Dairy Calf Mortality Rate: The Association of Daily Meteorological Factors and Calf Mortality

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ABSTRACT

The number of dairy heifer calves born each day, the number of these calves which died prior to 36 days of age and the actual date of death were recorded and analyzed for possible associations with weather factors. The demographic data on dairy calves were supplied by 16 farms in Tulare County, California for the months of July to December 1973.

High temperatures in the summer and low temperatures in the winter were associated with an increased risk of death. Calves born during the periods of extreme temperatures had a higher risk of death than those born on more temperate days, while death, when it occurred was temporally related to days of extreme temperatures. Periods of increased risk of death often were associated with large temperature fluctuations irrespective of the absolute temperature.

Nonmeteorological factors specific to invidual farms also appeared to influence daily calf mortality rates.

RÉSUMÉ

Cette expérience visait à enregistrer et à analyser, en tenant compte des conditions climatiques, les données suivantes: le nombre de génisses naissant chaque jour, le nombre de celles qui moururent avant d'avoir atteint 36 heures d'âge, ainsi que la date de leur mort. De juillet à décembre 1973, 16 cultivateurs du comté de Tulare, en Californie, recueillirent ces données à l'intention des auteurs.

La chaleur estivale et le froid hivernal représentèrent un risque accru de mortalité. Les génisses nées durant les périodes les plus chaudes ou les plus froides s'avérèrent plus sujettes à la mort que celles qui naquirent à une période plus tempérée. Lorsque la mort survenait, on pouvait l'associer à des jours où la température était particulièrement chaude ou froide. Les périodes de risque accru de mortalité coïncidèrent souvent avec des écarts importants de température, indépendamment de la température absolue.

Des facteurs étrangers à la météorologie, mais particuliers à certaines fermes, semblèrent également exercer une influence sur le taux de mortalité.

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INTRODUCTION

The possible effect of climate on monthly calf mortality rates on dairy farms in Tulare County, California has been reported. Hot, dry summer weather and cold, windy, damp winter weather were both significantly related to increases in the monthly calf mortality rates (13). In addition, other factors such as calf management, calf housing and the number of calves born per month were studied. However, no association between these variables and the monthly calf mortality rate was found (15).

The primary purpose of the present study was to ascertain if daily weather patterns were associated with daily calf death losses. Also, we examined the ages at which calves died on each farm and from one time period to another.

MATERIALS AND METHODS

Data on births and deaths were obtained for heifer calves born July 1 to December 31, 1973 on 16[1] dairy farms in Tulare County (14). Each dairyman[1] recorded the date of birth and date of death of heifer calves. For this study only data on calves less than 36 days of age are presented.

Mortality rates were calculated on the basis of date of birth and date of death. The mortality rate by day of birth was defined as the percentage of calves born alive each day which subsequently died before 36 days of age. The mortality rate by day of death was defined as the percentage of live calves less than 36 days of age which died on that day.

In order to designate days or groups of days (periods) of increased risk of death, "significant" had to be defined with reference to the actual daily death loss. An average mortality rate for each month was calculated. Then. those days on which the three day moving average of the respective mortality rates exceeded the daily mean rate for that month were designated as high mortality days.

Farm 3 was the largest farm in the survey with more recorded calf deaths than all other farms combined. Thus, the above procedures were used to organize the data from this farm and its data were analyzed separately. On all other farms the observed number of deaths was pooled and analyzed collectively with high mortality periods being defined as described above except that the observed number of deaths was used in place of the actual rates.

The weather characteristics of the three defined mortality groups in each month (periods of high mortality by day of birth, periods of high mortality by day of death and periods of low mortality) were determined and differences between the weather patterns in the respective high and low mortality groups tested using discriminant analysis, a multivariate generalization of the "t" test (5, 24). Data for the weather factors (Table I) were obtained from the U.S. meteorological station located in Fresno, California (25).

