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DAIRY CALF MANAGEMENT, MORBIDITY AND MORTALITY IN ONTARIO HOLSTEIN HERDS. I. THE DATA

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ABSTRACT

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Heifer calf management practices and clinical outcomes were studied on 104 randomly selected Holstein dairy farms in southwestern Ontario between October 1980 and July 1983. Data were collected at both the farm level (all farms) and the individual calf level (1968 calves, 35 farms).

Farm-level management data were collected by means of questionnaires and farm visits. Calf-level management data were recorded by farmers on forms provided. Treatments for disease and mortality data were recorded by the farmers on the calves up to the age of weaning, the age at which calves were no longer fed milk or milk substitutes on a regular basis.

Farm size ranged from 23 to 154 calvings per year. Farm-level mortality rates per six-month season (winter/summer) were skewed, with a mean of about 6%, a median of zero, and a range of 67%. Morbidity rates were similarly skewed. Four percent of liveborn heifer calves died, 20% were treated for scours, and 15% were treated for pneumonia before the age of weaning.

Stated farm policies on calf rearing were implemented to varying degrees on different farms, as estimated from individual calf data. This posed particular problems for interpreting farm-level data, since the danger of committing an ecologic fallacy was high. The data set described in this paper formed the basis for an observational study of the interrelationships of heifer calf management and clinical outcomes.

INTRODUCTION

Over the past 30 years, a large body of literature has accumulated on the anatomical and physiological development of the young calf. Prenatal care of the dam, neonatal behaviour, immunoglobulin absorption, nutritional and feeding requirements, and various housing strategies, have all been studied

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under experimental conditions. Using this literature, supplemented by field surveys, studies on the genetics of calving ease and on rural sociopsychology, various authors have attempted to formulate what appear to be scientifically rational dairy calf rearing programs (Appleman and Owen, 1971, 1975; Oxender, 1979; Roy, 1980a, b; Le Blanc, 1981; Hancock, 1983a; Waltner-Toews, 1984). Nevertheless, the effectiveness of these programs in reducing calf morbidity and mortality in the field remains to be demonstrated.

Approaching the problem of neonatal dairy calf morbidity and mortality from a different perspective, other authors have set out to document the nature and magnitude of the problem in the field, in both biological and economic terms, in order to convince farmers and veterinarians of the need for scientifically rational calf rearing programs (Martin and Wiggins, 1973; Kilkenney, 1975; House, 1978; Aalund, 1979). These studies have relied on various sources of data, much of it collected for other purposes, and not all of it appropriate for estimating the population parameters needed to carry out the desired calculations. True estimates of calf morbidity and mortality are most appropriately derived from statistically and scientifically sound descriptive observational studies in the populations of interest.

The research study described in this paper was designed, firstly, to describe patterns of calf morbidity and mortality, management practices, and calf-related drug use on Holstein dairy farms in southwestern Ontario. Secondly, the inter-relationships of these variables at both the farm and the individual calf level were studied. Within this analytical framework, specific hypotheses were formulated relating to preventive treatments given to the dam, calving management, care of the newborn calf (including methods and timing of colostrum feeding and the administration of preventive treatments), and care of the calf from birth to weaning, particularly with regard to factors such as housing and feeding. Finally, some of the possible long-term sequelae of calfhood morbidity were evaluated. The overall objective of the research was to identify methods of calf husbandry associated with decreased morbidity, mortality and drug use in order to provide a rational basis for future calf management recommendations to dairy farmers.

This paper, the first in a series of four, describes the manner in which this observational study was designed and implemented, and summarizes, in a descriptive fashion, the basic results. Other papers, both those included in this series and some appearing elsewhere, will describe in more detail the findings of the study.

MATERIALS AND METHODS

Study population

This research was part of the Wintario Dairy Project, a three-year integrated, multi-disciplinary observational study of dairy farms in southwestern Ontario (Meek and Stone, 1983; Meek et al., 1985).
Project herds were selected from seven counties in southwestern Ontario: Bruce, Grey, Huron, Oxford, Perth, Waterloo, and Wellington. One of the herds was registered in Oxford county but was geographically situated in Middlesex county. The farms on these counties were chosen as candidates for the project because they were accessible for data collection from Guelph, and were considered to be representative of Ontario dairy farms in general.

The list from which the project farms were selected consisted of all the dairy farms in the above counties where Holstein cattle were kept, and on which the producers had been enrolled for at least five years on the supervised recording program of the Ontario Dairy Herd Improvement Corporation (ODHIC), or on the Record of Performance (ROP) program with milk samples centrally processed. It was expected that these farmers would be accustomed to recording reproductive and milk production data and hence might be more open to participating in a research study than other dairy farmers.

From a national standpoint, about one-third of Canada's dairy production is centred in Ontario. However, at the time the study was undertaken, only about half of Ontario dairy farmers were enrolled on ODHIC or ROP. Hence the sampling frame was probably biased towards the better-managed dairy farms in Ontario. The dairy farmers represented in this study could be expected to be leaders within the dairy industry, and perhaps be more receptive to heeding the results of recent research than other dairy producers. Characteristics of the farms enrolled in this study are described in more detail later in this paper.

From the original list, 110 farms were randomly selected by means of a computerized random number generating program. Letters describing the project and inviting farmers to participate were sent to the selected producers. More than three-quarters of those initially approached responded favourably. For each negative response, an alternate farm was randomly selected, until 110 producers had agreed to participate in the study. A series of meetings was then arranged with groups of these producers in order to explain the study in more detail. Data collection commenced in the autumn of 1980. The rate of loss or withdrawal over the two and one-half year period of the study was low. For various reasons, including a farm fire and a farm sale, six farmers withdrew during the first winter. By the spring of 1983, when data collection ceased, 100 farms remained on the study, although complete calf data were available for only 87 of those.

Of the 110 participating farms 38 were randomly assigned to an “intensive” observation group. Thirty-five of these completed data recording for the first winter, and 33 for the final winter of the project. On the intensive farms, data were recorded for each animal. Numbered ear tags or neck chains were provided to identify all heifer calves at birth. Three of the smaller farm owners chose to identify their calves by name only.

On the remaining farms, designated “extensive” farms, calves were identified as heifers or bulls, and data were recorded at the farm level only. The
geographic distribution of the farms which kept calf records, both intensive and extensive, is displayed in Table I. Initially, bull calf information was collected at the farm level on all farms. This was discontinued before the end of the first year due to large variations within and between farms on the length of keep and the quality of data recording, as well as to minimize the paperwork required of the farmers.

