significant association with the dependent variable. The remaining main effects that were not statistically significant ($P > .05$) were eliminated sequentially, starting with the least significant term. Table 4 presents the regression coefficients and associated values of the final model which explained 31 % of the variation in MINMAX ($R^2 = .31$, $P < .001$). Similar to the results observed in the *Cooperia oncophora* model above, only the effect of supplemental summer feeding and the *Ostertagia ostertagi* exposure level were significantly associated with the seasonal pattern of milk yield. The effect of increased supplemental feeding was similar between the two models, whereas *Ostertagia ostertagi* ($\beta_O = -.324$) had a greater effect on the seasonal pattern of milk production than did *Cooperia oncophora* ($\beta_C = -.202$). It can also be seen that the coefficient for OD_O decreased, from -.40 to -.32, after controlling for the effect of supplemental feeding.

Many of the studies investigating the relationship of parasitism and performance in mature dairy cattle have done so by an indirect means of monitoring response to anthelmintic treatment (19). Notwithstanding the fact that a majority of the studies demonstrate a positive milk yield response to anthelmintic treatment (20), the profitability of this management technique is not so well delineated as to recommend 'blanket treatment' of all cows or all herds (3,5,23). In this study, we evaluated the seasonal 'herd persistency' of milk production (MINMAX), rather than total milk yield *per se*, and this makes direct comparison with much of the scientific literature difficult. The greater impact of *Ostertagia ostertagi* observed in this study, relative to *Dictyocaulus viviparous* and *Cooperia oncophora*, is consistent with the pathophysiology of this nematode (11), and the results of other authors who discuss the importance of this gastrointestinal nematode (2,10,14,19). In this study, the observed association between *O. ostertagi* and *C. oncophora* and the seasonal pattern of milk production implies that exposure to these nematodes does have an impact on milk production in dairy herds in Prince Edward Island, and that the level of supplemental feeding is also an important variable in this relationship. Further examination of these relationships, and the impact of gastrointestinal nematodes relative to other factors affecting summer and fall milk production were examined in Chapter 8.

CONCLUSIONS

The ELISA technique for detecting antibodies to *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi*, appears to have been successfully adapted, and has subsequently been used in a number of studies under Canadian conditions. A number of herd level factors were investigated for their relationship with bulk milk antibody levels, and a number of significant associations were defined that were in agreement with other studies. Similarly, the optical density values were found to be significantly associated with the seasonal pattern of milk production. These observations suggest that bulk milk ELISA measurement of antibody levels has the potential to be a useful measure of between herd variation in parasite exposure.

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Table 1. Independent variables assessed for their relationship with bulk tank *Ostertagia ostertagi* and *Cooperia oncophora* optical density values from 74 Prince Edward Island dairy herds.

Variable
Average days-in-milk, all lactating cows (October 1994)
Average milk production per day (October 1994)
Average number of lactating cows (October 1994)
Anthelmintic use: 0 = no treatment, 1 = treatment of mature cattle[1]
Daily pasture dry matter (DM) allowance per cow[2]
Hectares of pasture used per lactating cow
Percentage of total daily DM requirements provided by stored feeds
Pasture forage (kg. DM) inventory per cow (late summer)
Percentage of total pasture area undergoing at least one mechanical harvest
Percentage of herd in first lactation (October 1994)

[1] No data were collected regarding anthelmintic treatment of nulliparous animals.

[2] (kg. pasture forage DM available $cow^{-1}day^{-1}$) / (kg. DM required $cow^{-1}day^{-1}$ - kg DM stored feeds $cow^{-1}day^{-1}$) See Chapter 5 for details.

Table 2. Optical density (OD) values from 74 Prince Edward Island bulk tank milk samples, determined by an enzyme-linked immunosorbent assay technique using crude extracts from *Cooperia oncophora*, *Dictyocaulus viviparous* and *Ostertagia ostertagi*. Milk samples collected in mid-late October 1994.

Antigen	Mean OD	Standard deviation	25th percentile	75th percentile
Cooperia oncophora	.52	.13	.43	.62
Dictyocaulus viviparous	.22	.11	.15	.28
Ostertagia ostertagi	.58	.13	.49	.68

Table 3. Regression coefficients, standard errors, 95 % confidence intervals and P values for multiple regression models predicting *Ostertagia ostertagi* and *Cooperia oncophora* optical density values. Data from 74 Prince Edward Island dairy herds. Optical density readings from bulk tank milk samples collected in October 1994.

	Coefficient	Standard error	95 % confidence interval	P value
Cooperia oncophora (Model R^2 = .22, P < .001)				
October average milk yield[1]	-.011	.003	(-.017, -.004)	.00
Proportion of DM as stored feed[2]	-.140	.052	(-.244, -.035)	.01
Intercept	.853	.079	(.695, 1.010)	.00
Ostertagia ostertagi (Model R^2 = .38, P < .001)				
October average milk yield[1]	-.013	.003	(-.019, -.007)	0.00
Anthelmintic use[3]	-.069	.026	(-.122, -.016)	0.01
Proportion of DM as stored feed[2]	-.122	.047	(-.215, -.030)	0.01
Proportion primiparous cows[4]	-.272	.128	(-.527, -.018)	0.04
Intercept	1.063	.077	(.909, 1.217)	0.00

[1] Average test-day milk yield (kg $cow^{-1}day^{-1}$) in October 1994. Source: APHIN (7)

[2] Percentage (as a decimal) of total DM requirements provided by stored feeds in late summer 1994.

[3] 0 = no treatment, 1 = treatment of mature cattle with anthelmintic

[4] Percentage (as a decimal) of lactating animals in first lactation in October 1994.

Table 4. Regression coefficients, standard errors, 95 % confidence intervals and P values for multiple regression models with the seasonal pattern of milk production (MINMAX[1]) as the dependent variable. Data from 74 Prince Edward Island dairy herds.

	Coefficient	Standard error[2]	95 % confidence interval	P value
Cooperia oncophora model (Model R^2 = .23, P <.001)				
Proportion of DM as stored feed[3]	.134	.039	(.056, .212)	.00
Bulk milk *C. oncophora* OD[4]	-.202	.083	(-.368, -.036)	.02
Intercept	.768	.057	(.654, .881)	.00
Ostertagia ostertagi model (Model R^2 = .31, P <.001)				
Proportion of DM as stored feed[3]	.121	.037	(.047, .196)	.00
Bulk milk *O. ostertagi* OD[4]	-.324	.090	(-.502, -.145)	.00
Intercept	.860	.063	(.734, .985)	.00

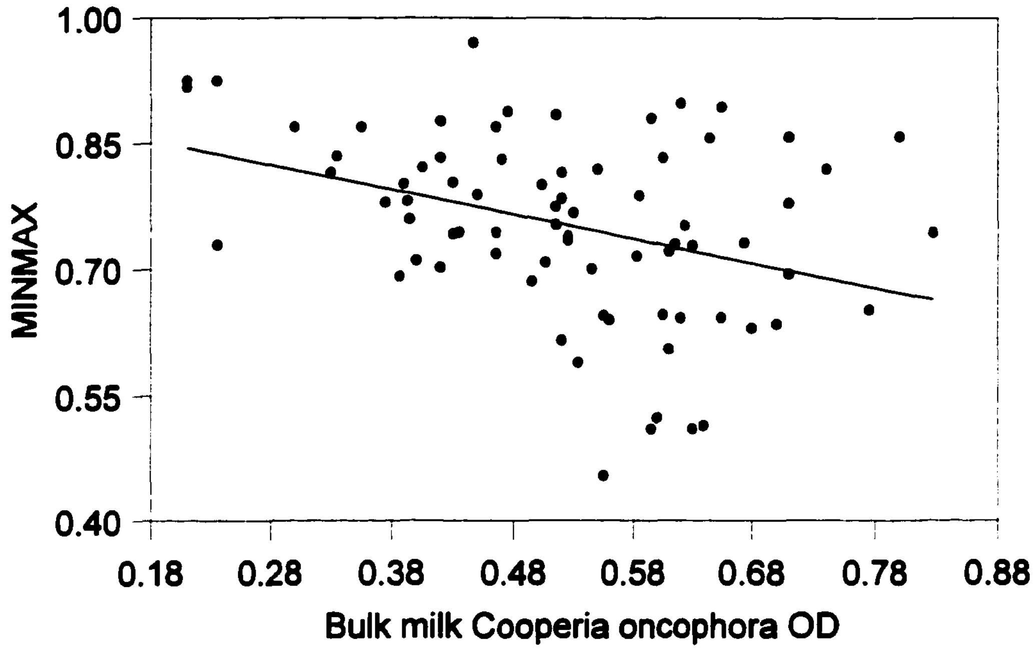
1 Seasonal pattern of milk production: minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

2 White's robust variance estimator (27,28) used to account for heteroscedasticity.

3 Percentage (as a decimal) of total DM requirements provided by stored feeds in late summer 1994.

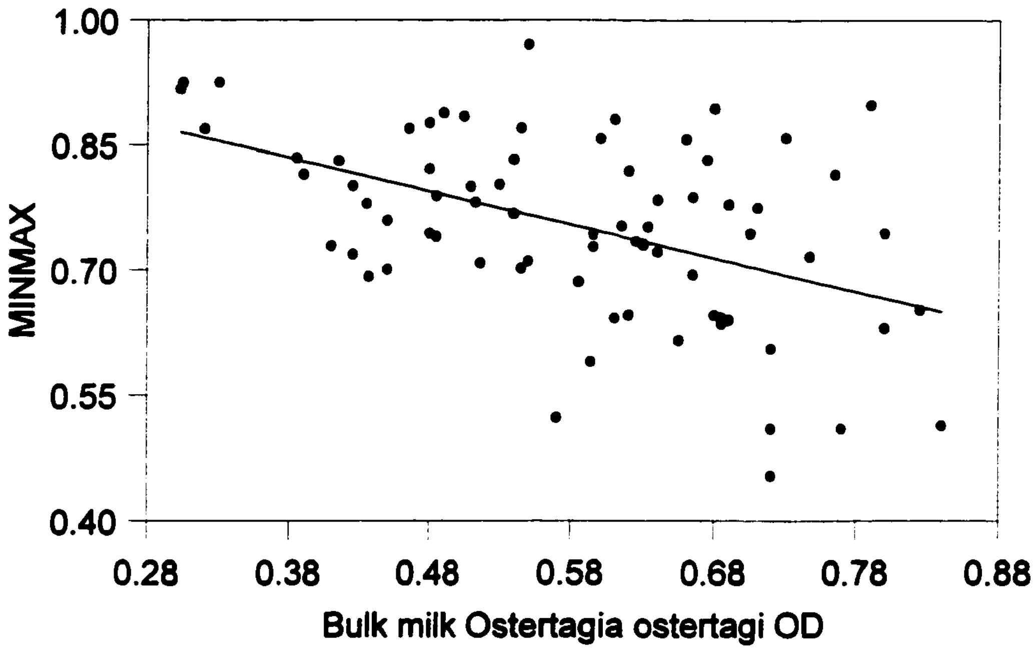
4 Average bulk tank milk ELISA optical density value - October 1994.

Figure 1. Scatterplot and fitted regression line ($\beta = -.29$, $P < .001$) of MINMAX[1] vs. October 1994 bulk tank *Cooperia oncophora* (ELISA) optical density values ($R^2 = .13$). Data from 74 Prince Edward Island dairy herds.



[1] Seasonal pattern of milk production: minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Figure 2. Scatterplot and fitted regression line (β = -.40, P < .001) of MINMAX[1] vs. October 1994 bulk tank *Ostertagia ostertagi* (ELISA) optical density values (R^2 = .23). Data from 74 Prince Edward Island dairy herds.



[1] Seasonal pattern of milk production: minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Chapter 8

Association of Herd Nutrition, Demographic and Management Factors with Seasonal Patterns of Milk Production in Dairy Herds in Prince Edward Island, Canada

INTRODUCTION

The Animal Productivity and Health Information Network database (12) contains individual cow and herd summary data from Prince Edward Island dairy herds that utilize the milk recording services of the Atlantic Dairy Livestock Improvement Corporation. Provincial average test-day milk yield follows a consistent temporal pattern, with peak milk yield being realized in June and the nadir production occurring in November, after a steady decline during the summer and fall months. However, there is substantial between-herd variation evident in the seasonal pattern of production, with some herds demonstrating seasonally stable production and others displaying seasonal variation much more marked than the provincial average.

