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EPIDEMIOLOGIC APPROACHES USED IN A HERD HEALTH PRACTICE TO INVESTIGATE NEONATAL CALF MORTALITY

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ABSTRACT
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Epidemiologic methods were applied in an investigation into causes of neonatal mortality on a 1400-cow dairy in the southern San Joaquin Valley of California. A format for collation of information on birthdate and date of death was assembled into a matrix which improved conceptualization of the data and which simplified procedures for estimation of mortality rates. Contemporary and birth cohort life table methods, mortality density estimations and relative risk assessment were used to ascertain if there were high-risk groups of calves that could be identified by age, day-of-the-week born, day-of-the-week died and sex. During the outbreak of neonatal diarrhea on this dairy, female calves were found to have experienced an atypically higher rate of mortality (10.7%) than did males (5.3%). Calves of both sexes died between the ages of 9 and 19 days. In addition, the risk of dying was 11 times greater for calves born on Wednesdays than for those born on Saturdays. These findings formed the basis for recommended changes in management of neonatal calves on the dairy.

INTRODUCTION
Veterinary epidemiology includes the study of factors which may contribute to health or ill-health in animal populations. Disease events can be thought of as having spatial and temporal dimensions; an animal acquires a condition while at a certain location at a certain time when at a certain age. Analytic methods are available which permit measurement and evaluation of relationships between factors associated with a time and/or a place and disease. Because many diseases appear at specific times of the year and at specific ages, measurement of occurrence and risk of disease can aid in diagnosis of etiologic agents and/or focus on predisposing factors present during a specific disease outbreak.

Prerequisites to measurement of risk of disease are assemblage, collation and organization of records and data pertinent to the disease investigation.
In herd health practice this may be costly to the veterinarian in time to laboriously sort and make information available or in computer hardware and software to do the same. A perception of tedious and complex data transcription may thwart any motivation by the practitioner to incorporate quantitative methods in disease investigation and surveillance.

The purpose in this report was to present the use of some epidemiologic measures of disease, including survivorship analysis and mortality density, as they were applied in a herd health practice to help describe factors associated with neonatal calf mortality in a large California dairy. A format, referred to here as a matrix, was utilized for manual collation and organization of demographic data necessary for computations of mortality rates and proportions.

**NATURE OF THE PROBLEM**

In mid-January 1985, a dairyman complained of excessive diarrhea and mortality in calves on a 1400-cow dairy in the southern San Joaquin Valley of California. Approximately 400 male and female calves less than 2 months of age were housed without any age-related order in individual hutches. The problem appeared in calves less than one month of age, although a more precise age at onset could not be determined initially. Examination of calves clinically and at necropsy failed to identify common etiologic agents known to cause diarrhea and/or death in calves. At that point in the investigation it was believed that a better understanding of overall patterns of calf disease on this dairy would help define possible predisposing factors and causes of the neonatal mortality. Consequently, examination of records was undertaken to describe age-specific mortality and to test if certain management practices and/or host characteristics were associated with death.

**APPROACH**

*Records used in matrix*

Records of live births were collected retrospectively from January to November 1984, and prospectively through to May 1985. Information on date of birth, sex and date died or removed from the herd was transcribed from calf records maintained by the dairy to a time-and-event matrix which contained the number of calves at risk (R) and dead (D) for day-of-birth, day-of-month and age. The time-and-event matrix was viewed as an array of R and D cells, which contained numbers of calves present for an age, a date-of-birth and a day-of-month. In this application, the event was death of a neonatal calf.

The number in the \(R_j\) cell, representing the number of calves at risk of dying that were \(j\) days old on the \(i\)th day of the month, was computed
by subtracting the number in the $D_{i-1,j-1}$ cell from the number in the $R_{i-1,j-1}$ cell. Calves were considered to be one day old on their day of birth. The matrix presented data in a format that facilitated computations and that offered a visual overview of past events.