TABLE I

Geographic distribution of Holstein dairy herds in southwestern Ontario keeping heifer dairy calf records for the Wintario Dairy Project, 1980–83

| County    | Initiala | Extensive | Total | Finalb | Extensive | Total |
|-----------|----------|-----------|-------|--------|-----------|-------|
|           | Intensive | Extensive |       |        |           |       |
| Bruce     | 3         | 16        | 19    | 3      | 11        | 14    |
| Grey      | 5         | 6         | 11    | 5      | 5         | 10    |
| Huron     | 3         | 13        | 16    | 3      | 12        | 15    |
| Oxford    | 11        | 10        | 21    | 10     | 8         | 18    |
| Perth     | 8         | 12        | 20    | 7      | 9         | 16    |
| Waterloo  | 2         | 1         | 3     | 2      | 1         | 3     |
| Wellington| 3         | 10        | 13    | 3      | 7         | 10    |
| Middlesex | 0         | 1         | 1     | 0      | 1         | 1     |
| Total     | 35        | 69        | 104   | 33     | 54        | 87    |

a Enrolled on project and completing data recording for winter of 1980–81.
b Completed calf data collection phase of project, summer 1983.
c Farm project classification, see text for explanation.

Observations were recorded on calves by the farmer from the time the calves were born until they were weaned, the latter being defined as the time when calves were no longer fed milk or milk substitute on that farm. On the intensive farms, data continued to be collected on individual calves beyond weaning, thus allowing for the evaluation of some long-term effects of calfhood experience.

For purposes of data recording and analysis at the farm level, each 12-month period was divided into two ‘seasons’, with the first winter being slightly truncated to give farmers adequate time to become accustomed to keeping the appropriate records. The five seasons of the study were thus as follows: 1 January 1981–15 May 1981 (Winter 1); 16 May 1981–15 November 1981 (Summer 1); 16 November 1981–15 May 1982 (Winter 2); 16 May 1982–15 November 1982 (Summer 2); and 16 November 1982–15 May 1983 (Winter 3). Although all farms were used for descriptive purposes, only those farms with at least two live heifer calves born during a given season were included in the analysis of management effects.
Data collection: management factors

Technicians of the Wintario Dairy Project visited each herd about 10 times per year throughout the study. Also, the author periodically visited all farms. Some of the farms participated in a vaccine field trial and were visited more frequently during the winter of 1982–83. Details of this latter field trial are discussed elsewhere (Waltner-Toews et al., 1985).

All farms were visited before mid-December 1980, their calf rearing facilities were examined, and a 15-page, 84-question survey on calf management practices was administered, by the author, in a personal interview. This questionnaire had been pre-tested on veterinary colleagues and on a group of dairy farmers, not involved in the study, near Barrie, Ontario. As a result of these pre-tests, parts of the questionnaire were extensively re-written. At the end of the first year of data collection, a review questionnaire containing 12 questions from the original questionnaire was mailed to each farm. Completed questionnaires were returned by mail or via the Wintario project technicians at their regular visits. For ease of final coding, and because most husbandry factors are by nature qualitative (housing and feed types, for instance), all questions on both questionnaires were structured to yield categorical answers. At the end of the study, as part of a more general management survey, dairymen were asked to note any recently implemented calf management policy changes. These questionnaires, modified by information on policy changes gleaned via notes, phone calls and farm visits throughout the study, formed the basis of the farm-level management data set.

The validity of the management data was checked in two ways. Firstly, calf housing, and sometimes feeding and other practices, could be assessed during inspection of the premises, both at the initial farm visit, and during later visits by the project technicians. Secondly, at the end of the study, farm-level management classifications of intensive farms (based on questionnaires) were compared to actual practices on those farms (based on individual calf records). For instance, farms were classified according to whether or not farmers said they routinely administered vitamins (Yes) or not (No) to newborn calves during the summer. Then, based on individual calf records, the proportion of newborn calves actually given vitamins was calculated for each farm. The mean proportion of calves receiving the vitamins in the Yes category was then contrasted with the mean proportion of calves given vitamins in the No category, using a Student’s t-test. Since farm management policies sometimes changed from year to year, only data collected between 16 November 1981 and 15 November 1982 were used for this purpose.

Farmers on intensive farms were provided with 'calf birthday forms'. These forms were originally provided on a tear-off pad, and contained spaces for animal identification, date of birth, sire and dam identification, and recording of prepartum injections to the dam such as vaccines or selenium. Check-offs were also included for place, ease and time (i.e., day or night) of
calving, navel treatments, and timing and method of first colostrum feeding. At the end of the first year, these forms were modified. Thereafter they were printed on stiff cardboard, to be kept in a 3-ring binder. The daily log sheet (see next section) was printed on the back of each calf birthday form, so that all information on each calf could be kept in one place. Specific changes were also made in the content of the form. Under calving ease, the unassisted category was subdivided into attended and not attended. The check-off on type of colostrum was deleted, and spaces were added for heart-girth measurements, weaning date, date of removal of the calf from the dam, and type of calf housing provided.

Data collection: response variables

Daily log sheets were provided to all farms. These consisted of sheets on a tear-off pad, with spaces for animal identification, date, event (birth, disease, death, sale, etc.) and treatment (type and frequency). On the extensive farms, these forms were used unchanged throughout the study. On the intensive farms, as mentioned earlier, these forms were integrated with the calf birthday forms part-way through the study. Data on morbidity and drug use were thus based primarily clinical diagnoses by the dairymen, and true morbidity was estimated by the farmers' treatments for disease. Farmers categorized the reason for treatment, when possible, as scours, pneumonia, or 'other reasons', which included such things as navel ill and unspecified illnesses. Part-way through the study, farmers on the intensive farms were provided with measuring tapes to take heart-girth measurements of calves at birth, and again at two weeks and weaning (Coburn Weight-by-breed Dairy Cow Tape, The Coburn Co., Whitewater, WI 53190, U.S.A.). These measurements were used to estimate weights and weight gains.

Data storage and validation: methods

All individual calf data and all outcome data were stored in two computer record-keeping files, using a commercially available data management system, MABRA (Sharp, 1980, 1981). The 'birthday' file contained the individual calf birthday form data and the 'event' file contained the log-sheet events from both intensive and extensive farms.

At the end of the study, 10 farms were randomly selected from the complete list of intensive and extensive farms and all paper records were checked against computer files. For intensive farms, the birthday and event files were linked, and checks were made for duplications, misspellings and other mismatches between the files. For each calf in the birthday file, where applicable, age (in days) at death, sale, and first treatment for all diseases (including scours and pneumonia), and specifically for scours and pneumonia, were calculated and recorded.