There is a paucity of scientific literature dealing with factors associated with seasonal patterns of herd average test-day milk yield. There has been some investigation of seasonal variation in bulk milk yield from farms (5,30) and numerous studies have examined the effect of calving season on milk yield (23,26,28,31). While various authors have reported or proposed that environmental influences (8,23,47), or farm-to-farm variation in management and nutrition were responsible for variation in milk production patterns (1,8,13,24,37), there have, apparently, been no studies reported in the literature that address directly the factors associated with seasonality of test-day milk yield.

Numerous factors were postulated to influence the seasonal pattern of milk production manifested by a herd. Previous chapters of this thesis have investigated in detail a number of these factors including;

- the rations fed during the stabling period and during the midsummer grazing period (including the management of, and projected yield from pasture),
- the body condition score of the lactating cattle, at the end of the stabling period and during the midsummer grazing period, and
- the exposure to *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi*, as reflected by optical density values obtained from an ELISA test for antibodies to these parasites, carried out on bulk milk samples.

Numerous significant associations were found among the variables representing these factors and the seasonal pattern of milk production. However, the inter-relationships and relative importance of these factors could not be ascertained from the individual analyses.

The purpose of this portion of the study was threefold; 1) to summarize some of the pertinent herd demographic and management data and examine the unconditional associations between these data and the seasonal pattern of milk production, 2) to examine the conditional associations, and inter-relationships of the aforementioned factors and those reported on in previous chapters and, 3) to determine the relative importance of those factors found to have a significant association with the seasonal pattern of milk production exhibited by a herd.

MATERIALS AND METHODS

As previously described (see Chapter 3, p. 40-41 for details), a subset of all the dairy herds in Prince Edward Island was selected to investigate factors associated with seasonal variations in milk production, as observed in test day milk production data available from the Animal Productivity and Health Information Network database (12). Data were available from multiple sources, including questionnaires, detailed ration assessments (including stored feeds and pasture), complete herd body condition appraisals, a bulk tank milk internal parasite antibody survey, and an electronic database containing individual cow data.

Demographic and Herd Management Data

Various herd level demographic and herd management factors were available from questionnaire data collected during two herd visits carried out in the spring (late April and early May) and in the summer (late August and early September) of 1994. Questionnaires were designed based on ones utilized in a previous study carried out in the same herds during 1993. As much as possible, multiple choices were given to the producers, or an objective answer was sought, in order to minimize the introduction of error cr bias due to interpretation by the investigators. Preliminary field testing was carried out using a convenience sample of dairy producers who were clients of the Farm Service Clinic at the Atlantic Veterinary College, prior to finalizing the questionnaires for use during the data collection visits. The two investigators who performed the herd visits collectively reviewed the final version of the questionnaires to ensure a consistent understanding of the questions and recording of information.

All questionnaire data were manually entered into a database program (4), and summary statistics, including minimum and maximum values were inspected for all variables. Twelve herds were randomly selected and the information in the database was verified against the questionnaires. After verification of the data, the database was converted to a STATA data file (41) for all further processing and analyses.

A number of the responses from the questionnaires were condensed into summary variables. For example, the total area under cultivation was divided by the number of "full-time labour equivalents" to arrive at a summary variable representing the number of hectares per worker. The constituent terms and the summary variable were then included in the subsequent analyses. Categorical variables were inspected and empty or very infrequently selected categories were consolidated into other categories.

Subsequent to the data management carried out as described above, the seasonal pattern of milk production was regressed on each questionnaire variable and each summary variable in turn, to check for unconditionally significant associations.

Nutrition, Body Condition and Parasitologic Data

Nutritional, body condition and parasitological information was also available for the study herds. Following the modeling approach outlined in Chapter 1 (p. 7-8) the associations between these variables and the seasonal pattern of milk production were previously explored. Details of the source of these data and the relationships can be found in Chapters 5, 6, and 7, respectively. However, the interaction of these variables, and the contribution of these factors to the seasonal pattern of milk production while controlling for other factors, was not investigated in the previous chapters. Variables were selected from these primary analyses for further examination in this study.

Statistical Analyses

Table 1 presents the independent variables which were evaluated for their relationship with the seasonal pattern of milk production. Variables included were; 1) those found to have a significant relationship ($P < .10$) in previous analyses of nutritional, body condition and parasitological factors, 2) various questionnaire-derived demographic and management factors found to be significantly associated ($P < .10$) with the seasonal pattern of milk production as described above, and, 3) other variables not significantly associated ($P > .10$) with the seasonal pattern of milk production but postulated to have possible interactions with other independent variables. Correlations between the independent variables, as well as with the dependent variable, were examined. Scatterplots of each independent variable versus the dependent variable were also examined.

All possible two-way and three-way interaction terms of the independent variables were generated. A linear regression model containing all main effects and subsets of related two-way and three-way interaction terms was fit. The three-way interaction terms were assessed using Wald's test of significance (19), and were removed from the model if they were not significant at the $P = .05$ level. This process was repeated with the two-way interaction terms.

After examination and evaluation of the interaction terms, the main effects were assessed in a backwards elimination manner. The 'least significant' term with a significance value greater than five percent was removed from the model, unless it was part of a statistically significant interaction term, in which case it was retained. This process was reiterated until all remaining terms were significant at $P < .05$. After the removal of a non-significant term, previously removed terms were sequentially re-evaluated in the reduced model to see if they were significant under the 'new' conditions.

Detailed residual diagnostics were carried out on the final model to determine if any of the assumptions of linear regression were violated or if there were any observations or covariate patterns that significantly affected the results. Raw, studentized , and jack-knife residuals were calculated, graphically examined with histograms and normal probability plots, and formally tested for normality with the Shapiro-Wilk test (36,38). Observations with extreme residual values were examined, and the regression model was re-evaluated without the observations having residual values in the upper and lower 5 % of the distribution. The effect on the coefficients, the standard error estimates and the model R^2 was subjectively assessed. Scatterplots of residual values versus fitted values were examined for trends and for the presence of heteroscedasticity for the whole model and for each main effect. The presence of heteroscedasticity for the full model and for each term in the model was formally assessed using the Cook-Weisberg test (10,17), which models the variance as a function of the fitted values, or as a function of a specific variable. Evidence of omitted power terms (x_i^2, x_i^3 and x_i^4, and $\hat{y}^2$, $\hat{y}^3$ and $\hat{y}^4$) was assessed by the Ramsey test, which incorporates power terms of each variable into the model and evaluates their statistical significance (16,33).

To graphically check for observations with simultaneously high leverage and high residual values, a leverage value versus residual (absolute) value plot was examined. Three separate statistics which summarize the graphical information were calculated; DFITS (3,44), Cook's Distance (9) and the Welsch Distance (43) statistic. Although mathematically related to one other, each summarizes the residual and leverage values somewhat differently. The DFITS statistic for an observation is a scaled difference between its predicted values, calculated with and without the observation in the model. The Cook's Distance statistic for an observation is a scaled measure of the distance between the coefficient vectors, calculated with the observation included and excluded in the model. The Welsch distance statistic is based on the DFITS statistic, but includes an additional leverage normalization factor. All three statistics were calculated for each observation to determine which, if any, observations were consistently identified as warranting further investigation. Observations with values greater than specified cutoff values (2,3,6,40) were thus identified.

The DFBETA statistic (40), which is a measure of the impact of an observation on the individual regression coefficients, was calculated for each observation, for each term in the model. The difference between the coefficient estimates obtained with an observation included in and omitted from the model is scaled by the standard error of the coefficient. The resulting value is a measure of how many standard error units the observation changes the coefficient estimate.

Multicollinearity between the independent variables was evaluated by removing each term from the final model and subjectively assessing the stability of the remaining coefficients and the accompanying standard error estimates. If a term or multiple terms are highly correlated with other terms, the removal of one of the terms will result in a substantial change in the regression coefficient or standard error estimate for the correlated term(s). The presence of multicollinearity was also formally evaluated by calculating a variance inflation factor (VIF) for each independent variable. The VIF is a function of the multiple correlation coefficient which results from regressing each independent variable against all the other independent terms in the model (7,40).

Appendix I provides details of the cutoff values for the various statistics as suggested by selected authors.

Finally, the reliability of the final model was assessed using a cross-validation procedure (25). A subset of 75 % of the herds was randomly selected, and a regression model was fit using a backwards elimination procedure with only these observations. The starting set of variables were those found to be significant in model 2, when all observations were included. The resulting equation was used to predict values for the remaining herds, based on their covariate patterns. The correlation between the observed and predicted values for this second group was squared and subtracted from the model R^2 obtained from the initial group. This difference is known as the "shrinkage on cross-validation." A STATA procedure was written to repeat this process multiple times (n = 100) in order to obtain a more accurate point estimate and determine the distribution of the "shrinkage" values. For each iteration of the procedure a newly generated set of random numbers was used to select the subset of the herds included for estimating the regression model.

To permit comparison of the variables as to their importance it was necessary to weight the coefficients relative to the observed or expected range of values. Direct comparison of the coefficients was not justified, due to the differences in the units and range of expected values of the different variables. The standard error of the coefficient was one possible alternative (40), but the interquartile range of observed values was used in this analysis.

Results

A total of 73 herds were included in the final dataset, as presented in these analyses. Complete nutritional data were available for 75 herds (Chapter 5), although two herds were not included in the final analysis because they were very small (average of 13 lactating cows) and were composed almost exclusively of non-Holstein breeds. Additionally, one of these herds was operated as a 'hobby farm', and the owner of the second was employed in full-time, 'off-farm' position. It was judged, *a priori*, that these herds were sufficiently dissimilar from the remaining herds to warrant their exclusion from the analyses.

Summary statistics for all variables found in the multiple regression models can be found in Table 2. There was, on average, a 25 % decline in average test day milk yield from June to November 1994. Lactating cows were housed in free stalls or loose housing in 20.5 % of the herds, and 63 % of the herds were on a regular (at least monthly) herd health program with a veterinarian. "Other significant livestock species" was defined as any number of livestock, other than dairy cattle and youngstock, being on the farm in economically meaningful numbers. Beef cattle, swine, and poultry were present in amounts meeting this criterion on 34.2 % of the study herds. A potable water source at pasture or in the exercise lots was available in 32.9 % of the herds. Since no farms had their lactating cattle herds under total confinement on a year-round basis, this question was applicable for all herds. For each herd, the average "days-in-milk" (DIM) in June was subtracted from the herd average DIM observed in November 1994. This calculation showed that, on average, the herds included in this study were 22 days (S.D. = 40.7) further in lactation in November than in June.

Regression Model 1.

This model, the most comprehensive of the three presented, included the independent variables found in Table 3. (Appendix J contains the correlation matrix of the dependent and independent variables.) Although the presence of potable water at pasture or in the exercise paddocks did not demonstrate any significant correlation with the seasonal pattern of milk production, this model included a significant two-way interaction term which indicated that the effect of non-forage dry matter (DM) feeding was dependent on the presence of water at pasture. Before creating the interaction term, the non-forage DM variable was centered by subtracting the mean value, so as to reduce the structural correlation between the interaction term and the 'water' variable. The correlation between the two independent variables was reduced from .95 to .21 through the use of this technique. The observed interaction was further investigated to see if this effect was significant at all levels of non-forage DM, since the interaction term resulted in an inexplicable relationship between water at pasture and non-forage DM feeding at levels of non-forage DM feeding below (approximately) the mean. Figure 1 demonstrates graphically the effect of this interaction, and shows that at levels below (approximately) 6.8 kilogram of non-forage DM the presence of potable water at pasture has a net negative effect on the seasonal pattern of milk production. Therefore, a categorical variable was created by grouping the non-forage DM feeding values into low, average, and high categories. It was found that only the interaction term formed by water at pasture and the high level of non-forage DM feeding was statistically significant. This was interpreted to mean that the presence of potable water in the pasture increased the positive effect of feeding additional non-forage DM during the summer months only for those herds feeding high levels of non-forage DM. However, the hypothesis that the coefficients for both interaction terms were zero could not be rejected at the 5 % level, so the categorical terms were removed from the model for the subsequent analysis.

Although the VIF values ($\bar{x}$ = 1.39, range = 1.13 - 1.96) did not appear to indicate the presence of significant multi-collinearity, the removal of the interaction term did cause a 27 % decrease in the *Ostertagia ostertagi* optical density coefficient. This is indicative of possible confounding between these two variables.

