DISSERTATION

DAIRY COW MORTALITY

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Craig Stephen McConnel

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY CRAIG MCCONNEL ENTITLED DAIRY COW MORTALITY BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Ashley E. Hill

Jason E. Lombard

Daniel H. Gould

Advisor: Franklyn B. Garry

Department Head: D. Paul Lunn

ABSTRACT OF DISSERTATION

DAIRY COW MORTALITY

Dairy cow mortality levels in the United States are excessive and increasing over time. This is both a financial concern and an important animal welfare issue. Summary studies of dairy cow removal have been in the literature for decades although information specifically related to dairy cow mortality has been sparse. Even though the increase in dairy cow mortality has generated concern within the industry, the reality is that there is no standard by which to define what might be considered the 'natural' or 'normal' level of mortality in dairy cow production. No evidence suggests that there is any one thing that has led to the rise in mortality and that could be reversed to lower death rates. Rather, numerous agents (influential persons, places, or things) apparently act in concert to influence specific outcomes that may lead to death. The "agents" intimated to be responsible for increasing mortality have been primarily described through the analysis of associations between mortality levels and descriptors such as days postpartum, parity, herd size, and genetics. Such analyses may provide a means for understanding populations at risk but can only illustrate broad principles related to manageable risk factors, potential mitigation procedures, or specific pathologic outcomes. Other studies have attempted to define individual occurrences of death based on the final outcome. Rather than looking at population levels of diseases and associated levels of death, these studies have focused on the pathophysiologic or anatomic descriptions of specific deaths.

Such analyses fail to account for the non-biologic unconstrained inputs such as management and environmental factors that ultimately set a pathologic sequence in motion within an at-risk population. Ultimately, with regard to excessive and increasing dairy mortality the difficulty lies in defining the problem (establishing what distinguishes farms with higher death rates from those with more desirable rates) and locating the problem (finding where the trouble really lies within the complex of causal networks on a dairy). This leads to the problem of identifying the actions that might effectively narrow the gap between what-is and what-ought-to-be. Understanding the complexity within such a system demands the recognition of its evolving ecology. Within this evolving industry there is no legitimate means for resetting practices and outcomes back to some undefined acceptable level. Rather than attempting to reverse the irreversible, it would be wise to instead work within the system to improve outcomes through sound scientific principles. The intention of the following work is to characterize and elucidate such principles in an effort to facilitate best intentions becoming better outcomes.

Craig Stephen McConnel
Clinical Sciences
Colorado State University
Fort Collins, CO 80523
Summer 2010

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

Dairy cow mortality in the United States

Dairy cow mortality levels in the United States are excessive and increasing over time. This is both a financial concern and an important animal welfare issue (Thomsen et al., 2006). Summary studies of dairy cow removal have been in the literature for decades (Seath, 1940, Asdell, 1951, O'Bleness and Van Vleck, 1962), although information specifically related to dairy cow mortality has been sparse (Thomsen and Houe, 2006). Seath used Kansas Cow Testing Association data from 1930 to 1935, for 37 herds representing 1,883 cows, to demonstrate that death losses represented 2.0% of the total dairy cow inventory (Seath, 1940). More expansive Dairy Herd Improvement Association (**DHIA**) data from 1932 to 1949, for 17 states representing 2,792,188 cows, demonstrated that 1.1% of the total cows on test died (Asdell, 1951). Death losses over those years were remarkably uniform with yearly levels ranging from 0.9% to 1.2%.

A review covering the years 1965 to 2006, found 19 studies focused on dairy cow death (Thomsen and Houe, 2006). Of these studies, 2 included data since 2000, 6 were from the US, 10 incorporated information related to causes of death, and measures of mortality ranged from 1 to 5%. More recent studies outside of the US have demonstrated a steady increase in dairy cow mortality. In Denmark, the mortality rate rose from 2% in 1990 to 4% in 2001 (Thomsen et al., 2007). Likewise, the mortality rate in Ireland increased from 3.2% in 2003 to 4.1% in 2006.   Within the US, DHIA data from 2001 through 2006 representing 3,629,002 lactations in 2,054 herds located in 38 states primarily east of the Mississippi river, demonstrated an annualized death rate of 6.6% (Pinedo et al., 2010). National DHIA data (15,025,035 lactations in 45,032 herds)from 1995 through 2005, demonstrated an overall death frequency of 3.1% on a lactation basis (5.7% on a cow basis) with observed lactational death frequencies increasing from 2.0% in 1995 to 4.6% in 2005 (Miller et al., 2008). Similarly, the USDA:APHIS:VS National Animal Health Monitoring System (**NAHMS**) Dairy surveys have reported steady increases in cow losses, from 3.8% of the January 1996 inventory, to 4.8% of the January 2002 inventory, and 5.7% of the January 2007 dairy cow inventory (USDA, 2007b).

Although the increase in dairy cow mortality has generated concern within the industry, no standard exists by which to define what might be considered the 'natural' or 'normal' level of mortality in dairy cow production (Thomsen and Houe, 2006). The insidious rise in death rates over the past decades suggests that aspects of the dairy industry have changed to the detriment of the cattle, and it can be tempting to define some "thing" that has created this problem. As an example, the case has been made that specific regulatory events have substantially influenced on-farm deaths, such as the 2004 rules prohibiting non-ambulatory cattle from entering the food chain and the updating in 2005 of recommendations regarding humane transport within the US (Fetrow et al., 2006). Similarly, rising mortality rates in Ireland have been suggested to be consequent to revised rules for slaughter of cattle post BSE as well as fitness-to-transport regulations (Maher et al., 2008). While such regulatory modifications undoubtedly influence on-farm mortality, they cannot account for the overall rise in dairy cow mortality across the years. In fact, there is no evidence that there is any one thing that has led to the rise in mortality and that could be reversed. Rather, numerous influential agents (persons, places, or things) apparently act in concert to influence specific outcomes that may lead to death.

Associations with mortality

The "agents" responsible for increasing mortality have been primarily described through the analysis of associations between mortality levels and population characteristics such as parity, disease prevalence, days in lactation, or pregnancy status (Thomsen and Houe, 2006, Bar et al., 2008, Dechow and Goodling, 2008, Miller et al., 2008, Pinedo et al., 2010). Higher rates of common production diseases are often related to an increase in mortality (Norgaard et al., 1999, Thomsen et al., 2007). A large proportion of dairy cow deaths (Stevenson and Lean, 1998, Thomsen et al., 2004, Pinedo et al., 2010) and the highest frequency of health disorders are associated with early lactation, including locomotor disorders that may result in euthanasia (Shanks et al., 1981, Markusfeld, 1993, Green et al., 2002). A high proportion of deaths have been shown to occur during the first 15 to 30 days after calving with the highest proportion occurring during the first few days after calving (Milian-Suazo et al., 1988, Faye and Perochon, 1995, Menzies et al., 1995, Stevenson and Lean, 1998, Thomsen et al., 2004) If homeostatic mechanisms cannot respond to the tremendous metabolic and endocrine challenges related to parturition and the onset of lactation, diseases such as clinical hypocalcemia, ketosis, retained fetal membranes, metritis, mastitis, and abomasal displacement may occur (Goff and Horst, 1997, Melendez and Risco, 2005). Higher mortality has also been found among older cows (Faye and Perochon, 1995, Dematawewa and Berger, 1998, Stevenson and Lean, 1998, Thomsen et al., 2004, Miller et al., 2008, Pinedo et al., 2010). This may be partly explained by increased incidences of certain diseases such as hypocalcemia, ketosis, and retained fetal membranes with increased parity (Markusfeld, 1993, Gröhn et al., 1998, Houe et al., 2001). Further, annualized death rates have been shown to be higher for non-pregnant cows relative to pregnant cows. This may be due to preferential treatment of pregnant cows when they get sick and is also likely a result of healthier cows getting pregnant sooner (Pinedo et al., 2010).

Other studies have demonstrated that management and environmental factors can be related to dairy cow mortality. Increases in herd size, average somatic cell count, or the proportion of purchased cows have been shown to result in an increasing mortality risk at the herd level (Norgaard et al., 1999, Smith et al., 2000, Thomsen et al., 2006, Pinedo et al., 2010). It has been suggested that while larger herd sizes with increased mechanization contribute to less attention per cow and increased mortality, higher levels of physiologic stress and increased mortality can also stem from increases in concentrate consumption and average milk yield per cow (Norgaard et al., 1999). Culling decisions may also influence death rates. One study demonstrated a negative correlation between live culling rates and deaths suggesting that herds that delay culling decisions have increased numbers of deaths (Pinedo et al., 2010). Seasonal patterns have been associated with mortality as well. Summer has been shown to be the season with the greatest risk for death in the US and abroad (Vitali et al., 2009, Pinedo et al., 2010).

Genetics have been implicated as an underlying component of increasing death losses due to genetic selection biased toward production indices, with little consideration of animal longevity or disease occurrence. In fact, data suggest that Jersey and crossbred dairy cows do have reduced mortality levels relative to purebred Holsteins (Miller et al., 2008, Rogers, 2009). However, estimates suggest that only about 1% of the variation in the likelihood that a cow will die during a lactation is genetic. That said, genetic variation might be proportionally greater if death loss was expressed on a lifetime rather than a lactation basis (Miller et al., 2008). Nonetheless, genetic trends for productive life have been favorable over the past couple of decades (AIPL, 2008), implying that the decline in dairy cow survival is primarily the result of changes in herd management as opposed to genetic selection (Dechow and Goodling, 2008).

The aforementioned studies established associations between mortality and population characteristics, management and environmental factors, and genetics. These endeavors attempted to provide statistically relevant insight into what might be considered a chaotic system according to management theory. Management theory describes chaotic systems as having unconstrained agents that are present in large numbers. Insight into the operation of such systems can be gained through the application of statistics and probability distributions (Snowden, 2008). Relative to mortality, the agents described above generally encompass numerous concepts that are more or less intangible and hence unconstrained. For example, describing the relationship between increased mortality and descriptors such as days postpartum, parity, herd size, and genetics may provide a means for understanding populations at risk but can only illustrate broad principles related to manageable risk factors (e.g. transition cow problems; age-related issues), potential mitigation procedures (e.g. cows per employee; genetic diversity), or specific pathologic outcomes (e.g. incidence of retained fetal membranes or lameness). In other words, establishing associations between dairy cow mortality and these pertinent agents provides a bird's eye view of the problem without providing explicit solutions based on cause and effect.

Pathophysiologic and anatomic descriptors of death

On the other hand, other studies have attempted to define individual occurrences of death based on the final outcome. Rather than looking at population levels of diseases and associated levels of death, these studies have focused on the pathophysiologic or anatomic descriptions of specific deaths. Some of the earliest research into removals attempted to classify specific reasons for cow deaths based on available records or producer recollection. As such, the relative importance of dystocia, accidents, traumatic reticuloperitonitis, bloat, and hypocalcemia as underlying problems was specified (O'Bleness and Van Vleck, 1962, White and Nichols, 1965). However, capturing information regarding why cows die can present a substantial challenge. Thomsen and Houe's review of dairy cow mortality found that only 10 of 19 studies gave some information on causes of death, and none of the diagnoses were founded on necropsy examination (Thomsen and Houe, 2006). Only a single study discriminated between cows that were euthanized and those that died unassisted (Thomsen et al., 2004). Consequently, perceptions based solely on antemortem histories have played a significant role in determining recorded causes of death within much of the relevant literature.

Categories used to describe the deaths have been relatively uniform across studies and have included: accidents, calving disorders, digestive disorders, locomotor disorders, metabolic disorders, udder/teat disorders, other known reasons, and unknown reasons. The level of detail is variable and most studies have a relatively large proportion of causes classified as 'unknown' (16-46%) (Thomsen and Houe, 2006). Similar descriptors for causes of death were used within the NAHMS Dairy 2007 survey which documented the percentage of cow deaths due to: calving problems (15.2%), scours, diarrhea, or other digestive problems (10.4%), euthanasia due to lameness or injury (20.0%), mastitis (16.5%), respiratory problems (11.3%), poison (0.4%), lack of coordination or severe depression (1.0%), other known reasons (10.2%), and unknown reasons (15.0%) (USDA, 2007b). Although these categorical groupings are commonly used there is no information in the literature to validate that these groupings are useful for directing management changes or that they are even used for such a purpose.

Thorough necropsy-based postmortem evaluations are an important component for defining the pathologic reasons underlying dairy cow deaths. Numerous publications have touted the benefits of and procedures for performing field necropsy examinations (White, 2005, Mason and Madden, 2007, Wagner, 2007). A dead animal that is not evaluated by necropsy is a total economic loss to a producer; however, a thorough necropsy examination may provide valuable management information that may benefit the herd. Nonetheless, the value of a postmortem evaluation is directly related to the accuracy and maintenance of data collected and its application to operational management. Maintaining accurate postmortem records can be difficult and can limit the capacity to easily retrieve records that might provide valuable insight into historical death patterns and guide future health planning and programs (White, 2005). Recently, a study based on diagnostic laboratory submissions of dead cattle in England and Wales demonstrated the increase in detail that postmortem evaluations can provide (Watson et al., 2008). Similar categories to those listed previously were described based on body systems (systemic, digestive, respiratory, urinary, musculoskeletal, nervous, skin, circulatory, reproductive, and other) but specific disease manifestations were also provided within each category. Unfortunately, although the diagnostic submissions were capable of providing specific findings relative to individual deaths, this level of detail can be difficult to analyze for underlying herd-level problems and is limited in its account of the sequence of events that led to the death.

The attempts to classify deaths according to pathophysiologic and anatomic descriptors are dependent on an understanding of mortality as part of an ordered system. As described within management theory, this requires repetitive relationships between cause and effect that can be discovered by empirical observation, analysis, and other investigative techniques (Snowden, 2008). An understanding of the relationships at hand allows for the prediction of the future behavior of the system and the manipulation of it toward a desired end state. The fact that agent behavior is constrained within such a system enables the predictability. As per this system the causality underlying mortality is ordered according to what can be defined as the proximate or immediate cause of death. For example, death due to respiratory disease might define the end point of a progressive bacterial infection. Likewise, death resulting from septic metritis might describe the termination of a sequence initiated by dystocia. Whatever the final pathologic outcome, this method of delineating underlying causes of mortality is reliant on a readily defined sequence of biologic events assumed to be more or less capable of being constrained or affected. The presumption is that each *disease* is a distinct entity with a distinct cause—an ontological conception of disease (Hamlin, 1995) that tends to view prevention and control in terms of vaccines and antimicrobials. This system fails to account for the non-biologic unconstrained inputs that ultimately set a pathologic sequence in motion within an at-risk population. In other words, this method of describing dairy cow mortality focuses predominantly on the finite pathophysiologic failures without appropriately acknowledging the continuum of events and agents that eventuated in that failure.

A wicked problem and system complexity

Even in the face of low mortality rates relative to today's standards, past studies suggested that the main objective of dairy research and educational programs related to cow disposals should be to produce cows with longer effective lives. Emphasizing prevention, early recognition, and prompt treatment of injuries and diseases such as mastitis and infertility, and focusing on proper feeding and management, was recognized to bring about increased longevity and improve the economic efficiency of herd operations (Asdell, 1951, Parker et al., 1960). These considerations are no different today. The differences lie in the details related to particular herd characteristics and practices and specific manageable outcomes.

With regard to excessive and increasing dairy mortality the difficulty lies in defining the problem (establishing what distinguishes an observed condition from a desired condition) and locating the problem (finding where in the complex of causal networks the trouble really lies). Ultimately this leads to the problem of identifying the actions that might effectively narrow the gap between what-is and what-ought-to-be (Rittel and Webber, 1973). In fact, there is no definitive statement of "The Problem." It is an ill-defined set of evolving interlocking issues and constraints (Conklin, 2006). The reality is that rising dairy cow mortality poses a "wicked problem" for which context is often more important than content, and learning is more important than order and structure (Snowden, 2001).

Wicked problems were described by Horst Rittel in response to the limitations of the linear "systems approach" of design and planning that focused primarily on efficiency (Rittel and Webber, 1973). Wicked problems are distinguished by the 6 following primary characteristics: 1) A wicked problem has no definitive formulation. Attempting to understand the problem is dependent upon ideas for solving it. In other words, understanding rising mortality and resolving the problem are concomitant to each other. 2) Wicked problems have no stopping rule. Since no definitive "The Problem" exists, no definitive "The Solution" exists either. Dairy cows will continue to die. The issue is at what point death rates are low enough. 3) Solutions to wicked problems are not right or wrong. Solutions for mortality will be viewed as "better," "worse," "good enough," or "not good enough." Assessments of proposed solutions vary and depend on stakeholders' independent values and goals. 4) Every wicked problem is essentially unique. Dairy farms are composed of so many novel factors and conditions, all embedded within a dynamic social context, that the problem of mortality will necessarily require individualized solutions. 5) Every solution to a wicked problem is a "one-shot operation." Dairy systems are complex and every implemented solution has unintended, often irreversible consequences that evolve over an extended period of time. 6) Wicked problems have no given alternative solutions. A host of potential solutions arises but some solutions may never even be considered. No criteria exist by which to determine that all solutions to the problem of rising mortality levels have been identified and explored (Rittel and Webber, 1973, Conklin, 2006).

Each of the aforementioned characteristics of a wicked problem can be used to describe the problem/solution space of rising dairy cow mortality. Engaging the problem requires exploring dairy system complexity. Research focused on increasing death rates historically has approached the problem from opposite ends of the spectrum, attempting to describe it through chaotic or ordered systems. This approach has focused primarily on content while ignoring context. Although it is most certainly useful to establish associations between population characteristics and mortality, or between specific disease entities and higher death rates, mitigation strategies must be based on an understanding of why those associations or diseases are present in the first place. A more thorough approach lies in the middle and is based on a third type of system called a complex adaptive system. Within this type of system agents are lightly, but not fully, constrained while in turn modifying the nature of the system through their interactions. This involves co-evolution in that each agent within such a system exerts selective pressures on the others, within an environment that itself creates pressures, thereby affecting each other's and the system's evolution. In other words, complexity is a science concerned with multiple connected, interdependent, interacting agents (Snowden, 2001, Snowden, 2008).

The numerous interacting agents within an individual dairy farm community comprise a complex network of connections. These connections form a system that is inherently altered through any process that attempts to break it into its component parts or subject it to analysis. The whole is always different from the sum of its parts and is a product of evolution. Cause is intertwined with effect, and the sheer number of connections means that predictive rules are not applicable. A constant shift in the farm community's dynamic occurs, influencing interactions between agents (cows, people, nutrition, facilities, weather, etc.) and even within agents (emotional or physical variations in workers, or biologic fluctuations within cattle). Understanding the complexity within such a system demands the recognition of its evolving ecology. Importantly, with co-evolution comes the associated phenomenon of irreversibility. Complex systems only move forward from the present. Consequently, managing such a system requires flexible interventions based on simple actions that can themselves evolve into complex and desirable behaviors (Snowden, 2008).

The problem of dairy cow mortality is best evaluated and addressed at an ecological level. By definition, ecology is the science of organisms as affected by environmental factors; the study of the environment and the life history of organisms (Blood and Studdert, 1999). Previous attempts at studying rising mortality have failed to integrate dairy ecology into the matrix of evaluation. The ecology defines the context from which researchers have extracted content. This attempt to create order and structure from what is otherwise a very complex system has ultimately limited our understanding of how best to address rising mortality levels. Putting the "complexity" back into the discussion of this problem is required if the industry is to truly move forward and take meaningful action.

The following chapters attempt to pursue a logical discussion of the problem of dairy cow mortality through a sequence informed by historical perspectives but driven by current understanding. As such, the first three chapters describe mortality from a bird's eye view utilizing national and Colorado-centric data to describe associations between mortality and overarching influential agents. As with previous database driven studies these analyses approach the problem as a more or less chaotic system. The fourth chapter focuses on finite pathophysiologic features related to proximate causes of death. As discussed above, this approach describes the problem principally as an ordered system. The fifth chapter moves forward with a discussion of options for integrating ecological principles into records related to dairy cow death, addressing the issue in terms of a complex adaptive system. The concluding chapter focuses on the future of efforts to deal with rising mortality, discussing options for better data capture that facilitates dialogue and learning within the co-evolutionary dairy community.

Progress within the dairy industry is a product of best intentions that at times lead to unfortunate unintended consequences. Rising death rates reflect one such consequence. Within this evolving industry there is no legitimate means for resetting practices and outcomes back to some undefined acceptable level. Rather than attempting to reverse the irreversible, the system should be approached from within to improve outcomes through sound scientific principles. The intention of the following work is to characterize and elucidate such principles in an effort to facilitate best intentions becoming better outcomes.

CHAPTER 2: EVALUATION OF FACTORS ASSOCIATED WITH INCREASED DAIRY COW MORTALITY ON U.S. DAIRY OPERATIONS[1]

INTRODUCTION

Dairy cow mortality causes financial losses and is an important animal welfare issue (Thomsen et al., 2006). Results from the USDA:APHIS:VS National Animal Health Monitoring System (**NAHMS**) Dairy 2002 survey reported that 4.8% of dairy cows die on-farm across the country each year (USDA, 2002a). This level of mortality represents an increase from 3.8% of the January 1996 inventory, and is a relatively high death rate compared with that of beef cows or feedlot animals for which annual death rates are estimated at 1 to 1.5% (NAHMS, 1997, USDA, 2000b). Dairy Herd Improvement Association (**DHIA**) records from the late 1990's suggest that dairy cow death rates are even higher. A study of 11,259 DHIA cow records ending in 1998, from all regions except the West, reported death rates of 5.9 to 7.7% (Smith et al., 2000). Variability in causes of death and rates of occurrence on different operations arises due to the complex nature of dairy management systems. In the NAHMS survey 'unknown reasons' accounted for the single largest percentage (20%) of producer-attributed reasons for dairy cow deaths, followed by calving difficulty problems (17%), mastitis (17%), and lameness or injury (14%) (USDA, 2002a).

Dairy cow survival is influenced by both management and genetic factors (Weigel et al., 2003). Cows that are genetically superior milk producers tend to be

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genetically less superior for fertility and survival (Dematawewa and Berger, 1998).Thus, with large increases in daily milk production the ability to convert energy reserves to production may be at the expense of cow health and reproduction (Dechow et al., 2004, Lucy, 2001, Tsuruta et al., 2005). Increased average yields in milk, fat, and protein have occurred alongside associated increases in reproductive and metabolic diseases (Dechow et al., 2004). Some subclinical physiologic or metabolic problems may increase the likelihood of death. Numerous such problems have been described and can be identified including subclinical hypocalcemia, subacute ruminal acidosis, severe negative energy balance and other metabolic disease in early lactation, trace mineral and vitamin deficiency, poor immune responsiveness in the postpartum period, and feed quality problems that induce gastrointestinal disturbances or specific toxicoses (Politis et al., 1996, Mallard et al., 1998, Piccinini et al., 2004). Other clinically recognizable health problems that increase the risk of death or culling in dairy cows include calving difficulty, coliform mastitis, clinical hypocalcemia, and paratuberculosis (Dohoo and Martin, 1984, Milian-Suazo et al., 1989, Wenz et al., 2001).

There are complex genetic and phenotypic relationships among yield, fertility, and survival. Management decisions and other variables contribute to the complexity of the relationships. Although cows with the genetic potential for high production appear to have a lower genetic potential for survival, producers may provide better management (e.g. feed and health care) for those high producing cows. Such preferential treatment may lower mortality rates for high yielding cows relative to those for low yielding cows (Dematawewa and Berger, 1998) and lead to a decrease in mortality with increasing milk production at the herd level (Smith et al., 2000, Thomsen et al., 2006). Nonetheless, as producers adopt new and more intensive production methods in an effort to lower costs and increase yields, systematic problems with animal care may arise, particularly in herds where less individual attention is possible (Norgaard et al., 1999). As herds continue to expand, it is becoming increasingly important to identify factors that affect the health and survival of high-producing dairy cows (Weigel et al., 2003). The objective of this study was to examine a wide variety of herd management practices and herd characteristics to identify risk factors associated with increased cow mortality in US dairy herds.

MATERIALS AND METHODS

During the NAHMS Dairy 2002 study, data were collected from farms in 21 states that represented 82.8% of US dairy operations and 85.5% of the US dairy cow population. Regions and states included in the study were: West=California, Colorado, Idaho, New Mexico, Texas and Washington; Midwest=Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin; Northeast=New York, Pennsylvania and Vermont; Southeast=Florida, Kentucky, Tennessee and Virginia. During the first phase of this study a general management questionnaire was administered to dairy farms with one or more dairy cows on January 1, 2002. Only farms which participated in Phase I and had 30 or more dairy cows were eligible to participate in Phase II. The Phase II questionnaires covered topics including general management, animal health, herd characteristics, handling of manure and waste treatment, milking procedures, biosecurity, and cattle inventory. Of the 1008 operations completing Phase II, 953 had complete data and were eligible for inclusion in the analysis.

The survey design was a stratified random sample with unequal selection probabilities within each stratum. The unequal selection probabilities were implemented to ensure that large dairy operations were represented in the sample. Weights were created for each operation to account for the selection probabilities and for non-response. Complete details of the study design and sample weighting are published elsewhere (USDA, 2002b). Continuous variables were classified into categories based on the lowest 25%, middle 50%, and highest 25%.

The association between dairy cow mortality and 119 *a priori* operation-level management practices and/or characteristics was evaluated univariately via a Chi-square test. The percentage of dairy cow mortalities was determined by dividing the number of cows that died during 2001 by the number of dairy cows (both dry and in milk) present on January 1, 2002 for each operation (**Figure 2.1**). Mortality levels were categorized into low, moderate, and high groups (< 2.5%, 2.5% – 6.25%, and > 6.25%) to be used as the outcome variables in the analysis. Independent variables which met the univariate screening criteria (P-value < 0.15) were evaluated using an unweighted ordinal logistic regression with stepwise model selection using the ologit procedure of STATA (STATA 9.2, Statacorp, College Station, TX). A second ordinal logistic model was constructed because the statistical software did not allow for a stepwise selection method that accounted for the study design and weighting. After the variable selection procedure in the first model, variables with P-values < 0.05 were entered into an ordinal logistic procedure that incorporated the study design and the sampling weights in order to appropriately estimate model coefficients and associated standard errors. Interactions between the final selected variables were evaluated as well.

RESULTS

Eighty of the 119 risk factors explored in the univariate analysis met initial screening criteria for further evaluation of association with dairy cow mortality (**Table 2.1**). Region of the country and adult herd size were associated with dairy cow mortality. Operations reporting greater than 355 adult cows were associated with increased levels of mortality ($P < 0.0001$; **Table 2.1**), as were those operations in the West, Midwest, and Southeast relative to the Northeast ($P = 0.0002$). A higher rolling herd average milk production (> 22,000 lbs/cow per year) was associated with higher levels of mortality ($P < 0.05$). Other management practices such as feeding a total mixed ration (71.1% of operations; $P < 0.0001$), using forage test results to balance rations (87.1% of operations; $P < 0.0001$), using milk urea nitrogen to determine ration composition (33.5% of operations; $P = 0.0002$), administering bovine somatotropin (36.4% of operations; $P < 0.0001$), and routine drenching of fresh cows (25.8% of operations; $P = 0.0292$) were all associated with a higher level of mortality.

Numerous health management variables describing heifer and cow vaccinations and nutritional supplementation were associated with increased levels of mortality ($P < 0.05$; **Table 2.1**). Variables describing herd levels of disease and illness demonstrated increased levels of mortality with increased levels of disease problems ($P < 0.05$; **Table 2.1**). Specifically, reproductive problems such as higher levels of abortions, retained placentas, and other reproductive problems (e.g. dystocia, metritis) were all associated with increased mortality levels. Similar increases in mortality were observed with increased levels of respiratory problems, lameness, diarrhea, displaced abomasums, and clinical mastitis.

Various parameters describing operation facilities were associated with mortality levels. Higher levels of mortality were associated with the use of free stalls as the primary housing facility for lactating dairy cows (53% of operations; $P < 0.0001$), and with herds that did not provide an outside area for lactating dairy cows (30.6% of operations; $P = 0.0125$). If the primary housing facility for maternity cows was a multiple animal area (43.1% of operations) there was an association with increased mortality levels ($P < 0.0001$). Conversely, operations primarily housing maternity cows in an individual animal area (26.2% of operations) were associated with reduced levels of mortality ($P = 0.0121$). For variables related to biosecurity, dairies that brought cattle onto the operation were associated with increased levels of mortality ($P = 0.0007$).

Of the 80 variables that passed the screening process, only 7 that were significantly associated with mortality level at the univariate level remained in the final weighted ordinal logistic model (**Table 2.2**). There were no significant interactions between variables in the final model. Model results indicated the odds of a herd having a higher level of mortality were 2.75 times as high among herds with a high percentage (> 3.4%) of respiratory problems during 2001, and 1.71 times as high among herds with a moderate level (0.1% - 3.4%) of respiratory problems, as compared to herds with no documented (0%) respiratory problems (**Table 2.2**). The odds of a herd being in a higher category of dairy cow mortality were 2.89 times as high among herds with a high percentage (> 16.1%) of lameness during 2001, and 2.34 times as high among herds with a moderate level (3.4% - 16.1%) of lameness, as compared to herds with a low level

(≤3.3%) of lameness. Further, the odds of a herd being in a higher category of dairy cow mortality were 2.27 times as high among herds with a high percentage (> 41.2%) of sick cows treated at least once with antibiotics during the preceding 12 months, and 1.61 times as high among herds with a moderate level (12.8% - 41.2%) of sick cow treatments, as compared to herds with a lower level (≤12.7%) of sick animals treated with antibiotics.