In this study, the terms 'crude morbidity' and 'all diagnoses' are used inter-
changeably to refer to a pooled morbidity category, which includes all calves treated therapeutically, for whatever reason. Preventive treatments were similarly recorded. Preventive treatments to calves, at both the farm and the individual animal level, were defined as treatments administered to calves in the absence of recognizable disease. Most of these preventive treatments were administered to calves at birth or shortly thereafter. The age of a calf less than or equal to one day old was considered to be one day, greater than one up to two, two days, and so on.

Where possible, days to removal from dam, and days to weaning were also calculated. Any negative ages that resulted from these calculations were checked and corrected or deleted, as appropriate. Likewise, all deaths, sales and first treatments beyond the calculated age at weaning were corrected or deleted, as appropriate. All days to removal from dam beyond four days were checked against paper records and corrected if necessary.

The number of days of treatment prior to weaning, and the drugs used at first treatment, were also recorded for each calf in the expanded birthday file.

Questionnaire data were entered into fixed format computer files in the Conversational Monitor System (CMS) of IBM (1977). At the end of the survey, these files were restructured to conform to the five, six-month seasonal time periods of the study. If a farmer had changed his management during a six-month period, his farm was classified according to the policy followed for the greatest proportion of the given season. Farm-level outcomes were calculated from the Event file for each of the five seasons. For each period, for each farm, the number of calves born, the number dead, and number treated (all diagnoses combined), and the number treated for scours and pneumonia separately, were calculated. This information was then combined with the appropriate questionnaire file.

Finally, two large files were constructed: 'summer', containing all data pertaining to the two summer periods; and 'winter', containing all the data pertaining to the three winters. A variable called YEAR identified each block of information within each of the two files according to the year in which it occurred (80–81, 81–82, 82–83).

During each of the first two years of the study, field technicians of the Wintario Dairy Project were asked to rate all farmers on record keeping practices (i.e. completeness of records), and on this basis to place them into three categories: poor, good, excellent. This was repeated for intensive farms only in the final year of the study. These ratings, coded as one, two and three, respectively, were included in all multivariate farm-level analyses.

Record keeping was also evaluated by comparing heifer calf treatment rates before, during and after the vaccine field trial on three groups of farms. Farms in Part A of the trial were subjected to intense scrutiny and veterinary visits every two weeks from late November of 1982 until early March, 1983. Farms in Part B of the trial were intensive farms, and hence kept individual calf records; they were visited about every five weeks during the period of
the field trial. Finally, an 'other' category included the extensive farms, none of them involved in the field trial. These farms were visited by the Wintario Dairy Project technicians on their regular rounds. These comparisons would be expected to give an indication of the effects of degree of supervision on intensity of record keeping and/or treatment, and the degree to which this might distort the estimation of true morbidity.

Data analysis

Statistical analyses were performed using the Statistical Analysis System (SAS, 1982), Biomedical Data Programs (BMDP) (Dixon, 1983), plus programs written in a programming language (APL) by Dr I.R. Dohoo. All tests of statistical significance were carried out at the \( P < 0.05 \) level unless otherwise stated.

The variable 'treatment days per calf' was calculated, for each farm, as (number of calf-days of treatment) ÷ (number of live-born calves) for each of the six-month seasons, and was used as an indicator of calf morbidity at the farm level. This measure does not differentiate between a few calves subjected to lengthy treatments or many calves treated each for a short time. In order to estimate how treatment days per calf translated into the proportion of calves treated per farm, individual calf data from intensive farms were used, and the proportion of calves treated was regressed on treatment days per calf for the period from 1 January 1981 to 15 May 1983.

**TABLE II**

| Intensity of supervision | June— Aug. 1982 | Sept.— Nov. 1982 | Dec. 1982— Feb. 1983 | March— May 1983 |
|--------------------------|----------------|------------------|----------------------|----------------|
| Part A                   | 1.51           | 2.12             | 2.91                 | 1.12           |
| Part B                   | 0.67           | 1.47             | 1.47                 | 1.20           |
| Other                    | 0.79           | 1.32             | 0.95                 | 0.50           |

\( a \) Includes only farms in each time period with at least one heifer calf born. The rates were calculated as (number of calf treatment days) ÷ (number of heifer calves born) for each time period.

\( b \) Farms subjected to frequent veterinary visits as part of vaccine field trial during December 1982 to February 1983. The farms were originally selected for inclusion in the trial because of higher than average calf treatment rates.

\( c \) Intensive farms, included in vaccine field trial at farm randomization level, and hence subjected to less intensive scrutiny than those in Part A.

\( d \) Farms not involved in the vaccine field trial.
RESULTS

Comparison of computer records with paper records, and examination of negative ages, misspellings and other mismatches indicated few problems with data entry and storage.

Treatment days per calf for heifer calves belonging to various subsets of farms related to the vaccine field trial are displayed in Table II. Treatment days per calf were higher for calves on farms in Part B of the trial than in those not involved in the trial, and were highest in those farms involved in Part A of the trial. This was anticipated, since farms in Part A were selected for the field trial on the basis of expected higher calf morbidity. What is noteworthy in Table II, however, is that the same general patterns of disease

TABLE III

Proportion of dams and heifer calves known to be subjected to particular management events on Holstein dairy farms in southwestern Ontario with different stated management policies, 1981–1982

| Policy                                      | Category | Number of farms | Mean % animals positive | $P$ value of difference $^b$ |
|---------------------------------------------|----------|-----------------|-------------------------|-----------------------------|
| Cows routinely given vitamin injections prepartum: winter | Yes      | 8               | 47.6                    | < 0.03                      |
|                                             | No       | 26              | 5.5                     |                             |
| Cows routinely given vitamin injections prepartum: summer | Yes      | 6               | 63.6                    | < 0.001                     |
|                                             | No       | 27              | 6.3                     |                             |
| Newborn calves routinely given vitamin injections: winter | Yes      | 10              | 38.5                    | < 0.06                      |
|                                             | No       | 22              | 5.8                     |                             |
| Newborn calves routinely given vitamin injections: summer | Yes      | 7               | 38.1                    | < 0.08                      |
|                                             | No       | 26              | 3.5                     |                             |
| Newborn calves routinely given antimicrobials: winter | Yes      | 6               | 44.6                    | < 0.005                     |
|                                             | No       | 28              | 6.8                     |                             |
| Newborn calves routinely given antimicrobials: summer | Yes      | 5               | 20.0                    | < 0.50                      |
|                                             | No       | 28              | 3.2                     |                             |
| Navels routinely treated on newborn calves | Yes      | 13              | 79.6                    | < 0.001                     |
|                                             | No       | 21              | 13.5                    |                             |
| First colostrum by free choice suckle only | Yes      | 22              | 81.9                    | < 0.001                     |
|                                             | No       | 12              | 18.0                    |                             |
| First colostrum usually given in first 2 h | Yes      | 2               | 43.8                    | < 0.70                      |
|                                             | No       | 32              | 54.2                    |                             |
| Calvings routinely assisted                | Yes      | 31              | 70.5                    | < 0.65                      |
|                                             | No       | 3               | 77.8                    |                             |

$^a$These calculations are based on data collected between 16 November 1981 and 15 November 1982.