The time at which the problem began was suggested by a temporal pattern of deaths apparent when viewing the December matrix of female calves (Table I). A cluster of mortality appeared following the Christmas holidays (note highlighted deaths in Table I), suggesting that altered management schedules or activities may have contributed to the mortality. The coincidence of deaths occurring at that time prompted examination of records for evidence of excessive risks of death associated with personnel responsible for calf health. Analyses of day-of-the-week-specific mortality rates are presented later in this report.

**Mortality rates**

Monthly rates of mortality were computed to provide a standard quantification of mortality and to form a basis for evaluation of progress and examination of differences in management between groups of calves. Monthly rates of mortality were computed by three methods using a contemporary cohort life table, a birth cohort life table and mortality density. Contemporary cohorts, defined as all calves present for any of the neonatal period during the month of interest, were examined at the time of the outbreak to provide a current estimate of age-specific mortality. Birth cohorts were followed to measure actual age-specific survival using data that became available during and after the outbreak. These measures of actual mortality provided confirmation of estimates from contemporary cohorts made earlier, and permitted a prospective assessment of control efforts. Estimates of mortality density and relative risk were used to provide an overall measure of neonatal calf mortality during a month and to compare amounts of death experienced by different groups of calves.

The life table method using contemporary cohorts provided estimated rates of mortality for all calves up to 28 days of age during the month of December. This method estimated mortality by computing the cumulative proportion of calves remaining alive at each day of age during that month. The cumulative proportion, $P_j$, surviving to the $j$th day of age was computed as

$$P_j = P_{j-1} s_{j-1}$$

where $s_j$ was the proportion of calves that were $j$ days old and that did not die (survived) during the $j$th day of age and $P_1$ (the cumulative proportion surviving to Day 1) = 1 (Schwabe et al., 1977). The $s_j$ was calculated from the matrix as

$$1 - \left\{ \left( \sum_{i=1}^{n} D_j \right) + \left( \sum_{i=1}^{n} R_j \right) \right\}$$
TABLE I
Matrix for number of female calves dying (D) and at-risk of dying (R) up to 28 days of age during December 1984 on a dairy in the southern San Joaquin Valley of California