Herds with a low percentage of cows that were culled less than 50 days in milk (≤2.0%) were 1.97 times more likely to have a higher level of mortality than were herds with a moderate level (2.1% - 20.8%) of cows that were culled less than 50 days in milk. The odds of a herd being in a higher category of dairy cow mortality were 1.78 times as high among herds with a longer (> 13.9 mo) calving interval compared to herds with a shorter (≤ 12.9 mo) calving interval. Herds that fed a total mixed ration were 2.08 times more likely to have a higher level of mortality than were herds that did not feed a total mixed ration. Additionally, herds located in the West, Southeast, and Midwest were respectively 2.53, 2.18, and 2.07 times more likely to experience a higher level of dairy cow mortality than were herds in the Northeast.

DISCUSSION

The national scope of the sampling, including information regarding management practices and characteristics of dairy production, provided this current study with a unique data set. There are relatively few studies focusing on dairy cow mortality (Gardner et al., 1990, Faye and Perochon, 1995, Stevenson and Lean, 1998, Norgaard et al., 1999, Thomsen et al., 2004, Thomsen and Houe, 2006, Thomsen et al., 2006). A primary focus has often been on describing mortality relative to population characteristics such as parity, disease prevalence, or days in lactation while attempting to specify causes of death.

Some studies have, however, focused on management factors and their relationships to dairy cow mortality (Norgaard et al., 1999, Smith et al., 2000, Thomsen et al., 2006). An increase in herd size, average somatic cell count, or the proportion of purchased cows has been shown to result in an increasing mortality risk at the herd level. Lower mortality risks have been found for herds that were pasture grazed during the summer, organic versus conventional, used free stall barns with deep litter, or had increasing milk production at the herd level (Smith et al., 2000, Thomsen et al., 2006). Others have suggested that while larger herd sizes with increased mechanization contribute to less attention per cow and increased mortality, higher levels of physiologic stress and increased mortality can also stem from key production figures such as increasing concentrate consumption and average milk yield per cow (Norgaard et al., 1999).

In the present study, univariate associations were demonstrated between higher mortality levels and increasing herd size, dairy location, production parameters related to nutritional and health management, specific disease problems and treatments, facilities, and biosecurity. Contrary to previous reports, this study found that herds with higher annual rolling herd averages for milk production were more likely to be associated with higher mortality levels than were the lowest producing herds. The final multivariate model retained factors associated with management and health and reproductive problems, achieving variable reduction and assessment given the presence of the other variables in the model. Specifically, the final model demonstrated increased odds of a higher level of mortality when a total mixed ration was fed, and for those operations with the lowest level of culled cows less than 50 days in milk, the longest calving interval level, or increased levels of respiratory problems, lameness, or antibiotic treatments of sick cows.

Higher rates of common production diseases are often related to an increase in mortality (Norgaard et al., 1999, Thomsen et al., 2007). A large proportion of dairy cow deaths (Stevenson and Lean, 1998, Thomsen et al., 2004) and the highest frequency of health disorders are associated with early lactation, including locomotor disorders that may result in euthanasia (Green et al., 2002, Markusfeld, 1993, Shanks et al., 1981). If homeostatic mechanisms cannot respond to the tremendous metabolic and endocrine challenges related to parturition and the onset of lactation, diseases such as clinical hypocalcemia, ketosis, retained fetal membranes, metritis, mastitis, and abomasal displacement may occur. Diseases such as laminitis, ovarian cysts, endometritis, and anestrus that typically become clinically apparent later postpartum are related to this early postpartum period as well (Melendez and Risco, 2005). Failing to recognize and appropriately manage or remove those animals suffering from severe disease and disorders during early lactation may be at the expense of increased mortality levels. Factors within the final model that were associated with dairy cow mortality included variables representing herd reproduction, disease recognition and treatment, and early postpartum culling, highlighting the influence and importance of the transition period on the health and productivity of dairy cows.

The calving interval for a dairy represents numerous facets of an operation's herd and reproductive health and management indices. Herd size and calving interval have been positively correlated (USDA, 2002a) and the shift toward larger dairies has created a new management paradigm (Lucy, 2001). Complex interactions between variables such as dairy expansion and labor management, disease control within confinement dairies, inbreeding and selection for production traits, hormonal manipulation, and heat abatement dictate calving intervals (Pryce et al., 2000, Lucy, 2001) and mirror the interwoven physiologic and management factors that potentially determine mortality rates.

Economic pressure drives the structural development of dairy farming and has necessitated the intensification of production through the comprehensive rationalization of production systems alongside productivity increases (Norgaard et al., 1999). Intensive management practices such as animal crowding and feeding high levels of concentrate may contribute to higher levels of physiological stress. These practices in tandem with changes in the physical environment (increased mechanization, larger herd sizes) that contribute to less attention per cow, altered culling practices, and an influx of purchased cows may adversely influence death rates (Norgaard et al., 1999, Weigel et al., 2003, Thomsen et al., 2006). For large, intensively managed herds, training and oversight of employees becomes increasingly important. The ability of dairy personnel to adequately identify disease in individual animals and respond with prompt, appropriate individual animal attention is limited by the extent of their experience and training (Ruegg, 2001). Since a preponderance of sick cows on large dairies are identified, diagnosed, and treated by farm workers with limited training, increased health problems and deaths may be associated with inadequate training and subsequent inadequate clinical disease management or animal removal.

Variations in regional US death losses have been described previously (Smith et al., 2000). This association may relate to regional differences in aspects of the physical environment, nutrition, and management factors. After adjusting for other factors, this study demonstrates that herds located in the West, Southeast, and Midwest experienced a significantly higher level of dairy cow mortality than herds in the Northeast. One of the most striking facets of regional dairy production involves the trend for herd expansion at the expense of farm numbers. Increases in disease-related problems as a function of inadequate biosecurity have been documented following herd expansions (Faust et al., 2001). Additionally, increases in physiological strain as well as a more stressing environment following expansion (Norgaard et al., 1999, Weigel et al., 2003) may limit the resistance of cattle when exposed to infectious agents (Thomsen et al., 2006). Regional variations in mortality levels may relate to problems associated with dairy herd expansion.

The goal of this analysis was to identify features of dairy operations that might be managed differently to decrease mortality rates. The Dairy 2002 survey was not specifically designed to assess causes of mortality, and therefore it should be expected that some of the identified associations with mortality would not be as well focused as desired. The univariate analysis demonstrated associations between higher mortality levels and numerous health management variables describing the administration of vaccinations and nutritional supplementation. Rather than implying that vaccination or vitamin and mineral supplementation cause mortality, it is more likely that operations confronted with animal health challenges incorporate such management strategies. Similarly, variables such as respiratory disease and lameness were strongly associated with dairy mortality, but this observation does not identify that these conditions cause mortality. It is more plausible that some management features not specifically identified with this dataset promote both high levels of dairy cow health challenges and also high levels of dairy mortality. Future studies should attempt to identify specific features of intensified dairy production and management likely to adversely influence cow health and survival.

CONCLUSIONS

Dairy cow mortality is an increasing problem in the dairy industry. Analysis of a wide variety of herd characteristics and practices at the national level suggests that health problems in tandem with physical and management changes related to intensification are predictors of mortality. When analyzing causes of dairy cow mortality, consideration should be given to operational attributes such as the use and composition of a total mixed ration, the calving interval, region of the country, and herd levels of respiratory disease, lameness, sick cow treatments, and early postpartum culling.

Table 2.1: Herd management variables associated (P < 0.15) with dairy cow mortality by univariate analysis of data from 953 operations in 21 states.

Variable Description	Level	Herds (%)	Herds by mortality (%)			Chi-sq P-value
			<2.5%	2.5 - 6.25	>6.25	
All operations (weighted)		100	21.3	52.3	26.4	
Dairy Herd Information and Management Practices						
Region						
CA, CO, ID, NM, TX, WA	West	20.4	14.6	54.8	30.6	0.0002
IL, IN, IA, MI, MN, MO, OH, WI	Midwest	44.4	19.5	52.8	27.7	
FL, KY, TN, VA	Southeast	27.5	15.4	53.8	30.8	
NY, PA, VT	Northeast	7.7	31.0	49.1	19.9	
Herdsize						
The number of dairy cows, whether dry or in milk, on this operation on January 1st, 2002. (Including dairy heifers that had calved.)	>355	27.4	12.3	59.8	27.9	<0.0001
	66 - 355	49.4	20.1	53.8	26.1	
	30 - 65	23.2	34.6	40.2	25.2	
Current annual rolling herd average for milk production	>22,000 lbs	29.5	16.2	58.6	25.2	0.0424
	17,001 - 22,000 lbs	47.9	22.2	49.7	28.1	
	≤17,000 lbs	22.6	25.5	49.8	24.7	
This operation fed a total mixed ration	yes	71.1	16.3	53.7	30.0	<0.0001
	no	28.9	33.7	48.8	17.5	
Forage test results were used to balance feed rations	yes	87.1	19.4	52.3	28.3	<0.0001
	no	12.9	34.6	52.3	13.1	
MUN (milk urea nitrogen) was used to determine ration composition	yes	33.5	14.2	54.6	31.2	0.0002
	no	66.5	24.9	51.1	24.0	
Lactating dairy cows received bST (bovine Somatotropin)	yes	36.4	13.6	57.5	28.9	<0.0001
	no	63.6	25.7	49.3	25.0	
Fresh cows were routinely drenched (oral liquid or paste) with propylene glycol or another energy source	yes	25.8	15.5	54.7	29.8	0.0292
	no	74.2	23.2	51.4	25.4	
The majority of cows were milked less than 3 times per day	yes	81.5	23.1	51.3	25.6	0.0124
	no	18.5	13.4	56.7	29.9	
Average number of days dairy cows were dry during 2001	>65	21.5	14.3	55.8	29.9	0.0127
	60 - 65	55.3	23.0	53.5	23.5	
	≤59	23.2	23.9	46.2	29.9	
Average calving interval, in months, for dairy cows during 2001	>13.9	35.1	15.8	52.1	32.1	<0.0001
	13.0 - 13.9	44.7	21.0	52.7	26.3	
	≤12.9	20.2	30.9	51.7	17.4	
After birth dairy heifer calves were normally separated from the dam:	immediately	56.7	18.4	54.1	27.5	0.0694
	after nursing <12 hrs	22.5	24.2	49.4	26.4	
	12-24 hrs	13.8	30.2	48.9	20.9	
	>24 hrs	7.0	18.3	53.5	28.2	

During 2001, the percent of dairy cows culled from the herd (excluding cows that died)	>30%	26.3	15.5	55.1	29.4	0.0123
	16 - 30%	53.4	21.2	53.1	25.7	
	≤15%	20.3	28.9	47.1	24.0	
Percent of dairy cow culls that were culled because of disease during 2001	>20%	8.5	7.0	63.9	29.1	<0.0001
	8 - 20%	20.0	11.0	56.7	32.3	
	≤7%	71.5	25.9	49.8	24.3	
A third or more of culled cows are removed within the first 50 days in milk	yes	12.2	21.9	43.1	35.0	0.0453
	no	87.8	21.2	53.6	25.2	
Percent of culled cows less than 50 days in milk (early lactation) during 2001	>20.8%	24.7	22.1	46.5	31.4	<0.0001
	2.1 - 20.8%	49.8	18.3	59.6	22.1	
	≤2.0%	25.5	27.0	42.5	30.5	
Percent of culled cows between 50 and 199 days in milk (mid-lactation) during 2001	>33.3%	26.2	24.0	49.4	26.6	0.0861
	10.1 - 33.3%	41.8	17.1	55.8	27.1	
	≤10.0%	32.0	24.9	49.2	25.9	
Percent of culled cows 200 days or more in milk (late-lactation) during 2001	>80.0%	21.8	27.8	46.3	25.9	0.0157
	43.8 - 80.0%	53.3	17.8	56.3	25.9	
	≤43.7%	24.9	23.6	48.0	28.4	
Used the same equipment to handle manure and feed cattle	yes	57.7	20.0	51.0	29.0	0.0883
	no	42.3	23.2	53.8	23.0	
Health Management						
Heifers were normally vaccinated against Infectious Bovine Rhinotracheitis	yes	84.4	20.3	51.8	27.9	0.1391
	no	15.6	26.1	52.3	21.6	
Heifers were normally vaccinated against Bovine Viral Diarrhea	yes	86.1	19.6	52.2	28.2	0.0009
	no	13.9	32.6	49.3	18.1	
Heifers were normally vaccinated against Parainfluenza Type 3	yes	79.3	19.3	52.2	28.5	0.0045
	no	20.7	28.6	51.3	20.1	
Heifers were normally vaccinated against Bovine Respiratory Syncytial Virus	yes	78.0	20.0	51.4	28.6	0.0198
	no	22.0	25.9	54.3	19.8	
Heifers were normally vaccinated against Leptospirosis	yes	80.5	19.6	51.9	28.5	0.0062
	no	19.5	28.1	52.6	19.3	
Heifers are normally vaccinated against Johne's disease (Mycobacterium paratuberculosis)	yes	4.5	16.3	44.2	39.5	0.1435
	no	95.5	21.8	52.1	26.1	
Heifers were normally vaccinated against Clostridia	yes	52.7	17.1	51.0	31.9	<0.0001
	no	47.3	26.3	52.5	21.2	
Heifers were normally vaccinated against E. coli mastitis	yes	35.8	16.6	54.9	28.5	0.0239
	no	64.2	24.1	50.0	25.9	
Heifers were vaccinated against at least one of the following: BVD, IBR, PI3, BRSV, H. somnus, Lepto, Salmonella, E. coli mastitis, or Clostridia	yes	90.7	20.2	52.3	27.5	0.0282
	no	9.3	31.5	48.9	19.6	
Cows were normally vaccinated against Clostridia	yes	44.1	16.8	51.6	31.6	0.0003
	no	55.9	25.6	51.9	22.5	
Cows were normally vaccinated against Bovine	yes	88.6	19.8	52.8	27.4	0.0015

Viral Diarrhea	no	11.4	34.2	46.5	19.3	
Cows were normally vaccinated against Leptospirosis	yes	85.9	19.8	53.2	27.0	0.0070
	no	14.1	31.4	47.2	21.4	
Cows were normally vaccinated against Parainfluenza Type 3	yes	80.4	19.3	52.8	27.9	0.0062
	no	19.6	29.5	48.9	21.6	
During the last 12 months, the majority of cows have been vaccinated for Coliform mastitis	yes	50.1	16.9	54.9	28.2	0.0026
	no	49.9	25.8	50.2	24.0	
During the last 12 months, the majority of cows have been vaccinated for Salmonella	yes	17.6	15.1	58.7	26.2	0.0832
	no	82.4	22.2	51.0	26.8	
Cows were vaccinated against at least one of the following: BVD, IBR, PI3, BRSV, H. somnus, Lepto, Salmonella, E. coli mastitis, or Clostridia	yes	92.7	20.4	52.7	26.9	0.0172
	no	7.3	34.2	46.6	19.2	
Lactating cows were normally given selenium in feed	yes	82.1	21.7	50.1	28.2	0.0797
	no	17.9	20.7	58.6	20.7	
Lactating cows were normally given a selenium injection	yes	25.7	17.2	52.7	30.1	0.1044
	no	74.3	22.8	52.0	25.2	
Lactating cows were normally given vitamins A-D-E in feed	yes	84.6	20.6	51.3	28.1	0.0283
	no	15.4	23.0	59.2	17.8	
Lactating cows were normally given a vitamin A-D-E injection	yes	21.8	15.2	49.5	35.3	0.0011
	no	78.2	23.0	53.0	24.0	
Anionic salts were fed to springing heifers	yes	24.3	16.0	53.7	30.3	0.0406
	no	75.7	23.1	51.9	25.0	
Anionic salts were fed to cows that are close to calving	yes	30.1	17.2	53.7	29.1	0.0996
	no	69.9	22.9	51.9	25.2	
Lactating cows were normally given limited potassium in the dry cow ration	yes	62.8	17.5	55.3	27.2	0.0011
	no	37.2	27.5	47.6	24.9	
Disease and Illness						
Percent of dairy heifers and cows that aborted during 2001	>4.6%	26.5	15.0	50.9	34.1	<0.0001
	1.5 - 4.6%	51.3	20.3	55.5	24.2	
	≤1.4%	22.2	31.3	46.4	22.3	
Percent of dairy cows with infertility problems (not pregnant 150 days after calving) during 2001	>16.7%	29.6	16.1	50.7	33.2	<0.0001
	4.1 - 16.7%	51.8	20.7	52.9	26.4	
	≤4.0%	18.6	31.5	53.5	15.0	
Percent of dairy cows with other reproductive problems (e.g. dystocia, metritis) during 2001	>5.3%	30.5	15.6	54.1	30.3	<0.0001
	0.1 - 5.3%	24.8	18.4	60.8	20.8	
	0%	44.7	26.9	46.4	26.7	
Percent of dairy cows with a retained placenta (more than 24 hours postpartum) during 2001	>11.5%	28.3	17.6	49.8	32.6	0.0152
	3.1 - 11.5%	53.0	21.3	54.9	23.8	
	≤3.0%	18.7	27.1	48.9	24.0	
Percent of cows affected with reproductive disease in the last 12 months	>10%	24.6	15.8	51.7	32.5	0.0017
	1 - 10%	38.3	19.3	54.7	26.0	
	0%	37.1	27.7	49.9	22.4	

Percent of dairy cows with respiratory problems during 2001	>3.4%	25.8	13.5	51.1	35.4	<0.0001
	0.1 - 3.4%	41.2	16.9	58.1	25.0	
	0%	33.0	33.1	46.1	20.8	
Percent of dairy cows with lameness during 2001	>16.1%	29.9	15.6	54.8	29.6	<0.0001
	3.4 - 16.1%	50.9	20.6	51.3	28.1	
	≤3.3%	19.2	32.1	51.3	16.6	
Percent of dairy cows with diarrhea for more than 48 hours during 2001	>2.9%	26.9	15.5	55.0	29.5	0.0013
	0.1 - 2.9%	26.1	17.1	56.3	26.6	
	0%	47.0	27.1	48.6	24.3	
Percent of cows affected with diarrhea or other digestive disease in the last 12 months	>5.2%	24.8	16.1	52.1	31.8	0.0446
	0.1 - 5.2%	27.0	21.3	51.7	27.0	
	0%	48.2	24.5	52.3	23.2	
Percent of cows treated with antibiotics for diarrhea or other digestive disease in the last 12 months	>2.2%	24.7	17.3	51.9	30.8	0.0410
	0.1 - 2.2%	10.8	15.5	56.3	28.2	
	0%	64.5	24.3	52.2	23.5	
Percent of dairy cows with a displaced abomasum during 2001	>5.2%	28.7	15.2	53.3	31.5	0.0002
	0.1 - 5.2%	49.4	20.9	52.4	26.7	
	0%	21.9	30.5	50.9	18.6	
Percent of dairy cows with clinical mastitis (presence of abnormal milk and/or inflamed udder) during 2001	>20%	26.2	17.1	52.6	30.3	0.0306
	7 - 20%	53.5	21.0	52.5	26.5	
	≤6%	20.3	27.9	51.5	20.6	
Some dairy cows had neurologic problems during 2001	yes	22.0	13.1	59.3	27.6	0.0028
	no	78.0	23.7	50.4	25.9	
This operation has had cows with signs consistent with hemorrhagic bowel syndrome within the last 5 years	yes	16.9	11.8	59.4	28.8	0.0045
	no	83.1	23.0	51.0	26.0	
Percent of affected/sick cows that were treated at least once with antibiotics for any disease or disorder in the last 12 months, not including dry cow treatments or preventative treatments	>41.2%	24.9	13.8	53.3	32.9	0.0003
	12.8 - 41.2%	50.1	22.6	50.6	26.8	
	≤12.7%	25.0	27.0	54.8	18.2	
Facilities						
During 2001 the primary outside area for lactating dairy cows was a drylot	yes	36.7	18.2	55.3	26.5	0.1473
	no	63.3	23.2	50.6	26.2	
During 2001 the primary outside area for lactating dairy cows was on pasture	yes	32.7	29.8	48.3	21.9	<0.0001
	no	67.3	17.3	54.2	28.5	
During 2001 the primary housing facility for lactating dairy cows was a tie stall or stanchion	yes	26.7	34.1	43.4	22.5	<0.0001
	no	73.3	16.6	55.6	27.8	
During 2001 the primary housing facility for lactating dairy cows was a freestall	yes	53.0	15.8	55.4	28.8	<0.0001
	no	47.0	27.4	49.0	23.6	
During 2001 lactating dairy cows did not have an outside area	yes	30.6	16.2	52.9	30.9	0.0125
	no	69.4	23.6	52.0	24.4	
During 2001 the primary outside area for maternity housing was on pasture	yes	32.4	27.5	48.3	24.2	0.0039
	no	67.6	18.4	54.2	27.4	

During 2001 the primary outside area for maternity housing was a drylot	yes	35.0	14.2	58.3	27.5	0.0002
	no	65.0	25.2	49.0	25.8	
During 2001 the primary housing facility for maternity cows was an individual animal area (pen)	yes	26.2	26.9	51.9	21.2	0.0121
	no	73.8	19.4	52.4	28.2	
During 2001 the primary housing facility for maternity cows was a multiple animal area	yes	43.1	15.0	55.5	29.5	<0.0001
	no	56.9	26.1	49.8	24.1	
During 2001 the primary housing facility for maternity cows was a tie stall or stanchion	yes	8.2	37.4	34.9	27.7	0.0003
	no	91.8	19.9	53.8	26.3	
Maternity housing was separate from housing used for lactating dairy cows	yes	74.2	18.6	53.7	27.7	0.0013
	no	25.8	29.2	48.1	22.7	
Separated cows that were close to calving from other dry cows	yes	76.7	19.4	53.2	27.4	0.0223
	no	23.3	27.6	49.4	23.0	
In the winter the ground or flooring that lactating cows stand on was dry most of the time	yes	33.6	27.3	47.5	25.2	0.0033
	no	66.4	18.1	54.9	27.0	
In the summer the ground or flooring that lactating cows stand on was dry most of the time	yes	51.1	24.3	51.8	23.9	0.0331
	no	48.9	18.3	52.7	29.0	
During the last 12 months, some cows drank from a single cup/bowl waterer used by multiple cows	yes	43.8	28.3	48.1	23.6	<0.0001
	no	56.2	15.9	55.5	28.6	
During the last 12 months, some cows drank from a single cup/bowl waterer used by one cow only	yes	7.8	30.4	45.6	24.0	0.1220
	no	92.2	20.6	52.8	26.6	
During the last 12 months, some cows drank from a water tank or trough (covered or uncovered)	yes	93.6	20.6	52.8	26.6	0.0823
	no	6.4	32.3	44.6	23.1	
Biosecurity						
Cattle (calves, heifers, cows, or bulls) were brought onto the operation during 2001	yes	55.9	17.0	54.2	28.8	0.0007
	no	44.1	26.7	49.9	23.4	
Percent of the herd composed of bred dairy heifers, lactating dairy cows, or dry dairy cows brought onto the operation during 2001	>27.7%	8.9	12.2	55.6	32.2	0.0003
	5.6 - 27.7%	20.4	16.5	52.9	30.6	
	0.1 - 5.5%	11.5	12.1	54.3	33.6	
	0%	59.1	26.2	51.2	22.6	
Dairy cows, dairy heifers, or their feed had some physical contact with deer or other members of the deer family (such as elk, moose, etc.)	yes	45.1	25.9	48.8	25.3	0.0051
	no	54.9	17.5	55.2	27.3	
Cattle contact with other livestock, elk, and deer was limited in the last 12 months	yes	49.2	16.4	55.3	28.3	0.0007
	no	50.8	26.2	49.2	24.6	
Dairy cows, dairy heifers, or their feed had some physical contact with dogs	yes	65.5	23.0	49.1	27.9	0.0190
	no	34.5	18.1	58.3	23.6	
During the last 12 months, some cows drank from a lake, pond, stream, river, etc.	yes	31.3	25.7	50.2	24.1	0.0667
	no	68.7	19.3	53.3	27.4	

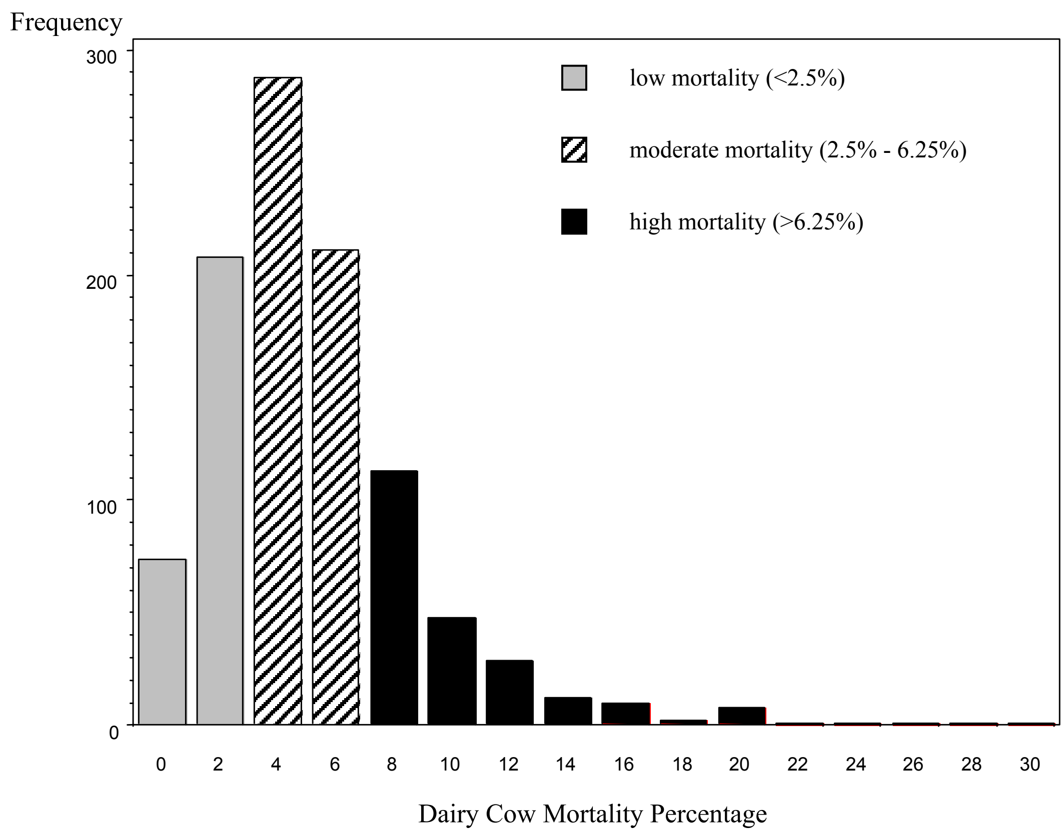
Table 2.2: Multivariate analysis of risk factors for high levels of dairy cow mortality on US dairies (n = 953 farms).

Variable	Level	Odds Ratio[1]	95% Confidence Interval	Final model P-value
Percent of dairy cows with respiratory problems during 2001	>3.4%	2.75	1.72 - 4.38	<0.001
	0.1 - 3.4%	1.71	1.16 - 2.52	0.007
	0%	Ref*		
Percent of dairy cows with lameness during 2001	>16.1%	2.89	1.70 - 4.87	<0.001
	3.4 - 16.1%	2.34	1.48 - 3.69	<0.001
	≤3.3%	Ref*		
Percent of affected/sick cows that were treated at least once with antibiotics for any disease or disorder in the last 12 months, not including dry cow treatments or preventative treatments	>41.2%	2.27	1.43 - 3.61	<0.001
	12.8 - 41.2%	1.61	1.09 - 2.38	0.017
	≤12.7%	Ref*		
Percent of culled cows less than 50 days in milk (early lactation) during 2001	>20.8%	1.48	0.92 - 2.38	0.103
	2.1 - 20.8%	Ref*		
	≤2.0%	1.97	1.31 - 2.97	0.001
Average calving interval, in months, for dairy cows during 2001	>13.9	1.78	1.13 - 2.78	0.012
	13.0 - 13.9	1.24	0.78 - 1.97	0.371
	≤12.9	Ref*		
This operation fed a total mixed ration	yes	2.08	1.43 - 3.01	<0.001
	no	Ref*		
Region	West	2.53	1.53 - 4.20	<0.001
	Southeast	2.18	1.16 - 4.11	0.016
	Midwest	2.07	1.30 - 3.28	0.002
	Northeast	Ref*		

[1]Odds of having a higher mortality level

* Reference category

Figure 2.1: The frequency distribution of annual herd level dairy cow mortality on US dairies (n = 953 farms) for 2001 (USDA, 2002a), categorized into low (< 2.5%), moderate (2.5% - 6.25%), and high (> 6.25%) groups.