Regression Model 2.

After the removal of the interaction term from Model 1, the model was reassessed. It was found that the dichotomous term representing the presence of potable water at pasture was not significantly associated with the seasonal pattern of milk production with the other variables in the model (P = .62). The regression coefficients, standard error estimates, significance level, and 95 % confidence intervals of the remaining dependent variables in model 2 can be found in Table 4.

Detailed residual diagnostics were carried out as described. Figure 2 is a normal probability plot of the residual values. Graphical examination of the residuals did not demonstrate any trends, and the Cook-Weisberg test did not identify heteroscedasticity of the residuals when modeled as a function of the fitted values. However, when the residuals were modeled as a function of the *Ostertagia ostertagi* optical density values, evidence was found of heteroscedasticity (P = .04). A robust estimator of variance (45,46), which provides estimates robust to the presence of heteroscedasticity, was therefore used in place of the standard estimator. This did not have any substantial effect on the standard error estimates, or the significance level of the coefficients. Figure 3 is a scatterplot of the leverage value versus the absolute value of the residual for each observation. Four observations from this scatterplot were identified by the leverage, DFITS, Cook's Distance and Welsch Distance statistics as potentially being of undue influence on the regression results. However, the values for these observations were at, or just above, the most conservative cutoff values identified in Appendix 8A, and were therefore not expected to have a significant impact on the outcome. Similarly, observations with a DFBETA statistic (absolute) value greater than the conservative cutoff level of .23 (as per Belsley et. al. (2)) were identified, although the maximum DFBETA value of .51 did not even approach the cutoff value of 1, as suggested by Bollen and Jackman (3). The data associated with the identified observations were examined for errors which could have been the cause of the increased values. No errors were found. The effect of each observation on the model R^2 was also assessed by repeating the analysis with and without each observation and calculating the percentage change in R^2. Four observations were associated with a 2 % or greater change (increase or decrease) in the model R^2, with a maximum increase and decrease of 3.5 % and -2.9 % respectively.

The sequential removal of each independent variable from the model did not result in any marked changes to the coefficients for the other variables. This suggests that multi-collinearity among the variables was not a concern, and this was also reflected by the low VIF values ($\bar{x}$ = 1.18, range = 1.11 - 1.34).

The reliability of the model was assessed by calculating the shrinkage on cross-validation. The process was re-iterated 100 times, with randomly selected subsets of 75 % of the herds. The mean shrinkage on cross-validation was .07, with a standard deviation of .14, indicating that, on average, a reduction of 7 percentage points was observed in the model R^2.

Regression Model 3.

A third, and final, multiple regression model was constructed by eliminating from the model those factors which were not thought to have a direct biological relationship with the seasonal pattern of milk production. These included the following variables: lactating cow housing type, use of a veterinary-directed herd health program and, presence of significant amounts of non-dairy livestock on farm. The variables that remained in the model were: herd average kilogram of non-forage DM fed per day, proportion of daily DM requirements provided by stored feeds in late summer, bulk milk *Ostertagia ostertagi* optical density values and, difference in average 'days-in-milk' from June to November.

Regression modeling and diagnostics were carried out as described above. All two-way and three-way interactions of the four remaining variables were assessed, and none were found to be statistically significant. The significance of the main effects was evaluated, and the proportion of daily DM requirements provided by stored feeds in late summer was found to be not significant at the 5 % level (P = .06). It was decided to eliminate this variable from the model due its failure to be significant at the 5 % level, and the insubstantial improvement observed in the model R^2 when the term was included (R^2_{FULL} = .61, $R^2_{REDUCED}$ = .59). Robust variance estimates were used as described earlier, since the residuals, when modeled as a function of the *Ostertagia ostertagi* optical density values, continued to exhibit evidence of heteroscedasticity (P = .03). The details of the final 3-term multiple regression model can be found in Table 5.

The majority of the residual diagnostic tests identified one observation as being the most influential, although it was usually below or just above the test specific cut-off value. When the regression model was repeated without this observation, the coefficient estimate associated with the *Ostertagia ostertagi* optical density values was the only one that showed any significant change, from -.280, to -.314 after removal.

The reliability of the model was assessed by calculating the shrinkage on cross-validation as above. Multiple iterations (n = 100) demonstrated a mean shrinkage on cross validation of .03, with a standard deviation of .16.

Ranking of variables by relative importance

To permit an evaluation of the 'importance' of each variable, it was necessary to weight each coefficient relative to the range of its expected values. The interquartile range for each variable, representing the values encompassing the central 50 % of the observed values, was used to weight each coefficient in regression models 2 and 3. The results can be found in Table 6.

In both models 2 and 3, the seasonal pattern of calving, as reflected in the "change in average DIM from June to November", was ranked number one with respect to the impact on the seasonal pattern of milk production. The negative coefficient indicates that herds that demonstrated a higher herd average DIM in November relative to June also had greater seasonal variation in milk production (i.e. herd average test-day milk yield per cow was substantially lower in the fall relative to that observed in early summer) .

Three dichotomous variables related to herd management ranked next in relative importance in model 2. Participating in a regular herd health program (visits at least once per month) with a veterinarian was associated with a decrease in the seasonal variation in milk production, as was housing the lactating cattle in free stalls or in loose housing. Conversely, the presence of other significant numbers of livestock on the farm was associated with an increase in the seasonal variation in milk yield. The average amount of non-forage DM fed per cow per day during the summer was ranked just below the fourth ranked variable. A pcsitive value indicated that, as the daily amount of non-forage DM increased, there was a concurrent increase in the seasonal consistency of milk production. The bulk milk *Ostertagia ostertagi* optical density values ranked 6th, and indicated that increased exposure to this internal parasite was associated with an increased seasonal variation in milk yield, after controlling for other factors. Finally, although the proportion of the total daily DM requirements provided by the stored feed ration showed a positive relationship with the seasonality displayed by a herd, this variable had the least impact on the results relative to the other variables.

In model 3, the bulk milk *Ostertagia ostertagi* optical density values had the same importance as the "change in average DIM from June to November". Finally, ranked third, the kilograms of non-forage DM had a similar effect in model 3 as in model 2.

GENERAL DISCUSSION

The *a priori* removal of 2 herds from the analysis which had data available was justified due to the specific situations found on those farms. "Hobby farmers" usually have goals and priorities guiding their decision making which are significantly different from those held by producers striving to maintain a commercially viable enterprise. To use the data from hobby farms (which concurrently had a very unusual breed profile) to generate information and recommendations for the rest of the dairy community did not seem justifiable. In retrospect, these herds should have been excluded at the data collection phase of the study.

Large scale, epidemiologic studies do not necessarily lend themselves to explaining high proportions of the variability inherent in complex biological systems. The models developed from the data collected in the current study explain a large proportion of the variability in the patterns of seasonal milk production in Prince Edward Island, as evidenced by the high R^2 values of .755, .717, .594 in models 1, 2, and 3, respectively.

Reliability of the models

The reliability of models 2 and 3 was assessed using a cross-validation procedure. Kleinbaum et. al. (25) suggest that models with a cross validation shrinkage of less than .1 can be considered reliable. The mean shrinkage observed after performing multiple iterations of this procedure on models 2 and 3 was .07 and .03, respectively. This evidence suggests that the models were reliable.

Average days in milk

The association between seasonal variation in milk production and the change in herd average DIM was very consistent (β= -.001 in all models) and highly statistically significant in all models. This observed and robust association was not unexpected. The Animal Productivity and Health Information Network database presents a calculated variable, "adjusted corrected milk", as described by Nordlund (29), which adjusts actual test day milk yield to a consistent stage of lactation, proportion of first lactation animals in the herd, and bulk tank fat percentage (12). As discussed in Chapter 2, this variable demonstrated approximately only half as much seasonal decline as the actual test day milk production, indicating that the combination of factors used to calculate this variable was significantly associated with the seasonal pattern of milk production in Prince Edward Island. In this analysis, in which the adjustment factors were considered independently of one another, only the change in herd average stage of lactation was demonstrated to be significantly associated with the seasonal pattern of production.

Kahn (20), using a herd-level simulation model described previously (21,22), investigated the role of the summer decline in conception rate on the pattern of total monthly milk production in Israeli dairy cattle, which was characterized by a peak in March-April and a trough in August-September. The model incorporated the effects of climate on production, and found that seasonal variation in conception rate was the dominant factor responsible for the depression of monthly milk yield at the herd and multiple herd levels. The author suggested that this resulted in having a higher proportion of the herd in the dry period at certain times of the year, with a concomitant decrease in the total monthly milk production. Logic would imply that the herd average DIM would be increasing prior to the time of having a high proportion of the herd in the dry period, and that the DIM would be decreased as these dry cows commenced their subsequent lactation. This reasoning is supported by the smooth transition in total monthly milk yield observed across the seasons.

Related to stage of lactation is the issue of lactation persistency. At the individual cow level, various environmental and genetic factors affect the persistency of lactation (15), and the economic aspects of differing persistency patterns have been investigated (11,39,42). Enevoldsen et. al. (14), in a factor analysis assessing the effect of various herd management types on production, found that a factor containing a number of variables related to the variability of individual cow peak milk yield and persistency was significantly associated with the total herd milk production per year. The relative importance of each of these variables was not clearly distinguishable. The current study, examining factors associated with seasonal variation in average test-day milk yield per cow per day, was not designed to differentiate the intertwined effects of peak production and persistency. The relative impact of these factors on the outcome variable could therefore not be determined.

Non-forage dry matter feeding and proportion of dry matter requirements fed

The observed relationship between the level of non-forage DM feeding and the proportion of total daily DM requirements provided by stored feeds in the late summer and the seasonal pattern of production is consistent with that described in Chapter 5. The consistent appearance of the non-forage DM variable in all models, and its ranking relative to the proportion of total DM requirements provided by the stored ration in late summer, suggests that the effect of the stored feed ration in the summer on milk yield is primarily modulated through the grain and other non-forage components of the ration. This is consistent with the results obtained in other studies which examined the effects of concentrates on milk yield (18,35). As discussed previously, however, this relationship between the level of concentrate feeding and milk yield has not always been clearly evident (27,34), and is doubtlessly influenced by other concurrent factors.

Ostertagia ostertagi exposure

Ostertagia ostertagi exposure, as estimated by optical density values determined by the use of the bulk milk ELISA test, continued to demonstrate a significant association with the seasonal pattern of milk production, even after controlling for other factors. The direction of the association was consistent through all three models, although the magnitude of the coefficient varied from -.145 to -.280, and was not unduly influenced by any particular observation or group of observations.

Housing, herd health and other herd management factors

Oltenacu et. al. (30), in a study investigating herd level factors associated with seasonal variation in bulk milk shipments, demonstrated a trend for stanchion housed cattle to have greater seasonal variation in bulk milk shipments, although statistically, it was not significant (P = .18). While care must be taken in extrapolating factors associated with seasonal variation in bulk milk shipments to variation observed in individual cow milk yield, these results were consistent with the finding in the current study. Other herd-level factors, used as proxy measures of the overall "management level", were also investigated (30), and, although some weak trends were observed, few statistically significant relationships were found. Caine and Stonehouse (5) have suggested that better herd management was associated with less seasonal variation in bulk milk shipments. If this hypothesis is extended to seasonal variation in average daily individual cow milk yield, the observed association between a regular herd health program and a decreased seasonal variation in milk production, can be attributed to a better level of overall management. The observed negative relationship between other livestock species on the farm and the seasonal pattern of milk production could similarly be attributed to a decrease in the management level of the dairy herd, due to, for example, these other interests requiring significant attention and management.

In this study, we also investigated the association of producer perceptions regarding seasonal variation of "income over feed costs" and the observed seasonal pattern of milk production (Table 1). Oltenacu et. al. (30) found that producers who perceived a greater income over feed cost in the spring than at other times of the year, also showed greater seasonal variation in bulk milk shipments. This supported the conclusion of Quinn and Wasserman (32) who found that an important reason for the increased seasonal variation in bulk milk shipments was the farmers' opinion that higher profit was realized in the spring. Although there was a trend in the current study for producers to show greater seasonal variation in milk production if they felt their income over feed costs was highest in the spring, this trend was not significant (P = .20).