$^b$Based on Student’s $t$-tests. See text for explanation.
treatment (higher in autumn and winter than in spring or summer) held, despite differences in intensity of record keeping and/or treatment rates for diseases, for all three groups of farms. This in turn suggests that these data reflect true natural phenomena, rather than artifacts of record keeping.

There was no evidence of any differences, either between years or between intensive and extensive farms, of general record-keeping diligence as measured by the technicians' scores. Overall, the mean record-keeping score was 2.3 on a scale of three. While such an average of ordinal data may have no inherent meaning, it does serve to indicate that record-keeping on these farms was thought to lean toward the good-to-better, rather than the bad-to-worse categories.

The relationship between farm-level policies as stated in questionnaires, and practices as reflected in individual calf birthday forms, are displayed in Table III. Although there were significant differences in the recorded adoption of specified managerial practices at the calf level, between farms with differing stated management policies, these data suggest that a number of the stated policies may have been implemented at the individual calf level less than 50% of the time.

**Descriptive results: individual calf**

There were 1968 live heifer births over the period of the study. Of these, about 20% were treated for diarrhea, 15% were treated for pneumonia (with or without diarrhea), and less than 4% died (Table IV). Based on heart-girth measurements taken on 634 calves, the average birthweight was estimated to

| TABLE IV |
|---|
| Morbidity and mortality rates in 1968 heifer calves on Holstein dairy farms in southwestern Ontario, 1980--83 |

| Percent of first occurrence | Age (days) | Duration (days) |
|-----------------------------|------------|-----------------|
|                             | Mean (SD)  | Median          | Mean (SD)  | Median |
| Crude morbiditya            | 34.96      | 26 (27)         | 16          | 5 (6)  | 3 |
| Scours                      | 20.48      | 16 (16)         | 12          | 3 (3)  | 2 |
| Pneumonia                   | 15.35      | 41 (30)         | 37          | 5 (6)  | 3 |
| Died                        | 3.76       | 33 (35)         | 18.5        | —      | — |

a Crude morbidity includes all diagnoses, including scours and pneumonia. Note that none of these classifications are mutually exclusive. For instance, a calf may have first been treated for scours, then for pneumonia, and finally died. It would thus appear in all four categories. Age and duration were measured in days. Calves were considered to be one day old at birth.
be 45.6 kg. The estimated daily weight gain up to two weeks of age was 0.5 kg (n=148) and up to weaning was 0.7 kg (n=244).

Sixteen bulls, each having sired 25 or more calves, accounted for 52.8% of the bulls used to sire these calves. Factors relating to individual calf management are displayed in Tables V, VI and VII. Most calves were born in indoor calving pens (60%); based on data from the revised birthday forms, almost 40% of births were not attended. Overall, 8-9% of calvings required special assistance (calf jacks, caesarians, abnormal presentations); some manual assistance was given in another 40%. Most calves were born between 6 a.m. and 10 p.m., with difficult calvings no more likely to occur at night than during the day. Most calves did not have their navels treated at birth, and only about 50% of them were known to receive first colostrum within 2 h of being born.

**TABLE V**

Management of 1968 individual heifer calves on Holstein dairy farms in southwestern Ontario, 1980-83: calving ease (%)

| Calving ease                          | Original birthday form (n=1245) | Revised birthday form* (n=723) |
|---------------------------------------|-------------------------------|-------------------------------|
| Not attended                          | 50.3                          | 38.5                          |
| Attended: normal unassisted           |                               |                               |
| Normal assisted (hand pull)           | 39.0                          | 36.5                          |
| Normal assisted (calf jack)           | 6.6                           | 5.8                           |
| Caesarian section                    | 0.2                           | —                             |
| Abnormal presentation (assisted)      | 2.5                           | 2.2                           |
| Unknown                               | 1.5                           | 2.1                           |

*The calf birthday form was revised during the second year of the study. In the revised form, unassisted calvings were subdivided into those that were attended and those that were not attended. The 50.3% in the original birthday form includes all unassisted calvings.

Descriptive results: farm level

The number of calvings resulting in a lactation, per farm, from 1 October 1981 to 30 September 1982, was used as an indicator of farm size. On this basis, farm size ranged from 23 to 154 calvings per year, with a mean of 53 and a median of 45. Seventy-five percent of the farms had 60 or fewer calvings during the year. This means that approximately three-quarters of the study farms had a heifer calf population of fewer than 30 per year, or about two to three heifer calves born per farm, per month.

Farm-level mortality rates and treatment days per calf are displayed in Tables VIII and IX. The fact that only 73 farms were used for calculating the rates in Winter 3 indicates that 14 farms had fewer than two heifer calves
### TABLE VI
Management of 1968 individual heifer calves on Holstein dairy farms in southwestern Ontario, 1980–83: calving management (%)

| Variable                  | Detail                      | Percent of calves |
|---------------------------|-----------------------------|-------------------|
| Place of calving          | Indoor pen                  | 60.2              |
|                           | Stanchion                   | 19.4              |
|                           | Freestall                   | 2.6               |
|                           | Pasture                     | 13.3              |
|                           | Outdoor pen or corral       | 2.1               |
|                           | Other                       | 1.2               |
|                           | Unknown                     | 1.2               |
| Time of calving           | Night (10 p.m. to 6 a.m.)   | 28.6              |
|                           | Day (6 a.m. to 10 p.m.)     | 69.7              |
|                           | Unknown                     | 1.7               |
| Age at first colostrum    | < 2 h                       | 49.8              |
|                           | > 2 h                       | 48.6              |
|                           | Unknown                     | 1.6               |
| Navel treatment           | Not done                    | 60.0              |
|                           | Iodine                      | 22.3              |
|                           | Chlorhexidine               | 8.3               |
|                           | Wound spray                 | 3.8               |
|                           | Creolin                     | 2.4               |
|                           | Other                       | 0.2               |
|                           | Unknown                     | 3.1               |
| Method of first colostrum feeding | Free choice suckle | 25.2 |
|                           | Assisted suckle             | 14.5              |
|                           | Nipple (pail or bottle)     | 7.2               |
|                           | Pail (no nipple)            | 42.6              |
|                           | Drench                      | 3.5               |
|                           | Other                       | 5.2               |
|                           | Unknown                     | 1.8               |