CHAPTER 3: HERD FACTORS ASSOCIATED WITH DAIRY COW MORTALITY IN THE UNITED STATES

INTRODUCTION

Summary studies of dairy cow removal have been in the literature for decades (Seath, 1940, Asdell, 1951, O'Bleness and Van Vleck, 1962), although information specifically related to dairy cow mortality has been sparse (Thomsen and Houe, 2006). A review covering the years 1965 to 2006, found 19 studies that focused on dairy cow death (Thomsen and Houe, 2006). Of these studies, 2 included data since 2000, 6 were from the US, and 10 incorporated information related to causes of death. The average mortality was in the range between 1 to 5%. National DHIA data (15,025,035 lactations in 45,032 herds) from 1995 through 2005, demonstrated an overall death frequency of 3.1% on a lactation basis (5.7% on a cow basis) with observed lactational death frequencies increasing from 2.0% in 1995 to 4.6% in 2005 (Miller et al., 2008). Similarly, the USDA:APHIS:VS National Animal Health Monitoring System (**NAHMS**) Dairy surveys have reported steady increases in cow losses, from 3.8% of the January 1996 inventory, to 4.8% of the January 2002 inventory, and 5.7% of the January 2007 dairy cow inventory (USDA, 2007b).

Even in the face of low mortality rates relative to current levels, past studies suggested the need to increase the productive lives of dairy cattle (Asdell, 1951, Parker et al., 1960). There was a recognition that emphasizing prevention, early recognition, and prompt treatment of injuries and diseases such as mastitis and infertility, and focusing on proper feeding and management, would bring about increased longevity and improve the economic efficiency of herd operations. These considerations are no different today. The differences lie in the details related to particular herd characteristics and practices, and specific manageable outcomes.

Studies have historically focused on culling independent of mortality. However, even some of the earliest research into removals attempted to classify specific reasons for cow deaths based on available records or producer recollection. As such, the relative importance of dystocia, accidents, traumatic reticuloperitonitis, bloat, and hypocalcemia as underlying problems was specified (O'Bleness and Van Vleck, 1962, White and Nichols, 1965). Whereas traumatic reticuloperitonitis and hypocalcemia may be less of a problem with current management strategies, dystocia and accidents certainly remain problematic, and modern practices have given rise to a new set of concerns such as abomasal displacements, hemorrhagic bowel syndrome, lameness, and multifactorial transition cow issues (McConnel et al., 2010a). The indication is that underlying causes of dairy cow mortality may change over time, providing a moving target for addressing management practices and herd characteristics influencing death loss.

Continued assessments of available data are needed to combat the challenge of rising dairy cow mortality. The dairy industry should address the challenge of increasing mortality through a focused awareness and discussion of existing issues underlying this problem. A previous study utilizing data from the NAHMS Dairy 2002 survey found dairy cow mortality to be specifically associated with operational attributes such as the use and composition of a total mixed ration, the calving interval, region of the country, and herd levels of respiratory disease, lameness, sick cow treatments, and early postpartum culling. Broadly speaking, these findings suggested that health problems in tandem with physical and management changes related to intensification are predictors of mortality (McConnel et al., 2008). The objective of the current paper was to expand on these findings through an analysis of the NAHMS Dairy 2007 survey. While the Dairy 2002 and 2007 surveys had numerous similarities, the Dairy 2007 survey data set incorporated a number of variables, such as those related to milk quality, milking procedures, and disease confirmation, that were not available from the 2002 survey. Consequently, the current study provided a basis for a more thorough and directed data set from which to describe and analyze a variety of current herd management practices and herd characteristics and their association with dairy cow mortality in the US.

MATERIALS AND METHODS

Data Collection

The NAHMS Dairy 2007 study included farms in 17 states that represented 79.5% of US dairy operations and 82.5% of the US dairy cow population. States included in the study were: California, Idaho, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New Mexico, New York, Ohio, Pennsylvania, Texas, Vermont, Virginia, Washington and Wisconsin. The survey design was a stratified random sample with unequal selection probabilities within each stratum. Unequal selection probabilities were implemented to ensure that large operations were represented in the sample. To account for the selection probabilities and for nonresponse, weights were created for each operation. The analysis incorporated weights to allow inferences to the target population (i.e. the population of dairy operations in the 17 states).

During the first phase of the study operations were randomly selected from a sampling list maintained by the National Agricultural Statistics Service (NASS). Completed surveys were obtained from 2,194 operations of the 3,554 on the sampling list. Only farms that participated in phase I and had 30 or more dairy cows were eligible to participate in phase II. Of the 1,077 eligible operations, 582 consented to continue and completed the second phase questionnaires. Of these 582 operations, 459 had complete data for all selected variables and were included in this analysis.

Questionnaires covered topics that included dairy herd information and management practices, milk quality and milking procedures, births, illness, deaths, disease confirmation, health management, housing, and biosecurity. Herd inventories were recorded as the number of dairy cows on the operations on January 1, 2007. Dairy cow deaths referred to the total number of dead cows during calendar year 2006. Other descriptors referred to dairy practices and outcomes specific to calendar year 2006 or the 12 months previous to survey administration. Surveys were administered by NASS enumerators, veterinary medical officers, and animal health technicians between January and August, 2007. Additional details of the study design and sample weighting are published elsewhere (USDA, 2007a).

Statistical Analysis

The association between dairy cow mortality and 162 a priori identified operation-level management practices or characteristics was evaluated. Continuous predictor variables were plotted against the log of the percent deaths to evaluate linearity. Continuous variables that were not linearly related to death rate were converted to and evaluated as categorical variables, which resulted in 136 categorical and 26 continuous variables. Categorical and continuous variables were evaluated individually using a weighted, negative binomial model in STATA (StataCorp, College Station, TX). The number of deaths was the outcome and the offset was the log of the number of dairy cows present on January 1, 2007. Variables that met univariable screening criteria ($P < 0.05$), including an assessment of correlations using Pearson product-moment correlation for categorical variables and Spearman rank-order correlation for continuous variables, were evaluated using a weighted, stepwise, forward selection, negative binomial regression model created in STATA. Entry into the final model required that variables have a p-value of ≤ 0.049. Retention within the model required a p-value of ≤ 0.05. The final weighted model included only predictor variables with p-values < 0.05.

RESULTS

Univariable Associations

Of the 162 management factors explored in the univariate analysis, 47 categorical and 13 continuous variables met initial screening criteria for further evaluation of association with dairy cow mortality (**Table 3.1**). Variables that did not meet initial screening criteria included descriptors for milk production, days dry, lactating rations, equipment use relative to handling feed and manure, and guidelines for calving intervention. Of those variables that were evaluated further, herd size was associated with dairy cow mortality ($P = 0.0015$). Based on incidence rate ratios (**IRR**; ratio of the risk of death in an exposed group to the risk of death in an unexposed group), this analysis predicted a 7.5% increase in mortality for herds with 100-499 adult cows (6.1% mortality), and a 27.3% increase in mortality for herds with ≥ 500 cows (7.2% mortality), relative to herds with 30-99 dairy cows (5.7% mortality). Cow mortality also increased as the number of cows per employee increased ($P = 0.0026$). Operations with > 56 cows per employee were predicted to have 7.1% mortality as opposed to operations with 24 to 56 cows per employee (6.1% mortality) and ≤ 23 cows per employee (5.5% mortality).

A number of management practices were positively associated with mortality (**Table 3.1**). Increased mortality was associated with feeding a TMR (predicted mortality: 4.6% vs. 6.7%; $P < 0.0001$), using forage tests to balance rations (predicted mortality: 4.7% vs. 6.5%; $P = 0.0020$), and administering bST (predicted mortality: 5.6% vs. 7.5%; $P < 0.0001$). Mortality was dependent upon the individual responsible for milking ($P < 0.0001$). Decreased mortality was observed if the majority of cows were milked by the owner/operator (5.3%) as opposed to family members of the owner (5.7%) or non-family hired workers (7.0%). Milking less than 3 times per day was also associated with decreased mortality (predicted mortality: 5.8% vs. 7.7%; $P < 0.0001$). Other herd indices associated with mortality included the average bulk tank somatic cell count ($P = 0.0012$) and the average calving interval ($P = 0.0013$). Decreasing somatic cell counts in cells per mL (>300,000; 200,000-299,000; <200,000) led to decreased predicted mortality (7.1%; 6.5%; 5.5%, respectively). As the calving interval in months decreased (>14; 13.1-14.0; ≤13.0), mortality was predicted to decrease (7.8%; 6.6%; 5.9%, respectively) as well.

Several health management variables describing heifer and cow vaccinations and nutritional supplementation were significantly associated with mortality (**Table 3.1**). Variables describing herd levels of disease and illness demonstrated increased mortality with increased levels of disease problems. Specifically, infertility problems, retained placentas, and other reproductive problems (e.g., dystocia, metritis) were all associated with increased mortality. Similar increases in mortality were observed with increased respiratory problems, diarrhea, mastitis, displaced abomasums, and lameness. As an example, for every 1% increase in the proportion of lame cows, mortality was predicted to increase 0.8%. Increased mortality was also associated with operations from which laboratory testing confirmed cattle infected with *Salmonella* (predicted mortality: 6.1% vs. 7.5%; P = 0.0063) or *Mycobacterium avium* subspecies *paratuberculosis* (**Map**; predicted mortality: 6.0% vs. 7.0%; P = 0.0066).

Various parameters describing operation facilities and biosecurity were associated with mortality (**Table 3.1**). Mortality was increased for lactating dairy cows (predicted mortality: 5.6% vs. 6.8%; P = 0.0006) and for dry cows (predicted mortality: 5.9% vs. 7.0%; P = 0.0023) when the primary housing areas for these groups consisted of freestalls as opposed to tie stalls or stanchions, drylots, or pasture. Mortality increased when concrete was the predominant flooring type that lactating cows stood or walked on when not being milked (predicted mortality: 5.8% vs. 6.7%; P = 0.0149). For variables related to biosecurity, increased mortality was associated with dairies that brought cattle onto the operation (predicted mortality: 5.9% vs. 6.8%; P = 0.0079), and with increased visits onto the operation by people who had contact with the animals (P = 0.0005).

Multivariable Model

Of the 60 variables identified in the univariate analysis, 6 that were significantly associated with mortality remained in the final weighted, negative binomial regression model after the forward selection procedure (**Table 3.2**). Based on the incidence rate ratio, this model predicted 32.0% less mortality for operations that vaccinated heifers for at least one of the following: bovine viral diarrhea (**BVD**), infectious bovine rhinotracheitis (**IBR**), parainfluenza 3 (**PI3**), bovine respiratory syncytial virus (**BRSV**), *Haemophilus somnus*, leptospirosis, *Salmonella*, *Escherichia coli*, or clostridia. The final multivariable model also predicted a 27.0% increase in mortality for operations from which a bulk tank milk sample tested ELISA positive for bovine leukosis virus (**BLV**) at the time of the Dairy 2007 survey. Additionally, an 18.0% higher mortality was predicted for operations that used necropsies to determine the cause of death for some proportion of dairy cows that died or were euthanized. The final model also predicted that increased proportions of dairy cows with clinical mastitis (presence of abnormal milk and/or an inflamed udder) and infertility problems (not pregnant 150 days after calving) would be associated with increased mortality. For every 1% increase in the proportion of cows with clinical mastitis, mortality was predicted to increase 0.7%. Likewise, for every 1% increase in the proportion of cows with infertility problems, mortality was predicted to increase 1.1%. Finally, an increase in mortality was predicted to be associated with an increase in the proportion of lame or injured permanently removed dairy cows (excluding those that died). For every 1% increase in the proportion of permanently removed cows that were removed primarily because of lameness or injury, mortality was predicted to increase 0.4%.

DISCUSSION

The NAHMS dairy surveys provide an unparalleled vantage of the U.S. dairy landscape. Although mortality was previously evaluated using data from the Dairy 2002 study (McConnel et al., 2008), the current study is unique due to differences in the sampling, information gathered, and statistical methodology. Additional questions were asked during the Dairy 2007 study to obtain information that wasn't collected in 2002 but was thought to be associated with mortality. And although the Dairy 2007 survey was not developed solely to address dairy cow mortality, it did provide a useful platform from which to consider aspects of current dairy practices that might underlie mortality rates. Some of the variables associated with dairy cow mortality by univariable analysis were the same for this study as for a previous study that analyzed NAHMS Dairy 2002 survey data (McConnel et al., 2008). These variables included a number of operational practices and descriptors related to nutritional management such as feeding a TMR and using forage tests results to balance rations, and health management variables such as those describing heifer vaccinations and nutritional supplementation. Other similarities were found within several variables describing herd levels of disease and illness, operation facilities, and biosecurity practices. These findings agree with previous studies suggesting that mortality may be associated with greater rates of common production diseases, as well as physiologic stress linked to intensive management practices such as animal crowding and feeding high levels of concentrate (Norgaard et al., 1999, Thomsen et al., 2007). While the Dairy 2002 and 2007 surveys had similarities, the Dairy 2007 survey data set expanded upon the findings from the Dairy 2002 survey data and resulted in a unique final model.

A literal assessment of the final model's variables denotes some specific issues that are relevant to the problem of mortality. These variables include a herd's BLV infection status, mastitis, lameness, infertility problems, heifer vaccinations, and necropsy utilization. However, individual variables can be challenging to interpret as exemplified by the description of increasing mortality associated with BLV positive herds. The Dairy 2007 study tested bulk tank milk samples to document that 83.9% of US dairy operations were positive for BLV (USDA, 2008). Although lymphosarcoma is the most obvious negative outcome of BLV infection and can certainly adversely influence mortality rates (Olson, 1974), less than 5% of infected cattle typically show clinical signs of lymphosarcoma (Rhodes et al., 2003). In most cases it is expected that BLV-infected animals are culled due to decreased production before the emergence of any severe symptoms of illness (Brenner et al., 1989). In other words, it is unlikely that clinical disease caused by BLV infection was responsible for the overall increase in mortality observed for BLV positive herds.

A direct causal interpretation of the model's findings fails to acknowledge the subtle implications that the selected variables speak to. These included reproductive problems, non-infectious postpartum disease, infectious disease and infectious disease prevention, and the extensive information inherent within necropsy-based postmortem evaluations. The inclusion of BLV in the model underscored the capacity for a specific infectious agent to directly affect mortality rates. More importantly, it illustrated an overarching concept regarding the influence of management on adverse impacts from infectious disease. Just as it has been suggested that there may be management factors common to both a certain prevalence of BLV-infected cows and a reduction in herd-level milk production (Emanuelson et al., 1992), it is likely that there are specific management factors underlying both herd infections with BLV and higher levels of mortality. The point is not so much to question how much death is caused specifically by BLV infection, but rather to consider general operational differences that influence the infectious disease status for agents such as BLV and ultimately impact mortality levels.

This broad approach to disease evaluation is relevant as well to the variables describing the proportions of cows with mastitis, lameness or injury, and infertility problems. In the model, higher within herd prevalences of these variables were associated with increased mortality. Yet these associations do not imply cause and effect. The model does not necessarily suggest that an implicit outcome of mastitis, lameness, and infertility problems is death. Rather, it highlights the continuum of health problems that can include these specific diseases and that indicate underlying management issues related to disease prevention. Although mastitis can predispose to other diseases such as metritis, displaced abomasums, ketosis, and cystic ovaries (Gröhn et al., 2003), and infertility problems often follow such diseases (Harman et al., 1996, Gröhn and Rajala-Schultz, 2000), the issue at hand remains one of defining those specific management practices that eventuate in these poor outcomes including death. Further, although culling lame and injured cows may preempt some individual cow deaths, a rise in such forced culling may be indicative of other underlying problems that eventuate in higher mortality levels. Much like the BLV infection status of herds emphasizes underlying management issues related to infectious agents, increases in mortality associated with diseases and consequences of diseases such as mastitis, lameness, and infertility problems highlight the importance of targeting disease prevention and control.

Achieving explicit infectious and non-infectious disease prevention and control requires making informed management decisions. Similarly, optimizing decision making to combat rising mortality requires clearly defining the reasons that cows die through the use of thorough necropsy-based postmortem evaluations (McConnel et al., 2010a). The present model showed that there was an increase in mortalities on operations that utilized necropsies, suggesting that necropsies are used only when mortality reaches a level that prompts action by the producer. Necropsies are certainly warranted when mortality exceeds historic or comfortable levels. Necropsies also provide relevant information when there is a perceived treatment failure, when presenting signs are dramatic or unusual, when samples are required for confirming a tentative clinical diagnosis, or for characterizing a disease process when no antemortem observation has been made (Mason and Madden, 2007). Combining the information derived from a necropsy with background information related to clinical history and treatments helps expose those facets of management that influence poor outcomes (McConnel et al., 2009). Ultimately, a thorough postmortem evaluation incorporates the full gamut of information underlying a death and captures the essence of why a cow died, providing necessary insight into how best to prevent future occurrences.

Efforts at reducing mortality require sound, informed management decisions. This requires the incorporation of practices aimed at preventing underlying issues related to problems such as disease, traumatic events, nutritional accidents, or multifactorial failures linked to transition cow or negative energy balance issues (McConnel et al., 2010a). Clearly, prevention of diseases that increase deaths is more desirable than cure. The importance of preventative practices was shown within the model in that operations that incorporated heifer vaccinations into their management had reduced mortality. The Dairy 2007 study reported that more than 60% of operations vaccinated heifers against BVD, IBR, PI3, BRSV, and leptospirosis, and over 90% of operations vaccinated for at least one of the above infectious diseases or *H. somnus*, *Salmonella*, *E. coli*, or clostridia (USDA, 2007a). Vaccination aims to help avoid the introduction of disease agents to a farm, and to prevent the spread of disease agents and the severity of clinical disease among groups of animals on a farm. Yet attempting to ensure better disease resistance through vaccination is only one principle of biosecurity and biocontainment.

Disease prevention is a multifaceted endeavor best addressed through the same principles as those of the hazard analysis and critical control point (HACCP) system (Villarroel et al., 2007). Similarly, the prevention of the multitude of poor choices and harmful practices that can negatively influence mortality levels is best served by such an approach. A HACCP system identifies hazards, defines manageable risk factors and potential mitigation procedures, and designs an appropriate monitoring system to evaluate the effectiveness of control measures (Hubbert et al., 1996). The present model illustrated these principles well. Hazards associated with mortality, such as infectious and non-infectious disease, must be appropriately defined by thorough postmortem evaluations. With this information in hand critical control points can be established and actions specified to reduce the risk of negative outcomes. This might include implementing measures such as enhanced worker training focused on improving udder health or minimizing calving trauma. Finally, a monitoring system should be used to evaluate the effectiveness of control methods, again highlighting the utility of thorough postmortem evaluations to document concrete and dynamic information related to deaths for future reference and analysis (McConnel et al., 2010a).

CONCLUSIONS

Dealing with the problem of dairy cow mortality will require a concerted effort that recognizes and appropriately manages the numerous and diverse risks that ultimately give rise to increasing mortality. The model generated from this analysis of the NAHMS Dairy 2007 data specifically suggested that dairy cow mortality is associated with a herd’s BLV infection status, higher proportions of mastitis, lameness, and infertility problems, the utilization of necropsies to determine causes of death, and the incorporation of a heifer vaccination program. In more general terms this model illustrated that addressing management practices that underlie disease processes and result in increased mortality levels requires the generation of information detailing causes of death, and the implementation of preventative strategies to decrease the risk of death. As such, the incorporation of HACCP principles to combat rising mortality provides a proven risk-assessment approach for defining sound management practices to improve on suboptimal methods of control.

Table 3.1. Herd management variables associated (P < 0.05) with dairy cow mortality by univariable analysis of data from 459 operations in 17 states

Variable Description	Level	Herds (%)	Model Predicted Mortality %	Incidence Rate Ratio	Standard Error	X^2 P-value
Dairy Herd Information and Management Practices						
The number of dairy cows, whether dry or in milk, on this operation on January 1st, 2007. (Including dairy heifers that had calved.)	≥500	6.4	7.2	1.2725	0.0889	0.0015
	100 - 499	24.8	6.1	1.0754	0.0708	
	30 - 99	68.9	5.7	Referent		
The dairy operation's practices are best described as conventional (as opposed to grazing, a combination of conventional and grazing, or organic)	yes	68.6	6.5	1.1649	0.0782	0.0238
	no	31.4	5.6	Referent		
The number of cows per employee (i.e. paid and unpaid people, including owners and family members, assigned duties directly related to operation of the dairy)	>56	10.8	7.1	1.3008	0.1043	0.0026
	24 - 56	45.2	6.1	1.1253	0.0852	
	≤23	44.1	5.5	Referent		
The individual primarily responsible for balancing feed rations fed to dairy cows	Independent or Feed company nutritionist	67.0	6.6	1.2165	0.0814	0.0037
	Employee (nonveterinarian), Veterinarian, Operator/Owner	34.0	5.4	Referent		
Forage test results were used to balance feed rations	yes	86.6	6.5	1.3908	0.1473	0.0020
	no	13.4	4.7	Referent		
This operation fed a total mixed ration	yes	59.9	6.7	1.4561	0.1073	<0.0001
	no	40.1	4.6	Referent		
MUN (milk urea nitrogen) was used to determine ration composition	yes	49.8	6.7	1.1751	0.0662	0.0045
	no	50.2	5.7	Referent		
This operation relies on pasture during the growing season to provide part of the forage component of the ration	yes	52.9	5.7	0.8423	0.0469	0.0022
	no	47.1	6.7	Referent		
Lactating dairy cows received bST (bovine Somatotropin)	yes	21.6	7.5	1.3388	0.0718	<0.0001
	no	78.4	5.6	Referent		
Average calving interval, in months, for dairy cows during 2006	>14.0	12.9	7.8	1.3353	0.1106	0.0013
	13.1 - 14.0	28.3	6.6	1.1170	0.0651	
	≤13.0	58.9	5.9	Referent		
The proportion of dairy cows permanently removed from the herd (excluding cows that died) during 2006				1.0060	0.0024	0.0130
Percent of permanently removed cows (excluding those that died) between 50 and 199 days in milk (mid-lactation) during 2006				0.9972	0.0014	0.0428
The proportion of permanently removed dairy cows (excluding those that died) that were removed primarily because of lameness or injury during 2006				1.0057	0.0016	0.0003

The proportion of permanently removed dairy cows (excluding those that died) that were removed primarily because of diseases other than lameness or injury, udder or mastitis problems, or reproductive problems during 2006				1.0075	0.0031	0.0140
Milk Quality and Milking Procedures						
Average bulk tank somatic cell count for milk shipped during the last 12 months cells/mL	>300,000	29.1	7.1	1.2884	0.0898	0.0012
	200-299,000	40.3	6.5	1.1736	0.0745	
	<200,000	30.7	5.5	Referent		
Somatic cell count from a bulk tank milk sample taken during the time of survey administration	>365,500	28.0	6.8	1.2539	0.1016	0.0042
	188-365,500	48.0	6.7	1.2395	0.0850	
	≤187,000	24.1	5.4	Referent		
Individual(s) primarily responsible for milking the majority of cows	Hired worker(s) (non-family member)	24.6	7.0	1.3058	0.0788	<0.0001
	Family member(s) of owner	15.6	5.7	1.0717	0.1097	
	Owner/operator	59.8	5.3	Referent		
Fresh cows were milked less than 3 times per day	yes	92.3	6.0	0.8396	0.0502	0.0032
	no	7.7	7.2	Referent		
The majority of cows were milked less than 3 times per day	yes	93.0	5.8	0.7490	0.0441	<0.0001
	no	7.0	7.7	Referent		
Frequency of milker training	Trained 1 or more times per year	18.4	6.7	1.2438	0.0901	0.0070
	Trained as new employees only	35.6	6.5	1.2127	0.0870	
	No milker training	46.0	5.4	Referent		
Health Management						
Heifers were vaccinated against at least one of the following: BVD, IBR, PI3, BRSV, *H. somnus*, Lepto, *Salmonella*, *E. coli* mastitis, or Clostridia	yes	89.0	6.2	0.7513	0.0767	0.0046
	no	11.0	8.2	Referent		
Heifers were normally vaccinated against BVD	yes	85.1	6.2	0.8381	0.0740	0.0438
	no	14.9	7.4	Referent		
Heifers were normally vaccinated against *E. coli* mastitis	yes	24.7	6.8	1.1314	0.0619	0.0240
	no	75.3	6.0	Referent		
Heifers were normally vaccinated against leptospirosis	yes	77.4	6.1	0.8533	0.0613	0.0264
	no	22.6	7.2	Referent		
Lactating cows were normally given ionophores in feed	yes	34.2	7.0	1.2229	0.0654	0.0002
	no	65.8	5.7	Referent		
Lactating cows were normally given selenium in feed	yes	83.1	6.5	1.1972	0.0876	0.0151
	no	16.9	5.5	Referent		
Births, Illness, and Deaths						
Obstetrical gloves are worn during calving interventions	yes	67.6	6.6	1.1904	0.0819	0.0121
	no	32.4	5.6	Referent		
This operation has a system for scoring calving difficulty	yes	38.7	6.7	1.1261	0.0648	0.0394
	no	61.3	6.0	Referent		
Percent of dairy cows with respiratory problems during 2006	>5.0%	23.9	7.4	1.4301	0.1289	0.0004
	0.6 - 5.0%	38.4	6.4	1.2393	0.0975	

	≤0.5%	37.7	5.2	Referent		
Percent of dairy cows treated with antibiotics for respiratory disease	>3.9%	28.0	7.1	1.3498	0.1002	0.0001
	0.1 - 3.9%	28.6	6.6	1.2519	0.0826	
	0%	43.5	5.2	Referent		
Percent of dairy cows with diarrhea for more than 48 hours during 2006	>2.5%	24.6	7.0	1.2488	0.0836	0.0005
	0.1 - 2.5%	16.5	6.9	1.2294	0.0783	
	0%	58.9	5.6	Referent		
Percent of dairy cows affected with mastitis in the last 12 months	>24.6%	26.0	7.2	1.2666	0.0970	0.0064
	9.0 - 24.6%	49.4	6.2	1.0864	0.0733	
	≤8.9%	24.6	5.7	Referent		
Some dairy cows had neurologic problems during 2006	yes	15.0	7.6	1.2797	0.0822	0.0001
	no	85.0	6.0	Referent		
This operation has had cows with signs consistent with hemorrhagic bowel syndrome within the last 5 years	yes	19.6	7.2	1.2258	0.0725	0.0006
	no	80.4	5.8	Referent		
Necropsy was used to determine the cause of death for some proportion of dairy cows that died or were euthanized during 2006	yes	18.6	7.5	1.2445	0.0669	<0.0001
	no	81.4	6.1	Referent		
The proportion of dairy heifers and cows that aborted during 2006				1.0290	0.0068	<0.0001
The proportion of dairy cows with clinical mastitis (presence of abnormal milk and/or inflamed udder) during 2006				1.0084	0.0020	<0.0001
The proportion of dairy cows with clinical mastitis (presence of abnormal milk and/or inflamed udder) that was treated with antibiotics				1.0053	0.0019	0.0038
The proportion of dairy cows with lameness during 2006				1.0082	0.0016	<0.0001
The proportion of dairy cows with a retained placenta (more than 24 hours after delivery) during 2006				1.0195	0.0036	<0.0001
The proportion of dairy cows with infertility problems (not pregnant 150 days after calving) during 2006				1.0144	0.0021	<0.0001
The proportion of dairy cows with reproductive problems (e.g., dystocia, metritis) during 2006				1.0103	0.0026	<0.0001
The proportion of dairy cows with a displaced abomasum during 2006				1.0226	0.0070	0.0009
Disease Confirmation						
Laboratory testing during the last 12 months confirmed Salmonella from cattle on the operation	yes	8.1	7.5	1.2222	0.0910	0.0063
	no	91.9	6.1	Referent		
Laboratory testing during the last 12 months confirmed Johne's disease (*Mycobacterium paratuberculosis*) from cattle on the operation	yes	22.7	7.0	1.1681	0.0670	0.0066
	no	77.3	6.0	Referent		
A bulk tank milk sample taken during the time of survey administration tested ELISA positive for Bovine Leukosis Virus	yes	83.9	6.6	1.4324	0.1357	0.0002
	no	16.1	4.6	Referent		
Housing						
The primary housing facility/outside area for lactating dairy cows was a covered freestall during 2006	yes	37.7	6.8	1.2157	0.0688	0.0006
	no	62.3	5.6	Referent		

The primary housing facility/outside area for lactating dairy cows was a tie stall or stanchion during 2006	yes	45.3	5.4	0.8358	0.0610	0.0142
	no	54.7	6.5	Referent		
The primary housing facility/outside area for lactating dairy cows was pasture during 2006	yes	9.3	4.7	0.7239	0.0804	0.0040
	no	90.7	6.5	Referent		
The primary housing facility/outside area for dry (nonlactating) cows was a covered freestall during 2006	yes	27.4	7.0	1.1827	0.0653	0.0023
	no	72.6	5.9	Referent		
The primary housing facility/outside area for dry (nonlactating) cows was pasture during 2006	yes	16.8	5.4	0.8280	0.0623	0.0130
	no	83.2	6.5	Referent		
Concrete is the predominant flooring type that lactating cows stand or walk on when not being milked	yes	57.1	6.7	1.1615	0.0710	0.0149
	no	42.9	5.8	Referent		
The ground or flooring that lactating cows stand on most of the time during the summer is usually dry	yes	60.3	5.8	0.8615	0.0472	0.0067
	no	39.7	6.7	Referent		
Biosecurity						
Cattle (calves, heifers, cows, or bulls) were brought onto the operation during 2006	yes	44.3	6.8	1.1533	0.0618	0.0079
	no	55.7	5.9	Referent		
Some dairy cow replacements that entered the milking herd in 2006 were raised off of the operation or were born off of the operation.	yes	24.1	7.1	1.2096	0.0674	0.0006
	no	75.9	5.9	Referent		
During the last 12 months, this operation controlled access to cattle feed by other livestock and wildlife, such as elk, deer, and raccoons	yes	48.5	6.7	1.1476	0.0627	0.0123
	no	51.5	5.8	Referent		
During the last 12 months, some cows drank from a lake, pond, stream, river, etc.	yes	33.4	5.6	0.8553	0.0519	0.0104
	no	66.6	6.6	Referent		
Rodent control (such as cats, traps, chemical/bait, etc.) was used in the last 12 months	yes	94.4	6.2	0.7163	0.0726	0.0007
	no	5.6	8.6	Referent		
During an average week, the number of visits by people who came onto the operation, including employees, veterinarians, neighbors, nutritionists, milk haulers, etc.	>54	10.4	7.0	1.1769	0.0871	0.0321
	11 - 54	45.9	6.1	1.0170	0.0701	
	≤10	43.8	6.0	Referent		
During an average week, the number of visits made to the operation by people (including employees, veterinarians, neighbors, nutritionists, milk haulers, etc.) that involved contact with animals				1.0018	0.0005	0.0005

Table 3.2. Multivariable analysis of herd factors associated with dairy cow mortality on US dairies (n = 459 farms)

Variable Description	Level	Model Predicted Mortality %	Incidence Rate Ratio	Standard Error	P-value
Intercept		4.8		Baseline	
A bulk tank milk sample taken during the time of survey administration tested ELISA positive for Bovine Leukosis Virus	yes		1.2696	0.1134	0.008
	no			Referent[1]	
Heifers were vaccinated against at least one of the following: BVD, IBR, PI3, BRSV, *H. somnus*, Lepto, *Salmonella*, *E. coli* mastitis, or Clostridia	yes		0.6804	0.0684	<0.001
	no			Referent	
Necropsy was used to determine the cause of death for some proportion of dairy cows that died or were euthanized during 2006	yes		1.1795	0.0643	0.002
	no			Referent	
The proportion of dairy cows with clinical mastitis (presence of abnormal milk and/or inflamed udder) during 2006			1.0066	0.0019	0.001
The proportion of dairy cows with infertility problems (not pregnant 150 days after calving) during 2006			1.0111	0.0020	<0.001
The proportion of permanently removed dairy cows (excluding those that died) that were removed primarily because of lameness or injury during 2006			1.0041	0.0016	0.009

[1]Reference category.