| Date | Day | Age (days) |
|------|-----|------------|
|      | 1 Sa | 0 2 0 0 2 0 0 2 0 2 0 1 0 3 0 3 0 2 0 3 0 1 0 2 0 1 0 0 |
|      | 2 Su | 0 0 0 2 0 0 2 0 0 2 0 2 0 1 0 3 0 3 0 2 0 3 0 1 0 2 0 1 0 2 |
|      | 3 Mo | 0 3 0 0 0 2 0 2 0 0 0 2 0 2 0 2 0 1 0 3 0 3 0 2 0 3 0 1 0 2 |
|      | 4 Tu | 0 3 0 3 0 0 2 0 2 0 2 0 0 2 0 2 0 1 0 3 0 3 0 2 0 3 0 1 0 3 |
|      | 5 We | 0 3 0 3 0 3 0 0 0 2 0 2 0 0 2 0 2 0 1 0 3 0 3 0 2 0 3 0 2 3 |
|      | 6 Th | 0 4 0 3 0 3 0 3 0 0 0 2 0 2 0 0 2 0 2 0 1 0 3 0 3 0 2 0 3 0 2 |
|      | 7 Fr | 0 1 0 4 0 3 0 3 0 3 0 3 0 3 0 2 0 2 0 1 0 3 0 2 0 3 0 2 0 3 |
|      | 8 Sa | 0 6 0 1 0 4 0 3 0 3 0 3 0 3 0 2 0 2 0 1 0 3 0 2 0 3 0 2 0 3 |
|      | 9 Su | 0 3 6 0 1 0 4 0 3 0 3 0 3 0 3 0 2 0 2 0 1 0 3 0 2 0 3 0 2 0 3 |
|      | 10 Mo | 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 3 0 2 0 2 0 1 0 3 0 2 0 3 0 2 0 3 |
|      | 11 Tu | 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 2 0 2 0 1 0 3 0 2 0 3 0 2 0 3 |
|      | 12 We | 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 2 0 1 0 3 0 2 0 3 0 2 0 3 |
|      | 13 Th | 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 2 0 1 0 3 0 2 0 3 0 2 |
|      | 14 Fr | 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 2 0 1 0 3 0 2 0 3 |
|      | 15 Sa | 0 4 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 2 0 1 0 3 0 2 |
|      | 16 Su | 0 3 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 2 0 3 0 2 |
|      | 17 Mo | 0 4 0 0 1 4 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 3 0 3 |
|      | 18 Tu | 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 3 0 3 0 3 |
|      | 19 We | 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 20 Th | 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 21 Fr | 0 2 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 22 Sa | 0 4 0 2 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 23 Su | 0 4 0 4 0 2 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 24 Mo | 0 4 0 4 0 2 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 25 Tu | 0 4 0 4 0 4 0 4 0 2 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 26 We | 0 6 0 4 0 4 0 4 0 4 0 2 0 2 0 3 0 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 2 0 3 0 6 0 1 0 4 0 0 0 3 0 3 |
|      | 27 Th | 0 2 0 6 0 4 0 4 0 4 0 4 0 2 0 2 0 1 0 3 1 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 0 0 3 0 3 |
|      | 28 Fr | 0 2 0 2 0 6 0 4 0 4 0 4 0 4 0 2 0 2 0 1 0 3 1 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 0 0 3 0 3 |
|      | 29 Sa | 0 1 0 2 0 2 0 6 0 4 0 4 0 4 0 4 0 2 0 2 0 1 0 3 1 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 0 0 3 0 3 |
|      | 30 Su | 0 3 0 1 0 2 0 2 0 6 0 4 0 4 0 4 0 2 0 2 0 1 0 3 1 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 0 0 3 0 3 |
|      | 31 Mo | 0 2 0 3 0 1 0 2 0 2 0 6 0 4 0 4 0 2 0 2 0 1 0 3 1 2 0 4 0 0 0 3 0 3 0 2 0 1 0 4 0 0 0 3 0 3 |

where \( n \) was the number of days in the month. Consideration of animals lost-to-follow-up was not made in computation of cumulative proportions because all calves, even male calves, were retained up to 28 days of age. This method used data available at the onset of the investigation for contemporary calves present during December and permitted examination of estimated age-specific mortality \( (1-P_j) \) up to 28 days of age. Table II presents computations of \( s_j \) and \( P_j \) for female calves less than 29 days of age that were present during the month of December. For December the mortality rate was estimated to be 10.7% \((1-0.893)\) for females and 5.3% for males (data not shown). The age-specific survival rates indicated that calves of both sexes would begin to die at about 9 days of age, but females suffered more severely as demonstrated by the continued decline in survival (Fig. 1). Although examination of the contemporary cohort did not provide actual mortality rates, it did provide early estimates from which some
TABLE I (continued)

| Date | Day | Age (days) |
|------|-----|------------|
| 15   | Sa  | 0 4 0 2 0 0 |
| 16   | Su  | 0 0 0 4 0 2 |
| 17   | Mo  | 0 1 0 0 0 4 |
| 18   | Tu  | 0 2 0 1 0 0 |
| 19   | We  | 0 1 0 2 0 1 |
| 20   | Th  | 0 3 0 1 0 2 |
| 21   | Fr  | 0 2 0 3 0 1 |
| 22   | Sa  | 0 3 0 2 0 3 |
| 23   | Su  | 0 3 0 3 0 2 |
| 24   | Mo  | 0 1 0 3 0 3 |
| 25   | Tu  | 0 2 0 1 0 3 |
| 26   | We  | 0 2 0 2 0 1 |
| 27   | Th  | 0 0 0 2 0 1 |
| 28   | Fr  | 0 2 0 0 0 2 |
| 29   | Sa  | 0 1 0 2 0 0 |
| 30   | Su  | 0 1 0 3 0 1 |
| 31   | Mo  | 0 0 0 3 0 2 |

General appreciation was gathered for age and sex as possible factors associated with mortality. Actual measures of survivorship could not be obtained until calves had been observed from birth to 28 days of age.