The daily number of births on farm 3 (separately) and on farms 6, 12 and 14 (combined) was noted and an average number of births per day calculated for each month. All days on which the three day moving averages of the number of births exceeded the daily mean for that month were designated high birth days. Discriminant analysis was used to ascertain if the weather on high birth days differed from that on low birth days.

The number of deaths recorded by date of birth and date of death which occurred on each day of the week was cumulated. The median age at death on each farm and the median age at death for each month was determined.

RESULTS

Farm 3 had complete data on 167 dead calves with an average death loss of 0.9 calves/day (Tables II and III). The remaining 13 farms had data on an additional 144 calf deaths for an average death loss of 0.8 calves/day (Tables IV and V). Farms 6, 12 and 14, with 25, 21 and 31 recorded deaths, respectively, accounted for 53.5% of all recorded deaths in the 13-farm group.

In general, the high mortality periods were composed of clusters of days with two or more recorded deaths per day and/or two or more successive days with recorded

[1]Two farms (2 and 11) were unable to provide dates of death for their heifer calves and data from these farms, with the exception of estimates of age at death, were excluded from this study. See Table X for a description of completeness of data.

TABLE I. Daily Weather Factors[a] Utilized in the Study of Daily Calf Mortality on Dairy Farms in Tulare County, July-December 1973

Variable Number	Variable Symbol	Daily Factors Measured	
1	T_M	Maximum temperature °F	
2	T_m	Minimum temperature °F	
3	T_A	Average temperature °F	
4	T_F	Temperature fluctuation (#1-#2)	
5	T_{DP}	Dew point temperature °F	
6	F_L	Light fog present	
7	F_H	Heavy fog present	
8	R	Inches of rain	
9	B.P.	Barometric pressure (″Hg)	
10	W_A	Average windspeed (mph)	
11	W_F	Fastest windspeed (mph)	
12	S_H	Hours of sunshine	
13	S%	#12 as a percentage of total possible hours	
14	SC_D	Sky cover during the day in "tenths"	
15	SC_N	Sky cover during the night in "tenths"	
16	T_M'	Interdiurnal change	(+ if value of variable same as or greater than previous day; — if value of variable less than previous day)
17	T_m'	Interdiurnal change	(+ if value of variable same as or greater than previous day; — if value of variable less than previous day)
18	B.P.′	Interdiurnal change	(+ if value of variable same as or greater than previous day; — if value of variable less than previous day)

[a]Data obtained from U.S. meteorological station at Fresno, California (25)

deaths. It was also apparent that individual high mortality periods in the group of 13 farms were comprised primarily of multiple deaths on one or two farms (Tables IV and V).

On Farm 3 a significant number of days which were classified as high mortality periods by day of birth also were designated as high mortality periods by day of death (Table VI). No significant overlap occurred between these two periods on the 13 remaining farms.

Discriminant analyses of weather patterns which existed during periods of different mortality risk (Table VII) indicated that, in general, the most extreme temperatures (hottest days in summer, coldest days in winter) occurred during the high mortality periods by date of death. The temperatures in the high mortality periods by date of birth were somewhat less extreme, while the days of low mortality had the most temperate weather patterns.

On farm 3, in the months of July, October and November extreme temperatures existed during the periods of increased mortality rates. There was little difference in the temperatures of the mortality groups in the months of August and September. In December the periods of elevated mortality were warmer than the periods of little mortality. However, the higher mortality rate groups had significantly greater wind speeds (W_F) than the low mortality periods.

On the remaining 13 farms the temperatures in periods of increased death losses were more extreme than those in the periods of low death losses during the four months of August through November. The temperatures during periods of increased death losses in the months of July and December were more moderate than the temperatures during periods of few deaths.

Thus, in the pairwise comparison of temperatures in the high mortality periods versus those in low mortality periods, in 14 instances the elevated mortality periods had the more radical temperatures, four comparisons were tied (no difference) and in six cases the high mortality periods had the most moderate temperatures. (The critical value for the sign test at $p = 0.05$ is 15.)