CHAPTER 4: ADDRESSING THE WICKED PROBLEM OF DAIRY COW MORTALITY ON COLORADO DAIRIES

INRODUCTION

The USDA:APHIS:VS National Animal Health Monitoring System (**NAHMS**) Dairy surveys have reported steady increases in US cow deaths, from 3.8% of the January 1996 inventory, to 4.8% of the January 2002 inventory, to 5.7% of the January 2007 dairy cow inventory (USDA, 2007b). Dairy Herd Improvement Association (**DHIA**) data from 2001 through 2006 representing 3,629,002 lactations in 2,054 herds located in 38 states primarily east of the Mississippi river, demonstrated an annualized death rate of 6.6% (Pinedo et al., 2010). DHIA data representing 487,970 cows in 765 herds within 8 western states recorded 6.9% of dairy cows as having died during 2009. DHIA data specific to Colorado documented that 9.1% of dairy cows died during 2004, 8.2% died during 2007, and 14.1% died during 2009 (DHI Computing Services). Although these levels of dairy cow mortality have generated concern within the industry, the reality is that there is no standard by which to define what might be considered the 'natural' or 'normal' level of mortality in dairy cow production (Thomsen and Houe, 2006).

The insidious rise in death rates suggests that aspects of the dairy industry have changed to the detriment of the cattle, and it can be tempting to define some specific factor or agent that has created this problem. As an example, the case has been made that specific regulatory events have substantially influenced on-farm deaths, such as the 2004 rules prohibiting non-ambulatory cattle entering the food chain and the updating in 2005 of recommendations regarding humane transport within the US (Fetrow et al., 2006). Although such regulatory modifications undoubtedly influence dairy cow mortality, they cannot account for the overall rise in dairy cow mortality across the years. In fact, no evidence suggests that there is any one thing that has led to the rise in mortality (McConnel et al., 2009). Rather apparently numerous influential agents (persons, places, or things) act in concert to influence specific outcomes that may lead to death.

With regard to excessive and increasing dairy cow mortality, defining the underlying problem (establishing what distinguishes farms with higher death rates from those with more desirable rates) and locating the problem (finding where the trouble really lies within the complex of causal networks on a dairy) is difficult. This leads to the equally intractable problem of identifying actions that might effectively narrow the gap between what-is and what-ought-to-be (Rittel and Webber, 1973). Ultimately no singular definition of "The Problem" exists in that excessive mortality seems to be associated with an ill-defined set of evolving interlocking issues and constraints (Conklin, 2006, McConnel et al., 2010a). Rising dairy cow mortality appears to pose a "wicked problem" and as with all wicked problems the information needed to understand the problem depends on the ideas proposed to solve it (Rittel and Webber, 1973).

Wicked problems were described by Horst Rittel in response to the limitations of the linear "systems approach" of design and planning that focused primarily on efficiency (Rittel and Webber, 1973). Wicked problems are distinguished by the 6 following primary characteristics. 1) No definitive formulation of a wicked problem exists. Understanding the problem of rising mortality and resolving it are concomitant to each other. 2) Wicked problems have no stopping rule. Since there is no definitive "The Problem," there is no definitive "The Solution." Dairy cows will continue to die. The issue is at what point death rates are low enough. 3) Solutions to wicked problems are neither right nor wrong. Solutions for excessive mortality will be viewed as "better," "worse," "good enough," or "not good enough." Assessments of proposed solutions vary and depend on stakeholders' independent values and goals. 4) Every wicked problem is essentially unique. Although dairy farms often incorporate similar infrastructure and practices, the dynamic social context specific to each farm dictates that the problem of mortality will necessarily require individualized solutions. 5) Every solution to a wicked problem is a "one-shot operation." Dairy systems are complex and every implemented solution has unintended, often irreversible consequences that evolve over an extended period of time. 6) Wicked problems have no given alternative solutions. A number of potential solutions arise but other possible solutions may never even be considered. No criteria exist by which to determine that all solutions to the problem of rising mortality levels have been identified and explored (Rittel and Webber, 1973, Conklin, 2006).

Each of the aforementioned characteristics of a wicked problem can be used to describe the problem and solution interface of rising dairy cow mortality. Engaging the problem requires exploring dairy system complexity. Understanding the complexity within such a system demands the recognition of its evolving ecology. The numerous interacting agents within the dairy community comprise a complex network of connections. Constant shifts in the community's dynamic influences interactions between agents (cows, people, nutrition, facilities, weather, etc.) and even within agents (emotional or physical variations in workers, or biologic fluctuations within cattle). This involves co-evolution in that each agent within such a system exerts selective pressures on the others, within an environment that itself creates pressures, thereby affecting each other's and the system's evolution (Snowden, 2001). Importantly, with co-evolution comes the associated phenomenon of irreversibility. Complex systems only move forward from the present, they cannot reset and start again. Consequently, managing such a system requires flexible interventions based on simple actions that can themselves evolve into complex and desirable behaviors (Snowden, 2008).

Progress within the dairy industry is a product of best intentions that at times lead to unfortunate unintended consequences. Rising death rates reflect one such consequence. Within this evolving industry there is no legitimate means for resetting practices and outcomes back to some undefined acceptable level. Rather than attempting to reverse the irreversible, the system should be approached from within to improve outcomes through sound scientific principles. The intent of the current study was to characterize and elucidate areas within the Colorado dairy industry that might be targeted to facilitate best intentions becoming better outcomes.

MATERIALS AND METHODS

Data Collection

The Colorado Dairy Health Management Survey (**CDHMS**) was developed to assess qualitative and quantitative aspects of Colorado dairy farms that were felt to potentially influence or be associated with dairy cow survivability. All Colorado Grade-A dairies listed with the Colorado Department of Public Health and Environment were eligible for inclusion in the survey. Producers were contacted throughout Colorado and a convenience sample was chosen based on willingness to participate and a target of at least 50% of the total number of dairies. The survey was conducted in-person by one or two of the authors (CSM and FBG) who met on the farm with the producer or manager. Surveys were completed at the time of administration, aside from necessary follow-up related to data entry inconsistencies or additional records' analysis. Herd inventories were recorded as the number of dairy cows on the operation at the time of survey administration. Qualitative and quantitative descriptive data referred to dairy practices and outcomes for the twelve months prior to survey administration. Surveys were administered between October 2007, and March 2010.

The survey was comprised of three parts. A qualitative form captured details related to facility descriptors, herd management characteristics, nutritional management practices, biosecurity and expansion descriptors, and labor management indices. Facility descriptors included items such as housing structures, pen distributions, methods for restraint, concrete prevalence, types of bedding, and heat abatement methods. Herd management characteristics detailed milking frequency, record keeping systems, veterinary services, reproductive practices, dry cow therapy, hoof care programs, and vaccine usage. Nutritional management practices covered feed/forage testing, ration formulation and delivery, and water sources for cows. Biosecurity and expansion descriptors asked about specific biosecurity practices, test and control programs for specific diseases, dairy cow replacement oversight and management, and contact with other animals. Labor management indices documented owner and family involvement with the operation, employee numbers, duration of employment and oversight, and incorporation of training sessions.

A quantitative form captured details regarding herd inventory, specific production indices, health events, and removals. Past and current inventories of dairy cows (lactating and dry) were recorded. The current inventory was categorized by lactation status, breed, and parity. Herd levels of the average milk production, somatic cell count (**SCC**), days dry, calving interval, age at first calving, number of calvings, and total live calves born were recorded. The annual percentage of adult cows with specific diseases such as clinical mastitis, lameness, and respiratory problems were documented. Removals were broken into permanent removals and deaths, and categorized according to days in milk (**DIM**) and parity. Permanent removals and deaths were classified according to specific diseases or problems. The percentage of the dead cows that were necropsied was recorded as well.

Additionally, a "real-time" crowding assessment was performed to assess current stocking densities and pen construction in pens felt to influence transition cow outcomes. Pen walks were conducted for a far-off dry pen, a close-up maternity pen, and a fresh cow (transition) pen. A description of the pen's structure was recorded and the occupancy and square footage were enumerated. Details regarding bunk space or lock-ups, stall numbers and dimensions where applicable, and the number of water sources were recorded.

Statistical Analysis

The association between dairy cow mortality on Colorado dairies and 247 a priori identified operation-level management practices or characteristics was evaluated. Continuous predictor variables were plotted against the log of the percent deaths to evaluate linearity. Continuous variables that were not linearly related to death rate were converted to and evaluated as categorical variables, which resulted in 225 categorical and 22 continuous variables. Categorical and continuous variables were evaluated individually using a negative binomial model in SAS (version 9.1, SAS Inst. Inc., Cary, NC). The number of deaths in the preceding 12 months was the outcome and the offset was the log of the number of dairy cows present at the time of the survey. Forty-six variables that met univariable screening criteria ($P < 0.1$) were evaluated for correlations using Pearson product-moment correlation for categorical variables and Spearman rank-order correlation for continuous variables with a 0.5 cutoff. Ten remaining variables were evaluated using a stepwise, forward selection, negative binomial regression model created manually in SAS. Entry into the final model required that variables have a p-value of ≤ 0.05. Retention within the model required a p-value of ≤ 0.05.

RESULTS

Descriptive Data

Sixty-two Grade-A Colorado cattle dairies were surveyed. This represented over 50% of the approximately 120 Grade-A dairies currently in the state of Colorado and included 27 herds enrolled in DHIA. Dairies were surveyed in 12 of the 19 Colorado counties currently housing dairies. Adult dairy cow (lactation ≥ 1) inventories ranged from 45 to 10,161 (median: 813; mean: 1,484). Permanent removals (culled and dead) in the 12 months preceding the survey as a percent of the inventory at the time of the survey ranged from 12.2% to 67.2% (median: 31.1%; mean: 33.1%). The culling percent ranged from 4.1% to 57.8% (median: 23.0%; mean: 24.5%). The mortality percent ranged from 3.2% to 15.8% (median: 8.3%; mean: 8.6%).

Univariable Associations

Of the 247 variables explored in the univariable analysis, 7 categorical and 3 continuous variables met initial screening criteria for further evaluation of association with dairy cow mortality (**Table 4.1**). Included variables represented areas detailing herd management characteristics, nutritional management practices, biosecurity and expansion descriptors, labor management indices, and health events. The use of an internal sealant at the time of drying off cows was associated with dairy cow mortality (P = 0.0980). Based on an incidence rate ratio (ratio of the risk of death in an exposed group to the risk of death in an unexposed group), this analysis predicted a 15.9% increase in mortality for herds that did use internal sealant (9.4% mortality) versus those that did not (8.1% mortality). Increased mortality was also associated with the use of a siderophore receptor and porin (**SRP**) vaccine in cows (predicted mortality: 9.6% vs. 8.0%; P = 0.0421), and with feeding ionophores to cows (predicted mortality: 9.3% vs. 7.6%; P = 0.0321). Operations that brought in replacements from outside sources or that raised replacements in a facility with cattle contact from other operations were predicted to have increased mortality as well (predicted mortality 9.3% vs. 8.0%; P = 0.0879). Mortality was also dependent upon the individual responsible for delivering feed to the cows (P = 0.0442). Decreased mortality was observed if the feed was delivered by the owner or a family member of the owner (7.3%) as opposed to non-family hired workers (9.1%). Further, mortality was associated with herd levels of lameness (P = 0.0876) and respiratory problems (P = 0.0159). Increasing levels of lameness (≤ 5.0%; 5.1 to 20.0%; > 20.0%) were predicted to increase mortality (7.3%; 8.7%; 9.7%, respectively). Similarly, increasing levels of respiratory disease (≤ 2.0%; 2.1 to 5.0%; > 5.0%) were predicted to increase mortality (7.5%; 8.4%; 10.5%, respectively).

Additionally, an increase in the proportion of veterinary hours per month spent on areas other than reproduction was associated with higher mortality (P = 0.0982). For every 1% increase in the proportion of veterinary hours spent on evaluating or treating fresh, sick, or lame cows, assisting with calvings, consulting on nutrition, analyzing records, or evaluating calves, mortality was predicted to increase 0.3%. Further, mortality was predicted to increase with an increase in the proportion of the inventory represented by cattle brought onto the operation in the preceding 12 months (P = 0.0917). For every 1% increase in the proportion of brought-on cattle, mortality was expected to increase 0.3%. Conversely, an increase in the average number of days that dairy cows were dry was associated with decreased mortality (P = 0.0328). For every 1 day increase in days dry, mortality was predicted to decrease 1.0% (surveyed range of days dry: 33-78; median and mean: 60).

Multivariable Model

Of the 10 variables identified in the univariable analysis, 3 that were significantly associated with mortality remained in the final negative binomial regression model (**Table 4.2**). No significant interactions were present between variables in the final model. Based on the incidence rate ratio, this model predicted 21.2% more mortality for operations that used an internal teat sealant at the time of drying off. The final multivariate model also predicted a 20.4% increase in mortality for operations that normally fed ionophores to dairy cows. Finally, this model predicted that an increase in the average number of days that dairy cows were dry would be associated with decreased mortality. For every 1 day increase in days dry, mortality was predicted to decrease 1.5%.

DISCUSSION

As with all wicked problems the act of defining the challenge of excessive dairy cow mortality is a function of exploring possible solutions (Rittel and Webber, 1973). Creating a shared understanding of the problem, and a shared commitment to the possible solutions, requires an intelligent dialogue about the different interpretations of the problem (Conklin, 2006). Ultimately, conceiving possible solutions requires an understanding of dairy complexity and the multiple connected, interdependent, interacting agents. In an effort to facilitate a useful discussion regarding dairy cow mortality, the current study attempted to elucidate influential agents within the context of the Colorado dairy industry. Rather than simply demonstrating associations between dairy mortality and specific management practices, formulating a dialogue from these findings provides an avenue for exploring common sense solutions to an otherwise complex problem. Although this dialogue will ultimately need to address problems unique to individual farms, the discussion must begin at an industry-wide level if it is to gain traction.

The current study demonstrated an average annual mortality percentage of 8.6%. This was higher than levels reported in recent studies (USDA, 2007b, Pinedo et al., 2010) and by DHIA for 27 Colorado herds in 2007. However, this percentage was lower than that reported by DHIA for 23 Colorado herds in 2009 (DHI Computing Services). These differences, while interesting, fail to comment on a more important aspect of the data. That is the finding that the mortality percent ranged from 3.2 to 15.8%. Averages may tell a story of excessive mortality, but the range suggests that variations within operations lead to drastically different outcomes. These differences speak to the opportunity for improving mortality levels. The difficulty is in clearly enunciating what these differences are so that strategies can be adopted to mitigate unfortunate unintended consequences.

The CDHMS was developed based on experience with NAHMS Dairy surveys and an understanding of the Colorado dairy industry. Variables that were included within this survey were felt to represent farm attributes potentially associated with dairy cow mortality. Just as no criteria are available to determine that all solutions to a wicked problem have been explored, no standard is present by which to determine that all data relevant to dairy cow mortality would be included within this survey. Nonetheless, 247 variables representing management practices and characteristics were ultimately evaluated for associations with mortality. The majority of these variables demonstrated no association with mortality based on the criteria used within this study. However, 46 variables did meet univariable screening criteria. Yet of these 46 variables only ten were left following an evaluation for correlations and only 3 variables remained in the final multivariable model.

The sequential reduction in variables is inherent to the aforementioned analytic process; however, it is worth noting the implication of the variable reduction as it pertains to dairy complexity. Although there were 46 individual associations between dairy characteristics and mortality, most of those characteristics were aligned with other pertinent dairy attributes. The numerous correlations between variables highlighted similarities in the structure and management of many of Colorado's dairies. However, the wide range in the annual mortality percentage suggested that common practices differed in their on-farm implementation. The specific manifestations and co-evolution of more-or-less universal practices within each dairy community ultimately dictated respective death rates. The distillation of these widespread practices and interwoven agents into a few representative variables provides an avenue for addressing the complexity inherent to the dairy industry and instrumental to the problem of mortality.

The dairy industry has fundamentally changed during the last century. Mechanization of production processes has to a large extent been instrumental in the intensification and structural development of larger herd units within the dairy industry (Norgaard et al., 1999). Mechanization and intensification have largely developed in response to a dairy economy primarily focused on efficiency of production. As a result, the various interacting agents within the complex dairy community have co-evolved to maximize production while accommodating uncertainties and unintended consequences. The variables within the final multivariable model represent this concept well (**Table 4.2**).

For example, the number of days in the dry or rest period has developed from the experience of practical dairymen over the course of time (Arnold and Becker, 1936). Variations in the recommended length of the dry period have evolved in an attempt to maximize production across adjacent lactations and over a lifetime (Kuhn et al., 2006); however, the optimal length continues to be investigated and is influenced by many interconnected factors. These factors include relative cow productivity, health status, available farm resources in terms of parlor pressure, feed supply, facilities, labor, pregnant replacement heifers, as well as uncontrolled events such as late gestation abortion, early parturition, unintended postponement of drying, and incorrect conception date. Further, the optimal range must consider the complex array of environmental factors that influence milk production (Bachman and Schairer, 2003), as well as the biological processes that occur within bovine mammary tissue during the dry period (Capuco et al., 1997, Wilde et al., 1997). As with the problem of dairy cow mortality, the solution to the most optimal length for a dry period must account for a set of interlocking issues and constraints that are ever evolving.

Similarly, mastitis poses a problem for which no easy solution exists. Early assessments of this problem explored mechanical, environmental, bovine, and human factors that might contribute to disease incidence or to its control (Pearson et al., 1972). The influence of intensification was considered, particularly with respect to work required per employee (Brookbanks, 1971) and the difficulty in maintaining cow comfort and cleanliness in bigger, more mechanized herds (Gould, 1967, Pearson et al., 1972). One particular area of concern was the establishment of new infections during the dry period (Neave et al., 1950, Oliver et al., 1956). As with the wicked problem of mortality, it was clear that formulating the problem required an assessment of possible solutions. Dry cow antibiotic therapy was eventually hailed as a breakthrough in 1968 (Pearson and Mackie, 1978), and internal teat sealants were also developed as a tool to help prevent new intramammary infections during the dry period (Meaney, 1976, Halasa et al., 2009). Yet no one factor or formula existed to control mastitis and dry cow therapy was considered only part of the control system (Pearson and Wright, 1969). The most important contribution was suggested to come from the producer in the application of sound principles of dairy management and husbandry (Pearson et al., 1972, Green et al., 2007).

More recently, ionophores have been incorporated into dairy rations primarily to enhance the energy status of the cow during the transition period and early lactation (Duffield et al., 2008a). They have been demonstrated to increase milk production, improve milk production efficiency, reduce loss of body condition, and provide health benefits including lower incidence of ketosis, displaced abomasum, pasture bloat, and mastitis (McGuffey et al., 2001, Ipharraguerre and Clark, 2003, Duffield et al., 2008b). Yet prolonged exposure to ionophores in the dry period may be associated with an increased risk of dystocia and retained placenta (Duffield et al., 2008b). Maximizing the economic returns from the implementation of ionophores requires a thorough understanding of their effects on the metabolism, performance, and health of transition and lactating dairy cattle (Ipharraguerre and Clark, 2003). As with dry cow therapy, however, the beneficial effects provided by ionophores ultimately are a function of the application of sound principles of dairy management and husbandry.

The three variables within the final multivariable model provide a useful perspective on the evolution of the dairy industry. Although these variables were all associated with mortality the associations do not infer cause-and-effect. Rather than any of these practices specifically causing death, history suggests that they represent responses to numerous other interconnected attributes that potentially influence death. As with all wicked problems no definitive specification of the problem of dairy cow mortality exists. Nonetheless, exploring effects such as those described above provides a means for demonstrating the interplay between formulating a wicked problem and conceiving solutions. Ultimately this is a good first step toward facilitating best intentions becoming better outcomes.

CONCLUSIONS

Dairy systems have evolved with a focus on maximizing (efficiency, production) rather than necessarily optimizing (health, welfare). Addressing the challenge of dairy cow mortality is dependent upon working within dairy systems to manipulate their co-evolutionary ecology. It is the contextual framework of the problem that must be explored if a useful narrative is to be developed regarding the evolution of this challenge. As evidenced by the association of mortality with the length of the dry period and with the use of ionophores and internal teat sealant, a discussion of this problem must take into account the underlying intent. Imminently justifiable reasons exist for why the dairy industry has adopted the practices it has. As demonstrated above, interventions such as dry cow therapy and ionophores provide options for working within the system to mitigate detrimental unintended consequences while facilitating continued progress. Additionally, manipulating the length of the dry period attempts to maximize output while adjusting for the ecological network of inputs within a dairy community. These aspects of the industry have simply arisen in response to its continued evolution. Nonetheless, progress on the issue of dairy mortality will require a renewed focus on the context within which the evolving industry operates. Eventually this will serve to build a shared understanding of the dimensions of the problem and the constraints and criteria for possible solutions. Ultimately this may cultivate a narrative that transcends logical analysis to stimulate the empathy and understanding necessary for directing more contextually aware decisions.

Table 4.1. Variables associated (P < 0.1) with dairy cow mortality by univariable analysis of data from 62 operations in Colorado.

Variable Description	Level	Herds (%)	Model Predicted Mortality %	Incidence Rate Ratio	Standard Error	X^2 P-value
Herd Management Characteristics						
This operation uses an internal teat sealant at the time of drying off.	yes	40.3	9.4	1.1593	0.0889	0.0980
	no	59.7	8.1	Referent		
This operation normally vaccinates cows using a siderophore receptor and porin (SRP) vaccine.	yes	38.7	9.6	1.1987	0.0877	0.0421
	no	61.3	8.0	Referent		
The proportion of veterinary hours per month spent on areas other than reproduction (i.e. fresh/sick/lame cow evaluation/treatment, calving assistance, calf evaluation, etc.).				1.0027	0.0017	0.0982
Average number of days that dairy cows were dry.				0.9895	0.0049	0.0328
Nutritional Management Practices						
This operation normally feeds ionophores to the cows.	yes	59.7	9.3	1.2207	0.0905	0.0321
	no	40.3	7.6	Referent		
Biosecurity and Expansion Descriptors						
Dairy cow replacements that entered the herd in the last 12 months were brought in from outside sources and/or were raised in a facility with cattle contact from other operations.	yes	50.0	9.3	1.1651	0.0884	0.0879
	no	50.0	8.0	Referent		
The proportion of the current inventory represented by cattle brought onto the operation in the last 12 months.				1.0027	0.0016	0.0917
Labor Management Indices						
Individual(s) primarily responsible for delivering feed to the dairy cows.	Hired worker(s) (non-family member)	72.6	9.1	1.2467	0.1072	0.0442
	Owner/Family member(s) of owner	27.4	7.3	Referent		
Health Management						
Percent of dairy cows with lameness during the last 12 months.	>20.0%	24.2	9.7	1.3328	0.1271	0.0876
	5.1 - 20.0%	53.2	8.7	1.1916	0.1120	
	≤5.0%	22.6	7.3	Referent		
Percent of dairy cows with respiratory problems during the last 12 months.	>5.0%	22.6	10.5	1.3947	0.1150	0.0159
	2.1 - 5.0%	46.8	8.4	1.1123	0.1004	
	≤2.0%	30.6	7.5	Referent		

Table 4.2. Multivariable analysis of factors associated with dairy cow mortality on Colorado dairies (n = 62 farms)

Variable Description	Level or Range	Model Predicted Mortality %	Incidence Rate Ratio	Standard Error	P-value
Intercept		7.0	Baseline[1]		
This operation uses an internal teat sealant at the time of drying off.	yes		1.2120	0.1031	0.024
	no		Referent		
This operation normally feeds ionophores to the cows.	yes		1.2037	0.1022	0.029
	no		Referent		
Average number of days that dairy cows were dry.	33 - 78		0.9848	0.0048	0.002

[1]The baseline is based on an average of 60 days dry in operations that do not feed ionophores and do not use teat sealant.

CHAPTER 5: A NECROPSY-BASED DESCRIPTIVE STUDY OF DAIRY COW DEATHS ON A COLORADO DAIRY[2]

INTRODUCTION

Increasing levels of dairy cow mortality pose a challenge to the U.S. dairy industry. The USDA:APHIS:VS National Animal Health Monitoring System (**NAHMS**) Dairy 2007 survey reported that 5.7% of dairy cows (~ 520,000 cows) die on-farm across the country each year, a significant increase from 4.8% of the January 2002 inventory, and 3.8% of the January 1996 inventory (USDA, 2007b). These rising mortality levels represent a problem both in terms of financial losses and compromised animal welfare (Thomsen and Houe, 2006). An important first step in combating this problem lies in more clearly defining the reasons that cows die. Determining the cause of death provides invaluable information for preventing future deaths and improving herd health. However, relatively few U.S. dairy operations utilize necropsies in an effort to determine the cause of cow death. The NAHMS Dairy 2007 study reported that necropsies were performed on only 13% of operations (~9,750 operations) and only 4.4% of dead dairy cows (~23,000 cows) (USDA, 2007a). Without the information provided by a necropsy determining the cause of death is often dependent upon producer perceptions.

A literature review identified 19 studies between 1965 and 2006 that focused on dairy cow mortality in countries with relatively intensive dairy production (Thomsen and Houe, 2006). While 10 of the 19 studies provided information about causes of death,

[2]Originally published in *J Dairy Sci* 92(5):1954-1962.

none of the diagnoses were founded on necropsy examination. Only a single study discriminated between cows that were euthanized or died unassisted (Thomsen et al., 2004). Categories used to describe the deaths were relatively uniform across studies and included: accidents, calving disorders, digestive disorders, locomotor disorders, metabolic disorders, udder/teat disorders, other known reasons, and unknown reasons (Thomsen and Houe, 2006). Similar descriptors for causes of death were used within the NAHMS Dairy 2007 survey which documented the percentage of cow deaths due to: calving problems (15.2%), scours, diarrhea, or other digestive problems (10.4%), euthanasia due to lameness or injury (20.0%), mastitis (16.5%), respiratory problems (11.3%), poison (0.4%), lack of coordination or severe depression (1.0%), other known reasons (10.2%), and unknown reasons (15.0%) (USDA, 2007b). Although these categorical groupings are commonly used there is no information in the literature to validate that these groupings are useful for directing management changes or that they are used for such a purpose.

Thomsen and Houe's review demonstrated a range of mortality levels from 1 to 5% between studies with wide variations in the percentage of deaths ascribed to specific categories. In fact, there is no information within the literature that assesses whether death losses were accurately assigned to these categories. Excluding a few outliers, accidents generally accounted for 5 to 13% of deaths , udder/teat disorders for 8 to 25% of deaths , and metabolic disorders for 8 to 18% of deaths (Thomsen and Houe, 2006). When euthanized cows were grouped independently, locomotor disorders accounted for the single largest percentage (40%) of such deaths (Thomsen et al., 2004). The limitations of such surveys lead to a significant percentage of deaths allotted to categories such as 'other known reasons'

(10 to 70% of deaths), or 'unknown reasons' (4 to 46% of deaths), nomenclature that does not delineate causality or suggest preventative strategies (Thomsen and Houe, 2006).