The birth cohort life table method was used to measure actual mortality in calves born in December and followed through to 28 days of age. It was possible to pursue a birth cohort analysis because sufficient data were available to permit follow-up of a large number of calves from birth to 28 days of age. Cumulative proportions of calves surviving were computed as for the contemporary cohort.

Survivorship of male and female calves born in December was compared using the cohort life table method (Fig. 2). Age-specific cumulative proportions of calves surviving indicated that deaths began in 9–10-day-old calves, which was an age similar to that estimated from the contemporary method. Survival did not differ between males and females up to approxi-
TABLE II

Life table of age-specific (s) and cumulative (P) rates of survival up to 28 days of age for contemporary female calves present during December 1984 on a dairy in the southern San Joaquin Valley of California

| Age (days) | Number (died) | Number at risk | Daily proportion remaining alive (s) | Cumulative proportion alive (P) | Standard error of P |
|------------|---------------|----------------|------------------------------------|--------------------------------|-------------------|
| 1          | 0             | 86             | 1.000                              | 1.000                          | −                 |
| 2          | 0             | 86             | 1.000                              | 1.000                          | −                 |
| 3          | 1             | 83             | 0.988                              | 1.000                          | −                 |
| 4          | 0             | 83             | 1.000                              | 0.988                          | 0.012             |
| 5          | 0             | 83             | 1.000                              | 0.988                          | 0.012             |
| 6          | 0             | 82             | 1.000                              | 0.988                          | 0.012             |
| 7          | 0             | 79             | 1.000                              | 0.988                          | 0.012             |
| 8          | 0             | 78             | 1.000                              | 0.988                          | 0.012             |
| 9          | 1             | 76             | 0.987                              | 0.975                          | 0.017             |
| 10         | 3             | 74             | 0.959                              | 0.935                          | 0.028             |
| 11         | 1             | 68             | 0.985                              | 0.935                          | 0.031             |
| 12         | 1             | 67             | 0.985                              | 0.921                          | 0.031             |
| 13         | 1             | 66             | 0.986                              | 0.907                          | 0.033             |
| 14         | 0             | 64             | 1.000                              | 0.893                          | 0.035             |
| 15         | 0             | 67             | 1.000                              | 0.893                          | 0.035             |
| 16         | 0             | 65             | 1.000                              | 0.893                          | 0.035             |
| 17         | 0             | 65             | 1.000                              | 0.893                          | 0.035             |
| 18         | 0             | 63             | 1.000                              | 0.893                          | 0.035             |
| 19         | 0             | 63             | 1.000                              | 0.893                          | 0.035             |
| 20         | 0             | 64             | 1.000                              | 0.893                          | 0.035             |
| 21         | 0             | 63             | 1.000                              | 0.893                          | 0.035             |
| 22         | 0             | 62             | 1.000                              | 0.893                          | 0.035             |
| 23         | 0             | 64             | 1.000                              | 0.893                          | 0.035             |
| 24         | 0             | 63             | 1.000                              | 0.893                          | 0.035             |
| 25         | 0             | 60             | 1.000                              | 0.893                          | 0.035             |
| 26         | 0             | 60             | 1.000                              | 0.893                          | 0.035             |
| 27         | 0             | 58             | 1.000                              | 0.893                          | 0.035             |
| 28         | 0             | 57             | 1.000                              | 0.893                          | 0.035             |

aData from Table I.

mately 13 days of age, after which time mortality in females continued at a greater rate than in males.