Non-significant variables

Of perhaps as much interest as the variables that exhibited significant associations with the seasonal pattern of milk production, were those that were not found to be of consequence in explaining the between herd variability in seasonal patterns of milk production. The seasonal pattern of milk production was found to be statistically independent of the herd size, the genetic potential, the herd average 305 day milk yield, the level of pasture management and the pasture forage yield, when assessed in a multiple regression model. This demonstrated lack of a relationship could be a consequence of: 1) the genuine absence of an epidemiologically associative or biologically causative relationship, 2) a lack of statistical power (i.e. inadequate observations) to detect the relationships, or 3) an improper or unrefined methodology or technique for collecting pertinent and critical data, especially as related to the pasture management and yield variables. However, the high R^2 values obtained suggested that the data were of good quality, and the strong associations found indicated that a lack of power was not likely a problem. (The majority of the variables which were not statistically significant had probability values (P) greater than .25.)

Residual diagnostics

When constructing a regression model it is important to fully evaluate the integrity and stability of the model, and its ability to replicate the observed values accurately. Analysis of residuals is the method most commonly used to evaluate a model's adherence to the conventional assumptions of linear regression, and to assess the impact of each observation, or covariate pattern, on the model results.

The residual diagnostics did not identify any observations, which, when removed from the models, would substantially alter the interpretation of the full model. The small degree of heteroscedasticity associated with the *Ostertagia ostertagi* optical density values could not be ameliorated by means of a number of transformations and was therefore dealt with by using a robust estimator of variance (45,46) described earlier.

The second (Table 4) and third (Table 5) models were the most thoroughly evaluated and appeared to be robust and stable to the omission of variables and observations, suggesting the associations observed were reliable, and that there was no significant multi-collinearity amongst the variables. Formally evaluated, using the shrinkage on cross-validation calculation, the models also appeared to be internally consistent and reliable.

Ranking of variables by relative importance

The calculation of the product of the observed interquartile range and associated coefficient for each variable, permitted the comparison and ranking of the terms as to their relative importance. Direct comparison of the coefficients from a regression model is usually not possible due to the variability in the units and the ranges of observed values. The primary rank accorded to the difference in average DIM between November and June in both models 2 and 3, is illustrative of its importance in determining seasonal patterns of milk production. Especially notable is the ranking of the bulk milk *Ostertagia ostertagi* optical density values in model 3, the most parsimonious of the models presented. This warrants further investigation of the importance of internal parasites and their impact on production in lactating cattle in the region.

CONCLUSIONS

Various factors postulated to affect the seasonal patterns of milk production observed in Prince Edward Island dairy herds were investigated. Included were: herd demographic and descriptive variables, nutritional status and management variables, pasture management techniques and predicted yield, exposure to internal parasites, and cow body energy reserves. The unconditional and conditional associations between these variables and the seasonal pattern of milk production were evaluated, as was inter-variable interaction and confounding.

A significant proportion of the variability in seasonal patterns of average test-day milk production observed in Prince Edward Island dairy herds was explained by the regression models developed. The models were thoroughly evaluated, and appeared to be reliable, consistent and stable.

Increased exposure to *Ostertagia ostertagi*, an increase in the average "days-in-milk" and the presence of significant amounts of other livestock species were associated with an increased level of seasonal variation in production. Conversely, increased non-forage dry matter (and total dry matter) feeding, free-stall housing of the lactating cattle, and a regular herd health program were associated with greater seasonal consistency in herd average test-day milk yield values.

In summary, the three most important factors found to have a statistical and biologically explicable association with the seasonality of herd average test-day milk production were: 1) reproductive management (seasonal difference in DIM), 2) internal parasite exposure levels (bulk tank milk *Ostertagia ostertagi* optical density values) and, 3) nutritional management (supplementary feeding of grains and concentrates).

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Table 1. Variables evaluated using multivariable regression analysis for their relationship with the seasonal pattern of milk production in Prince Edward Island dairy herds. Selection was based on a demonstrated unconditional association with the seasonal pattern of milk production ($P < .10$), or on a postulated interaction with other variables of interest.

Variable	Type[1]
DEMOGRAPHIC AND GENERAL INFORMATION	
Lactating cow housing: tie stall / free stall	B
Regular herd health program with veterinarian	B
Number years responsible for nutrition of lactating cows	C
Significant numbers of other livestock species on premises	B
Acreage cropped per full-time equivalent - 1994	C
PRODUCTION INFORMATION	
Average number of cows milking - 1994	C
Percentage of herd in first lactation - June 1994	P
Percentage of herd in first lactation - November 1994	P
Difference in average days-in-milk between November and June 1994	C
Herd average genetic index for milk - 1994	C
Average 305 day milk yield - 1993	C
Average bulk tank milk fat percentage - June 1994	C
Average bulk tank milk fat percentage - November 1994	C
NUTRITION INFORMATION	
Kilogram non-forage dry matter (DM) fed - summer '94	C
Percentage of total DM requirements from stored feed - summer '94	P
Pasture dry matter allowance per day	C
Ration professionally balanced for lactating cows since November 1993	B
Potable water available at pasture	B
OTHER INFORMATION	
Herd average adjusted body condition score - summer '94	C
Bulk tank milk *Ostertagia ostertagi* optical density -October '94	C
Producer's perception of season of highest "income over feed cost"	B
Pasture management index	C

[1] Variable type: B = Binary (0/1), C = Continuous, P = Proportion (0 - 1)

Table 2. Summary statistics for dependent and independent variables used in multiple regression models. Data from 73 Prince Edward Island dairy herds.

Variable	Mean	Standard Deviation	25th, 75th percentile
Seasonal pattern of milk production[1]	0.76	0.108	(.701, .833)
Lactating cow housing: tie stall / free stall	0.21	•[2]	•
Regular herd health program	0.63	•	•
Significant numbers of other livestock species	0.34	•	•
Difference in average DIM (Nov. - June 1994)	21.9	40.7	(-8.5, 46)
Kilogram non-forage dry matter (DM) per day	7.08	1.78	(5.85, 8.39)
Proportion of daily DM req'ts from stored feed	0.69	0.272	(.50, .90)
Potable water available at pasture	0.33	•	•
Bulk milk *Ostertagia ostertagi* optical density	0.58	0.131	(.483, .683)

[1] Seasonal pattern of milk production: Minimum herd average daily milk yield during October-November-December expressed as a proportion of the maximum herd average daily milk yield during May-June-July 1994.

[2] Standard deviation and percentiles not given for dichotomous (0/1) variables

Table 3. Multiple regression model (Model 1) with seasonal pattern of milk production[1] as dependent variable. Model $R^2 = .755$, $P = .000$.

Variable	Coefficient Estimate	Stand. Error[2]	P	95% Confidence Interval
Kilogram non-forage DM[3] cow^{-1} day^{-1}	0.008	0.004	0.078	(-.003, .018)
Proportion of DM requirements from stored feeds[4]	0.067	0.026	0.012	(.013, .121)
Bulk milk *O. ostertagi* optical density[5]	-0.188	0.060	0.003	(-.309, -.066)
Lactating cow housing[6]	0.054	0.016	0.002	(.017, .092)
Regular herd health program[7]	0.048	0.016	0.004	(.018, .078)
DIM difference: November - June '94[8]	-0.001	0.000	0.000	(-.002, -.001)
Other livestock on farm[9]	-0.043	0.015	0.006	(-.073, -.012)
Potable water source at pasture[10]	0.003	0.015	0.853	(-.028, .034)
Non-forage DM-water interaction[11]	0.025	0.009	0.001	(.007, .044)
Intercept	0.820	0.043	0.000	(.725, .915)

[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1(p. 5) for details.

[2] Robust standard error estimates (45,46) used due to evidence of mild heteroscedasticity; rounded to 3 significant digits.

[3] Total kg. non-forage dry matter (DM) fed per cow per day in late summer 1994. Includes grain, mixed grain rations, concentrates, supplements, and potatoes.

[4] Total kilogram DM fed from all stored feed sources expressed as a percentage of the DM requirements calculated from the predicted herd average production (based on genetic potential) and the herd average cow weight.

[5] Bulk tank milk ELISA optical density reading for *Ostertagia ostertagi*.

[6] 0 = tie stall, 1 = freestall

[7] 0 = no herd health program, 1 = regular herd health program with veterinarian

[8] Average "days-in milk" (DIM) in November 1994 minus average DIM in June 1994

[9] 0 = no other livestock species on farm, 1 = significant number of other livestock species on farm

[10] 0 = no potable water source at pasture, 1 = potable water source at pasture

[11] (Kilogram non-forage DM cow^{-1} day^{-1}) • (Potable water source at pasture)

Table 4. Multiple regression model (Model 2) with seasonal pattern of milk production[1] as dependent variable. Model R^2 = .717, P = .000.

Variable	Coefficient Estimate	Stand. Error[2]	P	95% Confidence Interval
Kilogram non-forage DM[3] cow^{-1} day^{-1}	0.018	0.004	0.000	(.011, .026)
Proportion of DM requirements from stored feeds[4]	0.059	0.028	0.043	(.002, .116)
Bulk milk *O. ostertagi* optical density[5]	-0.145	0.059	0.017	(-.262, -.027)
Lactating cow housing[6]	0.050	0.017	0.004	(.017, .084)
Regular herd health program[7]	0.055	0.015	0.001	(.025, .084)
DIM difference: November - June '94[8]	-0.001	0.000	0.000	(-.001, -.001)
Other livestock on farm[9]	-0.048	0.015	0.003	(-.079, -.017)
Intercept	0.666	0.057	0.000	(.552, .780)

1 Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. (See Chapter 2 for details.)

2 Robust standard error estimates (45,46) used due to evidence of mild heteroscedasticity; rounded to 3 significant digits.

3 Total kg. non-forage dry matter (DM) fed per cow per day in late summer 1994. Includes grain, mixed grain rations, concentrates, supplements, and potatoes.

4 Total kilogram DM fed from all stored feed sources expressed as a percentage of the DM requirements calculated from the predicted herd average production (based on genetic potential) and the herd average cow weight.

5 Bulk tank milk ELISA optical density reading for *Ostertagia ostertagi.*

6 0 = tie stall, 1 = freestall

7 0 = no herd health program, 1 = regular herd health program with veterinarian

8 Average "days-in milk" (DIM) in November 1994 minus average DIM in June 1994

9 0 = no other livestock species on farm, 1 = significant number of other livestock species on farm

Table 5. Multiple regression model (Model 3) with seasonal pattern of milk production[1] as dependent variable. Model $R^2 = .594$, P = .000.

Variable	Coefficient Estimate	Stand. Error[2]	P	95% Confidence Interval
Kilogram non-forage DM[3] cow^{-1} day^{-1}	0.019	0.004	0.000	(.011, .027)
Bulk milk *O. ostertagi* optical density[4]	-0.280	0.058	0.000	(-.396, -.163)
DIM difference: November - June '94[5]	-0.001	0.000	0.000	(-.002, -.001)
Intercept	0.810	0.048	0.000	(.713, .906)

[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

[2] Robust standard error estimates (45,46) used due to evidence of mild heteroscedasticity, rounded to 3 significant digits.

[3] Total kg. non-forage dry matter (DM) fed per cow per day in late summer 1994. Includes grain, mixed grain rations, concentrates, supplements, and potatoes.

[4] Bulk tank milk ELISA optical density reading obtained using *Ostertagia ostertagi* antigen.

[5] Average "days-in milk" (DIM) in November 1994 minus average DIM in June 1994

Table 6. Ranking of variables from 2 multiple regression models (Model 2 and Model 3) with the seasonal pattern of milk production[1] as dependent variable. Model coefficient estimates multiplied by the interquartile range of the observed values.

	Coefficient Estimate	IQR[2]	Coefficient × IQR	Rank[3]
Model 2. (Table 4)				
Kilogram non-forage DM[4] cow^{-1} day^{-1}	0.018	2.54	0.046	5
Proportion of DM req'ts from stored feeds[5]	0.059	0.40	0.023	7
Bulk milk *O. ostertagi* optical density[6]	-0.145	0.20	-0.028	6
Lactating cow housing[7]	0.050	1.00	0.050	3
Regular herd health program[8]	0.055	1.00	0.055	1
DIM difference: November - June '94[9]	-0.001	54.50	-0.055	1
Other livestock on farm[10]	-0.048	1.00	-0.048	4
Model 3. (Table 5)				
Kilogram non-forage DM[3] cow^{-1} day^{-1}	0.019	2.54	0.048	3
Bulk milk *O. ostertagi* optical density[6]	-0.280	0.20	-0.055	1
DIM difference: November - June '94[9]	-0.001	54.50	-0.055	1

[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. (See Chapter 2 for details.)