### TABLE VII
Management of 1968 individual heifer calves on Holstein dairy farms in southwestern Ontario, 1980–83: preventive treatments (%)

| Procedure         | Detail               | Percent animals treated |
|-------------------|----------------------|-------------------------|
| Drugs to dam      | Scour vaccine        | 7.6                     |
|                   | Vitamin ADE          | 21.7                    |
|                   | Vitamin D alone      | 2.5                     |
|                   | Selenium (+ vitamin E) | 6.4                |
| Drugs to calf     | Scour vaccine        | 0.6                     |
|                   | Antimicrobials       | 13.6                    |
|                   | Vitamins (unspecified) | 18.1                |
|                   | Selenium (+ vitamin E) | 4.8                |

*Preventive treatments to dam must have been administered < 6 weeks before expected calving date. Preventive treatments to calves were given to calves free of clinical disease. Most of these were administered at birth or very shortly thereafter.*
TABLE VIII

Heifer calf mortality rates, by season, on southwestern Ontario Holstein dairy farms, 1981–83

| Season     | Number of farms | Mean (%) | Median (%) | 75th percentile (%) |
|------------|-----------------|----------|------------|---------------------|
| Winter 1   | 103             | 6.39     | 0.00       | 10.53               |
| Summer 1   | 104             | 6.72     | 0.00       | 8.33                |
| Winter 2   | 103             | 6.50     | 0.00       | 11.11               |
| Summer 2   | 97              | 4.83     | 0.00       | 8.01                |
| Winter 3   | 73              | 3.88     | 0.00       | 1.52                |

* Rates were calculated as (number of calves died) ÷ (number of live-born calves), per farm, per season. This excludes farms with < two births in a given season. See text for full explanation of seasons.

TABLE IX

Treatment days per heifer calf (all diagnoses included) on southwestern Ontario Holstein dairy farms, 1981–83

| Season     | Number of farms | Mean (days) | Median (days) | 75th percentile (days) |
|------------|-----------------|-------------|---------------|------------------------|
| Winter 1   | 103             | 2.04        | 0.94          | 2.23                   |
| Summer 1   | 104             | 0.99        | 0.50          | 1.20                   |
| Winter 2   | 103             | 1.84        | 0.78          | 2.52                   |
| Summer 2   | 97              | 1.00        | 0.57          | 1.47                   |
| Winter 3   | 73              | 1.52        | 0.57          | 1.95                   |

* Rates were calculated as (number of calf days of treatment) ÷ (number of live-born calves) per farm, per season. Excludes farms with < two births in a given season. See text for full explanation of treatment days, as well as of how seasons were structured.

born during that season. The distribution of mortality was skewed at the farm level, that is, in any given six-month period at least half the farmers lost no live-born heifer calves from birth to weaning, with mortality rates ranging from zero to 67%. Farm morbidity rates were similarly skewed, with half the farmers administering less than one treatment day per calf in a given season. This suggests that many farmers had few disease problems with their calves, whereas a few had moderate to severe problems. Correlations of morbidity rates from one season with those of the next indicated significant consistency from season to season and year to year (r values ranged from 0.28 to 0.82). No similar consistency was observed for mortality rates.

Some results of the initial questionnaire on farm management policies are summarized in Tables X to XII. No major changes in policies occurred over the three years of the project. There was a slight shift toward the use of more routine preventive treatments (vaccines, vitamins, antimicrobials) in
both dams and calves, although the increase in vaccine use in the final winter of the study was primarily attributable to participation in the vaccine field trial. In the second year of the study, farmers gave lower estimates about the proportion of calvings they usually attended. For both summer and winter,

**TABLE X**

Heifer calf management policies on 104 Holstein dairy farms in southwestern Ontario, 1980: personnel and housing

|                       | Summer | Winter |
|-----------------------|--------|--------|
| Who raises the calves?| Owner  | 65.4   |
|                       | Family | 31.7   |
|                       | Hired help | 2.9 |
| Where do cows calve?  | Box stall | 37.5 |
|                       | Tie stall | 1.9 |
|                       | Pasture/corral | 59.6 |
|                       | Other | 1.0    |
| Calf housing          | Individual pens | 49.0 |
|                       | Group pens | 22.1 |
|                       | Hutches | 17.3  |
|                       | Other | 11.6   |

*Numbers represent percent of farms in each category.*

**TABLE XI**

Heifer calf management policies on 104 Holstein dairy farms in southwestern Ontario, 1980: preventive treatments

**Use of routine preventive treatments to calves during first three days of life**

|                      | Vitamins | Vaccines | Antimicrobials |
|----------------------|----------|----------|----------------|
| None given           | 70.2     | 94.2     | 79.8           |
| Winter only          | 7.7      | 3.8      | 3.8            |
| Winter and summer    | 22.1     | 1.9      | 16.3           |

**Use of routine preventive treatments to dams within six weeks of expected calving date**

|                      | Vitamins | Vaccines |
|----------------------|----------|----------|
| None given           | 77.9     | 96.2     |
| Winter only          | 0.6      | 1.0      |
| Winter and summer    | 12.5     | 2.9      |

*Numbers represent percent of farms in each category.*
there was a shift away from group pens (which initially comprised almost one quarter of calf housing systems) to hutches and individual pens. There was also a decreased use of both milk replacer and milk, and an increased use of sour colostrum, as the primary calf feed.