The weather variable most often used to discriminate between the temperature patterns in the mortality groups was the number of degrees of temperature fluctuation (T_F). Large fluctuations were associated with the periods of high mortality, irrespective of the absolute temperatures which existed at that time. i.e. in the hot months of July and September, the transitional climatic month of October and the relatively cold month of November.

Some differences existed with respect to temperature between periods of high and low births (Table VIII). On farm 3 the periods of high births were associated with the most moderate temperatures during July, August and December and with the most extreme temperatures during September and November. On farms 6, 12 and 14 the periods of high births were associated with the most radical temperatures during August, September, October and November. During the months of July and December the periods of high births were characterized by more temperate weather. Thus the periods of increased births were associated with extremes of temperature on six occasions. (The critical value for the sign test at $p = .05$ is 10.)

The observed frequencies of deaths on each day of the week (Table IX) did not differ significantly from the number expected. Thursdays had the lowest frequency of recorded deaths on farm 3, while on the remaining farms, Sunday had the lowest number of deaths by date of birth and Wednesday the lowest by date of death. The number of deaths on each of the first four days of the week on farm 3 tended to be higher than the number recorded for each of the last three days of the week.

The average of the median age at death (Table XI) on all farms[2] was less than eight days (7.23). Farms 3, 5, 9, 10 and 12 had a significant number of deaths in older calves and the median age at death on these farms exceeded the age of 7.23 days.

The median age at death also varied from month to month (Table XII). No particular pattern was evident, although the median age at death of calves born during December on farm 3 was at least twice as high as the median age at death of calves born in July or November. Similarly, the median age at death for calves on other farms was greatly increased dur-

[2]Farm number 1 excluded. See Table X.

TABLE II. Date of Birth of Heifer Calves Which Died Before 36 Days of Age on Farm 3 in Tulare County, July-December 1973

Day of month	July	August	September	October	November	December	Day of month
1		... + (20)	.. + (15)	.. +	.. + (2.5)	+	1
2	+	.	... +	. + (10)		. + (7)	2
3	... + (7)		..	+		+	3
4	... +	.		.	. + (11)	...	4
5		. +	.	+	. +		5
6		. + (15.5)	.	.			6
7	.. + (6)	... +					7
8	. +	.	.				8
9			...			...	9
10		.	+	. +	+		10
11			. +	+	. +		11
12			.... + (9)	. + (7.5)	.. + (10)	..	12
13	...	.	+	. +	.. +	+	13
14		.. + (13)	.. +	.. +	+	.	14
15		.	.	.. +			15
16	.	.		.. +		.	16
17	.. +	.	. + (7)				17
18	.. + (6)	. + (17)	.				18
19	. +	...			. +		19
20		. +			. + (3.5)	.	20
21		... + (15)	..		+	+	21
22	.. +	. +				... + (12.5)	22
23	.... +	.. +			. +	. +	23
24	... +	..	. +		. + (3)	.	24
25	.. +	+	.. + (5)	.	. +		25
26	+ (4)	.. + (8)	. +	+			26
27	.. +	.. +		. + (9)			27
28	. +	.... +		+		... +	28
29	.. +	.				... + (16)	29
30	. +	.....	..	.		.. +	30
31	+	+ (4)		.		+	31

Each dot represents the birth date of one calf which died before 36 days of age. The + signs indicate the high mortality periods as defined by a three day moving average of the mortality rate. The median age, in days, at death for the calves born during high mortality periods is shown to the right of the + signs and is enclosed in parentheses ing the month of September. The median age at death also varied from one high mortality period to another within any given month (Tables II, III, IV and V). In general, there was no consistent pattern to the occurrence of different ages at death. However, in August on farm 3, the calves born during high mortality periods in the first three weeks of the month were somewhat older when they died than calves born in most other periods.

DISCUSSION

Observational studies of natural phenomena in populations of animals such as mortality in dairy calves are infrequently found in the literature. Nevertheless, such studies are useful in elucidating cause and effect relationships and in evaluating the efficacy of various prophylactic and/or control measures (11).