Based on the findings from past studies focusing on dairy cow mortality, a number of suggestions for future studies have been recommended. These include recording a measure of the mortality level, place and year of study, study design, sampling method, sample size, and method of death (Thomsen and Houe, 2006). Information regarding causes of death is also warranted in an effort to more precisely establish specific diagnoses and associated risk factors. The current study hypothesized that a necropsy examination is superior to owner perceptions for establishing a proximate cause of death. The objective of this study was to describe dairy cow deaths on a Colorado dairy over a one-year period and explore necropsy-based classification systems that might inform management actions aimed at reducing dairy cow deaths.

MATERIALS AND METHODS

This observational study was conducted from March 1st, 2005 through February 28th, 2006 on a high producing (approximately 11,500 kg milk/cow/year), commercial dairy in northern Colorado. The dairy had completed an expansion 5 years prior to the study to achieve a stable inventory of approximately 1,450 Holstein cows (lactating and dry). Lactating cows were predominantly housed in freestall barns using sand bedding with a single dry lot devoted to cows with reproductive problems and late lactation low-producing individuals. The average somatic cell count was 250,000 cells per mL and cows were milked three times a day. Approximately 40% of cows received bST. The hoof care program involved both the treatment of animals observed with lameness and twice annual maintenance trimming. Nutritional management included the use of a total mixed ration, routine milk urea nitrogen testing, forage testing, and ration formulation based on production and stage of lactation. The average dry period was 57 days with dry cows separated into far-off, close-up, and maternity pens consisting of dry lots bedded with straw. Cows were moved to the close-up pen 3 weeks prior to their predicted freshening date and to the multiple animal maternity pen approximately 1 week prior to predicted freshening. Heifers and mature cows were grouped together within the close-up and maternity pens. Fresh cows were penned separately from hospital cows, and first lactation cows were grouped separately from mature cows. Approximately 28 full-time staff participated in milking and cow management activities, with training sessions one to two times per year to cover protocols related to milking, calving, and fresh cow monitoring. Routine veterinary services were provided by the Colorado State University College of Veterinary Medicine. Operational management included the use of on-farm computer systems to track cow and herd level data.

Biographical information was collected on 1st lactation and greater cows and included source (home-raised versus purchased), age, parity, freshening date, and where applicable death date, days in milk at time of death, and type of death (euthanasia versus unassisted). The percentages of dairy cow mortalities by source and parity were determined by dividing the number of cows that died during the study by the number of dairy cows (both dry and in milk) present on the operation at the end of the study, March 1st, 2006. The proportions of deaths by season, type of death, source, and parity were compared using a chi-square test for equal proportions (PROC FREQ SAS, version 9.1, SAS Inst. Inc., Cary, NC). The type of death by season and source of animals by parity was also compared using a chi-square test. For comparative purposes the mortality percentage (i.e. the number of dead cows during the study period divided by the number of dairy cows present on the operation on March 1st, 2006), mortality rate (i.e. the number of cows dying out of the total number of cow years at risk during the year) and mortality risk (i.e. the number of cows dying divided by the number of cows that calved during the year) were calculated. The sold percentage, rate, and risk were similarly calculated for those cows that were sold during the year.

Throughout the study period an examination was performed on every cow that died. The examination included a necropsy except in cases where obvious traumatic accidents caused the death. When possible, Colorado State University (**CSU**) veterinarians performed antemortem clinical evaluations on animals to be euthanized. Prior to a necropsy examination the producer's (owner's) perception of the proximate cause of death (i.e. the most likely immediate cause of the death) was recorded and subsequently compared against specific necropsy findings such as those listed in **Figure 5.1**. Necropsy examinations were performed as soon as possible after death and within a maximum of 24 hours. The majority of necropsies were performed at the Colorado State University Veterinary Diagnostic Laboratory (**CSUVDL**) by pathologists. A small percentage of necropsies were performed at the dairy by CSU veterinarians when carcass transport was impractical. A single veterinarian with formal postgraduate training in necropsy techniques (Severidt et al., 2002) provided oversight and was ultimately responsible for documenting all necropsies. The submission of appropriate tissue or biologic samples for further diagnostics was discretionary and based on necropsy findings when additional insight was warranted to confirm or determine the cause of death. The proportion of deaths that were correctly defined by the producer relative to a necropsy examination was compared using a chi-square test.

Each death was characterized by a proximate cause based upon the necropsy examination. Each proximate cause of death was then categorized using 3 schemes founded on generalized etiologic principles and influenced by previous clinical history and treatments. These schemes included the broad categories that were used for classifying findings from the mortality study review (Thomsen and Houe, 2006) and which most closely align with descriptors used in on-farm databases, a diagnostic scheme used within the problem oriented veterinary medical record (Osborne, 2005), and an analysis focusing on the primary physiologic system derangement for each death. Review categories included accidents, calving disorders, digestive disorders, locomotor disorders, metabolic disorders, udder/teat disorders, other known reasons, and unknown reasons. The veterinary medical record scheme was based on the mnemonic acronym DAMN-IT with categories as follows: Degenerative; Anomalous, autoimmune; Metabolic; Nutritional, neoplastic; Inflammatory (infectious or noninfectious), immune mediated, iatrogenic, idiopathic; Traumatic, and toxic. The Physiologic classification system analysis recorded each death in terms of the most severely affected organ or body system felt to be primarily responsible for or affected by the proximate cause of death.

Placement of cases within the various schemes relied on both necropsy findings and any pertinent antemortem historical influences, such as health problems, trauma, or production issues, that were documented by dairy employees or attending veterinarians. As an example, there were 5 animals for which the proximate cause of death was attributed to a torn or ruptured uterus. Of these, 2 were damaged from either a uterine prolapse or torsion with no history of intervention prior to the damage occurring. These 2 cases were therefore categorized as calving disorders (Review), trauma (DAMN-IT), and uterus (Physiologic).

The other 3 cases were attributed to a history of inappropriate or inadequate handling of dystocias. These 3 cases were then categorized as calving disorders (Review), iatrogenic (DAMN-IT), and uterus (Physiologic).

For those animals that calved during the study period, an analysis of survival after calving was performed using the PROC LIFETEST procedure of SAS. Only cows that calved during the study period were included in this survival analysis to avoid a biased selection of proven survivors at the onset of the study. Days from calving to death were included in the model and the cows were stratified according to parity (1, 2, 3, or 4 and older). Differences in the beginning of the survival curves were evaluated using the Peto and Wilcoxon tests, whereas differences in the tail of the curves were evaluated using the log-rank test, with a P-value of ≤ 0.05 used to establish significant differences (Hosmer and Lemeshow, 1999). Animals that were sold for dairy purposes or slaughter prior to the end of the study or were alive at the end of the study were right censored.

RESULTS

The participating dairy's cow (lactating and dry) inventory on March 1st, 2005 was 1,465 and remained stable throughout the study, with a population of 1,462 cows on September 1st, 2005 and 1,463 cows on March 1st, 2006. During the study period 2,067 cows were enrolled of which 1,468 cows freshened, 507 cows were sold for slaughter, and 94 cows died. Comparisons of the proportions of deaths by type of death (euthanasia versus unassisted) and season demonstrated no differences within each category (P-values 0.30 and 0.61 respectively; **Table 5.1**). Similarly, the distribution of deaths by source (home-raised versus purchased) was not significantly different from the herd distribution (P-value 0.12);

however, the distribution of deaths by parity was significantly different with the largest percentage of deaths present in parity ≥ 4 (P-value < 0.001; **Table 5.2**). The type of death was independent of season (P-value 0.95); however, parity was dependent upon the source with the majority of home-raised cattle (86%) in their first or second lactation (P-value < 0.001). The various measures of mortality were comparable with a mortality percentage of 6.4%, a mortality rate of 6.4 deaths per 100 cow years at risk, and a mortality risk of 6.4 deaths per 100 lactations at risk. The sold percentage (34.7%), sold rate (34.7 cows sold per 100 cow years at risk), and sold risk (34.5 cows sold per 100 lactations at risk) were similarly equivalent.

Necropsies were performed on 83 of the 94 dead cows, with 72 of the necropsies performed at the CSUVDL and 11 by veterinarians on the dairy. No necropsies were performed on 11 of the cows because the antemortem history and cow examination revealed severe pathology due to traumatic accidents such as a broken leg or a lacerated milk vein, negating the requirement for a necropsy to establish the proximate cause of death. Of the cows not necropsied, 9 were euthanized in response to severe musculoskeletal damage. Adjunctive diagnostics such as histopathology, bacteriology, or virology were pursued in 51% of all cases (48/94) or 58% (48/83) of cases that were necropsied. These additional diagnostics were necessary for establishing a proximate cause of death in 6% (6/94) of all cases or 7% (6/83) of necropsied cases.

The producer's perception of the cause of death was recorded prior to each necropsy examination. This perception was deemed correct if it matched the proximate cause of death as defined by the primary necropsy findings. For example, if the producer classified the cause of death as 'pneumonia' and the necropsy defined the cause of death as ‘bronchopneumonia’ the producer’s perception was correct. However, the producer was incorrect if the perceived cause of death was recorded as ‘metritis’ whereas the postmortem findings might have included metritis but demonstrated that the immediate cause of death was toxic coliform mastitis. This level of detail was considered appropriate for establishing a correct diagnosis so that an accurate representation of the underlying health issue would be documented to help direct future endeavors at lessening mortality. The percentage of correct observations is recorded in **Table 5.3** for each Review grouping. Compared to the 96% of cases (90/94) where the cause of death was determined by postmortem examination, the producer was correct only 55% (52/94) of the time (P-value < 0.001). If accidents (100% correct) and locomotor disorders (83% correct) were removed from the total the producer was correct only 41% (29/70) of the time. Similarly, if only euthanized animals were taken into account, the producer was correct 79% (33/42) of the time; however, for those animals that died an unassisted death the producer’s assessment was correct only 37% (19/52) of the time.

As shown in **Figure 5.1**, the proximate causes of death could be represented by a number of relatively specific necropsy findings. However, this type of classification had limited utility in that it was highly detailed and failed to group deaths into potentially manageable subsets. Proximate causes of death were therefore categorized based on causal principles that might be affected to mitigate unfavorable outcomes (**Table 5.3**). The most generic categorization scheme involved that established within the review of literature related to dairy cow mortality (Thomsen and Houe, 2006). Alternative categories based on the DAMN-IT scheme and Physiologic system derangements provided slightly more specific groupings. As can be seen in **Table 5.3**, each Review group typically encompassed a number of groups within the other categories. However, the DAMN-IT and Physiologic category groups varied with respect to each other. For example, the Review group 'accidents' equated to a single DAMN-IT group ('trauma') that required 3 Physiologic groupings ('esophagus', 'musculoskeletal', and 'udder') to capture the same information. On the other hand, the single Review group 'locomotor disorders' related to only one Physiologic group 'musculoskeletal' but required two DAMN-IT groupings ('inflammation infectious' and 'inflammation noninfectious').

A total of 62 cows died of the 1,468 cows that calved during the study (4.2%). Probability of survival after calving for cows that calved during the study is presented in **Figure 5.2**. The survival curves for different parities were compared and indicated that differences were present both at the beginning (Wilcoxon P-value < 0.001, Peto P-value < 0.001) and toward the end (log-rank P-value < 0.001) of a lactation. Overall results for the study showed that 21% (20/94), 36% (34/94), and 45% (42/94) of deaths occurred by 6, 15, and 30 days respectively after calving (**Figure 5.3**). For younger cows (parities 1 and 2) 40% (21/52) of deaths occurred by 30 days after calving. For older cows (parities 3 and greater) 50% (21/42) of deaths occurred by 30 days after calving.

DISCUSSION

Reducing dairy cow mortality is an important challenge for the U.S. dairy industry. Cow mortality represents the most costly form of permanent removal from the herd, is a significant indicator of cow well-being, and appears to have occurred with increasing frequency over the last decade. Yet the dearth of literature specific to the subject suggests that this has not been adequately addressed. The industry's current understanding of dairy cow mortality is reliant upon descriptions largely founded on assumptions without the benefit of detailed postmortem evaluations. Consequently, the current literature tends toward analyses of factors associated with mortality levels rather than describing cow death relative to specific necropsy findings. These studies do not elucidate cause and effect and have limited utility for directing management decisions aimed at enhancing well-being while minimizing death rates.

Efforts to deal with this challenge require an understanding of when cows are most prone to die, what the predominant detrimental influences and specific pathologies are that underlie cow death, and how best to record and analyze mortalities to effectively direct management. A high proportion of deaths have been shown to occur during the first 15 to 30 days after calving (Milian-Suazo et al., 1988, Faye and Perochon, 1995, Menzies et al., 1995, Stevenson and Lean, 1998, Thomsen et al., 2004). Additionally, the distribution of deaths during the first 30 days of lactation is skewed, with the highest proportion occurring during the first few days after calving (Thomsen et al., 2004). The results from this current study confirm these findings in that 45% of the total deaths occurred within the first 30 days after calving and nearly half of those deaths occurred within the first 6 days of lactation (**Figure 5.3**). This is a likely result of the periparturient period's association with health problems including locomotor disorders (Shanks et al., 1981, Markusfeld, 1993, Green et al., 2002). Furthermore, additional studies have found a higher mortality among older cows (Faye and Perochon, 1995, Dematawewa and Berger, 1998, Stevenson and Lean, 1998, Thomsen et al., 2004, Miller et al., 2008). The present study supports this association (**Table 5.2; Figure 5.2**) which may be partly explained by increased incidences of certain diseases such as hypocalcemia, ketosis, and retained fetal membranes with increased parity (Markusfeld, 1993, Gröhn et al., 1998, Houe et al., 2001).

Understanding why cow mortality occurs can be very useful in preventing further occurrences. To this end it is helpful to know causes of death in conjunction with timing and occurrence rates. However, capturing information regarding why cows die presents a substantial challenge. Thomsen and Houe's review of dairy cow mortality found that only 10 of 19 studies gave some information on causes of death (Thomsen and Houe, 2006). The level of detail was variable and most studies had a relatively large proportion of causes classified as 'unknown' (16-46%). More recently, the NAHMS Dairy 2007 survey classified 15.0% of cow deaths due to unknown reasons (USDA, 2007b). Only when euthanized cattle are considered independently do the proportion of unknown causes substantially lessen (Thomsen et al., 2004), as might be expected since euthanasia is often preceded by a diagnosis. None of the 19 studies documented in the review utilized necropsies to determine the causes of death (Thomsen and Houe, 2006). Consequently, perceptions based solely on antemortem histories played a significant role in determining recorded causes of death. The present study suggests that a producer's perception of cause of death can be seriously flawed (45% incorrect overall), particularly when dealing with animals dying an unassisted death (63% incorrect).

This study was founded on the premise that a detailed necropsy examination would provide the best information for establishing causes of death. Although the study was conducted on a single dairy, many of the observations can be generalized because they consider whether commonly used descriptors of mortality are meaningful sources of information on which to base management decisions. As can be seen, different methods for classifying necropsy findings and causes of death can provide very different levels of detail. Individual deaths can be defined by specific findings (**Figure 5.1**) but this level of detail is difficult to analyze for underlying herd level problems and is itself limited in its account of the sequence of events that lead to the death. Although the proximate cause of death provided useful insight into underlying pathology, many cases involved multiple pathologic lesions which inevitably contributed to overall morbidity and undoubtedly influenced the final cause of death. For example, within this study an animal died of embolic, suppurative pneumonia that originated from hepatic abscessation with vena caval extension and sepsis. Although the animal ultimately died from pulmonary failure which may or may not have been treatable, the origins of her morbidity stemmed from the disease process that resulted in liver abscesses.

Categorization of this case resulted in 'lungs' (Physiologic), 'inflammation infectious' (DAMN-IT), and 'other known reasons' (Review) The generic 'other known reasons' category within the Review classification (**Table 5.3**) provides no useful information for understanding what ultimately led to a death. Nonetheless, on-farm databases have historically depended on capturing relevant information regarding dead cows in broad categories such as those within the Review system. While such a system of categories lacks the ability to define specific proximate causes of death, it does provide an avenue for grouping similar etiologies within databases that were not developed to deal with the specifics of cow mortality. Creating categories with more selective groupings such as those represented by the DAMN-IT and Physiologic schemes may provide a means for capturing specifics related to deaths that can be analyzed as whole. However, the use of such categories would require a change in the way current databases are constructed and utilized. Necropsy findings are essential for defining the ultimate or proximate cause of death but must be viewed in whole and within the context of preceding events that precipitated the death.

The information gained from a necropsy examination must be recorded in a format that can be used for formulating management strategies. Pertinent historical information relative to a cow's death should be integrated into any system that attempts to record why cows die. It has been shown that record systems which only allow a single reason for death or culling provide only partial documentation of the reason for removal (Bascom and Young, 1998). Simply capturing descriptors of the proximate cause of death fails to acknowledge that an individual death is often the end result along a continuum of failures. This provides an additional challenge as most record systems on U.S. dairies are focused on reproductive and milk production performance, and are primarily used by producers to evaluate the current status and performance of animals as well as to generate 'to do' lists. Health events are either not monitored, are poorly defined (e.g. categories such as illness, lame, or digestive are not sufficiently characterized to allow analysis of specific problems; or a specific disease such as hemorrhagic bowel syndrome is identified as HBS, BLDGUT, CLOST in the records), or are not recorded at all. Thus, the records are not configured to facilitate analysis of prior events that result in a current condition; in other words, it is difficult to assess cause and effect.

This study focused principally on using necropsy findings to categorize causes of death. Combining necropsy examination findings with other pertinent information in a complete postmortem evaluation would ideally provide a meaningful degree of detail when assessing causes of death, regardless of variations inherent in necropsy techniques and in the use of ancillary testing. Although the current study focused on necropsying all but the most obviously traumatic deaths, the practical application of necropsy examinations may necessitate a more targeted approach as determined by personnel and disposal constraints. While there are instances (accidents, locomotor disorders, euthanasias) where the information gained may not warrant the cost and effort required to perform a necropsy, this study suggests that there are numerous other cases where a necropsy could provide additional insight into the actual cause of death. Based on the frequency with which producers may incorrectly classify deaths, necropsies may provide necessary insight if health records are to be populated with useful and correct information. Although the costs incurred from necropsies vary depending on who performs the task, whether it be trained in-house personnel or a private veterinarian, the cost to benefit ratio will be directly related to the application of the necropsy-based information to operational management. The challenge remains in integrating the postmortem details in a comprehensive and useful strategy for combating rising levels of dairy cow mortality. To be successful, any efforts to manage rising mortality levels must view the problem as a whole. Focusing attention on those cows most at risk for disease and death, tracking and recording health events, and establishing proximate causes of death based on necropsy findings must be combined with an understanding of those facets of management that influence poor outcomes. Ideally, record system templates should be constructed that are consistent across operations and describe specific causes of death within the context of historical influences. Records of this quality would allow for easy determination of deaths over a period of time and could guide implementation of management practices or facility designs that ultimately reduce dairy cow mortality.

Table 5.1: Descriptive statistics and Chi-square analysis of 94 dairy cow deaths by type of death and season.

Category	Description	# of Deaths	% of Deaths	Chi-sq P-value
Type of Death	Euthanized	42	44.7	0.30
	Unassisted Death	52	55.3	
Season	Spring: Mar, Apr, May	18	19.2	0.61
	Summer: June, July, Aug	26	27.7	
	Autumn: Sept, Oct, Nov	24	25.5	
	Winter: Dec, Jan, Feb	26	27.7	

Table 5.2: Descriptive statistics and Chi-square analysis of 94 dairy cow deaths by source and parity. Mortality percent is calculated as the number of deaths divided by the herd inventory on March 1st, 2006, per respective category.

Category	Description	# of Cows	# of Deaths	Mortality %	Chi-sq P-value
Source	Home-raised	851	47	5.5%	0.12
	Purchased	612	47	7.7%	
Parity	1	645	28	4.3%	< 0.001
	2	393	24	6.1%	
	3	245	16	6.5%	
	≥4	180	26	14.4%	

Table 5.3: Three classification schemes for documenting causes of death in 94 dairy cows. The number of cows that died (unassisted or euthanized) are recorded along with the percent of deaths reflected by each Review classification. The percent of deaths for which the producer's perception of the cause of death was correct relative to that established by postmortem evaluation is also shown.

Review Classification[1]	DAMNIT Categories	Physiologic System	Euthanized	Unassisted Death	% of Deaths	Producer % Correct
Accidents	Traumatic	Esophagus	0	1	19.1	100
		Musculoskeletal	16	0		
		Udder	0	1		
Calving Disorders	Inflammatory Infectious	Musculoskeletal	1	0	14.9	64
		Uterus	2	4		
	Iatrogenic		2	2		
	Inflammatory Noninfectious		0	1		
	Traumatic		1	1		
Digestive Disorders	Inflammatory Infectious	Small Intestine	4	1	13.8	38
	Inflammatory Noninfectious		1	1		
		Abomasum	0	4		
	Traumatic	Forestomachs	0	2		
Locomotor Disorders	Inflammatory Infectious	Musculoskeletal	3	0	6.4	83
	Inflammatory Noninfectious		3	0		
Metabolic	Metabolic	Liver	0	1	2.1	0
		Systemic	0	1		
Udder/teat Disorders	Inflammatory Infectious	Udder	1	4	5.3	60
Other Known Reasons	Degenerative	Heart	0	1	34.0	28
	Iatrogenic	Abomasum	0	1		
		Lungs	1	2		
	Idiopathic	Abdomen/ peritoneum	0	2		
	Inflammatory Infectious		1	2		
		Heart	0	1		
		Liver	2	4		
		Lungs	1	7		
		Systemic	0	1		
	Inflammatory Noninfectious		0	2		
	Neoplastic		3	1		
Unknown Reasons	Idiopathic	Unknown	0	4	4.3	75

[1]Thomsen, P. T. and H. Houe. 2006. Dairy cow mortality. A review. Vet Q 28(4):122-129.

Figure 5.1. Postmortem findings representing the proximate cause of death for 94 cows that died between March 1st, 2005 and February 28th, 2006 on a Colorado dairy.

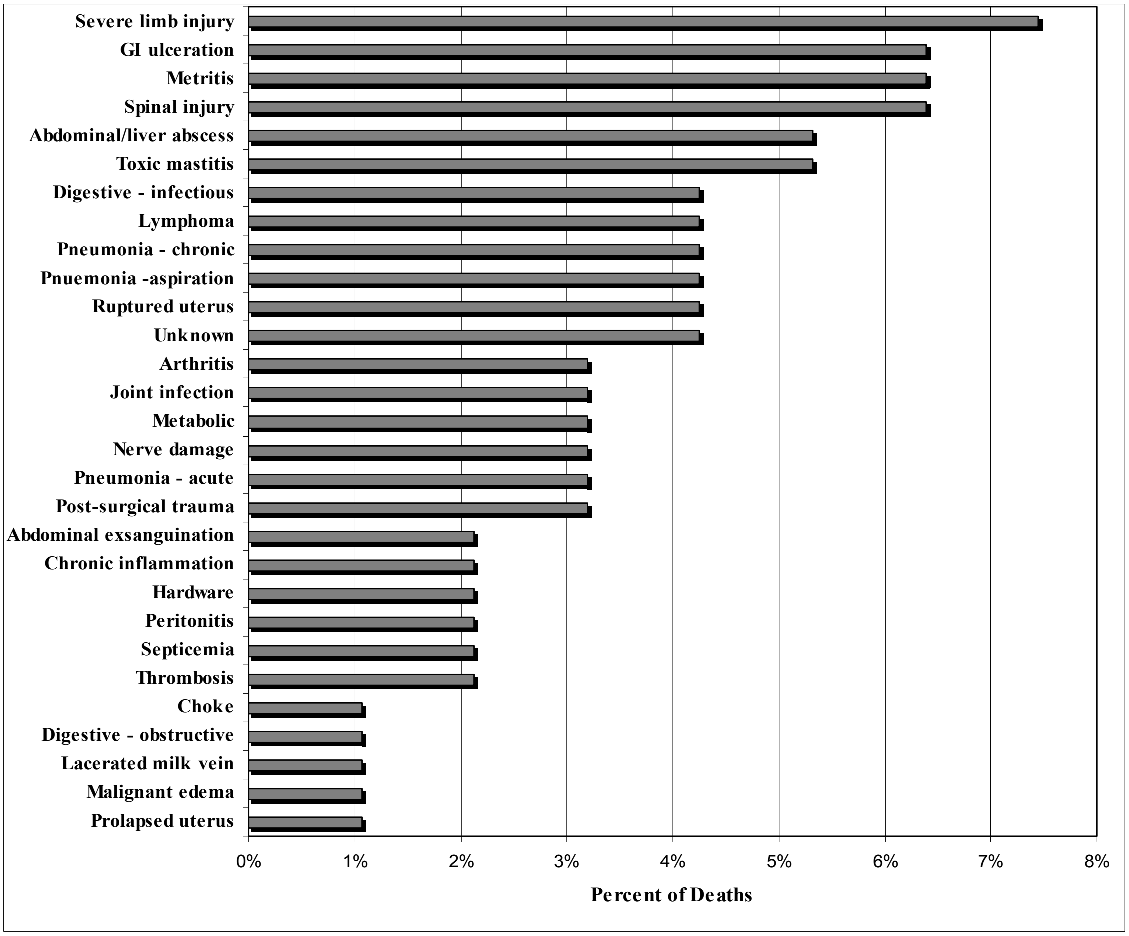


Figure 5.2: Probability of survival after calving for cows that calved between March 1st, 2005 and February 28th, 2006, by parity on a Colorado dairy

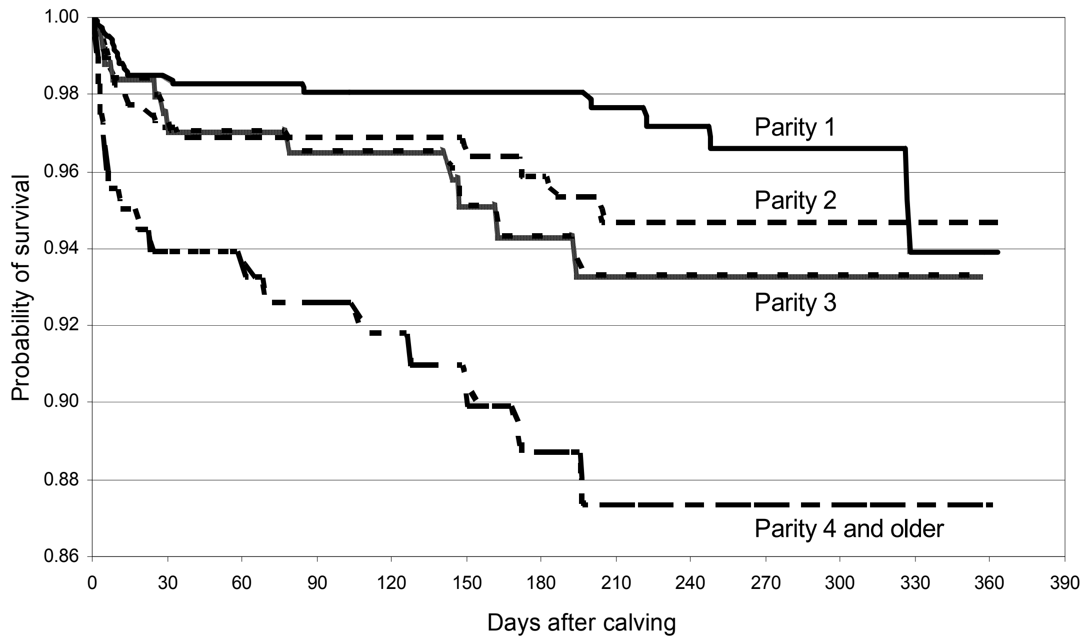
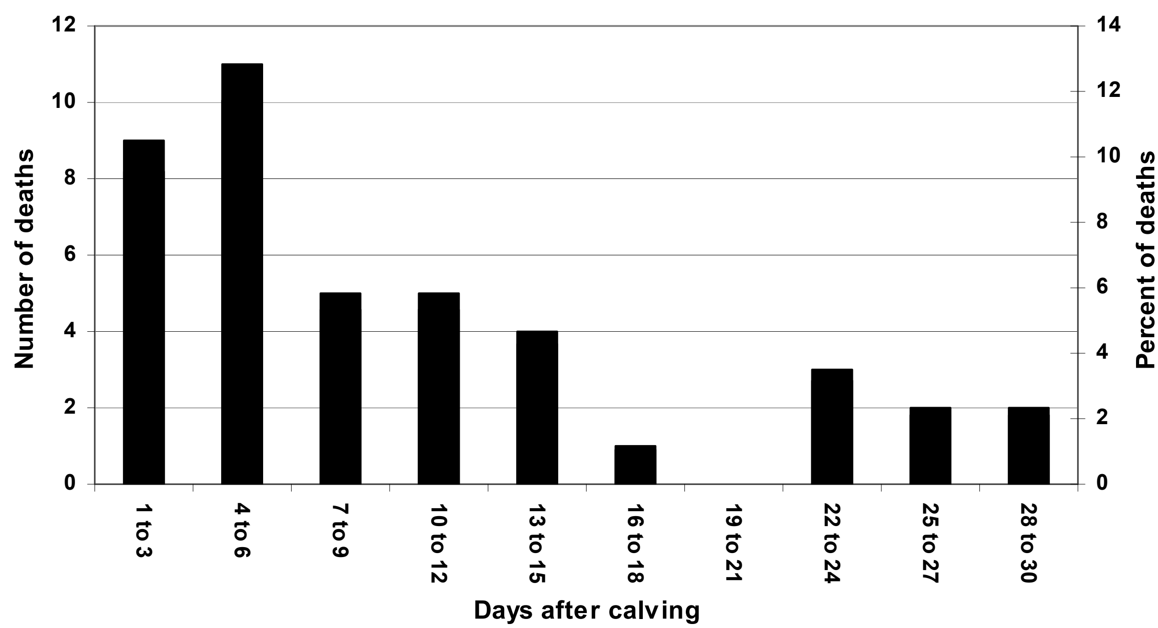


Figure 5.3: The number and percent of deaths in the first 30 days of the lactation for cows that died between March 1st, 2005 and February 28th, 2006 on a Colorado dairy.