In the regression of the proportion of calves treated on treatment days per calf, the best fit to the data (based on inspection of residuals) was obtained using natural log transformations of both variables, with the model being $Y = 0.55X - 1.21$, where $Y$ is the natural logarithm (ln) of the proportion of calves treated and $X$ is the ln of the number of treatment days per calf. The $R^2$ for the model was 0.755 ($F=101.4$, with 1,33 df; $P<0.0001$). In this

**TABLE XII**

Heifer calf management policies on 104 Holstein dairy farms in southwestern Ontario, 1980: feeding practices

| How do calves get their first colostrum? | 43.3 |
|----------------------------------------|------|
| Natural suckling (± supplementation)  |      |
| Nursing bottle/pail                    | 32.7 |
| Regular pail                          | 15.4 |
| Other                                  | 8.6  |

| What is the calf's main feed?          | 63.5 |
|----------------------------------------|------|
| Fresh milk                             |      |
| Discarded milk                         | 1.9  |
| Milk replacer                          | 23.1 |
| Colostrum                              | 4.8  |
| Combinations                           | 6.7  |

| Calf starter: begins when?             |      |
|----------------------------------------|------|
| < 2 weeks                               | 81.7 |
| 2–3 weeks                               | 12.5 |
| > 3 weeks                               | 5.9  |

| Calf starter is?                       | 62.5 |
|----------------------------------------|------|
| Commercial calf starter                |      |
| Home-mixed calf starter                | 8.7  |
| Dairy cow ration                       | 25.0 |
| Other                                  | 3.8  |

| When is hay offered?                   |      |
|----------------------------------------|------|
| < 2 weeks                               | 42.3 |
| 2 < 4 weeks                             | 24.0 |
| 4 < 6 weeks                             | 16.3 |
| > 6 weeks                               | 17.3 |

| At what age are calves weaned?          |      |
|----------------------------------------|------|
| 4 < 6 weeks                             | 11.5 |
| 6 < 8 weeks                             | 25.0 |
| 2 < 3 months                            | 43.3 |
| 3 < 4 months                            | 11.5 |
| > 4 months                              | 8.7  |

*a Numbers represent percent of farms in each category.
model, an increase of one day of treatment days per calf corresponded to an increase of 0.298 in the proportion of calves treated on the farm, that is, an increase of one treatment day per calf corresponded to an increase of about a third of the calves being treated.

DISCUSSION

Given that both the evaluation of calf rearing programs and the demonstration of a need for such programs depend on observational studies, it is essential to critically assess the design and results of studies already carried out, and to design new studies which redress the deficiencies in earlier studies.

In this regard, the selection of study subjects is a key component to consider in the design of observational studies. A descriptive observational study, in which one wishes to estimate population parameters such as calf mortality, requires that a true random sample be taken from the target population, or a population as typical of the target as possible. On the other hand, an analytical observational study designed for hypothesis testing may produce valid results if based on a purposive (nonprobability) sample, although it may suffer from decreased generalizability if the sample study group is not typical of the target population. Ideally, if the random sample is large enough, and one has available the resources required to collect sufficiently detailed information, the descriptive and the analytical objectives can be combined into one study.

Many previous studies of dairy calf management and survival have been structured as analytical studies, where a purposive, or sometimes simply a convenience, sample of farms has been taken in order to test specific hypotheses (Withers, 1952; Willoughby et al., 1970; Lopez-Nieto et al., 1972; Oxender et al., 1973; Ferris and Thomas, 1975; Bakheit and Greene, 1981; Hird and Robinson, 1982; Hancock, 1983b). Some authors have attempted to use results from such studies for inappropriate purposes, for instance, to estimate calf mortality or morbidity in the larger dairy population.

A few researchers have based their studies on random samples, or at least partially random samples (Martin et al., 1975; Leech et al., 1968; Simensen, 1982). By far the best of these studies — indeed probably the most scientifically sound and thorough research on calf mortality and management to appear in the literature to date — is that carried out by Leech et al., in Britain during 1962–63. The senior author of that report has also published a useful critique of the design and implementation of that study (Leech, 1971).

Within the past decade, the computerization of farm records has given researchers convenient access to larger databases. Coupled with cross-sectional mail or interview surveys, these data have served as a base for yet another group of observational studies (Speicher and Hepp, 1973; Hartman et al., 1974; Staples and Haugse, 1974; Bowman et al., 1977; Jenney et al., 1981; Simensen, 1982).
With few exceptions (Withers, 1952; Leech et al., 1968; Willoughby et al., 1970; Bakheit and Greene, 1981) the studies cited have relied on cross-sectional survey information, that is, on a combination of existent farm records and farmers' memories. Some of the biases and pitfalls inherent in these sources of information have been detailed elsewhere (Sackett, 1979). Indeed, at least one of the authors involved in previous calf survey research has commented on the unreliability of these kinds of data (Martin et al., 1975).

One of the main drawbacks of cross-sectional surveys is that the time ordering of management and outcome variables is usually unknown. For example, is a farmer injecting vitamins into his calves because they are scouring, are they souring because they were injected with vitamins, or are the two events simply coincidental? This difficulty usually arises because information has been gathered at the farm level only, making the probability of an ecologic fallacy high (Susser, 1973), that is, to assume that farm-level associations are operative in individuals. Farm-level management and outcome data should be evaluated at the individual-animal level within farms in order to assess the degree to which policies are implemented and hence to evaluate the validity of causal statements.

While some previous researchers (Leech et al., 1968; Willoughby et al., 1970; Ferris and Thomas, 1975; Bakheit and Greene, 1981; Simensen, 1982, 1983; Hancock, 1983b) have collected prospective individual animal data, the confounding role of farm-level variables in individual data analysis has often been ignored. In a few cases this confounding was acknowledged, but the appropriate analytical techniques to control for farm effect were either not available, or not applied. There remains, as well, a great need to integrate data from the two levels of concern (animal vs farm), in order to be able to determine whether calf management policies per se, or the implementation of those policies, are associated with altered calf morbidity and mortality.

The study described in this paper has attempted to draw on some of the strengths and avoid some of the deficiencies of earlier dairy calf management field research. Since the study used a truly random sample of farms already on a record-keeping system, the generalizability of the results may be restricted to those dairy farmers who have already demonstrated an interest in documenting and improving their management. This 'cost', however, was more than offset by the benefit of having available computerized reproduction and production data for the adult cows, as well as by having farmer-participants who were already oriented towards record-keeping systems in general.

The reliability of data used in observational studies has been of concern to many researchers and has been a major point of weakness in the conduct of several previous surveys of calf mortality. In this study, the initial questionnaire included a question on what the farmers perceived to be their usual calf mortality. The answer to this question was then compared with the actual mortality experienced by that farm over the next year. There was no significant relationship between the two figures. This may indicate, on the
one hand, that dairymen are not aware of what their actual calf losses are. On the other hand, this may simply further underline the lack of correlation between mortality rates from year to year.