Because of this lack of standard format for conducting observational studies, one often must devise methods to circumvent a multitude of problems. Some of these problems existed in this study. For example, although it is desirable to adjust for differences in the population at risk by calculating a *rate*, the correct denominator is often difficult and/or tedious to obtain. This was the case with the denominator for the mortality rate by day of death, which was the 35 day moving average of the number of live calves 35 days of age or less on each farm. Even after completing the required calculations, one is faced with the problem of comparing rates whose denominators differ greatly. That is, if the denominator is quite small, the mortality rates fluctuate widely whenever deaths occur.

TABLE III. Date of Death of Heifer Calves Which Died Before 36 Days of Age on Farm 3 in Tulare County, July-December 1973

Day of month	July	August	September	October	November	December	Day of month
1		.. + (8)	.... +		.		1
2		+	.... +				2
3			. + (8)		.. +		3
4		.	.... +	. +	+ (9)		4
5		. + (2.5)	... +	.. + (12.5)	... +	.	5
6		. +		. +	+		6
7		.	.				7
8	.. +		..				8
9	. +		...				9
10	. + (6)	.		. +		.	10
11	.. +		. + (10)	.... +			11
12	+		.... +	+		+	12
13	.		.	. +		.. + (4)	13
14		.		. + (9)	. +	+	14
15	.	.	..	. +	. + (13.5)	.	15
16	.		.	. +	+	+	16
17			.	... +	.	.. + (5)	17
18			..	. +	+	. +	18
19		.. +	.		. + (4)		19
20		... + (20)	.		. +		20
21	..	... +	.				21
22	+	. +		.		+	22
23	..		... +		.	.. + (14)	23
24	+	.	.. + (11)	.		+	24
25	... + (4)		... +		+	.	25
26	+				.. +	+	26
27	.. +	.. +	.	.	. + (3.5)	.	27
28	.. +	.. + (10)			. +		28
29	.... +	+	.		+		29
30	. +	.	..		.	. + (9)	30
31	. +	.. + (3)				. +	31

Each dot represents the date of death of one calf. The + signs indicate the high mortality periods as defined by a three day moving average of the mortality rate (by day of death). The median age, in days, at death for calves dying in the high mortality period is enclosed in parentheses to the right of the + sign

TABLE IV. Date of Birth and Owner Number of Heifer Calves Which Died Before 36 Days of Age on 13 Dairy Farms in Tulare County, July-December 1973

Day of month	July	August	September	October	November	December	Day of month
1		6 5 4 +	12	4 +	10		1
2	10	12 4 9 +	+	7 + (1.5)	6 + (18)		2
3		14 14 + (5)	4 + (14)	+	6	15 4	3
4		6 +	15 9 +	1		15 +	4
5		5 +	+	+		12 12 14 14 + (11)	5
6	12 + (8.5)	7 +		7	14 1 +	+	6
7	10 +	14	5		6 4 10 + (7.5)	7 9	7
8					14 +	8 12	8
9		14			+		9
10	12			9	7 5	12	10
11		6		+	+	15	11
12		14 +		7	6 4 + (15)		12
13	12 +	12 6 10 + (6)		+	12 +	12 6	13
14	6 + (9.5)	+	14 +	14		7 4 + (3)	14
15	+	14	6 6 16 + (14)			14	15
16	10		14 +	+	14 14 +	6	16
17			+	5 14 +	4 +		17
18			7	8 + (9)	+ (6)		18
19	7			14 14 +	6 4 +		19
20	+	12		+	6 +	16 14 14	20
21	9 +		9			9 +	21
22	14 +					12 +	22
23	+ (3.5)			9 +	14	12 12 16 14 14 +	23
24	6 +		12 +	10 + (10)	12 +	8 7 +	24
25	6 6 14 +		10 + (2)	+	15 + (17)	+ (6)	25
26	6 +	4	+	9	12 +	16 6 14 14 +	26
27		6 +	13	+	5	16 +	27
28		6 10 + (12)		12 + (25)		8 6 9 +	28
29		6 5 +		12 10 +		16 6 +	29
30	4 + (5)			+	5		30
31	14 +					14	31