CHAPTER 6: CONCEPTUAL MODELING OF POSTMORTEM EVALUATION FINDINGS TO DESCRIBE DAIRY COW DEATHS[3]

INTRODUCTION

Dairy cow mortality levels in the U.S. are excessive and increasing over time. Analysis of Dairy Herd Improvement data (15,025,035 lactations in 45,032 herds) demonstrated a 1.6% increase in death frequency from 1995 to 2005 (Miller et al., 2008). Similarly, the USDA:APHIS:VS National Animal Health Monitoring System (**NAHMS**) Dairy 2007 survey reported that 5.7% of the January 2007 dairy cow inventory died on-farm during 2006, a significant increase from 4.8% of the January 2002 inventory, and 3.8% of the January 1996 inventory (USDA, 2007b). These numbers are perhaps even more poignant when one considers that this increase in death is occurring even as the age of the U.S. dairy population declines (Hare et al., 2006). This is a growing concern for dairy producers, both because of the obvious economic liability it represents and because of ethical and welfare dimensions (Thomsen and Houe, 2006, NDAWB, 2008).

One might suspect an underlying genetic component to increasing death losses as a result of genetic selection biased toward production indices, with little consideration of animal longevity or disease occurrence. In fact, data suggest that Jersey and crossbred dairy cows have a substantially reduced mortality level relative to purebred Holsteins (Rogers, 2009). However, overall favorable genetic trends for survival imply that the decline in dairy cow survival is primarily the result of changes in herd management as

[3]Originally published in *J Dairy Sci* 93(1):373-386.

opposed to genetic selection (Dechow and Goodling, 2008). An exploration of U.S. herd characteristics and practices demonstrated associations between higher levels of mortality and management changes related to intensification (McConnel et al., 2008).

The preponderance of literature investigating dairy cow mortality has analyzed the association between mortality levels and population characteristics such as parity, disease prevalence, or days in lactation rather than describing cow death relative to specific necropsy findings (Thomsen and Houe, 2006, Bar et al., 2008, Dechow and Goodling, 2008, McConnel et al., 2008, Miller et al., 2008). Without necropsy examinations the recorded cause of death is often determined by producer perceptions (McConnel et al., 2009). Many disease conditions can present with similar clinical abnormalities that when used on their own to categorize causes of death can lead to misclassifications (Loneragan et al., 2001). An important step in defining cause and effect and combating rising mortality lies in more clearly defining the reasons that cows die through a thorough necropsy-based postmortem evaluation.

Recent publications have touted the benefits of and procedures for performing field necropsy examinations (White, 2005, Mason and Madden, 2007, Wagner, 2007). A dead animal that is not evaluated by necropsy is a total economic loss to a producer; however, a thorough necropsy examination can provide valuable management information that may benefit the herd (White, 2005). Although field necropsies can prove laborious, time-consuming, and at times fruitless, many reasons exist for performing them. Necropsies are warranted when morbidity or mortality exceed historic or comfortable levels, when there is a perceived treatment failure, for acquiring samples necessary for confirmation of a tentative clinical diagnosis, when presenting signs are dramatic or unusual, or to characterize a disease process when no antemortem observation has been made (Mason and Madden, 2007). Information derived from a necropsy should be viewed in conjunction with background information related to clinical history and treatments to form a thorough postmortem evaluation.

Whereas the costs incurred from necropsies vary depending on who performs the task, the value of a postmortem evaluation is directly related to the accuracy and maintenance of data collected and its application to operational management. It can be difficult to maintain accurate postmortem records that can be easily retrieved to provide valuable insight into historical death patterns and to guide future health planning and programs (White, 2005). Current record systems such as those provided for DHI herds can provide copious concrete data regarding life history features of dead cows but are not configured to facilitate analysis of prior health events that result in a current condition, nor do they assess the cause and effect of various phenomena. In fact, the least available dairy herd data comprise records of disease and management events and are subject to tremendous variability in the rigor and consistency of their recording (Kelton, 2006). Establishing record system templates that document dairy cow deaths consistently across operations and within the context of historical influences would allow for the easy determination of the number, distribution, and causes of deaths over a period of time and could guide management practices toward the goal of reduced mortality (McConnel et al., 2009).

The current study was founded on the premise that thorough postmortem evaluations could be used to explore causes of dairy cow death not simply as a function of anatomic pathologies but by viewing necropsy findings within the context of historical and environmental influences. Data collection forms have been created that facilitate the capture of concrete data related to the individual animal being evaluated (White, 2005). Such records typically focus on specific life history features (e.g. birth date, lactation number, lactational and reproductive status), health events, treatments, and necropsy and adjunctive diagnostic findings. Expanding and improving record systems to capture more data related to farm management dynamics can be facilitated through the use of conceptual modeling principles. Modeling provides a foundation for database schemes that prevent redundancy, provide easy entry and retrieval of information, and accommodate new and unexpected items of information (Lescourret et al., 1993). This study focused on organizing information generated from postmortem evaluations into a monitoring system that is based on the fundamentals of conceptual modeling and will potentially be translatable into current on-farm relational databases.

MATERIALS AND METHODS

The Problem as it Relates to Dairy Complexity

Necropsy examinations of dead animals to assess and monitor causes of death are rarely performed on U.S. dairies (USDA, 2007a), unlike other intensive livestock management systems, including poultry, swine, and feedlot enterprises (USDA, 2000b) where necropsy monitoring is routine. Dairy industry efforts to effectively decrease mortality losses are thus hampered by a lack of monitoring and information to provide an accurate assessment of the problem. Comparing the dairy and feedlot industries makes it easier to understand the apparent inertia associated with dairy postmortem evaluations. Within the feedlot industry a small number of observed disease complexes warrant action. Relative to dairy operations, cattle entering feedlots are typically subject to a shorter period within the system and are not faced with the various production challenges of a dairy cow. Demands on feedlot cattle do not include the physiologic challenges associated with pregnancy, parturition, and lactation. Nor are animals in a feedlot operation required to undergo the physical strain of processing (milking, reproductive exams, etc.) multiple times a day as is demanded from milking dairy cattle. As a result, the problems encountered by feedlot cattle are relatively limited and are consequently easier to monitor as compared to the substantially more complex dairy operations.

Feedlot versus Dairy Mortalities

The mortality ratio for cattle entering feedlots did not significantly increase from 1994 to 1999 based on the NAHMS Feedlot 1999 survey findings (Loneragan et al., 2001), yet during that same period the percentage of dead feedlot cattle that had a postmortem examination substantially increased from 45.9% to 53.9% (USDA, 2000a). This increase in postmortem examinations was primarily the product of an increase in necropsies performed by non-veterinarians (USDA, 2000a). Most of the feedlot associated deaths documented in the NAHMS survey resulted from bovine respiratory disease complex (61.2%), whereas 21.9% of animals were classified as having died from digestive tract disorders, and 16.9% died of other disorders (Loneragan et al., 2001).

Conversely, the percentage of dairy cows that die on-farm has significantly increased from 1996 to 2007 yet the NAHMS Dairy 2007 study reported that necropsies were performed on only 13% of operations (~9,750 operations) and only 4.4% of dead dairy cows (~23,000 cows) (USDA, 2007a). Further, the range of dairy producer-attributed causes of death within the Dairy 2007 study included lameness or injury

(20.0%), mastitis (16.5%), calving problems (15.2%), respiratory problems (11.3%), scours, diarrhea, or other digestive problems (10.4%), other known reasons (11.6%), and unknown reasons (15.0%). The perception is that dairy cows die from a wider range of problems than are typically recognized within the feedlot industry, yet substantially less effort is made in terms of postmortem evaluations to more fully define how and why dairy cows die.

Project Framework

This observational study was conducted on three (**A, B, C**) high producing (13,184; 11,915; and 11,275 kg milk/cow/year respectively), commercial dairies in northern Colorado. Dairy A participated in the study from October 2006 through November 2007, Dairy B participated from November 2006 through September 2007, and dairy C participated from October 2006 through January 2007. Dairies A and C maintained essentially stable inventories of 1,500 and 2,000 Holstein cows (lactating and dry) respectively. Dairy B's inventory of approximately 800 cows consisted of 25% Jersey and 75% Holstein cattle (lactating and dry). Lactating cows on dairies A and C were predominantly housed year around in freestall barns with bedding consisting of sand on dairy A and composted manure on dairy C. Lactating cows on dairy B were held in drylots during summer months and freestall barns bedded with sawdust during the winter months. All three dairies held dry cows in drylots. Arithmetic mean somatic cells counts were 247,698, 198,218, and 219,789 cells per mL for dairies A, B, and C respectively. Cows were milked three times a day on all of the dairies. Approximately 40% of cows on dairy A received bST whereas dairies B and C did not use bST. Hoof care programs on all dairies involved both the treatment of animals observed with lameness and twice annual maintenance trimming. Nutritional management for all dairies included the use of a total mixed ration and forage testing, with ration formulation by a professional consultant based on production and stage of lactation. The dry period was approximately 55 days for all dairies. Maternity housing was separate from housing used for other dry cows or lactating cows. On dairies A and B heifers and mature cows were grouped together within the close-up maternity housing, but on dairy C heifers and mature cows were grouped separately. On dairies A and C the majority of cows calved in a multiple animal area, while on dairy B the majority calved in an individual animal area cleaned after two or more calvings. Fresh cows were penned separately from hospital cows, and first lactation cows were grouped separately from mature cows on all dairies. Approximately 28, 18, and 43 full-time staff participated in milking and cow management activities on dairies A, B, and C respectively, with training sessions performed multiple times per year to cover protocols related to milking, calving, and fresh cow monitoring. Routine veterinary services on dairy A were provided by the Colorado State University College of Veterinary Medicine. Dairies B and C each employed an in-house veterinarian to provide veterinary services. Operational management on all dairies included the use of on-farm computer systems to track cow and herd level data.

Postmortem Evaluations

Throughout the study period a thorough postmortem evaluation was performed on a majority of cows that died on each dairy. Necropsies were performed on dairy A by one of two Colorado State University (**CSU**) veterinarians and on dairies B and C by the respective in-house veterinarians. All four participating veterinarians were trained in standard necropsy techniques (Severidt et al., 2002) via a necropsy protocol overview performed at the CSU Veterinary Diagnostic Laboratory prior to commencing the project. When possible, the participating veterinarians performed antemortem clinical evaluations on animals to be euthanized. Necropsy examinations were performed as soon as possible after death and within a maximum of 24 hours. If a participating veterinarian could not attend to a cow within 24 hours postmortem the animal was excluded from the study. The submission of appropriate tissue or biologic samples for further diagnostics was discretionary and based on necropsy findings when additional insight was warranted to confirm or determine the cause of death. Carcasses were disposed of through on site composting on Dairies A and C, and were removed by a renderer on Dairy B.

Results from the postmortem evaluation were recorded in a standardized format (**Figure 6.1**) that captured concrete data related to specific life history features (e.g. birth date, lactation number, lactational and reproductive status), health events, treatments, and necropsy findings. No timeframe was set prior to death for inclusion of events; rather, the veterinarian overseeing the postmortem examination recorded health problems and treatment episodes felt to have potentially influenced the final outcome of death. Most often this included health and treatment events within a current lactation, although data from a previous lactation did occasionally provide useful information related to a death. The participating veterinarians also included more dynamic data inherent to the dairy and felt to be relevant to the death. These data included aspects of operational management that were subject to change and considered integral to the poor outcome. Whereas it was felt that the proximate cause of death could most often be described through necropsy findings, the additional management oriented information provided a more thorough analysis of any underlying or key determinant causes of death. Borrowing from the language of pathology, this was comparable to establishing a "definitive diagnosis" through the naming of a disease (proximate cause) versus an "etiological diagnosis" that incorporates both cause and effect as might be defined by infectious agents and resultant lesions (key determinant causes).

Digital Image Capture

Digital images were taken during each necropsy to provide a general overview of the carcass, to document specific pathological changes, and to provide data validation for reported necropsy findings. Digital imaging has been used as part of the collection of necropsy information from feedlots. In feedlot animals, 4 to 8 views should be adequate for establishing a diagnosis, utilizing a standard necropsy technique and comprehensive written protocols (Wildman et al., 2000). In the current study, three standard images were taken: the unopened carcass lying on its left side, the opened abdominal cavity, and the opened thoracic cavity. Other images were discretionary and represented notable findings depicting abnormalities documented on the postmortem data sheet. For instance, if the only notable pathological alteration was gross evidence of hemorrhagic bowel syndrome then an additional digital image was taken of the affected intestinal section.

Conceptually Modeling Postmortem Findings

Results from the postmortem evaluation were conceptually modeled as described by Lescourret et al. (1993). Such a model provides analysis at a conceptual level in that it is free of the constraints of database management system implementation; a single model can be translated into different data structures. A representation of this conceptual data modeling is shown in **Figure 6.2** and was based on the "entity-relationship" approach, with entities describing real objects (cow, dairy) and relationships providing connections between such entities (i.e., cows belong to a dairy). In this model, the entity "cow" was defined by a number of concrete characteristics or attributes. Similarly, the entity "dairy" consisted of a number of potentially influential dynamic attributes. The relationship between the dairy and the cow also contained an attribute establishing the period of time that the cow was on the farm. However, the relationship between the dairy and the cow primarily served as a conduit for incorporating influential operational characteristics into the postmortem evaluation. Categories were then formulated upon this complete representation of the individual animal and dairy attributes such that a relationship formed between each death and a categorical descriptor for that death. This relationship between the cow and a death category was defined by an attribute based on the specificity of the cause of death. This relational attribute reflected whether a particular mortality was most effectively categorized via a proximate cause such as a specific disease, or a key determinant cause founded on more general temporal or managerial influences. Themes were then applied to like categories based on a relational attribute describing the type of death in terms of problems related to clinical disease, disease recognition or treatment, trauma, nutrition, or the stage of lactation.

Comparisons between Dairies

For comparison, each dairy's annual mortality and sold to slaughter percentages were calculated using the total number of dead and sold cows respectively over the 12 month period extending from November 1, 2006, to October 31, 2007, divided by the number of dairy cows present on the operation at the end of that period. For each dairy and for the combined dairies the distributions of total annual necropsied deaths by parity and by days postpartum were compared to the distributions of non-necropsied deaths using a chi-square test (PROC FREQ, SAS, version 9.1, SAS Inst. Inc., Cary, NC). Additionally, the distribution of deaths by parity, days postpartum, lactation status, pregnancy status, type of death (euthanized versus unassisted), and recumbency ≥24 hours prior to death were compared among dairies using chi-square testing. Similarly, the distribution of specific and combined health events and treatments that were recorded per necropsied animal were compared among dairies, as were the distribution of anatomic systems with pathologic necropsy findings, the primary anatomic pathology associated with death, and the distribution of necropsied animals placed within specific categorical themes. For all comparisons where more than 20% of contingency table cell counts were less than 5, SAS' PROC FREQ computed Fisher's exact test using the network algorithm of Mehta and Patel (Mehta and Patel, 1983). For evaluations of a single null hypothesis, $P \leq 0.05$ was considered statistically significant. For multiple comparisons the significance level was adjusted by dividing the desired significance level (0.05) by the number of null hypotheses evaluated.

RESULTS

Postmortem Comparisons of Life History Features

During the study, 174 postmortem evaluations were performed. Dairy C's involvement was restricted to 4 months due to the departure of the in-house veterinarian. Of the 174 postmortems, 68 were performed on dairy A, 39 on dairy B, and 67 on dairy C (**Table 6.1**). Of those 39 postmortems on dairy B, 7 were from Jerseys as opposed to Holsteins, a similar distribution to the breed distribution within the herd and comprising a relatively small sample from which to make meaningful comparisons based on breeds. Total deaths on dairies A, B, and C over a 12 month period extending from November 1st, 2006, to October 31st, 2007, were 111, 60, and 273 respectively. Herd inventories for the three dairies were 1,529 (A), 777 (B), and 2,255 (C) on October 31, 2007. Annual mortality percentages for dairies A, B, and C were 7.3%, 7.7%, and 12.1%, and the annual percentages of cattle sold to slaughter were 31.5%, 17.4%, and 30.4% respectively. The consequent percentages of overall removals that resulted from death loss rather than other, more economically favorable culling decisions equated to 18.8%, 30.8%, and 28.5% for dairies A, B, and C respectively. The distribution of necropsied deaths by parity did not differ from the distribution of annual non-necropsied deaths by parity (**Table 6.1**). Nor was the distribution of necropsied cows by days postpartum different from the distribution of annual deaths by days postpartum (**Table 6.1**). The distribution of necropsied cows by parity, days postpartum, pregnancy status, and recumbency status prior to death were not dependent upon the dairy (**Table 6.2**). However, the distributions of necropsied cows by lactation status and type of death were dependent upon the dairy (**Table 6.2**).

Postmortem Comparisons of Health Event, Treatments, and Necropsy Findings

Relevant health events and treatments were recorded for each of the 174 deaths. The distribution of deaths by specific health events and treatments showed some dependency upon the dairy (**Table 6.3**). Occurrences of milk fever and lameness varied according to dairy. When health events were categorized by the number of occurrences per animal (0, 1, 2, >2), there was no dependence upon the dairy. Of the treatments given, only the use of anti-inflammatories, IV fluids and electrolytes, and vitamins varied according to dairy. When treatments were categorized by the number of occurrences per animal (0, 1, 2, >2) the categories representing 2 and >2 varied with dairy. The distribution of deaths by specific anatomic lesion diagnoses, the number of anatomic systems with pathologic abnormalities per death (0, 1, 2, 3, 4, 5, >5), and the anatomic system with the primary pathology associated with death demonstrated some variation among dairies (**Table 6.3**). Pathological changes associated with the abdomen or peritoneum, abomasum, heart, liver, lungs, oral cavity, and trachea varied with dairy. The anatomic system listed as the primary pathology associated with death differed among dairies for the small intestine.

Digital Image Utility

Digital image documentation of dairy cow necropsies proved to be a complicated endeavor due in large part to the often varied disease processes culminating in a death. As shown in **Table 6.3**, over a third of deaths (36%) demonstrated 5 or more systems with evidence of pathology. Although not all documented pathologies were integral to the final outcome of death, capturing the relevant affected anatomic systems required a detailed examination with a thorough understanding of bovine physiology. While many images clearly captured a specific pathology, capturing all significant pathologies within an individual animal and providing sufficient explanation for images that failed to demonstrate pathologic context was difficult. For instance, ruptured vessels were easily enough observed within an image but often required a detailed explanation of the anatomic location and other potential pathologic influences if the cause of death was to be more fully understood. Ultimately, the digital images provided a discussion point when reviewing individual deaths but were not useful as the sole explanation of pertinent lesions. Their utility was limited by the complexities of the necropsy examination and reliant upon thorough input from the prosector.

Dairy and Veterinarian Differences

Although the majority of comparisons between dairies for life history features, health events, treatments, and necropsy findings were not significantly different, the differences identify difficulties in reliably documenting the complexities associated with dairy postmortems. The differences between dairies likely represented variations in operational management and environment, and veterinary perspective. For instance, dairy A likely documented higher levels of oral cavity and tracheal pathologies because a veterinarian on dairy A more closely scrutinized those anatomic systems, not because of a disease complex specific to that dairy. This potential for relativism underscores the importance of establishing an information system that views each death as a whole. For this study, this included the assessment by the participating veterinarians of more dynamic data related to operational management and considered important to the final outcome. While still subjective, these data provided a more complete picture of the events leading up to the death such that each death could be viewed within the context of the complexity of a cow's life on a dairy.

Conceptual Model

Relevant attributes related to the "dairy" and "cow" entities and the relationship between them were documented and applied to the conceptual model demonstrated in **Figure 6.2**. Each death was viewed in the context of the web of factors influencing the dairy and the cow. Categories were formulated in an effort to create a monitoring system describing mortality in terms of functional characteristics potentially amenable to performance evaluation, management oversight, and research.

As an example a 3 year old, primiparous, 21 day postpartum, Holstein was euthanized on January 11th, 2007 (life history features). Her death followed an initially transient period of recumbency several days postpartum that was accompanied by a rapid loss in condition and eventuated in permanent recumbency for a 2 day period prior to euthanasia (health events). She had been treated with oral and IV fluids, anti-inflammatories, and injectable vitamins and was floated in a water tank to mitigate side effects from recumbency (treatments). The postmortem examination demonstrated evidence of abomasal hyperemia, acute bronchopneumonia, metritis, and a moderate hepatic lipidosis (necropsy findings). A pertinent dairy attribute included the purchase of replacements (biosecurity and expansion), including this heifer from a dairy that failed to breed her in a timely fashion, resulting in over-conditioning and a late age at first calving. An additional and variable dairy attribute included a prolonged period of inclement weather at the time of this animal's demise (facilities and environment). The various concrete and dynamic attributes influencing this animal's death suggested that the "causal specificity" attribute within the relationship between the entities "cow" and "death category" was less a function of a specific proximate cause (i.e., a particular disease process) and more the result of key determinant issues related to the period of early lactation (i.e., multifactorial negative influences). The combination of an older, over-conditioned heifer at the time of calving, stress associated with an environmental change and inclement weather, and consequent immunologic, hepatic, and pulmonic pathologies terminated in permanent recumbency requiring euthanasia. Therefore this particular death was included within a category incorporating the multifactorial reasons for transition failure. The final relationship between this death category and its overarching theme was dictated by the "type of death" attribute's relationship to the stage of lactation, in this case specifically targeting transition cow or negative energy balance issues.

Specific Disease Processes with Variable Etiologies

In total, 21 death categories with 7 category themes were formulated based on the model guidelines. There were a number of disease processes that stood alone as proximate causes of death but may or may not have had manageable etiologies originating with other underlying determinants. Thematically, this set of categories encompassed specific disease processes with variable etiologies (**Table 6.4**). The explicit pathophysiologic attributes required specific categories yet the majority of these pathologies were undoubtedly manifestations of multifactorial problems; however, under the circumstances they provided a specific action or analytic point when clearly evident and clearly severe. Rather than bury specifics in generalities (i.e., the multifactorial and miscellaneous categories to follow), these disease entities were left as a stand-alone category if they captured the essence of the underlying etiology or if there was evidence that they might be amenable to management alternatives.

Failure of Disease Recognition or Treatment

Some initiating factors that eventuated in death were diseases for which there was a failure of recognition or treatment (**Table 6.4**). These problems could all be deconstructed into the periods of lactation in which they occurred but for the purposes of this study the sub-categorization appeared primarily relevant to pneumonia. The categories included failures in: lameness (primarily referring to chronic digital infections—not injury or trauma), mastitis, metritis, and pneumonia. The cases of pneumonia were further broken into lactational periods (early lactation: ≤60 DIM; mid/late lactation: >60 DIM), the purpose of which was to provide a delineation of the failed outcome not only in terms of the disease but with respect to relevant periods with inherent health challenges from which the disease problem arose. For instance, pneumonia during the early transitional period may be influenced by specific factors related to close-up maternity management whereas late lactational pneumonia may result from a very different set of underlying factors. While the temporal aspect of this categorization provided the context for the pathophysiology, the disease remained the target for directing management alternatives. This necessitated categories dictated by the failed disease intervention rather than the period during which the disease occurred.

Traumatic Events

The majority of deaths resulting from traumatic events were a consequence of trauma associated with parturition or injuries resulting in lameness (**Table 6.4**). This categorical theme also included an "iatrogenic: trauma" category. Although this covered a fairly wide arena (aspiration pneumonia, injection site abscesses, drug reactions, and surgical complications) the significance of this category lay in its documentation of those deaths that occurred not because of the initiating disease process but because of the attempt to treat that process. If those failures were ignored it would be too easy to chalk up a loss to an initial episode of pneumonia or a displaced abomasum rather than dealing with the underlying issue of worker training or surgical competence. As might be expected, this categorical theme represented more euthanasias than did any of the other themes (14/42), with the death category "lameness: trauma" accounting for more euthanasias (9) than any other specific category (**Table 6.4**).

Multifactorial Failures Linked to Transition or Negative Energy Balance Issues

The categorical theme with the most thorough incorporation of concrete and dynamic attributes encompassed multifactorial failures linked to transition cow or negative energy balance issues (**Table 6.4**). This subset of deaths represented early lactation failures following any combination of health events such as ketosis, diarrhea, milk fever, respiratory disease, retained placenta, metritis, poor body condition, and electrolyte imbalances—no one of which specifically led to any particular death but all of which contributed. These deaths could not be ascribed to any one cause due to the multiplicity of pathologies; rather, they represented a failure in the preparation for and adjustment to the early stages of lactation. As such, specific dynamic attributes of the dairy during these peripartum stages and the consequent relationship with the cow were critically influential in the final outcome of death.

Feed Management; Miscellaneous Events; Undetermined Causes

Three additional themes completed the categorization of deaths from this study (**Table 6.4**). These included an error in feed management due to improper mixing and delivery of barley within a TMR and miscellaneous findings that were not clearly preventable or treatable but could be broken into early (≤ 60 DIM) and late (>60 DIM) periods of lactation. The miscellaneous early lactational losses were not obviously attributed to transition or negative energy balance issues and were not easily defined in term of the pathologic sequence but tended to be due to infectious processes (e.g. flank myositis, peritonitis, or pericarditis) with unknown initiating causes. On the other hand, the late lactational findings were typically due to random and unmanageable events including a ruptured abdominal abscess of unknown origin, gastric vein rupture, and late gestational uterine rupture. The final theme included postmortem evaluations that demonstrated no proximate or key determinant causes of death such that the reasons for the deaths were left undetermined.

DISCUSSION

The Problem of Dairy Cow Mortality

It is time to rethink how the dairy industry approaches the issue of excessive mortality. Even in the face of economic and ethical concerns, little literature specific to the subject exists and evidence suggests a limited understanding for the reasons why cows die (Thomsen and Houe, 2006, McConnel et al., 2009). A tacit acceptance of the problem pervades the industry; to paraphrase, bad has become normal (Grandin and Johnson, 2005). Preceding events and dairy dynamics that influence poor outcomes must be simultaneously addressed to tackle this problem (McConnel et al., 2009), yet systems are typically not in place on dairies to accurately track and effectively analyze mortality data. Without a thorough understanding of the cause and effect underlying individual deaths, and a means for monitoring those deaths within a population, accountability cannot be established.

Detailing the Who, What, When, Where, How, and Why of Dairy Cow Deaths

Historically the best documented aspect of a cow's death has been its unique life history features such as identification, lactation number, and days in milk. This has typically provided an accurate account of "who" died. "What" caused the death is often only partially documented and typically without the benefit of a postmortem examination. However, even using a necropsy to establish the proximate cause of death may not provide adequate insight into the key determinant or underlying causes that eventuated in a death. Moreover, categorizing necropsy findings in a meaningful way is difficult and current on-farm record systems are not configured to efficiently or effectively capture such information (McConnel et al., 2009). Typically, the "when" and the "where" of a cow's death have effectively been left out of the monitoring equation and can be difficult to derive from a database. Although information related to specific temporal events such as calving are recorded, dynamic data related to a cow's time on a dairy, pen moves and crowding, environmental exposure, and other attributes establishing the cow's interaction with the dairy may be missing and are often poorly associated with the documented reason for a cow's death. Ultimately this results in a profound lack of understanding of "how" and "why" a cow truly died.

Creating Accuracy and Consistency in Record Keeping

Studies have explored systems for recording specific clinical diseases associated with dairy cows (Kaneene and Hurd, 1990, Kelton et al., 1998, Osteras et al., 2007). Difficulties arise from inconsistent standards for disease definitions and data presentation. Such data are necessary if disease is to be described, compared, and investigated on national and regional levels in an effort to efficiently modify the management practices that promote cattle health (Kelton et al., 1998). This need for consistent standards and more in-depth characterization of data has been explored relative to removals as a whole (Fetrow et al., 2006). Further delineation is required if dairy cow mortality is to be specifically and effectively addressed. Current methods for monitoring dairy mortality are variable, inconclusive, and often founded on assumptions (McConnel et al., 2009). The complexity inherent in dairy operations necessitates the incorporation of database models that rationalize the system. Through modeling it is possible to incorporate all attributes of dairy (herd-level) and cow (animal-level) entities into a rational explanation for a death. This accounting of mortality expands the equation to focus not only on how and why cows die but what can be done about it through the establishment of critical control points that can be targeted to mitigate losses.

The current study was derived from principles established in prior investigations (Thomsen and Houe, 2006, McConnel et al., 2008, McConnel et al., 2009). The development of nomenclature for why cows die has originated within pathophysiologic or anatomic descriptors, summing up individual occurrences of death based on the final outcome. Yet even that final outcome has historically been poorly defined and without the aid of a thorough postmortem examination. Additionally, links between a death and instigating attributes such as those associated with dairy management or a cow's health history have been overlooked or left out of records meant to describe and monitor mortality. Attention must be focused on those cows most at risk for disease and death, health events must be tracked and recorded, and proximate causes of death based on necropsy findings must be combined with an understanding of those facets of management that influence poor outcomes (McConnel et al., 2009). The continuum of events and failures that eventuate in a death must be appropriately modeled if a database is to be designed that can accurately and thoroughly monitor mortality on dairies. Ultimately it is the process leading to a death that captures the essence of why a cow died and provides the necessary insight into how best to prevent future similar occurrences.