Evaluation of questionnaire validity based on individual calf records indicated that questions asked of farmers with regard to calf management policy were in general able to separate farmers into management-type groups (Table III). However, the degree to which stated calf management policies were adhered to varied between farms, and between specific practices within farms. This may, at least in part, have been influenced by how different farmers interpreted the questions. The question of when calves receive their first colostrum is, for instance, open to differing interpretations. Farmers may be referring to when they know their calves first received colostrum (perhaps the first milking after calving) or when the calves probably received their first colostrum (which in the case of calves left with dams, could well be within 2 h of birth). Finally, the low rate of implementation of preventive vitamin and antimicrobial administration to calves in particular may reflect the fact that these practices were not recorded as check-offs on the calf birthday form, but required the farmer to make notes in the daily log sheets. Hence the recorded rates may underestimate the true rates.

The differentiation of problem from non-problem farms on the basis of stated calf management procedures is probably valid. The answers to some questions, such as those referring to place of calving, calf housing (validity data not shown), navel treatment of newborn calves, and method of feeding first colostrum (Table III) accurately reflect the real situation. Others, such as those referring to routine administration of vitamins or antimicrobials (and probably by analogy routines and content of calf feeding) differentiate groups of farms with regard to management practices. Nevertheless, given the low rate of implementation of stated farm policy at the calf level, the questionnaire results would be difficult to interpret without data available to clarify them at the individual calf level. Least valid are answers to questions assessing interference at calving and timing of first colostrum, which do not appear to differentiate significantly between recorded implemented farm policies.

The potential unreliability of farm records should not merely provide an occasion to throw up one's hands in despair at the fallibility of farmers, but rather to design studies and implement record-keeping systems which take these factors into account. Overall, it is best if stated management policies are interpreted conservatively, that is, as indicators of general management strategies or farmers 'mind-sets'. If associations found at the farm level are confirmed at the individual animal level, or in an experimental setting, then one can more reliably draw causal inferences.

The computerized reproductive data was used as a check on calving information provided in the written calf record forms, not only with regard to crude numbers of births in a given time period, but also with regard to specific dams and calving dates. The prospective, integrated nature of this pro-
ject, use of standardized calf birthday forms, and periodic visits by technicians and veterinarians all served to enhance the quality of the information gathered.

The mean farm-level mortality rates found in this study are similar to the 7.7% (excluding stillbirths) reported by Speicher and Hepp (1973) for Michigan, but lower than rates reported by Hird and Robinson (1982) from Minnesota (11–13.5%), Hartman et al. (1974) from New York state (15.8–27.2%), or Bowman et al. (1977) from Quebec (13.7%), all of which are comparable dairy farming areas. The use of mean herd rates can be misleading however, since many herds in this study lost no live-born heifer calves at all in a given six-month period, while several farms lost a third to two-thirds of theirs. Presumably similar patterns occur in other studies as well (see for instance, Leech et al., 1968). In this context, the median is perhaps a more appropriate indicator, at least to separate ‘problem’ from ‘non-problem’ farms.

The low actual percentage of individual heifer calves which died over the period of the study (3.76%) emphasizes the degree to which a few ‘problem’ farms can distort herd-level averages. The actual mortality based on individual calf data is almost exactly what was found by Leech et al. (3.74%) and only slightly above rates reported by Bakheit and Greene, and Simensen (both 1.2%). Perhaps, overall, dairy farmers are not experiencing high losses in their calves, especially in areas such as southwestern Ontario where small family farms still constitute the major portion of the dairy industry. Serious attention should therefore be paid to identifying and helping those farmers who are experiencing difficulties in this regard.

Heart-girth measurements were found to be highly variable, within and especially between farms, except perhaps under frequent, periodic supervision such as was provided during the vaccine field trial (Waltner-Toews et al., 1985). Much of the variation between farms could be attributed to differences in tension applied to the tape by different farmers. Simensen (1982) has reported that heart-girth measurements correlate well with calf weights, and are reproducible, if the weight load on the tape measure is defined. In the absence of such a tension-definition (such as occurred in this study) heart-girth measurements could only serve to make crude within-farm comparisons of calf weights. Farm-to-farm measurement variations would be expected to account, in large measure, for the wide range seen in birth weights (23 to 74 kg) and for the fact that the weights reported here were somewhat higher than those reported as ‘normal’ by other authors (Foley et al., 1972; Roy, 1980b). The rates of gain to two weeks and weaning were within the normal range.

Morbidity rates have not usually been measured in field surveys, perhaps due to problems of definition. The clinical treatment rates used to estimate morbidity in this study may be considered to be a measure of intensity and/or duration of treatment and, by proxy, of disease. Within a given geographic area such as southwestern Ontario, where farmers could be expected to have
an overall tendency to treat calves for similar clinical conditions, treatment rates may be as reliable an indicator of true morbidity as any detailed battery of diagnostic tests.

The descriptions of management variables are largely self-explanatory. At the farm level, the low use of routine preventive treatments and the relatively high use of group pens for calves are noteworthy (Tables X and XI). These are consistent, however, with the family farm nature of these enterprises as reflected in farm size and calf-care personnel. It is tempting to conclude that the low use of preventive antimicrobials reflects the ability of the dairymen to control disease problems using other strategies, including, for example, the use of calf hutches. On the other hand, the large proportion (50%) of calves who were not known to receive colostrum within 2 h of birth is somewhat disturbing.

The frequency of abnormal presentations is similar to that reported by Cady and Burnside (1981), as is the frequency of calf pulls and caesarian surgery.

The farm-level year-to-year correlations of outcomes indicate that clinical morbidity, rather than mortality, may be a better marker to identify farms which have calf problems, or on which farmers perceive themselves as having such problems.

Age and seasonal patterns of individual calf outcomes, and the inter-relationships of management and calf survival, will be discussed in subsequent papers in this series.

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REFERENCES

Aalund, O., 1979. Management of the newborn calf: an attempt at an economic analysis. In: B. Hoffman, I.L. Mason and J. Schmidt (Editors), Current Topics in Veterinary Medicine and Animal Science, Vol. 4. Calving Problems and Early Viability of the Calf. Martinus Nijhoff, Boston, pp. 525--538.

Appleman, R.D. and Owen, F.G., 1971. Relationship of the environment, including nutrition, to calf health: a review. Trans. Am. Soc. Agric. Eng., 14: 1083--1094.

Appleman, R.D. and Owen, F.G., 1975. Breeding, housing and feeding management. J. Dairy Sci., 58: 447--464.

Bakheit, H.A. and Greene, J.H., 1981. Control of bovine neonatal diarrhea by management techniques. Vet. Rec., 108: 455--458.