Each number in the body of the table, not enclosed in parentheses, represents the birth date of one calf which died before 36 days of age on that farm. Data from Farm 3 are given separately (Table II). Data from Farms 2 and 11 were incomplete and are excluded. The + signs indicate periods of high mortality as defined by a three day moving average of the number of deaths. The numbers in parentheses are the median age at death for calves born during high mortality periods and dying before 36 days of age.

Another problem arose in defining days of high mortality. We chose to identify these days using two bases. The first identified days of increased risk of mortality for newborn calves (high mortality by day of birth) and the second identified days of increased risk of mortality for older calves (high mortality by day of death). In the first instance we wished to identify factors acting on a newborn calf which might lead to its eventual death, whereas in the second case we wished to identify those factors present at, and thus possibly influencing, the time of death. In defining these high mortality days using a three day running average, it became apparent that on the smaller farms the use of mortality rates provided little information in addition to the actual number of deaths. Thus for the largest farm, farm 3, we retained the rates but we reverted to using the actual number of deaths on all other farms. For this reason the data from farm 3 were analyzed separately.

This procedure for defining high mortality days was not strictly a measure of multiple deaths per day but did identify those days or periods during which the risk of death was increased. Most isolated days with a small number of deaths were categorized as low mortality days. On the other hand, some days with few or no recorded deaths were classified as high mortality days (Tables II to V) if they were adjacent to days on which a large number of calves died. Thus, high mortality periods should be interpreted as periods during which the risk of death was increased and not necessarily as periods when the actual frequency of deaths was elevated.

A final problem was to decide on the source of weather data. The only source of detailed data was the Fresno meteorological station located approximately 40 miles north of central Tulare County. The climate of Fresno is similar to that of

TABLE V. Date of Death and Owner Number of Heifer Calves Which Died Before 36 Days of Age on 13 Dairy Farms in Tulare County, July-December 1973

Day of month	July		August		September		October		November		December		Day of month
1							14 13	+	10				1
2			6		9 5	+ (31.5)	4	+	5		1		2
3				+				+ (4)		+			3
4			4 4 4 14	+ (3)			12 7	+	10 9				4
5			6 12	+	4	+		+					5
6				+	4 12	+					5 15		6
7			5 6			+			9		4	+ (4)	7
8					5	+ (7.5)			6		15		8
9					12	+					5		9
10					6	+			10		8		10
11						+			6	+			11
12				+	10				4 14 14	+ (5.5)			12
13			10 14 6	+			7			+	12 12 7	+	13
14			14 6	+				+	7		9 12 12	+	14
15	12	+		+ (4.5)			10	+			12	+ (8)	15
16	10 12	+ (9)	9	+	12		14	+			14	+	16
17	12	+	14 14	+		+		+ (9)	10		14 14 6 7	+	17
18	10	+		+	5 15	+ (17)	7	+				+	18
19			14			+	8 9	+			15		19
20					7			+	4 6				20
21	7						14			+			21
22									14 12	+ (7.5)	14		22
23			14						4 4 12 14 6	+	16	+	23
24									5	+	14 12	+ (5)	24
25									14		14 12	+	25
26		+	7							+	14		26
27	6 6	+			16	+	1	+	6 6	+ (8)			27
28	6 10	+ (4)			14	+ (14)	14 14	+ (9)	12	+	16 16 12	+	28
29	6 14 14	+			9 6	+		+			6 7	+ (5)	29
30		+	6		9 6	+			15		14 14 8	+	30
31			6									+	31

Each number in the body of the table, not enclosed in parentheses, represents the date of death of one calf on that farm. Data from Farm 3 are given separately (Table III). Data from Farms 2 and 11 were incomplete and are excluded. The + signs indicate high mortality periods as defined by a three day moving average of the number of deaths. The numbers in parentheses are the median age at death for calves dying during the high mortality period

Tulare County and although data from this source may not reflect the microclimate within the calf pens, the data were deemed suitable for this study.