Although the postmortem evaluations in this study provided a representative sample of the participating dairies' dead cows (**Table 6.1**), the inclusion of a limited number of dairies within one region was not expected to provide a generalizable assessment of causes of mortality industry wide. Nor were the categorical descriptors derived from those deaths meant to provide a definitive nomenclature on which to base future monitoring systems. Rather, the model that was developed provides a foundation for pursuing database schemes that can more effectively monitor dairy cow mortality. The concrete and dynamic data (**Figure 6.2**) underlying a postmortem evaluation provides the structural integrity necessary for framing a cow's death; however, without database development that can capture these components for future evaluation there is little directive for guiding management alternatives.

CONCLUSIONS

The aphorism that "those who cannot remember the past are condemned to repeat it" (Santayana, 1917) appears particularly poignant with regard to the problem of dairy cow mortality. Until appropriate monitoring systems are developed there is little hope for establishing the systemic accountability necessary to direct change and every indication that this challenge will continue to afflict the industry as a whole. However, what may prove a challenging endeavor at the industry level certainly does not preclude individual operations from addressing this issue using knowledge at hand to formulate a best path forward. It is clear from this study and previous work in the area of dairy cow mortality that there are numerous underlying causes of cow deaths and an even greater number of ways to describe those deaths (Thomsen and Houe, 2006, McConnel et al., 2009). Yet even in the face of the various derivations for tracking mortality there are a few sound suggestions derived from these studies which may prove useful for combating this problem.

Formulate a strategy for performing thorough postmortem evaluations. Target those deaths that lie outside of obvious instances (accidents, locomotor disorders, euthanasias) so that the information gained warrants the cost and effort required to perform a necropsy. Incorporate farm employees into the process as a teaching tool to stimulate interest in the problem and as a means of demonstrating poor outcomes from potentially poor decisions. Utilize hard copy records such as those demonstrated in the current study (**Figure 6.1**) to capture as much detail as possible related to an individual death. Take the time to record dynamic aspects influencing a death that may not be available in standard record systems. Take digital photos to provide clarification for future questions that may arise regarding certain deaths. While mortality levels are generally greater than desired, the numbers are typically not so great that data sheets and photo documentation cannot be stored for future analysis.

Standardize health event nomenclature in simple and consistent terms that will provide useful background information not only for the analysis of deaths but other health related questions as well. Consider developing a coding system for deaths based on categories such as those described in this study and suitably tailored to an individual farm's challenges. An appropriate categorization scheme can partition overly specific details or apparently unmanageable generalities into functional themes. Record these codes on on-farm computer systems and organize hard copy necropsy sheets and digital photography accordingly for future reference and analysis. Taking such measures can provide direction for addressing problems as they arise. Perhaps as importantly, unpublished data and anecdotal evidence suggest that making progress toward resolving this issue may simply require acknowledging its importance. The act of recognizing rising mortality as a problem may, in fact, be the most fundamental step toward controlling its progression.

Table 6.1: Descriptive statistics and chi-square analysis of annual dairy cow deaths with no necropsy examination versus deaths with a necropsy examination on three dairies separately and in combination by parity and days postpartum. Due to multiple comparisons per category a P-value of ≤ 0.01 was used to establish significant differences.

		Dairy A			Dairy B			Dairy C			Combined Dairies		
		Necropsy			Necropsy			Necropsy			Necropsy		
		No	Yes	Chi-sq	No	Yes	Chi-sq	No	Yes	Chi-sq	No	Yes	Chi-sq
		n	n	P-val	n	n	P-val	n	n	P-val	n	n	P-val
Total per Dairy		43	68		21	39		206	67		270	174	
Parity	**1**	19	17	0.08	5	9	0.97	58	18	0.97	82	44	0.51
	2-4	22	43		9	18		110	37		141	98	
	≥5	2	8		7	12		38	12		47	32	
Days Postpartum	**≤15**	8	18	0.36	6	11	1.00	43	16	0.88	57	45	0.46
	16-30	5	5		4	7		23	9		32	21	
	31-60	5	3		3	5		28	8		36	16	
	>60	25	42		8	16		112	34		145	92	

Table 6.2: Descriptive statistics and chi-square analysis from 174 deaths on three dairies by parity, days postpartum, lactation status, pregnancy status, type of death, and recumbency status prior to death. A P-value of ≤ 0.05 was used to establish significant differences.

		Dairy A		Dairy B		Dairy C		Chi-square	Combined Dairies	
		n	**%**	**n**	**%**	**n**	**%**	**P-value**	**n**	**%**
Parity	**1**	17	25%	9	23%	18	27%	0.18	44	25%
	2-4	43	63%	18	46%	37	55%		98	56%
	≥5	8	12%	12	31%	12	18%		32	18%
Days Postpartum	**≤15**	18	26%	11	28%	16	24%	0.27	45	26%
	16-30	5	7%	7	18%	9	13%		21	12%
	31-60	3	4%	5	13%	8	12%		16	9%
	>60	42	62%	16	41%	34	51%		92	53%
Lactation status	**lactating**	66	97%	38	97%	58	87%	0.03	162	93%
	dry	2	3%	1	3%	9	13%		12	7%
Pregnancy status	**pregnant**	15	22%	4	10%	16	24%	0.21	35	20%
	open	53	78%	35	90%	51	76%		139	80%
Type of death	**euthanized**	24	35%	4	10%	14	21%	0.01	42	24%
	unassisted	44	65%	35	90%	53	79%		132	76%
Recumbent ≥24 hrs prior to death	**yes**	18	26%	16	41%	24	36%	0.26	58	33%
	no	50	74%	23	59%	43	64%		116	67%

Table 6.3: Descriptive statistics and chi-square analysis from 174 deaths on three dairies by specific health events, health events categorized by number of occurrences per animal, treatments, treatments categorized by number of occurrences per animal, specific anatomic systems with pathologic necropsy findings, the number of anatomic systems with pathologic abnormalities per death, and the anatomic system with the primary pathology associated with death. Relevant health and treatment events were assessed by the attending veterinarian and were focused on capturing information felt to have potentially influenced the final outcome of death. Due to multiple comparisons the significance level of P-values was adjusted by dividing the desired significance level (0.05) by the number of null hypotheses evaluated per category.

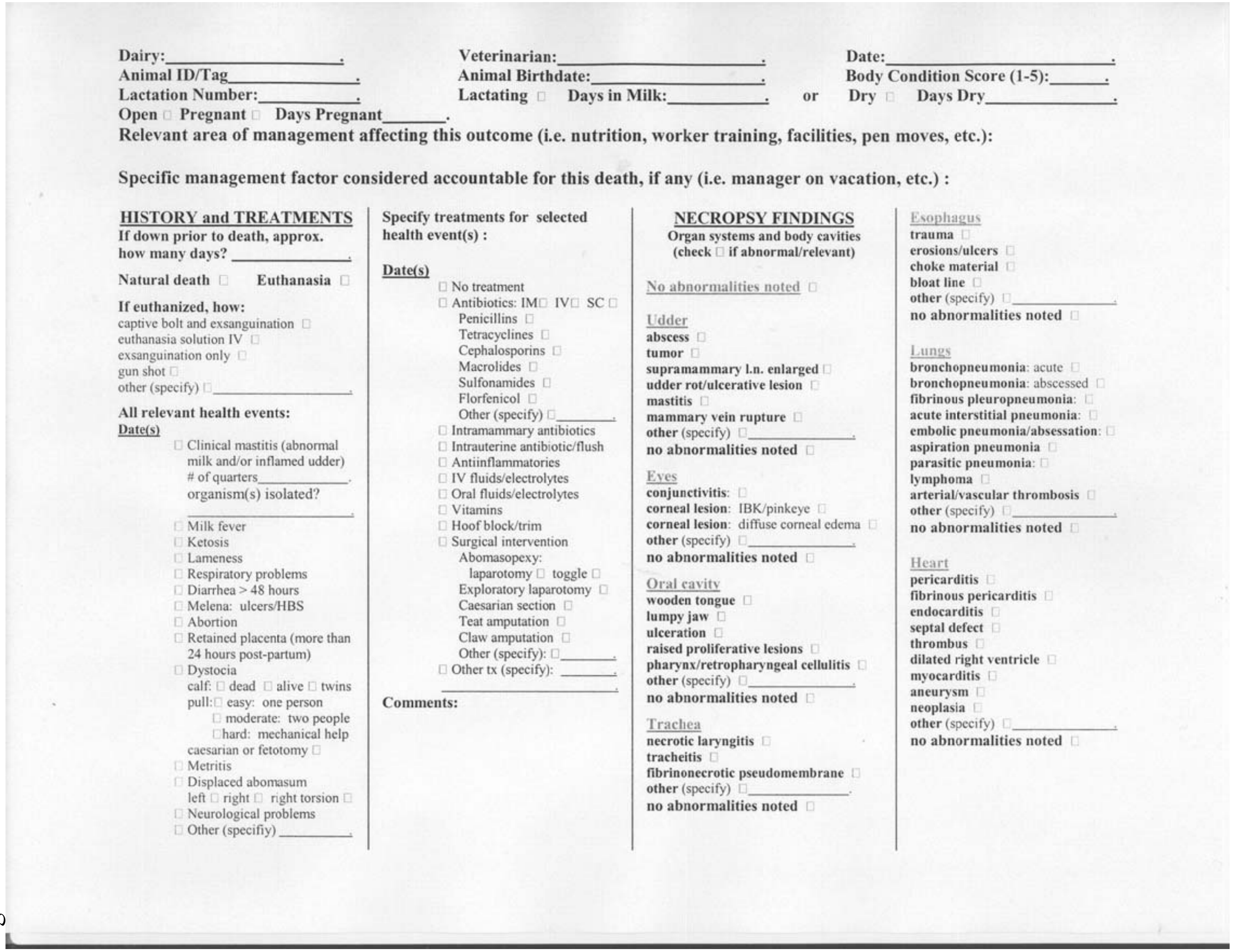
		Dairy A		Dairy B		Dairy C		Chi-sq	Combined Dairies	
		n	%	n	%	n	%	P-value	n	%
Health events (P significant ≤ 0.004)	Clinical mastitis	14	21%	12	31%	14	21%	0.42	40	23%
	Milk fever	1	1%	9	23%	4	6%	<0.004*	14	8%
	Ketosis	4	6%	2	5%	3	4%	1.00	9	5%
	Lameness	6	9%	3	8%	24	36%	<0.004*	33	19%
	Respiratory problems	10	15%	4	10%	8	12%	0.78	22	13%
	Diarrhea > 48 hrs	3	4%	5	13%	5	7%	0.28	13	7%
	Melena: ulcers/HBS	1	1%	2	5%	0	0%	0.24	3	2%
	Abortion	3	4%	2	5%	1	1%	0.65	6	3%
	Retained placenta	2	3%	5	13%	5	7%	0.15	12	7%
	Dystocia	12	18%	8	21%	13	19%	0.93	33	19%
	Metritis	9	13%	7	18%	12	18%	0.71	28	16%
	Displaced abomasum	8	12%	1	3%	16	24%	0.01	25	14%
	Neurological problems	1	1%	1	3%	1	1%	1.00	3	2%
Health event occurrences per animal (P significant ≤ 0.01)	0	16	24%	10	26%	8	12%	0.13	34	20%
	1	35	51%	13	33%	27	40%	0.16	75	43%
	2	12	18%	7	18%	21	31%	0.12	40	23%
	>2	5	7%	9	23%	11	16%	0.07	25	14%
Treatments (P significant ≤ 0.005)	No treatments	12	18%	2	5%	6	9%	0.10	20	11%
	Antibiotics (IM, IV, SC)	28	41%	25	64%	38	57%	0.05	91	52%
	Intramammary antibiotics	5	7%	4	10%	8	12%	0.66	17	10%
	Intrauterine antibiotic/flush	1	1%	0	0%	2	3%	0.62	3	2%
	Anti-inflammatories	25	37%	32	82%	47	70%	<0.005*	104	60%
	IV fluids/electrolytes	16	24%	20	51%	38	57%	<0.005*	74	43%
	Oral fluids/electrolytes	26	38%	19	49%	37	55%	0.14	82	47%
	Vitamins	1	1%	5	13%	30	45%	<0.005*	36	21%

	Hoof block/trim	2	3%	1	3%	6	9%	0.28	9	5%
	Surgical intervention	7	10%	2	5%	16	24%	0.01	25	14%
Treatment occurrences per animal (P significant ≤ 0.01)	**0**	18	26%	3	8%	9	13%	0.03	30	17%
	1	12	18%	7	18%	13	19%	0.96	32	18%
	2	22	32%	9	23%	6	9%	<0.01*	37	21%
	>2	16	24%	20	51%	39	58%	<0.01*	75	43%
Specific anatomic systems with pathologic necropsy findings (P significant ≤ 0.002)	**No abnormalities**	2	3%	1	3%	0	0%	0.44	3	2%
	Abdomen/peritoneum	33	49%	22	56%	13	19%	<0.002*	68	39%
	Abomasum	22	32%	5	13%	43	64%	<0.002*	70	40%
	Bladder	0	0%	1	3%	0	0%	0.22	1	1%
	Brain	0	0%	0	0%	1	1%	0.61	1	1%
	Esophagus	3	4%	0	0%	1	1%	0.45	4	2%
	Eyes	4	6%	4	10%	2	3%	0.28	10	6%
	Heart	29	43%	8	21%	38	57%	<0.002*	75	43%
	Kidneys	6	9%	1	3%	4	6%	0.53	11	6%
	Large intestine/cecum	5	7%	3	8%	3	4%	0.78	11	6%
	Liver	16	24%	18	46%	38	57%	<0.002*	72	41%
	Lungs	37	54%	10	26%	41	61%	<0.002*	88	51%
	Musculoskeletal	15	22%	11	28%	23	34%	0.28	49	28%
	Oral cavity	8	12%	0	0%	0	0%	<0.002*	8	5%
	Rumen, reticulum, omasum	12	18%	1	3%	6	9%	0.04	19	11%
	Small intestine	20	29%	15	38%	12	18%	0.06	47	27%
	Spleen	1	1%	0	0%	1	1%	1.00	2	1%
	Systemic	25	37%	16	41%	24	36%	0.86	65	37%
	Trachea	12	18%	0	0%	2	3%	<0.01	14	8%
	Udder	18	26%	10	26%	12	18%	0.45	40	23%
	Uterus	15	22%	12	31%	21	31%	0.43	48	28%
Number of anatomic systems with pathologic abnormalities per death (P significant ≤ 0.007)	**0**	0	0%	1	3%	0	0%	0.22	1	1%
	1	8	12%	4	10%	3	4%	0.35	15	9%
	2	11	16%	6	15%	9	13%	0.90	26	15%
	3	12	18%	10	26%	11	16%	0.47	33	19%
	4	12	18%	6	15%	18	27%	0.27	36	21%
	5	6	9%	9	23%	10	15%	0.13	25	14%
	>5	19	28%	3	8%	16	24%	0.04	38	22%
Anatomic system with the primary pathology associated with death (P significant ≤ 0.004)	**Abdomen/peritoneum**	7	10%	2	5%	2	3%	0.22	11	6%
	Abomasum	7	10%	2	5%	5	7%	0.62	14	8%
	Eyes	0	0%	1	3%	0	0%	0.22	1	1%
	Heart	4	6%	1	3%	4	6%	0.82	9	5%
	Liver	0	0%	3	8%	7	10%	0.01	10	6%
	Lungs	15	22%	4	10%	16	24%	0.21	35	20%
	Musculoskeletal	8	12%	5	13%	15	22%	0.20	28	16%
	Rumen, reticulum, omasum	5	7%	0	0%	1	1%	0.15	6	3%
	Small intestine	3	4%	11	28%	7	10%	<0.004*	21	12%
	Systemic	11	16%	2	5%	3	4%	0.06	16	9%
	Udder	3	4%	0	0%	3	4%	0.51	6	3%
	Uterus	3	4%	7	18%	4	6%	0.05	14	8%
	Undetermined	2	3%	1	3%	0	0%	0.44	3	2%

***Significant P-value based on multiple comparisons**

Table 6.4: Descriptive statistics, chi-square analysis, and mortality categories and themes describing 174 deaths on three dairies. Categories that refer to early and mid-late lactation periods encompass ≤ 60 DIM and > 60 DIM respectively. A P-value of ≤ 0.05 was used to establish significant differences.

	Combined Dairies									
	Total	**Euthanized**		**Dairy A**		**Dairy B**		**Dairy C**		**Chi-sq**
Death Category	**n**	**n**	**Category Themes**	**n**	**%**	**n**	**%**	**n**	**%**	**P-value**
Abomasum: right displacement	2	1	Specific disease processes with variable etiologies	14	21%	14	36%	10	15%	0.04
Gastrointestinal: infectious	2	0								
Gastrointestinal: perforated ulcer	7	0								
Hemorrhagic Bowel Syndrome	11	2								
Hepatic: abscesses	3	0								
Hepatic: lipidosis	3	0								
Neoplasia/Lymphoma	8	5								
Traumatic reticulopericarditis	2	1								
Lameness: failure	10	6	Failure of disease recognition or treatment: potentially linked to specific periods of lactation	15	22%	8	21%	25	37%	0.07
Mastitis: failure	10	0								
Metritis: failure	4	0								
Pneumonia: early lactation	8	1								
Pneumonia: mid-late lactation	16	3								
Calving trauma	12	2	Traumatic events	19	28%	10	26%	13	19%	0.50
Lameness: trauma	13	9								
Iatrogenic: trauma	17	3								
Early lactation: multifactorial	19	6	Multifactorial failures linked to transition cow or negative energy balance issues	3	4%	3	8%	13	19%	0.02
Feed management	1	0	Feed management	0	0%	0	0%	1	1%	0.61
Early lactation: miscellaneous	6	1	Miscellaneous events not conducive to prevention: linked to specific periods of lactation	14	21%	3	8%	4	6%	0.03
Mid-late lactation: miscellaneous	15	2								
Undetermined	5	0	Undetermined	3	4%	1	3%	1	1%	0.84



Dairy:________________.
Animal ID/Tag____________.
Lactation Number:__________.
Open □ Pregnant □ Days Pregnant______.

Veterinarian:__________________.
Animal Birthdate:_______________.
Lactating □ Days in Milk:__________. or Dry □ Days Dry____________.

Date:______________________.
Body Condition Score (1-5):______.

Relevant area of management affecting this outcome (i.e. nutrition, worker training, facilities, pen moves, etc.):

Specific management factor considered accountable for this death, if any (i.e. manager on vacation, etc.) :

HISTORY and TREATMENTS

If down prior to death, approx. how many days? __________.

Natural death □ **Euthanasia** □

If euthanized, how:
captive bolt and exsanguination □
euthanasia solution IV □
exsanguination only □
gun shot □
other (specify) □______________.

All relevant health events:
Date(s)
□ Clinical mastitis (abnormal milk and/or inflamed udder)
# of quarters__________.
organism(s) isolated?
________________.
□ Milk fever
□ Ketosis
□ Lameness
□ Respiratory problems
□ Diarrhea > 48 hours
□ Melena: ulcers/HBS
□ Abortion
□ Retained placenta (more than 24 hours post-partum)
□ Dystocia
calf: □ dead □ alive □ twins
pull:□ easy: one person
□ moderate: two people
□hard: mechanical help
caesarian or fetotomy □
□ Metritis
□ Displaced abomasum
left □ right □ right torsion □
□ Neurological problems
□ Other (specifiy) __________.

Specify treatments for selected health event(s) :

Date(s)
□ No treatment
□ Antibiotics: IM□ IV□ SC □
Penicillins □
Tetracyclines □
Cephalosporins □
Macrolides □
Sulfonamides □
Florfenicol □
Other (specify) □________.
□ Intramammary antibiotics
□ Intrauterine antibiotic/flush
□ Antiinflammatories
□ IV fluids/electrolytes
□ Oral fluids/electrolytes
□ Vitamins
□ Hoof block/trim
□ Surgical intervention
Abomasopexy:
laparotomy □ toggle □
Exploratory laparotomy □
Caesarian section □
Teat amputation □
Claw amputation □
Other (specify): □_______.
□ Other tx (specify): _______.
____________________.

Comments:

NECROPSY FINDINGS
Organ systems and body cavities (check □ if abnormal/relevant)

No abnormalities noted □

Udder
abscess □
tumor □
supramammary l.n. enlarged □
udder rot/ulcerative lesion □
mastitis □
mammary vein rupture □
other (specify) □____________.
no abnormalities noted □

Eyes
conjunctivitis: □
corneal lesion: IBK/pinkeye □
corneal lesion: diffuse corneal edema □
other (specify) □____________.
no abnormalities noted □

Oral cavity
wooden tongue □
lumpy jaw □
ulceration □
raised proliferative lesions □
pharynx/retropharyngeal cellulitis □
other (specify) □____________.
no abnormalities noted □

Trachea
necrotic laryngitis □
tracheitis □
fibrinonecrotic pseudomembrane □
other (specify) □____________.
no abnormalities noted □

Esophagus
trauma □
erosions/ulcers □
choke material □
bloat line □
other (specify) □____________.
no abnormalities noted □

Lungs
bronchopneumonia: acute □
bronchopneumonia: abscessed □
fibrinous pleuropneumonia: □
acute interstitial pneumonia: □
embolic pneumonia/absessation: □
aspiration pneumonia □
parasitic pneumonia: □
lymphoma □
arterial/vascular thrombosis □
other (specify) □____________.
no abnormalities noted □

Heart
pericarditis □
fibrinous pericarditis □
endocarditis □
septal defect □
thrombus □
dilated right ventricle □
myocarditis □
aneurysm □
neoplasia □
other (specify) □____________.
no abnormalities noted □

Figure 6.1: Postmortem data collection sheets.

Abdomen/peritoneum
peritonitis ☐
ascites ☐
peritoneal effusion ☐
hemoabdomen ☐
lipomatosis (fat necrosis) ☐
neoplasia: lymphoma, etc. ☐
abscess(es) ☐
adhesions: active ☐ chronic ☐
other (specify) ☐____________.
no abnormalities noted ☐

Kidneys
infarcts ☐
pyelonephritis ☐
tubular necrosis: pale/moist cortex ☐
atrophy: scarring, chronic disease ☐
hemoglobin stained: hemolysis ☐
other (specify) ☐____________.
no abnormalities noted ☐

Bladder
ulceration ☐
hemorrhage ☐
calculi ☐
cystitis ☐
other (specify) ☐____________.
no abnormalities noted ☐

Uterus
prolapse ☐
rupture ☐
arterial thrombosis ☐
arterial rupture ☐
metritis: mild/moderate ☐
metritis: toxic ☐
necrosis ☐
hydrops ☐
other (specify) ☐____________.
no abnormalities noted ☐

Spleen
neoplasia ☐
rupture ☐
other (specify) ☐____________.
no abnormalities noted ☐

Liver
abscesses ☐
thrombophelebitis ☐
chronic congestion: 'nutmeg' liver ☐
fatty liver: pale, rounded edges ☐
if fatty: moderate ☐ severe ☐
fractured/ruptured liver ☐
focal hemorrhage or necrotic infarcts:
bacillary hemoglobinuria ☐
scarring/fibrosis ☐
pigmented tracts/thickened bile ducts:
liver flukes ☐
gallbladder fibrinous casts ☐
neoplasia ☐
other (specify) ☐____________.
no abnormalities noted ☐

Rumen, reticulum, omasum
rumenitis: inflammation ☐
chronic rumenitis: shortened papilli and
scarring ☐
ulcers/erosions ☐
mycotic lesions ☐
TRP (hardware disease) ☐
omasal impaction ☐
neoplasia ☐
other (specify) ☐____________.
no abnormalities noted ☐

Abomasum
ulcer: acute, hemorrhagic ☐
ulcer: perforated ☐
ulcer: chronic, fibrosis ☐
rupture ☐
impaction ☐
parasites: *Ostertagia*, etc. ☐
neoplasia ☐

displacement: left ☐
displacement: right ☐
displacement: right w/ torsion ☐
other (specify) ☐____________.
no abnormalities noted ☐

Small intestine
hemorrhagic bowel syndrome:
intestinal blood clots ☐
enteritis: acute inflammation ☐
enteritis: hemorrhagic ☐
proliferative enteritis (Johne's) ☐
ulceration ☐
obstruction ☐
intussusception ☐
mesenteric torsion ☐
fibrinous casts ☐
Peyer's patch necrosis ☐
neoplasia ☐
other (specify) ☐____________.
no abnormalities noted ☐

Large intestine/Cecum
cecal torsion ☐
enteritis: acute, inflammation ☐
enteritis: hemorrhagic ☐
obstruction ☐
neoplasia ☐
other (specify) ☐____________.
no abnormalities noted ☐

Musculoskeletal
skeletal injury/trauma (broken leg, dislocated hip, stifle disease, etc.) ☐
soft tissue injury/trauma (perivulvar swelling, table injury, etc.) ☐
chronic lameness: claw disease ☐
footrot ☐
joint sepsis or abscess ☐
arthritis/synovitis: hock, stifle, etc. ☐
calving paralysis ☐
spinal trauma ☐
spinal abscess ☐

spinal neoplasia ☐
muscle abscess: trauma, injection ☐
myositis ☐
limb swelling/edema ☐
blackleg ☐
other (specify) ☐____________.
no abnormalities noted ☐

Brain
hemorrhage ☐
meningitis ☐
abscess ☐
neoplasia ☐
other (specify) ☐____________.
no abnormalities noted ☐

Systemic
anaphylaxis ☐
neoplasia ☐
septicemia ☐
other (specify) ☐____________.
no abnormalities noted ☐

Based on necropsy findings, which (up to 3) of the above organ system(s) appear to have been the primary cause of death?
1.____________________.
2.____________________.
3.____________________.

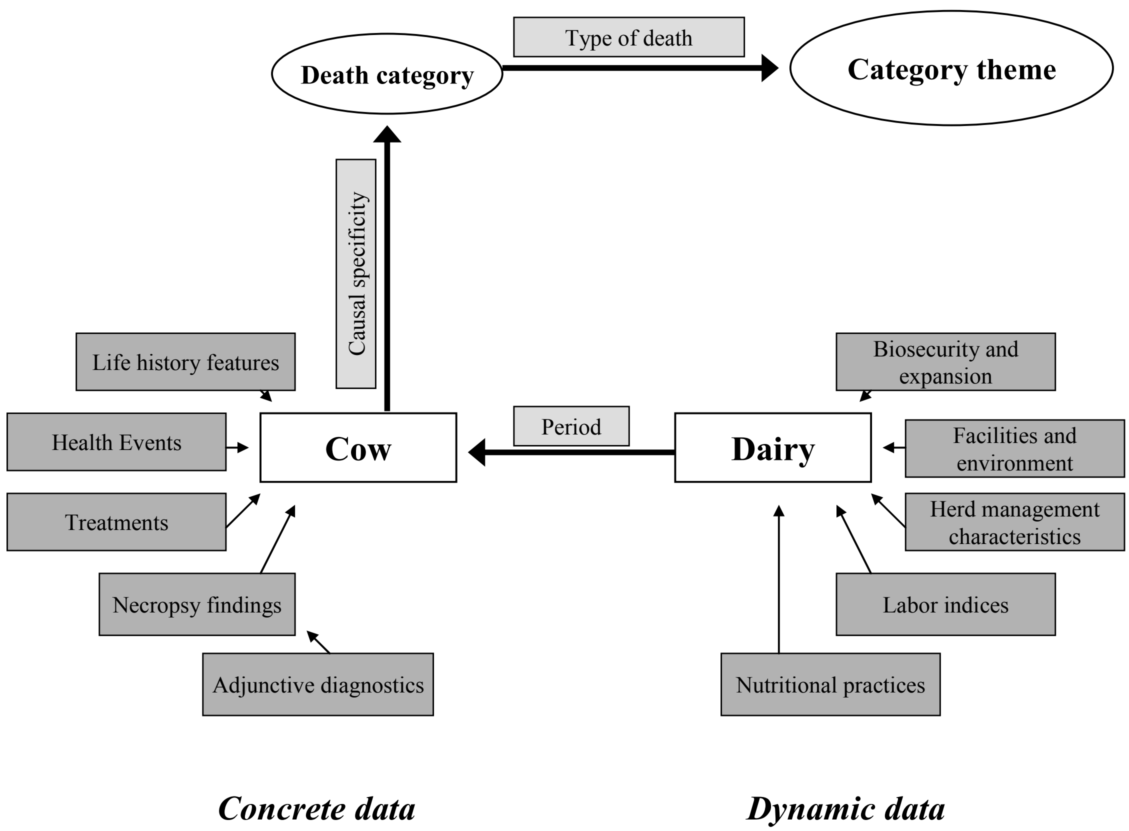
Histopath submitted? Specify:

Udder ☐	Lung ☐
Heart ☐	Kidney ☐
Uterus ☐	Spleen ☐
Liver ☐	Forestomach ☐
Abomasum ☐	Sml intestine ☐
Lg intestine ☐	Muscle ☐
Brain ☐	None ☐

Bacteriology/virology submitted?
Yes ☐ No ☐

Comments regarding necropsy findings:

Figure 6.2: Conceptual data model used to organize necropsy-based postmortem information into a categorical scheme developed for monitoring dairy cow mortality.