[2] IQR = Interquartile range of observed values

[3] Within-model ranking of variable x_i, as assessed by the absolute change in MINMAX associated with a one interquartile unit change in x_i.

[4] Total kg. non-forage dry matter (DM) fed per cow per day in late summer 1994. Includes grain, mixed grain rations, concentrates, supplements, and potatoes.

[5] Total kilogram DM fed from all stored feed sources expressed as a proportion of the DM requirements calculated from the predicted herd average production (based on genetic potential) and the herd average cow weight.

[6] Bulk tank milk ELISA optical density value obtained for *Ostertagia ostertagi*.

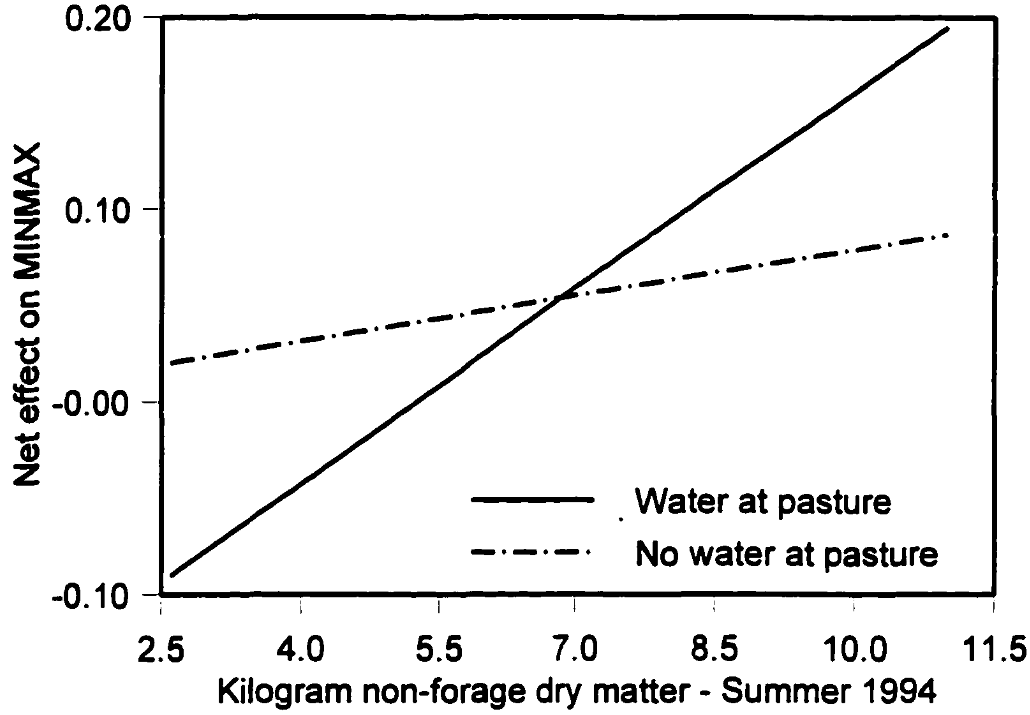
[7] 0 = tie stall, 1 = freestall

[8] 0 = no herd health program, 1 = regular herd health program with veterinarian

[9] Average "days-in milk" (DIM) in November 1994 minus average DIM in June 1994

[10] 0 = no other livestock species on farm, 1 = significant number of other livestock species on farm

Figure 1. Graphical representation of statistically significant (P = .01) interaction between level of non-forage dry matter feeding and potable water source at pasture and the net effect on the seasonal pattern of milk production[1]. See text for details.



[1] Seasonal pattern of milk production - minimum daily milk production during Oct-Nov-Dec expressed as a percentage of the maximum production during May-June-July. See Chapter 1 (p. 5) for details.

Figure 2. Standardized normal probability plot of studentized residuals from regression model 2.

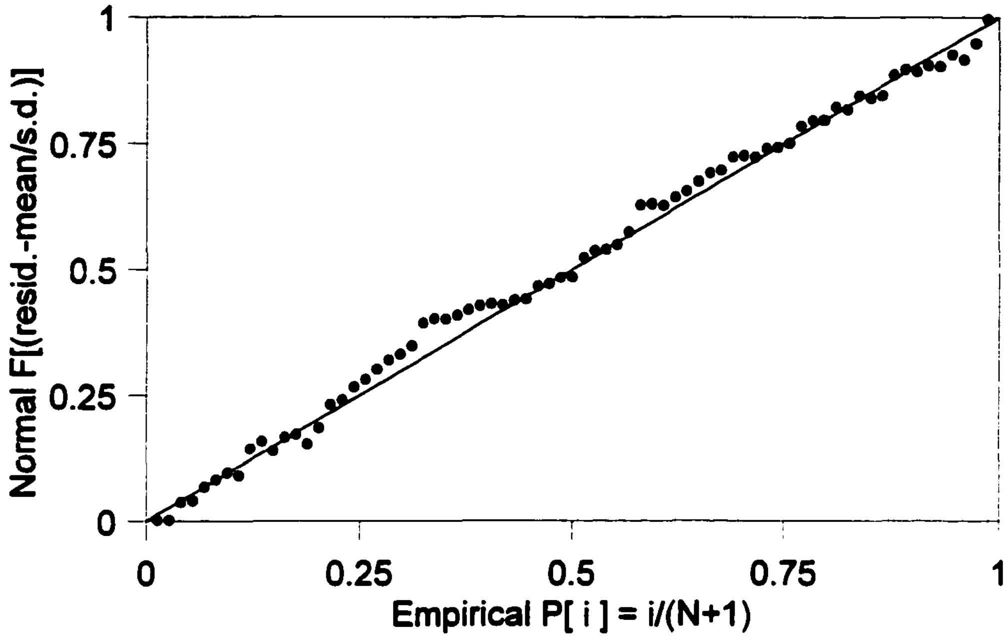
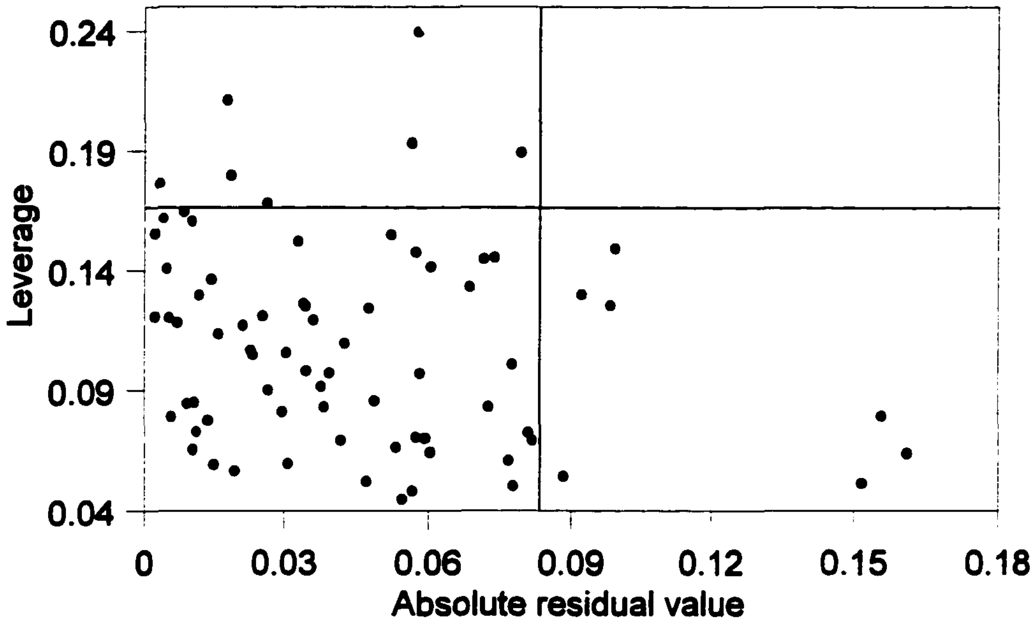


Figure 3. Scatterplot of leverage value versus absolute residual value for each observation (herd) in regression model 2 (n = 73). Horizontal and vertical lines demarcate the 90th percentile of the leverage and residual values, respectively.



Chapter 9

The Summer-Fall Slump Study:

A Concluding Synopsis

A pronounced and consistent temporal pattern is evident in the average test-day milk production in Prince Edward Island, Canada (PEI). Known colloquially as the "summer slump", this phenomenon is not unique to PEI, having been reported, at least anecdotally, in many dairying areas of the world. Upon further examination of the PEI data it became evident that there was marked herd-to-herd variation in the pattern of average test-day milk production, with some herds demonstrating marked seasonal variability and other herds maintaining seasonally consistent production. It was the purpose of this study to describe seasonal patterns of milk production observed in Prince Edward Island dairy herds, as well as to evaluate the economic performance of herds with respect to their seasonal pattern of production. Furthermore, this study was designed to ascertain which factors were significantly associated with the seasonal pattern of production demonstrated by a herd, and, in so doing, to provide dairy herd managers and owners with information with which to enhance the viability of their farm enterprises.

A calculated variable, MINMAX, was used to numerically summarize a herd's seasonal pattern of milk production. This variable expressed the minimum average test-day milk yield during the months of October, November and December as a percentage of the maximum average test-day milk yield realized during the months of May, June and July. Thus, values of .99 and .55 would indicate that the minimum production during the latter part of the year was 99 % and 55 %, respectively, of the maximum production in the late spring and early summer.

In Chapter 2, the year-to-year consistency of the seasonal pattern of production was investigated, using multiple years' data from a large number of PEI dairy herds. Provincially, for the years 1990 to 1994, the average nadir production in the fall was at 74.5 % of the peak production during May, June and July. It was found that herds tended to exhibit similar seasonal patterns of production from one year to the next. This suggested that the pattern of milk production observed in a herd was the result of one or more herd level factors, rather than being due simply to random variability among herds. This conclusion in turn, led to the development and implementation of the cross-sectional, analytical, observational study presented in the successive chapters.

Forty-five PEI dairy herds that demonstrated marked seasonal variation in average test-day milk production and 45 seasonally consistent herds, based on 1992 performance data, were enrolled in a study to investigate in detail the economic consequences of seasonal variation in milk production and to determine which factors were significantly associated with herd-to-herd differences in seasonality patterns. These herds were visited twice in 1993 and twice in 1994, at the end of the stabling period and during the mid-grazing season, to collect a wide array of individual cow and herd level data. In the final analyses, as presented in this thesis, only the data collected during 1994 was utilized. Substantial refinements in data collection techniques and the increased experience of the investigators resulted in 1994 data that were deemed to be superior to those collected in 1993. Other data, such as individual cow milk production records, and bulk tank milk samples were also available from various sources.

The economic consequences of seasonal variation in milk production were addressed in Chapter 3, using an "income in excess of (over) feed costs" approach. Detailed ration and pasture management information was used to calculate accurate herd level estimates of average daily feed cost per cow during both the stabling and pasturing seasons. Actual milk shipment records were used to calculate monthly and annual milk revenue. It was found that herds with higher summer average daily feed costs per cow maintained more consistent milk production per cow during the summer and fall months. It was also found that these herds had increased income in excess of feed costs as they remained more seasonally consistent in their milk production. Overall, an increase of 10 percentage units in the calculated seasonality parameter (MINMAX) was associated with an increase of $ 215.32 in milk revenue in excess of feed costs per cow per annum.

In evaluating the association of the reliance on pasture forage and the seasonal pattern of milk production, an estimate of the daily pasture forage availability per cow was required. Chapter 4 explored two methods for obtaining estimates of the expected increase in forage production resulting from the use of various pasture management techniques. The Delphi technique and conjoint analysis were used, and the results were compared - to each other, and to research results reported in the scientific literature. Good correlation was observed between the estimates obtained from the two survey methods, and the results demonstrated good agreement with data from published studies. The results of the conjoint analysis were subsequently used to calculate the total amount of pasture forage available for the grazing cattle.