The technique of combining survivorship experiences of contemporary calves provided an estimate of mortality before sufficient information was available for a birth cohort study. Age-specific rates of survival computed by both life table methods were helpful in considering possible etiologic agents. Results suggested that calves were dying at ages when diarrhea could be associated with rotavirus, coronavirus, enterotoxigenic *Escherichia coli* and cryptosporidia, but not with salmonella or bovine virus diarrhea virus (Blood et al., 1983; Radostits and Blood, 1985). Although an aggressive
search was made for etiologic agents in calves between 1 and 2 weeks of age, only cryptosporidia were found consistently.

The third method used to calculate monthly mortality considered the concept of mortality density (Kleinbaum et al., 1982). This method permitted a weighting of the number of calves at risk during a month according to the length of time the calf was present during the month. The rate was calculated as \((\text{number of calves dying during the month}) \div (\text{number of calves at risk})\).

![Graph](image1)

**Fig. 1.** Estimated age-specific survival of contemporary neonatal calves during December 1984 on a 1400-cow dairy in the southern San Joaquin Valley of California. Range delineated by brackets is the 95% confidence interval.

![Graph](image2)

**Fig. 2.** Actual age-specific survival of neonatal calves born during December 1984 on a 1400-cow dairy in the southern San Joaquin Valley of California.
calf-days-at-risk during the month). Calf-days-at-risk was calculated by summing numbers in all \( R_{ij} \) cells. The number dying was a sum of numbers in all \( D_x \) cells. In December the mortality density rate for males was 0.002 \([\frac{(4 \text{ deaths})}{(2156 \text{ calf-days-at-risk})}\]\). A convenient use of this rate was made by considering it as a monthly rate; for the 31-day month of December, the rate for males was 5.75 per 100 \([\frac{4}{2156 \div 31} = \frac{4}{69.54}\]\). The number 69.54 was thought of as the average number of male calves at risk of dying during December 1984. This rate was similar to that of 5.3\% estimated from the life table of December contemporary bull calves (data not shown). The rate for females present during December was 12.81\% \([\frac{8}{1936 \div 31}\]\), which was comparable in magnitude to the cumulative mortality of 10.7\% \([1-0.893]\) (Table II).

The excessive amount of death associated with female calves, as observed from life-table calculations (Figs. 1 and 2), was measured and tested for statistical significance using relative risk estimates derived from mortality densities. During the month of December, the relative risk of death in females compared to males was 2.23 \([12.81 \div 5.75]\). Using a large-sample Z-test (Kleinbaum et al., 1982), the chance was less than 1 in 10 \(P \approx 0.090\) that mortality in females was not greater than that in males, indicating that female calves experienced significantly higher rates of death in the first 28 days of life than did male calves. For January, the relative risk was 2.24 which was statistically more significant \(P<0.0125\) than that for December.

These rates revealed a relationship to death not apparent when calves were examined clinically in January, and lead to an admission by the calf manager that corticosteroids and up to four different antibiotics were being administered routinely only to heifer calves during the first week of life. These drugs were administered in the belief that such treatment prevented diarrhea. The amount of mortality attributable to a factor associated with being a female calf in January was 7.56 calves per 100 \([12.81 - 5.25]\). Once the practice of steroid and antibiotic use was discontinued, mortality in heifers returned to a more acceptable level of 5\% in February (Fig. 3).