Bowman, J.S.T., Moxley, J.E. and Kennedy, B.W., 1977. Dairy herd management practices and calf mortality. Mimeo presented at the Annu. Meeting Eastern Branch Can. Soc. Anim. Sci., Fredericton, NB.
Cady, R.A. and Burnside, E.B., 1981. Calving ease statistics in Ontario and methods of sire evaluation. Can. J. Anim. Sci., 61: 1102–1103.

Dixon, W.J. (Editor), 1983. BMDP Statistical Software. University of California Press, Berkeley, CA, 734 pp.

Ferris, T.A. and Thomas, J.W., 1975. Management factors influencing calf mortality and blood immunoglobulin levels in Michigan dairy herds. Mich. State Univ. Agric. Exp. Stat. Res. Rep. 271.

Foley, R.C., Bath, D.L., Dickenson, F.N. and Tucker, H.A., 1972. Dairy Cattle: Principles, Patterns, Profits. Lea and Febiger, Philadelphia, PA, p. 423.

Hancock, D.D., 1983a. Epidemiologic diagnosis of neonatal diarrhea in dairy calves. Bov. Proc., 15: 16–22.

Hancock, D.D., 1983b. Studies on the epidemiology of mortality and diarrheal morbidity in heifer calves in northeastern Ohio dairy herds. Ph.D. thesis. Ohio State University, Wooster, OH.

Hartman, D.A., Everett, R.W., Slack, S.T. and Warner, R.G., 1974. Calf mortality. J. Dairy Sci., 57: 576–578.

Hird, D.W. and Robinson, R.A., 1982. Dairy farm wells in southeast Minnesota: the relationship of water source to calf mortality rate. Prev. Vet. Med., 1: 53–64.

House, J.A., 1978. Economic impact of rotavirus and other neonatal disease agents of animals. J. Am. Vet. Med. Assoc., 173: 573–576.

International Business Machines Corporation, 1977. IBM Virtual Machine Facility 1370: CMS Command and Macro Reference, 2nd edn. IBM Corporation, Poughkeepsie, NY.

Jenney, B.F., Gramling, G.E. and Glaze, T.M., 1981. Management factors associated with calf mortality in South Carolina dairy herds. J. Dairy Sci., 64: 2284–2289.

Kilkenny, J.B., 1975. Economic aspects of perinatal ill-health in calves. In: J.M. Rutter, Perinatal Ill-Health in Calves. Commission of the European Communities, Brussels, pp. 173–186.

Le Blanc, M.M., 1981. Management of calf herd programs. Vet. Clin. North Am. Large Anim. Pract., 3: 435–445.

Leech, F.B., 1971. A critique of the methods and results of the British national surveys of disease in farm animals. Br. Vet. J., 127: 511–522, 587–592.

Leech, F.B., Macrae, W.D. and Menzies, D.W., 1968. Calf wastage and husbandry in Britain 1962–63. Animal Disease Surveys Report No. 5. Her Majesty’s Stationery Office, London.

Lopez-Nieto, E., Crenshaw, G., Franti, C.W. and Wiggins, A.D., 1972. A San Juaquin and Tulare County study of diarrhea in dairy calves. Calif. Agric., June: 6–9.

Martin, S.W. and Wiggins, A.D., 1973. A model of the economic costs of dairy calf mortality. Am. J. Vet. Res., 34: 1027–1031.

Martin, S.W., Schwabe, C.W. and Franti, C.E., 1975. Dairy calf mortality rate: characteristics of calf mortality rates in Tulare County, California. Am. J. Vet. Res., 36: 1099–1104.

Meek, A.H. and Stone, J.B., 1983. A systems approach to dairy farm management. Highlights of Agric. Res. (Ont.), 6(1): 4–6.

Meek, A.H., Martin, S.W., Stone, J.B., McMillan, I., Britney, J.B. and Grieve, D.G., 1985. The relationship among current management systems, production, disease and drug usage in Ontario dairy farms: the Wintario Dairy Project. Can. J. Vet. Res., 50: 7–14.

Oxender, W.D., 1979. Prevention of calf losses and infertility in cows. Compend. on Cont. Ed., 1(9): 59–615.

Oxender, W.D., Newman, L.E. and Morrow, D.A., 1973. Factors influencing dairy calf mortality in Michigan. J. Am. Vet. Med. Assoc., 162: 458–460.

Roy, J.H.B., 1980a. Factors affecting susceptibility of calves to disease. J. Dairy Sci., 63: 650–664.

Roy, J.H.B., 1980b. The Calf, 4th edn. Butterworths, London, 442 pp.
Sackett, D.L., 1979. Bias in analytic research. J. Chron. Dis., 32: 51–63.
SAS Institute Inc., 1982. SAS User's Guide: Basics, 1982 edn. (94 pp.) and SAS User's Guide: Statistics, 1982 edn. (584 pp.). SAS Institute Inc., Cary, NC.
Sharp, I.P. and Associates. 1980, 1981. MABRA: a record administration program. Toronto, Canada, 123 pp.; suppl. (1981) 37 pp.
Simensen, E., 1982, 1983. An epidemiologic study of calf health and performance in Norwegian dairy herds. Acta Agric. Scand., 32: 411–419, 421–427; 33: 57–64, 65–94.
Speicher, J.A. and Hepp, R.E., 1973. Factors associated with calf mortality in Michigan dairy herds. J. Am. Vet. Med. Assoc., 162: 463–466.
Staples, G.E. and Haugse, C.N., 1974. Losses in young calves after transportation. Br. Vet. J., 130: 374–378.
Susser, M., 1973. Causal Thinking in the Health Sciences. Oxford University Press, New York, pp. 60–63.
Waltner-Toews, D., 1984. Developing workable calf management programs. Bov. Proc., 16: 72–78.
Waltner-Toews, D., Martin, S.W., Meek, A.H., McMillan, I. and Crouch, C.F., 1985. A field trial to evaluate the efficacy of a combined rotavirus-coronavirus/E. coli vaccine in dairy cattle. Can. J. Comp. Med., 49: 1–9.
Willoughby, R.A., Butler, D.G. and Thornton, J.R., 1970. The influence of management and bovine serum protein on the incidence of diarrhea in calves. Can. Vet. J., 9: 173–177.
Withers, F.W., 1952–1953. Mortality rates and disease incidence in calves in relation to feeding, management and other environmental factors. Br. Vet. J., 108: 315–328, 382–405, 436–441, 472–483 and 109: 65–73, 122–131.