The relationships between various ration characteristics and the seasonal patterns of milk production were examined in Chapter 5. Univariable statistics and linear regression techniques were used to examine the relationship between seasonal patterns of average test-day milk production and the amount of dry matter, energy and protein provided by forage and non-forage feedstuffs, the daily pasture forage dry matter allowance per cow, and the overall level of pasture management. At increased levels of supplemental feeding of grains, concentrates, and silage (during the summer months), more consistent milk production was observed during the mid to late pasturing period. A similar effect was observed when assessing the percentage of the nutritional requirements met by the stored ration. When the amount of non-pasture dry matter being fed was controlled for, the amount of pasture dry matter relative to that required, and the overall pasture management level, were of little significance to the seasonal decline in milk production. The amount of non-forage dry matter (kg) fed per cow per day during the summer, and the percentage of the total daily dry matter requirements provided from stored feeds during the grazing period were carried forward to the final multivariable model. The daily pasture dry matter allowance per cow and the pasture management index were similarly retained.

Chapter 6 examined the association of the lactating cow body energy reserves and the seasonal pattern of milk production. An adjusted (standardized) herd average body condition score (BCS) was calculated for this purpose, to permit inter-herd comparisons. A weak positive relationship was found between the average amount of energy reserves, as estimated by the herd average BCS at the time of the summer visit, and the consistency of herd average test-day milk production during the summer and fall. No statistically significant relationships were detected between the seasonal pattern of milk production and the herd average body condition score at the beginning of the grazing period, or the change in herd average condition score. The summer, standardized herd average BCS was retained as a variable to be considered in the analyses in Chapter 8.

In Chapter 7, the relationship between level of exposure to *Cooperia oncophora*, *Dictyocaulus viviparous*, and *Ostertagia ostertagi* and the seasonal pattern of milk production was analyzed. Antibody levels in bulk tank milk samples were determined using an enzyme-linked immunosorbent assay. The strongest association with the seasonal pattern of milk production was demonstrated by the *Ostertagia ostertagi* antibody levels. Increased exposure to these abomasal nematodes was found to be associated with significantly increased seasonal variation in test-day milk production. This relationship persisted after controlling for a number of herd performance and management factors which were found to be associated with elevated *Ostertagia ostertagi* antibody levels, including, the average daily milk yield and proportion of the herd in first parity at the time of milk bulk milk evaluation, the use of anthelmintics in the mature herd, and the proportion of the total daily dry matter requirements provided by the stored feed component of the summer ration. From these analyses a number of additional variables were selected for inclusion in the multivariable modeling process, including the bulk milk *Ostertagia ostertagi* optical density values and the percentage of heifers in the herd at the time of the milk sampling.

The culmination of this thesis was provided in Chapter 8, in which multivariable modeling was used to explain the inter-herd variability in seasonal variation in average test-day milk production in PEI. In addition to the key variables identified in Chapter 5, 6 , and 7, information on herd reproductive performance and herd management data were included in the multivariable models. The models explained a significant proportion of the between-herd variability in the seasonal patterns of milk production (R^2 = .594 to .755), and were found to be robust and reliable after thorough examination. A number of biologically plausible factors were found to be statistically associated with the seasonality of herd average test-day milk production. These included herd level factors that measured (for the mature cow herd) the reproductive performance (seasonal difference in days-in-milk), the internal parasite exposure levels (bulk tank milk *Ostertagia ostertagi* optical density values) and the nutritional management during the summer (supplementary feeding of grains and concentrates). To rank the variables as to their relative importance, the regression coefficients were multiplied by the change in observed values from the 25th to the 75th percentiles (the interquartile range, IQR). Using this technique, reproductive performance (β = -.001, $\beta\times$IQR = -.055) and bulk milk *Ostertagia ostertagi* optical density values (β = -.28, $\beta\times$IQR = -.055) were shown to have a similar impact on the seasonal pattern of milk production in a herd, whereas the daily amount of non-forage dry matter per cow (β = .019, $\beta\times$IQR = .048) had a marginally lesser effect.

Finally, by means of previous, as well as ongoing efforts, the knowledge derived from this study has been transferred to the dairy community, with the intention of providing beneficial and pertinent information for decision makers and herd advisors.

APPENDICES A - J

APPENDIX A

Calculation of Daily Pasture Costs

Total pasture costs were calculated on the basis of farm specific information collected regarding pasture management techniques. Appendix D contains the data collection forms listing the information collected.

Fencing Costs

A number of assumptions were made to permit the calculation of fencing costs. All pasture fields were assumed to be contiguous and the perimeter around the total area was minimized. Total pasture area was divided by the number of fields used to calculate internal fencing requirements. Individual field sizes were used when calculating break fence requirements for strip grazing.

A local fence supplier was contacted and an average price per metre per year was calculated based on five strands of high tensile wire, pressure treated posts, the necessary hardware, and a small repair component. An allowance was also made for a number of gates to be included in the perimeter and internal fencing costs. These total costs ($150.00 Cdn./100 metre) were divided over a 25 year expected lifespan. Permanent internal fences were calculated at the same price as the perimeter fence, while break fencing was done with 2 strands of high tensile wire and temporary posts.

The costs for an energizer and ground rods were also included as a fixed cost per year for each farm.

Reseeding Costs

Reseeding costs were calculated based on the area, the type of pasture and the number of years since the pasture had been reseeded. A cost per acre was calculated which included the seed required as well as labour and equipment costs (4). For annual pasture the complete cost ($142.27/hectare) was assigned to the 1994 grazing season, whereas perennial seeding costs ($197.60/hectare) were divided over 5 years.

Fertilizer and Lime Costs

The number of fertilizer applications, the rate of application as well as the chemical composition of the fertilizer were recorded for all fields. Fertilizer and lime prices, including delivery and custom spreading, were obtained from a local fertilizer company. Lime costs were divided over five years due to the prolonged effect of a single application of lime (3). The total costs of lime and fertilizer applied were then calculated for each field. In situations where a cut of hay had been taken from the field before it was grazed, only one half of the costs were assigned as pasture costs.

Other Costs

Other costs included in the calculation of total pasture costs included taxes, interest and rental costs (2), and an annual maintenance allotment (1). These were calculated on a per hectare basis for all fields that had been utilized as pasture. Only one half of the costs were assigned as pasture costs if a cut of hay had been taken before grazing.

Total Costs

The average cost of pasture per hectare for the 69 farms that utilized pasture as a feed source during 1994 was $ 159.26 (Cdn.) with a standard deviation of 40.60, with minimum and maximum values of $ 82.41 and $ 267.76 respectively. The 10th and 90th percentiles were $ 112.50 and $ 208.38 respectively.

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1. McClelland, H. 1996. Final Report: Intensively Managed Rotational Pasture in Dairy Production. Quebec Department of Agriculture, PQ., Canada.

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3. Robinson, S., S. Clare, and M. Leahy. 1992. *Pasture Production*. Guelph, ON: Ontario Ministry of Agriculture and Food.

4. Thomas, W.G. and J.B. Goit. 1995. *Seven Months of Pasture: Guide to an extended season pasture system*. Truro, NS: Nova Scotia Department of Agriculture and Marketing.

APPENDIX B

Delphi Technique Forms

These documents have been reformatted from the original

to conform to the style of this thesis.

Department of Health Management
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550 University Ave., Charlottetown, P.E.I.
CANADA CIA 4P3

FIELD(Date)

FIELD(Name)
FIELD(Address)
FIELD(City), FIELD(Province)
FIELD(Postcode)

Dear FIELD(Salut),

I am contacting you because of your expertise in the area of pasture research/management with a request that you participate in the following exercise. We are using the Delphi technique as part of a research project we are carrying out on PEI.

The Delphi technique is a method of reaching a consensus from a group of experts. Participants are given the opportunity to rank or score various practices or factors which may be involved in a certain problem or situation. After these rankings have been summarized the results are sent out again - this time with the (anonymous) results from all the participants. An opportunity is then given to modify the original ranking or scores, based on the results from the other experts. This process is repeated, usually about 3 or 4 times, until a consensus (on the importance/impact of various factors) is reached, or the participants do not feel that they are willing to change their individual scores/rankings any further.

We are studying the effects of pasture quality and pasture management techniques on the ability of cows to produce milk during the grazing season. Ninety herds have been visited each of the past two summers, to collect information about (among many other things) pasture management practices. We would like to ask you to help out by telling us what you think the "value" of the following pasture management techniques are on a Prince Edward Island dairy farm. The end goal of this exercise is to estimate the total amount of herbage that the cows were able to consume from a field from the first day on pasture until the end of the grazing season.

If you have any questions or comments please feel free to contact me at the address below. **In order to expedite the process, I would ask that you send me pages 2-4 by facsimile as soon as possible.** I hope to summarize the results of the first round and return them to you in 1 weeks time. Thank you for your cooperation.

Sincerely,

Ernest Hovingh
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Atlantic Veterinary College
550 University Ave.
Charlottetown, PEI. C1A 4P3

e-mail: ehovingh@upei.ca
telephone: (902) 566-0995
facsimile: (902) 566-0958

By way of example:

Tiny Tim (TT) grows Scotia tomatoes in his 1 acre garden to sell at the farmers market. Over the course of one season he expects to get 100 boxes of tomatoes.

Assuming that the following paragraphs summarize your thoughts and research about the effects of various "tomato management practices", you would fill in the table as shown below.

If TT uses slug control tactics he can expect to get 107 (an INCREASE of 7) boxes of tomatoes. If he applies tomato cages to support the plants he can expect to yield 104 boxes of tomatoes. If he waters the plants daily he can expect 110 boxes of tomatoes and twice a week watering will yield 109 boxes. If he sells ½ of his plants to his neighbour before they produce tomatoes he will yield (for sale) 60 boxes (a DECREASE of 40 boxes).

TECHNIQUE	SPECIFICS	UNITS INCREASE	UNITS DECREASE	BASED ON...(*) L/R/E
slug control		7		L
tomato cages		4		R
watering	daily	10		E
	twice a week	9		R
½ of plants sold to neighbour			40	R
white picket fence around garden		0		E

THE SUMMER-FALL SLUMP PROJECT - PASTURE ASSESSMENT

Our "baseline" pasture is 1 acre of native ("never" reseeded...at least not in 25 yrs!) PEI pasture that has had NO lime within the last 5 years, NO commercial fertilizer within the last year and NO manure applied within the last 2 years and has not been 'clipped'. Cattle access is "continuous" for the whole grazing season (NOT used in rotation with other pastures nor strip grazed nor cut for hay) and at a "normal" stocking density.

If we assume that this acre of pasture produces 100 units of herbage during the course of the growing season, how much more or less do you estimate the following management practices will allow the same acre to produce FOR THE COWS TO GRAZE (in units):

Please indicate the method in which you arrived at this decision...whether based on Literature you are familiar with, based on your own Research data (or that done at your institution), or based on professional Experience (a.k.a. a "gut feel").

If you feel that a certain practice makes no difference in the yield expected from the pasture please indicate so by placing a "0" in either column.

Please score these techniques as applied individually, that is, if the **ONLY** thing a farmer did (as compared to our "baseline" pasture above) was to use that ONE management technique.

PASTURE MANAGEMENT TECHNIQUES: (applied individually)		UNITS INCREASE	UNITS DECREASE	BASED ON... L/R/E*
Rotational grazing	at least 14 days before cows went back on same field			
Strip grazing	forward strip grazing (no follow-up fence)			
	"true" strip grazing			
Lime application (within last 5 years)				
Manure application (within last 2 years)	light coat			
	medium coat			
	heavy coat			
Commercial fertilizer	15-15-15 - once in the spring			
	30-0-0 - once in the spring			
	15-15-15 - 2 or more times during the spring & summer			
	30-0-0 - 2 or more times during the spring & summer			
One cut of hay taken from field	first cut of hay removed before grazing			
Clipping	once or more during season			
"High" Stocking density	high stock. density - frequent movement (move ≥ 1/day)			
"Reseeding" of pasture	1-2 years ago			
	5-10 years ago			

* Based on... Literature summary / actual Research data (local/personal involvement) / professional Experience (a "gut-feel")

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550 University Ave., Charlottetown, P.E.I.
CANADA CIA 4P3

Field(Date)

Field(Name)
Field(Address)
Field(City), Field(Province) Field(Pcode)
Field(faxnum) (fax)

Dear Field(Salut),

Please find attached the results of the second iteration of the "Delphi technique" that we are using to rate pasture management techniques (you are respondent number Field(id_num)) as well as a form for any changes you may want to make to your current numbers. I have included the comments received on the last round. You are invited to respond to these concerns and comments.