To explore further the pattern of deaths observed after the Christmas holidays, day-of-birth-specific rates of mortality were examined for all calves born during December and January for the purpose of identifying adverse or beneficial influences individual personnel may have had on calf health at the time of birth. It was possible to examine for these effects because individuals who provided perinatal care to calves born on a given day of the week were designated to do so by a work schedule which remained unchanged during December and January. Rates were calculated for each of the 7 week days as \(\frac{\text{number of calves born on day-of-the-week } m \text{ and that died within the first 28 days of life}}{\text{number of calves born on day-of-the-week } m}\) \(\times \) the denominator was derived from the matrix by summing numbers in \( R \) cells for the one-day-of-age column corresponding
to the day-of-the-week \( m \). The numerator was a sum of numbers in the D cells which followed a birth cohort along the diagonal from the day of birth to 28 days of age. Calves born after December and January were followed into January and February (not shown in Table I) before the numerator could be defined. Day-of-the-week mortality rates for calves born in December and January are given in Table III. Table IV presents relative risks of mortality for calves born on each of the 7 days computed from rates in Table III. The risk of a calf dying within 28 days of age was 11 times greater if it was born on a Wednesday than on Saturday. The 95% confidence interval did not include 1.0 (1.46, 84.49) indicating that the

TABLE III

Rates of mortality for male and female calves specific for day-of-the-week born and day-of-the-week present during December 1984 and January 1985 on a dairy in the southern San Joaquin Valley of California

| Day of the week | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|-----------------|-----|-----|-----|-----|-----|-----|-----|
| **Birth day**   |     |     |     |     |     |     |     |
| Number died     | 4   | 5   | 6   | 9   | 5   | 11  | 1   |
| Number at risk  | 35  | 43  | 53  | 45  | 34  | 59  | 57  |
| Mortality rate  | 11.4| 11.6| 11.3| 20.0| 14.7| 18.6| 1.8 |
| (per 100)       |     |     |     |     |     |     |     |
| **Death day**   |     |     |     |     |     |     |     |
| Number died     | 9   | 9   | 7   | 4   | 7   | 4   | 5   |
| Number at risk  | 1201| 1197| 1197| 1197| 1189| 1090| 1210|
| Mortality rate  | 7.5 | 7.5 | 5.8 | 3.3 | 5.9 | 3.7 | 4.1 |
| (per 1000)      |     |     |     |     |     |     |     |
TABLE IV

Relative risks (95% confidence intervals) and association p-values of mortality for male and female calves born on each of the 7 days of the week during December 1984 and January 1985 on a dairy in the southern San Joaquin Valley of California

| Day-of-the-week (denominator) | Sun   | Mon   | Tue   | Wed   | Thu   | Fri   | Sat   |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Association p-value<sup>a</sup> |       |       |       |       |       |       |       |
| Sun                           | 0.98  | 1.00  | 1.00  | 0.37  | 0.73  | 0.40  | 0.07  |
| Mon                           |       | 0.57  | 0.58  | 0.57  |       | 0.77  | 1.00  | 0.005 |
| Tue                           | 1.01  | 1.03  |       | 1.00  | 0.74  | 0.31  | 0.05  |
| Wed                           | 0.57  | 0.58  | 0.57  |       | 0.77  |       | 1.00  | 0.005 |
| Thu                           | 0.78  | 0.79  | 0.77  | 1.36  |       | 0.78  | 0.03  |
| Fri                           | 0.61  | 0.62  | 0.61  | 1.08  | 0.79  |       | 0.004 |
| Sat                           | 6.33  | 6.44  | 6.28  | 11.11 | 8.17  | 10.33 |       |
|                               | (0.74,54.37) | (0.78,53.13) | (0.78,50.46) | (1.46,84.49) | (1.00,67.03) | (1.38,77.5) |

<sup>a</sup>Computed using a 2-tailed Fisher exact test.
### TABLE V

Relative risks (95% confidence intervals) and association p-values of mortality for male and female calves present on each of the 7 days of the week during December 1984 and January 1985 on a dairy in the southern San Joaquin Valley of California.