Although data were collected and analyzed on many weather variables (Table I) most did not differ among the three mortality groups. Thus it was decided to rank the mortality groups on the basis of temperature factors alone. No combined factors such as a windchill index were used and this limited our ability to precisely differentiate effects of weather among the various groups. For example, the high mortality groups in December were warmer than the low mortality groups. However, on days of high mortality the windspeed was significantly greater than on days of low mortality. The increased windspeed may have produced an effect similar to that of much cooler weather with low windspeeds.

Despite these limitations, the results of this study indicate that a majority of the periods during which the risk of death was increased was associated with extreme temperatures. The most extreme temperatures occurred during periods of high mortality by date of death, the most moderate temperatures in periods of low mortality and intermediate temperature conditions existed in periods of high mortality by date of birth. We do not assume that these high mortality periods are a direct result of the effect of weather extremes alone but that these adverse effects are additive to those of inadequate management (15) and the buildup of pathogenic microorganisms. Although the data in this study do not allow for evaluating the effects of these factors individually, one reasonable interpretation of these results would be that weather phenomena do have an influence on calf mortality and that more extreme temperatures are necessary to exert a harmful effect on a calf a few days of age or older than on a newborn calf.

However, the nature of any association between weather and calf deaths is unclear. With respect to newborn calves it could be that the behavioural changes which result from attempts to acclimatize to extreme temperatures reduce their ability to survive. For example, workers in Scotland (21) noted that calves born in cold weather were sluggish and needed assistance in order to obtain colostrum within a few hours of birth. Although the climate of Tulare County is not as severe as that of Scotland, temperatures of less than 45°F together with fog and/or rain commonly occur. Other authors suggest that calves born in hot environments (similar to that in Tulare County during the summer) are slow to nurse (23) or, following parturition, the dam may seek shade (2) and desert her calf. As previously noted, most calves in Tulare County are raised under conditions which allow direct exposure to the elements (15). Any of these conditions could lead to lower immunoglobulin levels in the calf and thus increase its susceptibility to infection.

In the present study, the effects of adverse weather on the newborn calf are confounded by the possible association between increased births and extremes in environmental temperatures. Except for farm 3, it appears that both increased numbers of

TABLE VI. The Number of Days in Defined Mortality Groups[a] on 14 Dairy Farms in Tulare County, California

			High risk of mortality by day of death		Chi-square statistic
Farm 3			Yes	No	
	High risk of mortality by day of birth	Yes	44	40	8.64
		No	31	69	($p \lesssim 0.05$)
Thirteen-farm group			Yes	No	
	High risk of mortality by day of birth	Yes	36	48	0.28
		No	39	61	($p \gg 0.05$)

[a]A group refers to the mortality category in which each day was classified, i.e. any given day may be categorized into one or more of the following groups: high mortality by day of birth, high mortality by day of death, or both, or neither (low mortality)

TABLE VII. The Association Between Weather Variables and Calf Mortality on 14 Tulare County Dairy Farms, July-December 1973

	Mortality group	Month					
		July	August	September	October	November	December
Farm 3	High mortality Day of birth	2* T_F	3* T_M	2* B.P.$^+$	2* T_F	2* B.P.	3* W_F
	High mortality Day of death	1* T_F	1.5	2	1* T_F	1* B.P., T_M	2* W_F
	Low mortality	3	1.5	2	3	3	1
Thirteen-farm group	High mortality Day of birth	3* T_{DP}, T_A	2* T_m	2* T_F	2* T_F	2* T_F, T_m^-	3* T_m
	High mortality Day of death	2* T_{DP}	1* T_m	1* T_F	1* T_F	1* T_F, T_m^-	2* T_m
	Low mortality	1	3	3	3	3	1