I will attempt to clarify the "cut of hay" question. This is one in which there still seems to be quite a lot of discrepancy in the estimates. I would like to compare the yield of two halves of one field. The one half is grazed continuously during the whole season and has not had any pasture management practices applied to it (our "baseline pasture"). The other half is not grazed initially, but has one cut of hay removed from it. It is then grazed by dairy cows ("identical" to those on the other side of the fence) as "aftergrass" for the remainder of the season. I would like to know how much less (or more) the cattle on the "cut of hay" side are able to graze from their pasture as compared to what the cows on the "baseline pasture" have consumed OVER THE WHOLE SEASON. The current answers range from 70% less to 10% more. That is to say, if the cows on the "baseline pasture" graze 100 tonnes of forage during the WHOLE grazing season, the cows on the aftergrass graze anywhere from 30 tonnes to 110 tonnes during the time they are on the aftergrass!

Please reply as soon as possible with any changes or comments you may have. There is space provided for your comments. Thanks again for participating!

Sincerely,

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phone: (902) 566-0995
fax: (902) 566-0958

...the DELPHI technique estimates...iteration 2...

"technique"	Respondent													
	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STD DEV
Rot. graze	12 LRE	20 LE	50 R	20 E	50 RE	25 E	-20 E	10 L	50 LE	50 LRE	50 LR	25 LE	28.50	22.25
Forward strip	10 L	10 LE	50 R	15 E	30 E	10 E	10 E	10 L	70 LE	20 L	25 L	50 LE	25.83	20.32
"true" strip	12 L	35 LE	60 R	20 E	80 E	30 E	-25 E	12 L	100 LRE	40 L	50 L	50 LE	38.67	33.16
Lime	15 L	4 E	10 E	10 E	10 R	15 E	15 E	5 L	20 E	15 E	10 L	15 E	12.00	4.65
Manure light	10 L	5 E	10 E	15 E	10 R	10 E	10 E	0 L	20 E	10 E	10 L	5 E	9.58	4.98
Manure med.	20 L	7 E	15 E	25 E	20 E	20 E	5 E	10 L	25 E	20 E	20 LR	10 E	16.42	6.84
Manure heavy	30 L	9 E	30 E	35 E	30 E	30 E	0 E	20 L	30 E	20 E	30 L	11 E	22.92	10.97
Fertiliz 15/3X1	20 L	15 L	18 E	20 RE	25 RE	30 E	20 E	5 LR	30 E	30 RE	20 LR	15 E	20.67	7.38
Fertiliz 3 0%X1	20 L	20 L	15 E	15 RE	20 RE	20 E	30 E	5 LR	20 E	20 RE	20 LR	15 E	18.33	5.77
Fertiliz 15/3X2	50 L	25 L	30 E	25 RE	40 RE	45 E	40 E	10 LR	40 E	30 RE	30 LR	28 E	32.75	10.82
Fertiliz 30%X2	35 L	30 L	25 E	20 RE	35 RE	30 E	-10 E	10 LR	20 E	30 RE	25 LR	28 E	23.17	12.59
Cut of hay	-40 L	-60 E	-25 E	-70 RE	-70 E	10 E	5 E	10 R	-20 E	10 E	-20 LR	3 E	-22.25	31.36
Clipped	3 L	7 E	10 E	0 E	3 LE	10 E	-10 E	5 L	10 E	10 E	20 LR	3 E	5.92	7.27
High stock density	10 L	35 E	60 E	20 E	80 E	30 E	10 E	10 L	30 E	25 RE	40 LR	45 E	32.92	21.26
Reseed 1 year	20 LRE	25 L	40 E	50 LR	30 E	20 E	15 R	10 L	30 E	25 RE	20 LR	25 E	25.83	10.84
Reseed 5 year	0 LRE	5 E	20 E	10 L	10 E	10 E	-20 R	0 L	0 E	5 E	10 LR	5 E	4.58	9.64

Reminders:

- the "baseline" pasture is described above

- we are asking you to evaluate the individual techniques as if they were the ONLY thing that was done, as compared to our "base" pasture (ie. if the *only* thing a producer did was to remove a cut of hay, how much would that change *the amount of grass available to the cows* from a theoretical yield of 100 units of forage from that field over the *whole* season.)

"technique"	Respondent: Field(Name)
Rot. graze	
Forward strip	
"true" strip	
Lime	
Manure light	
Manure med.	
Manure heavy	
Fertiliz 15/3X1	
Fertiliz 30%X1	
Fertiliz 15/3X2	
Fertiliz 30%X2	
Cut of hay	
Clipped	
High density	
Reseed 1 year	
Reseed 5 year	

- if the *basis* for your answer has changed since the last time...perhaps you just read a paper that deals with one or more of these techniques...please indicate this beside your new response.

- please put your "new" numbers in the table on the left and fax this page back to me as soon as possible.

- include any comments that you may have in the space below - either supporting your own decision or refuting another's...please be nice!!

- PLEASE WRITE CLEARLY - FAX MACHINES CAN DO WIERD THINGS TO HANDWRITING!!

COMMENTS

APPENDIX C

Conjoint Analysis Forms

These documents have been reformatted from the original

to conform to the style of this thesis.

Field(Date)

Field(Name)
Field(Address)
Field(City), Field(Province)
Field(Pcode)

Dear Field(Salut),

Greetings and happy new year!

It has been some time now since the Delphi technique in which you participated has been completed. The factsheet that resulted from that exercise has been received with interest and has been widely distributed. Thanks again for participating!

One of the problems we are currently faced with is how to arrive at an estimate of the increase in yield expected when a producer uses multiple pasture management techniques. We are not sure that it is valid to simply add up the increases expected from the individual techniques as determined by the Delphi exercise. We are using a formal method (commonly known as "conjoint analysis") for arriving at estimates of the techniques when they are used in combination and would ask you to participate. Only a single response is required from you (compared to the multiple iterations of the Delphi technique) and it should therefore not require as much of a time commitment on your part. I hope that you will participate! If you have any questions please feel free to contact me.

Many thanks!

Sincerely,

Ernest

Ernest Hovingh
Dept. of Health Management
Atlantic Veterinary College
550 University Ave.
Charlottetown, P.E.I.
C1A 4P3

(902) 566-0991 voice
(902) 566-0823 fax

Instructions for completing the Conjoint Analysis

Enclosed are 12 "cards" representing 12 different combinations (out of approximately 950 possibilities!) of pasture management techniques. (The definitions of the pasture management practices are the same as they were for the Delphi technique, and are included, along with a more detailed description of the baseline pasture, on the following page.) I would like you to use the following procedure to rank the cards and to provide an estimate of the yield of each profile.

1. Separate the cards into two (or three) piles - the 6 (or 4) with the LARGEST expected increase in yield and the 6 (or 4) with the LOWEST expected increase in yield (and the 4 with a MODERATE increase in yield if you use 3 piles).

2. Within each of the piles, place the cards in order of expected increase in yield - beginning with the profile that you would expect to give the maximum yield within the group and proceeding to the profile that would give the lowest yield within that group. Though it is likely to be difficult to rank some of the profiles within a group due to similar expected yields, your best guess is just fine! The two (three) groups can then be placed in order from the maximum to minimum increase in yield.

3. Write the ranking of each card on the space designated, beginning with "1" for the profile with the maximum yield and "12" for the profile with the lowest increase in yield.

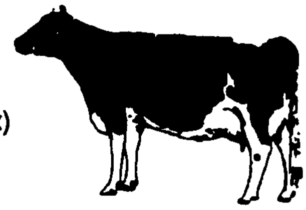
4. Provide an estimate for the percentage increase in yield (relative to the "baseline profile" - which has been included and has a "0" printed in the "% percent increase" box). It would be expected that the 'lowest increase' in yield would be the baseline profile (and thus it would have a rank of "12") - **unless there is a profile that you feel will actually produce a DECREASE in pasture yield (from "baseline") if used as indicated**.

   [These numbers are to have the same interpretation as the Delphi results; for example, a "90" would mean that you would expect that profile to yield 90% ***more*** forage than "baseline" profile (total yield = baseline * 1.9). A "200" would indicate that you expect the profile to yield 200% ***more*** than the baseline pasture (total yield = baseline * 3). You can use the factsheet (a copy of which is enclosed) as a starting point for your estimates if you wish.]

5. Provide an estimate of the yield of forage (tonnes of dry matter) from **one acre** of the **baseline pasture** on the card provided.

6. Place the cards in the return envelope provided and return them to me, along with any comments you may have.

If you have any questions, please contact me! (E-mail, phone, or fax)



Definitions used in the Conjoint Analysis:

Baseline pasture:

Our "baseline" pasture is native Prince Edward Island pasture (not reseeded within the last 5 years as a minimum, though usually not in the last 25 yrs!)) that has had NO lime within the last 5 years, NO commercial fertilizer within the last year and NO manure applied within the last 2 years and has not been `clipped'. Cattle access is "continuous" for the whole grazing season (NOT used in rotation with other pastures nor strip grazed nor cut for hay) and it is stocked at a "normal" stocking density. This pasture is considered the "baseline" - with a "% increase" of 0.

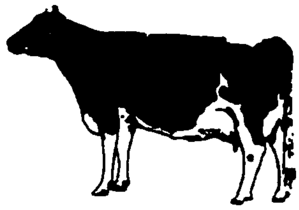
Terms used on the conjoint analysis profile cards:

Rotational grazing:	pasture grazed down to predetermined height - then rested at least 14+ days (usually more) before cows went back on same field
Lime application:	Standard application of lime at some point within last 5 years
Manure application:	medium coat of manure applied at least once within the last 2 years
Commercial fertilizer:	15-15-15 applied once in the spring 30-0-0 applied 2 or more times during the spring and summer
Reseeding of pasture:	pasture reseeded approximately 1 year ago pasture reseeded more (usually *much* more!) than 5 years ago

Other notes:

You can ignore the "Card" marks in the bottom right corner of the cards...they are there for our use in the processing of the cards!

I hope to present the results of this conjoint analysis and the Delphi Technique at the upcoming International Grasslands Congress...so please get your results to me as soon as possible! Thanks!!



Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	Within 5 yrs.	
Manure applied:	Medium (last 2 yr.)	% increase:
Fertilizer applied:	None (this season)	
Last reseeded:	1 yr. ago	

[Card 1]

Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	Medium (last 2 yr.)	% increase:
Fertilizer applied:	None (this season)	
Last reseeded:	> 5 yrs. ago	

[Card 2]

Farm Profile:

Grazing system:	None	Rank: _____
Lime applied:	Within 5 yrs.	
Manure applied:	None (last 2 yrs.)	% increase:
Fertilizer applied:	None (this season)	
Last reseeded:	1 yr. ago	

[Card 3]

Farm Profile:

Grazing system:	None	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	Medium (last 2 yr.)	% increase:
Fertilizer applied:	15-15-15 (once)	
Last reseeded:	1 yr. ago	

[Card 4]

Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	None (last 2 yrs.)	% increase:
Fertilizer applied:	30-0-0 (twice)	
Last reseeded:	1 yr. ago	

[Card 5]

Farm Profile:

Grazing system:	None	Rank: _____
Lime applied:	Within 5 yrs.	
Manure applied:	Medium (last 2 yr.)	% increase:
Fertilizer applied:	30-0-0 (twice)	
Last reseeded:	> 5 yrs. ago	

[Card 6]

Farm Profile:

Grazing system:	None	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	None (last 2 yrs.)	% increase:
Fertilizer applied:	None (this season)	
Last reseeded:	> 5 yrs. ago	

[Card 7]

Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	Within 5 yrs.	
Manure applied:	None (last 2 yrs.)	% increase:
Fertilizer applied:	15-15-15 (once)	
Last reseeded:	> 5 yrs. ago	

[Card 8]

Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	None (last 2 yrs.)	% increase:
Fertilizer applied:	30-0-0 (twice)	
Last reseeded:	> 5 yrs. ago	

[Card 9]

Farm Profile:

Grazing system:	None	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	Medium (last 2 yr.)	% increase:
Fertilizer applied:	15-15-15 (once)	
Last reseeded:	> 5 yrs. ago	

[Card 10]

Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	None (last 5 yrs.)	
Manure applied:	Medium (last 2 yr.)	% increase:
Fertilizer applied:	30-0-0 (twice)	
Last reseeded:	1 yr. ago	

[Card 11]

Farm Profile:

Grazing system:	Rotational	Rank: _____
Lime applied:	Within 5 yrs.	
Manure applied:	None (last 2 yrs.)	% increase:
Fertilizer applied:	30-0-0 (twice)	
Last reseeded:	> 5 yrs. ago	

[Card 12]

APPENDIX D

Pasture Data Collection Forms

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[illegible]

Herd ADLIC ID: ____________ Name: ______________________ Date of visit: ____________________ Investigator: EH / AF (Circle one)

Field ID	Size (ac.)	Access[1]	# of strips	Days / strip or field	First day on field	Type[2]	Hay or silage (0/1)[3]	Fertilizer (last 12 mos.)				H_2O in field (0/1)	Manure[5]	Dist. to mid-field (m)	Lime[6] (0/1)	Sward density[7]	Clipped[8] (0/1)	Last day[9]	Re-seed[10]	Date of switch[11]
								(0/1)	# of app'n	rate (lb/ac)	type[4]									

1 1= Continuous, 2= Rotational, 3= Strip-grazed, 4= Forward strip-grazed
2 1=perennial pasture, 0=annual ryegrass
3 (0/1) in all situations; 0=no, 1=yes
Cut of hay or silage removed prior to grazing access
4 Use fertilizer N-P-K formula notation; "xx-xx-xx"
5 Manure mechanically applied in last 2 yrs; 0=none, 1=light, 2=med, 3=heavy.
6 Lime application in last 5 yr; 1=yes, 0=no.
7 Sward density; 1= Normal, 2= Below, 3= Above average.
8 Field top clipped this year; 1=yes, 0=no.
9 Last day of use by lactating cows, if not used to the end of the season.
10 Last known (or guesstimated!) year of seeding.
11 Date field was switched from rotation or strip grazing to continuous use.