| Day-of-the-week (denominator) | Sun    | Mon    | Tue    | Wed    | Thu    | Fri    | Sat    |
|-------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Association p-value<sup>a</sup> |        |        |        |        |        |        |        |
| Sun                           | 1.00   |        | 0.80   | 0.27   | 0.80   | 0.88   | 0.30   |
| Mon                           |        | 1.00   | 0.80   | 0.27   | 0.80   | 0.27   | 0.30   |
| (0.40,2.51)                   |        |        |        |        |        |        |        |
| Tue                           | 1.29   | 1.29   |        | 0.55   | 1.00   | 0.55   | 0.58   |
| (0.48,3.45)                   | (0.48,3.45) |    |        |        |        |        |        |
| Wed                           | 2.27   | 2.27   | 1.76   |        | 0.39   | 1.00   | 1.00   |
| (0.70,7.35)                   | (0.70,7.35) | (0.54,5.70) |    |        |        |        |        |
| Thu                           | 1.27   | 1.27   | 0.98   | 0.56   |        | 0.55   | 0.58   |
| (0.47,3.40)                   | (0.47,3.40) | (0.34,2.79) | (0.16,1.91) |    |        |        |        |
| Fri                           | 2.03   | 2.03   | 1.57   | 0.89   | 1.59   |        | 1.00   |
| (0.63,6.57)                   | (0.63,6.57) | (0.46,5.35) | (0.22,3.55) | (0.47,5.42) |    |        |        |
| Sat                           | 1.83   | 1.83   | 1.41   | 0.80   | 1.44   | 0.90   |        |
| (0.62,5.44)                   | (0.62,5.44) | (0.45,4.43) | (0.22,2.79) | (0.46,4.52) | (0.24,3.34) |    |        |

<sup>a</sup>Computed using a 2-tailed Fisher exact test.
way in which newborn calves were managed on those days exerted a sizable influence on subsequent survival in those calves. High risks of death were seen also for calves born on Thursdays and Fridays, relative to Saturdays.

Two possible explanations were found for the difference between rates for Wednesdays and Saturdays. New bedding was spread in the maternity corral only during the days Monday to Friday, and usually on Thursdays or Fridays. Provision for a cleaner environment to calves born on weekends, compared to those born midweek, could have enhanced their survival. Another explanation was that the eldest of the calf handlers, who appeared less willing to feed good quality colostrum to calves, did not work on weekends. Consequently, calves born on Saturdays may have received more protection from infectious agents and, thus, experienced greater survival. Because the factors of bedding and calf-handler on day of birth, either independently or in combination, appeared to be highly associated with neonatal mortality, changes were made in bedding and colostrum management. It is believed that these changes contributed to improved survivorship observed in subsequent months (Fig. 3).

For day-of-the-week mortality (Table V), however, highest relative risk was found for calves at risk on Sundays and Mondays compared to Wednesdays ($2.27 = 7.5 \div 3.3$). Because the 95% confidence interval for this estimate included 1.0 ($0.70, 7.35$) it was concluded that the difference in mortality rates could have been observed by chance and that reasons for excessive mortality would probably not be related to events associated with day-of-death.

In conclusion, this application of epidemiologic methods was helpful in describing and solving a herd problem of neonatal calf diarrhea. Specific use of quantitative methods to analyze data was facilitated by collation of data in a matrix. Results of analyses demonstrated fruitful areas for management change and illustrated practical usefulness of epidemiologic methods in herd health practice.

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REFERENCES

Blood, D.C., Radostits, O.M. and Henderson, J.A., 1983. Veterinary Medicine. 6th edn. Bailliere Tindall, London, 1135 pp.
Kleinbaum, D.G., Kupper, L.L. and Morgenstern, H., 1982. Epidemiologic Research. Lifetime Learning Publications, Belmont, CA, pp. 283–288.
Radostits, O.M. and Blood, D.C., 1985. Herd Health. W.B. Saunders Company, Philadelphia, pp. 116–132.
Schwabe, C.W., Riemann, H.P. and Franti, C.E., 1977. Epidemiology in Veterinary Practice. Lea and Febiger, Philadelphia, 303 pp.