*The weather pattern in this group differed significantly ($p \lesssim 0.05$) from that in the low mortality group. The groups were assigned ranks (1 to 3) with the mortality group having the most extreme temperatures receiving rank 1 and the least extreme, rank 3. Extreme refers to relatively hot temperatures in July through October and to relatively cold temperatures in November and December. Tied ranks were assigned if a group did not differ significantly from the low mortality group on the basis of temperature. The weather variables present in the discriminant function at the first step when the F ratio was significant ($p \lesssim 0.05$) are shown

TABLE VIII. The Association Between Periods of Increased Numbers of Births and Weather Factors on 16 Tulare County Dairy Farms, July-December 1973

	Temperature during periods of increased births relative to the temperature in periods of low numbers of births	
Month	Farm 3	Farms 6, 12, 14
July	Cooler*	Cooler*
August	Cooler*	Warmer*
September	Warmer*	Warmer*
October	No difference	Warmer*
November	Cooler*	Cooler*
December	Warmer*	Warmer*

*Indicates a significant ($p \lesssim 0.05$) difference in temperature between the high and low birth periods

TABLE IX. The Distribution of Deaths on Each Day of the Week as Recorded by Day of Birth and Day of Death[a] on 16 Dairy Farms in Tulare County, July-December 1973

	Farm 3		All other farms	
	Day of		Day of	
Weekday	Birth	Death	Birth	Death
Sunday	32	30	14	29
Monday	22	30	25	22
Tuesday	31	26	19	15
Wednesday	26	29	24	12
Thursday	14	17	17	21
Friday	23	13	24	23
Saturday	19	22	21	22
Total deaths	167	167	144	144
Chi-square statistic	9.92 ($p > 0.05$)	11.67 ($p > 0.05$)	5.28 ($p > 0.05$)	8.47 ($p > 0.05$)

[a]See text for definition

births and increased risk of death on the day of birth are associated with the same radical temperature conditions. It is possible that extremes in temperature trigger the process of parturition, possibly by stimulating increases in the adrenal-steroid hormones. Further, elevated levels of these same hormones in the newborn calf could render it more susceptible to various infections. The effect of temperature extremes on the steroid levels in cattle (1, 3, 9, 26) and the role of steroids in increasing the susceptibility of the newborn to infections (6, 7, 10, 18) have been discussed elsewhere. This hypothesis should be tested in future studies designed specifically for this purpose.

If these study results are valid, the nature of the effect of extreme temperatures on calves at about the time of death would appear to be somewhat different than the effect on newborn calves. Since a cause must precede its effect (11), extreme temperatures must precede death. In this study, extreme temperatures and death occurred at about the same time and, in addition, the high mortality periods were, on the average, less than four days in duration. It seems unlikely that exposure to extreme temperatures would lead to the death of an otherwise healthy calf in such a short time period. Rather, it would appear more probable that calves which are already diseased or in a highly susceptible state may be adversely affected when exposed to adverse temperature conditions.

With regard to the effect of temperature extremes on calves, the number of degrees of temperature fluctuation was the variable best able to discriminate between the mortality groups, particularly during October when the weather frequently changes. Fluctuations of approximately 40° are not uncommon during the summer months and in October. During the winter, fluctuations in daily temperature may exceed

30°. In a previous study (13), we noted that increased rainfall was closely related to higher monthly calf mortality rates during winter. Although this variable was not important as a discriminator in the present study, this was possibly because of lower than average rainfall during the months of November and December in 1973. Also, it should be noted that although data on one weather factor often were sufficient to separate the mortality periods significantly, these factors (Table I) are correlated with each other and when the effects of one weather variable are measured so too are the indirect effects of other related variables.