[illegible]

Herd ADLIC ID: ____________ Name: ________________________ Date of visit: ______________________ Investigator: EH / AF (Circle one)

Field ID	Size (ac.) / Uniformity	HEIGHT (cm.) / LEGUME DENSITY (% BIOMASS) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

APPENDIX E

Relationship Between Sward Height and Herbage Organic Matter

Figure A4.1. Quadratic equation fitted to sward height/herbage organic matter data (see Table A4.1) from Johnson (1). Y= -903.9 + 201.36*height -3.31*(height^2). $P<.001$, $R^2 = .99$.

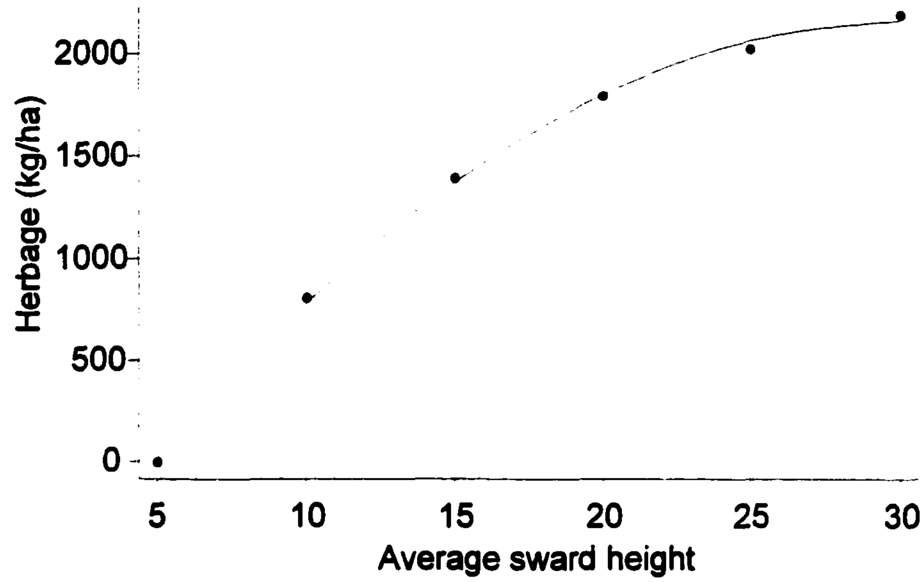

Table A4.1 Organic Matter yield (kg ha^{-1}) by sward layer from Johnson (1).

Sward Layer (X)	X^2	Mean Organic Matter Yield (kg ha^{-1})	Cumulative Organic Matter above 5 cm. (kg ha^{-1})
0-5 cm. (5)	25	1412	0
5-10 cm. (10)	100	805	805
10-15 cm. (15)	225	586	1391
15-20 cm. (20)	400	403	1794
20-25 cm. (25)	625	228	2022
25-30 cm. (30)	900	166	2188

Reference

1. Johnson, J.E. 1991. Sward height in grazing management. M.Sc. thesis, University of Guelph, Guelph, ON., Canada

APPENDIX F

Lactating Cow Ration Data Collection Form

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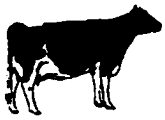

LACTATING COW RATION

THE SUMMER-FALL SLUMP PROJECT.

FARM ADLIC ID:____________ NAME:________________ DATE:__________

PAGE of DATA COLLECTED BY:

DEFINITIONS:

HIGH PRODUCER: more than ______________ kg milk/day

LOW PRODUCER: less than ______________ kg milk/day

DESCRIPTION OF FEED	AMOUNT FED PER DAY (specify units!!)	LAB ID.
FEED :____________________	HIGH PRODUCERS: ______________	
	AVERAGE PRODUCERS: ______________	
Vintage:____________________ Sample taken O Recent analysis available O Study ID:	LOW PRODUCERS: ______________	
FEED :____________________	HIGH PRODUCERS: ______________	
	AVERAGE PRODUCERS: ______________	
Vintage:____________________ Sample taken O Recent analysis available O Study ID:	LOW PRODUCERS: ______________	
FEED :____________________	HIGH PRODUCERS: ______________	
	AVERAGE PRODUCERS: ______________	
Vintage:____________________ Sample taken O Recent analysis available O Study ID:	LOW PRODUCERS: ______________	
FEED :____________________	HIGH PRODUCERS: ______________	
	AVERAGE PRODUCERS: ______________	
Vintage:____________________ Sample taken O Recent analysis available O Study ID:	LOW PRODUCERS: ______________	
FEED :____________________	HIGH PRODUCERS: ______________	
	AVERAGE PRODUCERS: ______________	
Vintage:____________________ Sample taken O Recent analysis available O Study ID:	LOW PRODUCERS: ______________	

APPENDIX G

Prediction of Dry Matter Intake & 305-day Milk Production

Formula to predict **dry matter intake** derived from table 6.1, *Nutritional Requirements of Dairy Cattle* (1).

DMI = 2.445 + (.0118 * WEIGHT) + (.3687 * 4%FCM)

Formula to predict energy and crude protein requirements, from table 6.3 (1).

DE = ((GRAZE * (4.53 + (.024 * WEIGHT))) + ((.66 + (.19 * FAT%)) * KGMILK)
CP = (152.11 + (422 * WEIGHT)) + ((43.6 + (11.54 * FAT%)) * KGMILK)

where:
DMI = dry matter intake (kg/day)
WEIGHT = cow live weight (kg)
4%FCM = 4 percent fat correct milk, where
4%FCM = (.4 * actual_production) + (15 * kg_of_milk_fat)
GRAZE = 1.15 for grazing herds, 1 for confined herds
KGMILK = actual milk production
FAT% = fat concentration in milk

Calculation of **305-day milk production** based on genetic indices:

305MILK = BREED + (GENINDEX * KGPT * 2)

where:
BREED = 8848 for Holsteins, 6966 for Aryshires
GENINDEX = herd average genetic index
KGPT = 53 if Holsteins, 40 if Aryshires

Reference

1. National Research Council. 1988. *Nutrient Requirements of Dairy Cattle*. 6th ed. Washington, D.C.: National Academy Press.

APPENDIX H

Weighting Matrix Used to Calculate Kappa

Figure H1. Weighting matrix used to calculate weighted kappa; to assess agreement in body condition scores assigned to 99 lactating dairy cows by 2 investigators (BCS1, BCS2).

BCS1 \ BCS2	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25
1.25	1.0	0.66	0.33	0	0	0	0	0	0	0	0	0	0
1.5	0.66	1.0	0.66	0.33	0	0	0	0	0	0	0	0	0
1.75	0.33	0.66	1.0	0.66	0.33	0	0	0	0	0	0	0	0
2	0	0.33	0.66	1.0	0.66	0.33	0	0	0	0	0	0	0
2.25	0	0	0.33	0.66	1.0	0.66	0.33	0	0	0	0	0	0
2.5	0	0	0	0.33	0.66	1.0	0.66	0.33	0	0	0	0	0
2.75	0	0	0	0	0.33	0.66	1.0	0.66	0.33	0	0	0	0
3	0	0	0	0	0	0.33	0.66	1.0	0.66	0.33	0	0	0
3.25	0	0	0	0	0	0	0.33	0.66	1.0	0.66	0.33	0	0
3.5	0	0	0	0	0	0	0	0.33	0.66	1.0	0.66	0.33	0
3.75	0	0	0	0	0	0	0	0	0.33	0.66	1.0	0.66	0.33
4	0	0	0	0	0	0	0	0	0	0.33	0.66	1.0	0.66
4.25	0	0	0	0	0	0	0	0	0	0	0.33	0.66	1.0

APPENDIX I

Cutoff values

The following method was used to identify cutoff values for the listed statistics and to identify potentially influential observations (4):

Studentized (jackknife) residuals: should be approximately normally distributed; i.e., $N(0,1)$ - no more than 5 percent of values should be greater than 1.96.

Leverage: $(2 \times (k+1))/n$

Cook's Distance: a conservative cutoff value, 4/n, was used (2)

DFITS: $2 \times (k/n)^{1/2}$ (1)

Welsch Distance: $3 \times (k)^{1/2}$ (3)

DFBETA: $|DFBETA_i| > 2 \times ((n)^{1/2})^{-1}$ (1), although a cutoff value of 1 has also been suggested (2).

where: k = number of independent variables (including the intercept) in regression model and,
n = number of observations

References

1. Belsley D.A., E. Kuh, and R.E. Welsch. 1980. *Regression Diagnostics*. New York: John Wiley & Sons.

2. Bollen, K.A., and R.W. Jackman. 1990. Regression diagnostics: an expository treatment of outliers and influential cases. In *Modern Methods of Data Analysis*. ed. J. Fox, and J.S. Long. Newbury Park: Sage Publications.

3. Chatterjee, S. and A.S. Hadi. 1986. Influential observations, high leverage points, and outliers in linear regression. Stat. Sci. 1:379.

4. StataCorp. 1997. *STATA Reference Manual Release 5*. College Station, TX., Stata Corporation.

APPENDIX J

Correlation Matrix - Chapter 8, Model 1

	MINMAX	A	B	C	D	E	F	G	H	AH	A_c	A_cH
MINMAX	1.000											
A	0.489	1.000										
B	0.391	0.078	1.000									
C	-0.494	-0.243	-0.312	1.000								
D	0.341	0.211	0.017	-0.262	1.000							
E	0.423	0.178	0.167	-0.218	0.109	1.000						
F	-0.579	-0.188	-0.284	0.161	-0.137	-0.165	1.000					
G	0.092	0.130	-0.018	0.133	0.205	0.134	-0.090	1.000				
H	0.140	-0.213	-0.049	0.054	-0.212	0.174	0.042	0.048	1.000			
AH	0.043	-0.036	-0.087	0.087	-0.209	0.217	0.042	0.044	0.953	1.000		
A_c	0.489	1.000	0.078	-0.243	0.211	0.178	-0.188	0.130	-0.213	-0.036	1.000	
A_cH	0.322	0.588	-0.117	0.102	0.031	0.121	-0.003	-0.016	-0.250	0.054	0.588	1.000

MINMAX seasonal pattern of milk production
A daily kg. non-forage dry matter cow^{-1}
B Percentage of daily DM req'ts from stored feeds
C bulk milk *Ostertagia ostertagi* optical density
D housing - tie stall / free stall (0/1)
E regular herd health - yes / no (0/1)
F difference in average days-in-milk (Nov. - June)
G other livestock on farm - yes / no (0/1)
H potable water at pasture (0/1)
AH interaction term (A * H)
A_c daily kg. non-forage DM cow^{-1} - centered about mean
A_cH interaction term (A_c * H)