To our knowledge, only two other studies (19, 20) have examined the possible effects of daily weather phenomena on calf diseases and neither of these referred to calf mortality *per se*. In the first study (20), 17 dairy Shorthorn calves were raised outdoors on grass during the spring months at an average temperature of 32°F. The authors recorded daily sunshine, rainfall and the minimum temperature at grass level. None of these variables was observed to be related to symptoms of ill-health in the calves. In the second study (19), daily temperature, barometric pressure and relative humidity were studied to ascertain if they were correlated with the incidence of gastroenteritis in calves. The author collected data on the onset of gastroenteritis in 322 calves and reported a significant association between the occurrence of this syndrome and decreases in relative humidity and barometric pressure.

We are also aware of previous studies which demonstrated that exposure

TABLE X. Median Age at Death of Heifer Calves on 16 Tulare County Dairy Farms, July-December 1973

Farm number	Median age at death (days)	Number of recorded death dates	Number of recorded deaths
1	Insufficient data	2	27
2[a]	7	0	17
3	8	167	171
4	5	11	11
5	11.5	8	8
6	5	25	25
7	4	12	12
8	4	4	6
9	12	10	10
10	10.5	10	10
11[a]	< 7	0	2
12	12.5	21	21
13	4	1	1
14	7	31	31
15	5	5	6
16	6	6	6

[a]Farm owner 2 recorded the age at death but not the date of birth or death. Farm owner 11 estimated the age of death but did not record the actual date of death

TABLE XI. Median Age of Death on 15[a] Tulare County Dairy Farms During July-December 1973

Month	Median age at death			
	Farm 3		Other farms	
	Day of Birth	Day of Death	Day of Birth	Day of Death
July	6 (35)	4.5 (26)	7 (17)	4 (13)
August	9.5 (46)	10 (27)	8 (26)	5 (22)
September	7 (31)	10 (53)	12 (15)	14 (19)
October	9 (18)	9 (18)	7 (18)	8 (15)
November	5 (12)	9 (17)	7.5 (26)	8 (28)
December	12 (26)	4.5 (14)	6 (42)	6 (35)

[a]Farm 1 excluded due to insufficient data; see Table IX
( )Observed number ot dead calves

to extremely cold and/or damp weather was not necessarily harmful to calves (4, 8, 17, 27). Indeed, for a variey of reasons, those calves which were raised outdoors fared better than the housed calves which were presumably sheltered from many of the effects of adverse weather. This indicates that climatic factors alone can seldom be held responsible for illness and death (16, 22), a philosophy to which we adhere. Nevertheless, the existence of an association between calf mortality and daily weather patterns in our study population cannot be denied. In our view, extreme temperatures do affect calf mortality, although the mechanism of this interaction remains poorly understood.

The overlap in periods of high mortality by date of birth and by date of death on Farm 3 suggests that factors necessary to the survival both of newborn calves and older calves were absent during these periods. Since this was not noted in the other group of farms, one could postulate that this overlap was due to intrafarm specific factors, for example, factors related to inadequate management and/or the effects of pathogenic microorganisms. Additional support for this hypothesis was gained in previous studies which indicated that managerial practices on this farm were highly variable and often inadequate (Huffman, E. M., C. W. Schwabe and S. W. Martin, University of California, Davis, California, unpublished data).

The day of the week appears to have no influence on mortality. If management practices change with the day of the week, these changes are either not of sufficient magnitude to alter the survivability of calves or the effects of such changes are dispersed equally over a number of subsequent days.

The median age at death varied from farm to farm and this may have been due to factors of management and/or housing local to a particular farm. In addition, the median age at death varied from month to month and from one period of time to another within a month. One might infer from this that different microorganisms were associated with the death of calves on different farms or during different periods of time on the same farm. Published data on cause-specific death rates in different ages of calves are insufficient, however, to accurately interpret these findings (12). Certainly, because of shifts in the age of death, care should be taken in selecting calves for postmortem examination to ensure that they are representative of the population of dead calves, at least with respect to age.

Certainly, no questions are decisively answered by this small pilot study. However, we believe that the methods developed in this study will provide a basis for more comprehensive studies on calf mortality in the future.

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