CHAPTER 7: CONCLUSIONS

Cause-of-death in human public health

The preceding body of work details an exploration of the problem of excessive and increasing dairy cow mortality. As with all "wicked problems" the information needed to understand the problem depends on the ideas proposed to solve it (Rittel and Webber, 1973). With regard to dairy cow mortality the fundamental question remains: Why do dairy cows die? Until solutions are formulated for this question it is impossible to determine what can be done to combat excess dairy cow death. For years our understanding of the cause of death has been based on the philosophically enigmatic concept of an Underlying Cause of Death. This holds true for human as well as veterinary medicine. Within literature relevant to human health the underlying cause of death has been "defined pragmatically as the entity initiating the causal chain leading to death (i.e. a single-cause basis)" (Maudsley and Williams, 1996). Unfortunately, this definition fails to address the often multifactorial nature of disease. Nor does it establish where the causal sequence begins.

The difficulty in classifying an underlying cause of death has proven controversial within the public health realm for well over a century (Hamlin, 1995). Cause-of-death data began to be collected in Great Britain in 1837 following the enactment of the Births and Deaths Registration Act of 1836. This legislation arose from a fear of typhoid and cholera epidemics originating within the urban squalor of the Industrial Revolution

(Davis, 1997). The law required that death be registered by cause, yet immediate controversy arose over what kinds of information should be collected and what to do with the information once it was collected. The impossibility of reducing complicated and varying sets of circumstances to a single category was clear from the outset yet the necessity of distilling data into usable targets was evident. A government official named Edwin Chadwick was interested in permanent sanitary reform and insisted that the most important factor underlying death was the *disease*. On the other hand, a medical statistician named William Farr took an interest in the *causes of the disease*, which during that period was taken to include determinants such as diet, working conditions, and emotional states. This philosophical debate eventually distilled into an argument over whether hunger and deprivation actually 'caused' or contributed significantly to mortality in England and Wales, a politically sensitive issue at the time following the enactment in 1834 of the Poor Law Amendment Act (commonly called the "new poor law" but labeled "the starvation act") (Hamlin, 1995).

Farr argued that the effects of hunger, "like the effects of excess, are generally manifested indirectly, in the production of diseases of various kinds" (Farr, 1839). He felt, however, that causes-of-death tables based on diseases per se could not possibly take into account all the "remote, incidental, or accessory circumstances in which the direct cause of death originated" (Poor Law Commission, 1970). Therefore, within Farr's nosological system the term 'starvation' served to provide an underlying causality to cases that might otherwise have been classified according to the immediate pathologic cause of death (**Figure 7.1**). His difficulty lay in formulating a system that was unambiguously exclusive, exhaustive, and facilitated empirical inference while integrating factors that might be considered ‘social’ (Eyler, 1979). For his part and largely due to his role in the social welfare policy of the day, Chadwick viewed the ‘starvation’ terminology as an embarrassing anathema and argued for more specific distinctions. His perspective was that the grouping of cases under the ‘starvation’ umbrella was a form of inconsistent speculation that was misleading and should not be used (Hamlin, 1995).

The crux of the matter was that as society changed in response to the Industrial Revolution so did perspectives on health and disease, eventually influencing the identification of antecedent events felt to impact causes of death. Ultimately, an ontological assumption that each disease is a distinct entity with a distinct cause won out over the older, physiological conception of disease with its philosophically complex view of disease as injury to the “constitution.” Constitutional medicine explained illness in terms of living conditions and personal histories rather than some particular disease. Each cause could contribute to many diseases and, in turn, each disease had many causes. The ontological derivation of disease mandated that the narrative history of a patient’s constitution be condensed to a single word. The consequence of this was to give up the possibility of considering the full variety of pathological influences an individual encounters (Eyler, 1979). Farr may have been interested in correlating the incidence of diseases with the circumstances of their occurrence, but he also understood that valuable information could be gained by grouping similar deaths into categories (Registrar General of England and Wales, 1856, Davis, 1997). As such, his nosological system was first and foremost an attempt to achieve general headings that would allow statistical investigation. Eventually the ontological conception of disease with its search for specific causes led to the International List of Causes of Death (World Health Organization, 2004a), but it was arguably at the expense of an “imperative for health” that was lost with the disappearance of constitutional medicine (Hamlin, 1995).

Fundamentally, the controversy between Farr and Chadwick serves to demonstrate general issues of classification and causation. At its heart, this is an inherently taxonomic problem of splitting, lumping, and recognizing degrees of natural relation. Classifying causes of death is complex and can only identify some components of a process that includes various combinations of actions and conditions—some of which may be entirely unrecognized. Consequently, a question of utility exists regarding attempts to identify a cause that implies other important components and surrounding circumstances. Ultimately, the identifier used to describe the cause is a function of the type of information being sought after. Farr pointed out that “several classifications may, therefore, be used with advantage; and the physician, the pathologist, or the jurist, each from his own point of view, may legitimately classify the diseases and the causes of death in the way that he thinks best adapted to facilitate his inquiries, and to yield general results” (Registrar General of England and Wales, 1856). Questions related to responsibility will focus attention on some factors whereas questions of periodicity, preventability, or remediation will focus attention on others (Hamlin, 1995).

A weakness in establishing a cause of death is that although death is factual, cause-of-death involves opinion and is more a matter of philosophy than fact (Emery, 1962). The accuracy of a coded underlying cause-of-death relative to the actual or ‘true’ cause of death is a function of the deductive and recording processes. Cause-of-death statements (**CODs**) in use internationally for human public health have been designed to identify a single underlying cause of death in a sequence of causes: immediate, intermediate, and underlying (**Figure 7.2**). This methodology sacrifices information that could be gained from coding for multiple underlying causes but was established as a best option for limiting misinterpretation and facilitating analysis (Maudsley and Williams, 1996). Even so, much has been made regarding the difficulty in achieving reliable and accurate human CODs (Smith Sehdev and Hutchins, 2001).

An invaluable tool for enhancing the quality of CODs is the autopsy. Autopsies have been shown to be a highly valuable educational and diagnostic tool in the final step of a clinical investigation. Used in conjunction with clinical information the autopsy remains the best standard by which to judge premortem diagnoses (Smith Sehdev and Hutchins, 2001). Yet autopsy rates have reportedly declined (Ayoub and Chow, 2008). In fact, the autopsy is purportedly undervalued precisely *because* it is retrospective and primarily educational (Maudsley and Williams, 1996).

Similarities between the British experience and the modern dairy

Clearly these issues related to establishing useful human cause-of-death metrics and categories also lie at the heart of research into dairy cow mortality. In fact, the underlying sea change surrounding the early period of Great Britain's human cause-of-death data collection is remarkably similar to the fundamental transmutation that has occurred within the dairy industry over the past several decades. The Industrial Revolution of 18th and 19th century Britain shifted populations from a homogenous agrarian lifestyle to an increasingly diverse, mechanized and urbanized setting. Along with the Industrial Revolution's shift in population dynamics and work conditions came the “poor law” policy and Farr’s representation of starvation as an economic phenomenon. His struggle to describe causes of death in meaningful terms was, in effect, a product of unintended consequences brought on by the industrialization of Britain’s society. For Chadwick, the public policy behind the development of “workhouses” for disenfranchised poor was not meant to represent the best of a bad lot, but was rather meant to be ideal in all respects. The optimal workhouse was expected to be full of positive feedbacks with “collateral benefits” popping up unexpectedly. It was simply not acceptable that the laws of political economy might be found incompatible with the laws of health (Hamlin, 1995).

Jump forward nearly 175 years and we see a very similar progression of events playing out within the dairy industry. Mechanization of production processes has to a large extent been instrumental in the intensification and structural development of larger herd units within the dairy industry (Norgaard et al., 1999). There is evidence that heavy mechanization and technological development has led to a decline in the number of employee working hours per dairy-cow. As of 1991-1993, the average workload per cow (85 hrs) is estimated to have been nearly halved from that spent per cow in 1973-1975 (160 hrs) (Larsen et al., 1996). In tie-stall farms the average man-minutes per cow spent milking and feeding declined from 14.2 in 1983, to 9.9 in 1994 (Agger and Alban, 1996). At the same time, the average dairy herd size has been increasing. According to NAHMS data, 23.3% of US dairy operations had more than 100 cows in 2006 compared to 11.5% in 1991 (USDA, 2007b), the continuation of a trend several decades in development.

Mechanization and intensification have developed in response to economic pressure (Norgaard et al., 1999). Unintended consequences have followed. As death rates have climbed the industry has struggled to come to terms with a clear approach for defining the problem. The modern dependency on an ontological conception of disease views prevention and control in terms of vaccines and antimicrobials and more or less fails to acknowledge the influence of living conditions and personal histories. In fact, addressing unintended failings of the modern dairy "workhouse" with all of its social and physical considerations can quickly muddy the waters separating professional concern from political unease. Dealing with detrimental unintended consequences requires openly accepting that the laws of the current dairy economy might at times be found incompatible with the laws of health.

As described within the Introduction to this dissertation, dairy ecology is best described as a complex adaptive system. This type of system consists of multiple connected, interdependent, interacting agents (Snowden, 2001). Consequently, exploring cause-of-death within such a system must incorporate a physiological conception of disease with its awareness of the philosophical complexity of the problem of disease causation. That is not to say that the ontological perspective of disease lacks merit, but that a more thorough inquiry into the causative factors underlying increasing mortality on dairies should incorporate an approach that embraces complexity. Such an approach acknowledges the irreversibility of complex systems and provides a strategy for working within the system to address problems as they evolve. Even so, efforts to define cause-of-death are inherently dependent on procured data, regardless of the underlying conception of disease, and record systems designed to capture that data are imperative.

Human health records

Ever since the inception of Farr's first nosological table attempts have been made to refine and enhance the statistical classification of human disease, injuries, and causes of death. This has culminated in the World Health Organization's International Classification of Diseases (**ICD**) (World Health Organization, 2004a). In fact, the general arrangement of the International List of Causes of Death within the ICD remains a function of Farr's principle of classifying diseases by anatomical site (World Health Organization, 1977). This classification system is based on the principle of distinguishing between general diseases and those localized to a particular organ or anatomical site. Consequently, statistical data on diseases is based on epidemic diseases, constitutional or general diseases, local diseases arranged by site, developmental diseases, and injuries. Although somewhat arbitrary, this system has proven useful for general epidemiological purposes (World Health Organization, 2004a).

Although its scope has expanded, the ICD was originally used to classify causes of mortality as recorded at the registration of death. The underlying assumption is that appropriate data related to causes of death can be obtained from medical certificates of cause of death. While there may be problems with proper completion and accuracy of CODs (Smith Sehdev and Hutchins, 2001), the standardized medical certificate CODs (**Figure 7.2**) have been designed to facilitate data retrieval. The causes of death to be entered on the certificate are "all those diseases, morbid conditions or injuries which either resulted in or contributed to death and the circumstances of the accident or violence which produced any such injuries" (World Health Organization, 2004a). From the standpoint of prevention of death it is necessary to break the chain of events or to effect a cure at some point. The most effective public health objective has been to prevent the precipitating or underlying cause. For this purpose the underlying cause of death has been defined as "(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury" (World Health Organization, 2004a).

The data derived from medical certificate CODs and classified according to the ICD is suitable for general epidemiological and many health management purposes. However, it does not always allow the inclusion of sufficient detail related to health status or health care. Consequently, the idea for a "family" of disease and health related classifications has been put forward (World Health Organization, 2004a). The ICD family covers a conceptual framework of definitions, standards, and methods that are not classifications in and of themselves but are closely linked to the ICD (**Figure 7.3**). One of these concepts includes the development of methods to support the local collection of information through "non-conventional methods" such as "community-based information" which involves community participation in the definition, collection, and use of health-related data. Community-based health information can cover health problems and needs, related risk factors, and resources and provides a method for filling information gaps and strengthening information systems (World Health Organization, 2004b).

Dairy health records

Whereas human cause-of-death statistics generally rely on a sequence of data captured in a standardized format, dairy cow deaths have been poorly defined, marginally recorded, and rarely analyzed. As explained above, records related to human deaths commence with CODs on certificates of death. The ICD is then used to translate these individual records detailing disease diagnoses and other health problems from words into an alphanumeric code which permits easy storage, retrieval, and analysis of the data. More recent efforts have begun to expand data capture to include the concept of a "family" of classifications that records additional information related to health status and health care. Further, "non-conventional" methods are being implemented as a means of obtaining information on health status where conventional methods (censuses, surveys, vital or institutional mortality statistics) have been found to be inadequate. Within this sequence of information gathering the fundamental step is the completion of CODs. Yet this cornerstone of human health records is essentially missing on dairies.

As detailed within the previous chapters, dairy information related to disease, injuries, and causes of death is limited. In fact, the least available dairy herd data comprise records of disease and management events and are subject to tremendous variability in the rigor and consistency of their recording (Kelton, 2006). Current record systems such as those provided for DHI herds can provide copious concrete data regarding life history features of dead cows but are not configured to facilitate analysis of prior health events that result in a current condition, nor do they assess the cause and effect of various phenomena (McConnel et al., 2010a). National and regional data sets derived from these record systems can be used to describe associations between mortality and population characteristics, aspects of management, and environmental factors but they are unable to predict underlying causes for specific deaths (Dechow and Goodling, 2008, McConnel et al., 2008, Miller et al., 2008, McConnel et al., 2010b, Pinedo et al., 2010). As with human cause-of-death tabulation, efforts to define underlying causes of dairy cow mortality require knowledge of the sequence of antecedent causes that eventuate in a death. Yet again, antemortem medical histories on dairies are suspect and necropsies are rarely performed. Consequently, on-farm databases have historically depended on capturing relevant information regarding dead cows in broad, ill-defined categories (McConnel et al., 2009).

Reinventing the wheel with regard to CODs

The lack of uniform CODs clearly limits the ability of the dairy industry to monitor mortality in relation to variables such as diseases and other health problems, and characteristics and circumstances of the animals affected. Although the conclusions drawn from the various derivations of available data provide insight into the problem of rising mortality, the reality is that missing and inconsistent data hinder progress. Preceding chapters within this dissertation have explored schemes for categorizing postmortem data (McConnel et al., 2009) and for establishing record system templates that document dairy cow deaths within the context of historical influences (McConnel et al., 2010a). These methodologies are similar in practice to the original nosology of Farr and ultimately to that of the ICD with its statistical and “family” classifications. Yet the need for standardized data to populate these schemas has largely been passed over as a record keeping issue that must simply be overcome. The reality is that this issue should be resolved rather than avoided.

The early period of human cause-of-death data collection was ultimately dependent on a legislative mandate that allowed Farr to accumulate background information for his nosological tables. Until the dairy industry adopts a similar protocol for collecting cause-of-death data it will remain difficult to accumulate legitimate information for addressing excessive mortality levels. Current on-farm record systems are focused on details related to an animal's life history features (e.g., birth date, lactation number, lactational and reproductive status). These are the sort of details that the US Standard Certificate of Death records prior to the CODs (**Figure 7.4**). It is the actual CODs (**Figures 7.2 & 7.4**) that have no realistic equivalent within dairy record systems.

Admittedly, at first glance this appears to be a difficult addendum to expect dairy records to adopt. Aside from the obvious issue of increasing data entry, there is the problem of reliable and accurate diagnoses. If mistakes on CODs are regularly made by medical professionals in the human realm (Smith Sehdev and Hutchins, 2001), there clearly should be concerns regarding the ability of dairy employees to appropriately complete CODs. On-farm data systems only nominally track the relevant health event and treatment information that may be needed to establish the chain of events culminating in a death. Further, information regarding rarely performed postmortem examinations is virtually nonexistent. Nonetheless, failing to try and address these limitations is tantamount to accepting defeat. Perhaps if dairy CODs were available and veterinarians were educated as to their utility, there might be a growing interest in tracking relevant information necessary for confronting the increase in dairy cow mortality.

Incorporating certificates of death with CODs into dairy systems is imminently possible. Clearly CODs would be different for cows than for humans, but the underlying principles would be the same. Individual life history features are available and could be easily transferred from on-farm databases into formatted computer-based death certificates. As with human CODs, Part I would record the estimated chain of events leading up to a death. Although the details defining the various causes of death (immediate, intermediate, and underlying) would be reliant on currently suspect concrete and dynamic data, it is foreseeable that a renewed focus on this challenge might provide the impetus to enhance dairy- and cow-related data acquisition including postmortem evaluations. Regardless, such an approach to documenting cause-of-death would expand on the current practice of typically coding death according to a single, generic pathophysiologic descriptor. Part II would record other significant contributors to the death and might be expanded to more fully capture the equivalent of "community-based information." Ultimately, a dairy death certificate might look something like that presented in **Figure 7.5**.

The Story

Human causes of death historically have been structured according to generalized classification schemes in an attempt to provide for statistical analysis. As Farr pointed out, "several classifications may, therefore, be used with advantage" (Registrar General of England and Wales, 1856). Any attempt at categorizing causes of death recognizes that statistical classifications have merit for determining disease prevalence in populations and for affecting decision-making processes regarding the distribution of resources in the fields of medicine and health (Smith Sehdev and Hutchins, 2001). The difficulty lies in incorporating both content and context into meaningful classifications of causes of death. This was at the heart of the conflict between Farr and Chadwick. Ultimately, Farr's nosological tables were necessarily biased toward content as a result of a developing ontological conception of disease and as a function of facilitating statistical analysis.

Within the preceding chapters various classifications have been explored relative to dairy cow mortality, culminating in a system based on conceptually modeling the continuum of events and failures that eventuate in a death (McConnel et al., 2010a). This methodology attempts to focus attention on both content *and* context. Nonetheless, a conceptual model of dairy cow mortality remains first and foremost a vehicle for providing statistical classifications that can be used to summarize data. Classification systems provide the order and structure needed to analyze content relevant to the wicked problem of dairy cow mortality. These systems provide organizational coping mechanisms that attempt to *study* and *tame* the problem. Certainly studying a novel and complex problem is natural and important, yet study alone leads only to more study and results in "analysis paralysis." Taming a wicked problem is a common way of coping by attempting to simplify the problem in various ways that make it more manageable. Neither studying or taming a wicked problem achieves a sustainable resolution (Conklin, 2006).

Farr noted that because "classification is a method of generalization" (Registrar General of England and Wales, 1856) the consequence is an inevitable partial loss of content, but principally context. As discussed within the Introduction to this dissertation, dairies form complex adaptive systems and within such systems context is often more important than content and learning can be more important than order and structure (Snowden, 2001). Actual progress on the issue of dairy mortality will require a renewed focus on context and learning. This involves recognition of the co-evolutionary ecology of a dairy farm community and the necessity of affecting the learning environment through the incorporation of dairy employees into the process of describing causes of death. Ultimately this serves to build a shared understanding of the dimensions of the problem and the constraints and criteria for possible solutions (Conklin, 2006).

Within the vernacular of management theory this process relates to the telling of the Story (narrative, dialogue) that best describes the process leading to a death. In essence, where statistical classifications attempt to record the “disease” as a singular entity, the Story tries to expound on the “causes of the disease” within an evolutionary context. Well-constructed stories increase descriptive capability and have the ability to convey complex and multi-layered ideas in a simple and memorable form to culturally diverse audiences (Snowden, 1999). The power of the Story is its ability to influence communication, knowledge elicitation, cultural change within a farm, and cross cultural understanding. Fundamentally, a Story has the capacity to stimulate interest in the problem while demonstrating poor outcomes from potentially poor decisions; in other words, it facilitates learning (Snowden, 2000a). If making progress toward resolving the issue of dairy cow mortality requires acknowledging its importance (McConnel et al., 2010a), then telling and documenting the causal narrative as a Story may provide a means to that end.

The narrative of a Story is analogous to the “non-conventional methods” and “community-based information” that the ICD is exploring with regard to the definition, collection, and use of health-related data (World Health Organization, 2004a). Establishing a narrative captures the essence of why a cow died and provides necessary insight into how best to prevent future similar occurrences within a co-evolving community. However, the Story must be purposefully constructed from anecdote that is often based on a conformist and revisionist history influenced by emphasis and de-emphasis within the dairy community. The anecdote underlying the Story is ultimately framed through W-fragments: Who, What, When, Where, and Why (Snowden, 2000a). Historically, dairy record systems have only marginally documented these W-fragments and the result has been a profound lack of understanding of why and how cows truly die (McConnel et al., 2010a). Importantly, any anecdote will have a number of turning points with the possibility for an alternative future dependent on a small change in a decision or some "environmental" factor. The reality is that there is often more truth revealed in an assessment of potential alternative histories than is achieved through the telling of the official Story. As with any story, archetypes exist and provide an accounting of the predominant issues on a farm (Snowden, 1999, 2000a). Extraction of archetypes over time provides insight into the evolving dynamic of a farm.

Formulating a Story from the CODs provides an avenue for exploring common sense solutions to otherwise complex problems. Whereas CODs are primarily focused on statistical classification and historical perspective, the Story provides an opportunity for real-time intervention in the form of employee education. Rather than solely focusing *training* on formal documentation summarizing best practices (i.e. protocols), fragmented stories of failure can be combined and recombined in novel and different ways that facilitate *learning* (Snowden, 2009). A conceptual blending of evolutionary failures can often teach as much if not more than successes; in fact, avoiding failure is more important than imitating success in the process of evolution (Snowden, 1999). Ultimately, stories of partial failure shift the focus from attempts at fail-safe systems to the design of more sensible and sustainable safe-fail systems (Snowden, 2008). Such systems acknowledge the inevitability of failure and seek to achieve progress through strategies that learn from and adapt to that failure. Rather than viewing failure as a demoralizing end-point the Story provides a common sense understanding from which to launch a journey of change (Snowden, 2000b).

Technology is available to capture and organize the Story within a computerized record system. Issue-Based Information System (**IBIS**) was developed as an argumentation-based approach for tackling wicked problems (Werner and Rittel, 1970) and has been applied to computer-based systems. Tools such as Compendium (http://compendium.open.ac.uk/institute/) and Dialogue Mapping™ (http://www.cognexus.org/id41.htm) (Conklin, 2006) incorporate IBIS and are designed to facilitate the capture of rational dialogue among a diverse set of stakeholders. However, for practical purposes on dairies it is likely to be more immediately beneficial to simply develop relevant Stories from Parts I and II of the CODs. If used regularly within employee educational sessions or meetings the data incorporated into CODs would remain fresh enough to derive appropriate anecdotes. From the basis of these anecdotes alternative histories could be explored and used to discuss potential interventions targeted to evolve into complex and desirable behaviors. Inevitably, the simple act of exploring death through dialogue would remove the layers that separate decision makers from raw data. This would cultivate an ethical awareness that is often missing when stakeholders focus solely on the abstract representation of deaths presented through statistical classifications. Ultimately the narrative would transcend logical analysis to stimulate the empathy and understanding necessary for directing more contextually aware decisions (Snowden, 2009).

No definitive solution to this wicked problem.

When William Farr was tasked with addressing death arising from unintended consequences of the Industrial Revolution, he recognized that a best-case scenario incorporated the story (context) with the concrete facts related to the death (content). Practical considerations, political pressure, and scientific thought of the day eventuated in a nosology that focused primarily on content; however, recent efforts at expanding human cause-of-death data are aiming to utilize more of the underlying context. The dairy industry is currently facing a very similar challenge to that faced by 19^{th} century Britain. As with all wicked problems the act of defining this challenge is a function of exploring possible solutions. Yet efforts to investigate dairy cow mortality have primarily focused only on studying and attempting to tame the problem using limited resources and without the benefit of CODs. Neither statistical classifications of cause-of-death nor the Story underlying causes of death have been appropriately addressed. Endeavors to thoroughly explore underlying causes of death and to build a shared understanding of the problem will require better data capture that facilitates dialogue and learning within the co-evolutionary dairy community. Although there is no single solution to this problem, the incorporation of death certificates with CODs into dairy record systems would be a good first step toward facilitating best intentions becoming better outcomes.

Figure 7.1: William Farr's first nosological table for the second half of 1837 (Farr, 1839)

Area in Square Miles.	Population according to Census of 1831.	Families in 1831. Employed chiefly in Agriculture.	Families in 1831. Chiefly in Trade, Manufactures, and Handicraft.	Families in 1831. Other Families.	Families in 1831. Total.
57,805	13,897,187	834,543	1,227,614	849,717	2,911,874

		Diseases.	Males.	Fem.	Total.
Epidemic, Endemic, and Contagious Diseases.		Cholera	246	214	460
		Influenza	220	264	484
		Small-pox	3,050	2,761	5,811
		Measles	2,340	2,392	4,732
		Scarlatina	1,238	1,282	2,520
		Hooping Cough	1,277	1,767	3,044
		Croup	879	776	1,655
		Thrush (1)	381	326	707
		Diarrhœa	1,451	1,304	2,755
		Dysentery	350	325	675
		Ague	39	37	76
		Typhus (2)	4,439	4,608	9,047
		Erysipelas (3)	237	245	482
		Syphilis	30	43	73
		Hydrophobia	13	3	16
		Total	16,190	16,347	32,537
Sporadic Diseases.	Of the Nervous System.	Cephalitis (4)	567	454	1,021
		Hydrocephalus	1,933	1,637	3,570
		Apoplexy (5)	1,447	1,264	2,711
		Paralysis	987	1,052	2,039
		Convulsions (6)	5,798	4,931	10,729
		Tetanus	45	11	56
		Chorea (7)	3	9	12
		Epilepsy (8)	278	292	570
		Insanity (9)	147	138	285
		Delirium Tremens	86	9	95
		Disease (10)	438	326	764
		Total	11,729	10,123	21,852
	Of the Respiratory Organs.	Laryngitis	11	13	24
		Quinsey	141	148	2-9
		Bronchitis	248	212	460
		Pleurisy	140	96	236
		Pneumonia	3,187	2,637	5,824
		Hydrothorax	557	438	995
		Asthma	1,020	744	1,764
		Consumption (11)	9,494	10.753	20,247
		Decline	3,474	4,033	7,507
		Disease (12)	653	523	1,176
		Total	18,925	19,597	38,522
	Of the Organs of Circulation.	Pericarditis	31	31	62
		Aneurism	37	15	52
		Disease (13)	834	648	1,482
		Total	902	694	1,596
	Of the Digestive Organs. Intestinal Canal.	Teething	998	905	1,903
		Gastro-Enteritis	1,710	1,686	3,396
		Peritonitis	35	47	82
		Tabes Mesenterica	228	209	437
		Ascites	28	23	51
		Ulceration (14)	96	74	170
		Hernia	150	102	252
		Colic	39	19	58
		Constipation (15)	253	208	461
		Worms	119	145	264
		Disease (16)	437	416	853
	Pancreas	Disease	..	2	2
	Liver	Hepatitis	91	92	183
		Jaundice (15*)	211	194	405
		Disease (16*)	716	605	1,321
	Spleen	Disease	4	8	12
		Total	5,115	4,735	9,850

		Diseases.	Males.	Fem.	Tot
Sporadic Disease.	Of the Urinary Organs.	Nephritis	37	23	6
		Ischuria	49	4	5
		Diabetes (17)	68	27	9
		Granular Disease	2	1	
		Cystitis	61	9	7
		Stone (18)	161	19	18
		Stricture	43	3	4
		Disease	262	47	30
		Total	683	133	81
	Of the Organs of Generation.	Childbed (19)	..	1,265	1,26
		Paramenia	..	49	4
		Ovarian Dropsy	..	21	2
		Disease (20)	13	150	16
		Total	13	1,485	1,49
	Of the Organs of Locomotion	Arthritis	7	8	1
		Rheumatism (21)	221	216	43
		Disease (22)	277	200	47
		Total	505	424	92
	Of the Integumentary System.	Carbuncle	14	5	1
		Phlegmon (23)	29	17	4
		Ulcer	37	45	8
		Fistula	39	12	5
		Disease (24)	39	27	6
		Total	158	106	26
	Of Uncertain Seat.	Inflammation	1,201	1,136	2,33
		Hæmorrhage (25)	369	213	58
		Dropsy	2,445	3,139	5,58
		Abscess	247	217	46
		Mortification (26)	305	276	58
		Scrofula (27)	286	255	54
		Carcinoma (28)	355	873	1,22
		Tumor	48	81	12
		Gout	67	12	7
		Intemperance (29)	70	15	8
		Atrophy	478	481	95
		Debility	1,328	1,078	2,40
		Starvation	34	29	6
		Malformations (30)	75	41	11
		Sudden Deaths	634	419	1,05
		Total	7,942	8,265	16,2
	Old Age.		5,674	7,017	12,6
Violent Deaths (31)			3,605	1,240	4,8
Causes not specified			3,718	3,376	7,0
		Total	75,159	73,542	148

Figure 7.2: International form of medical certificate of Cause of Death (World Health Organization, 2004a).

INTERNATIONAL FORM OF MEDICAL CERTIFICATE OF CAUSE OF DEATH

Cause of death		Approximate interval between onset and death
I Disease or condition directly leading to death*	(a)	....
	due to (or as a consequence of)	
Antecedent causes Morbid conditions, if any, giving rise to the above cause, stating the underlying condition last	(b)	....
	due to (or as a consequence of)	
	(c)	....
	due to (or as a consequence of)	
	(d)	....
II Other significant conditions contributing to the death, but not related to the disease or condition causing it	....	....
	....	....

**This does not mean the mode of dying, e.g. heart failure, respiratory failure. It means the disease, injury, or complication that caused death.*

Figure 7.3: International Classification of Diseases "family" of disease and health-related classifications (World Health Organization, 2004a).

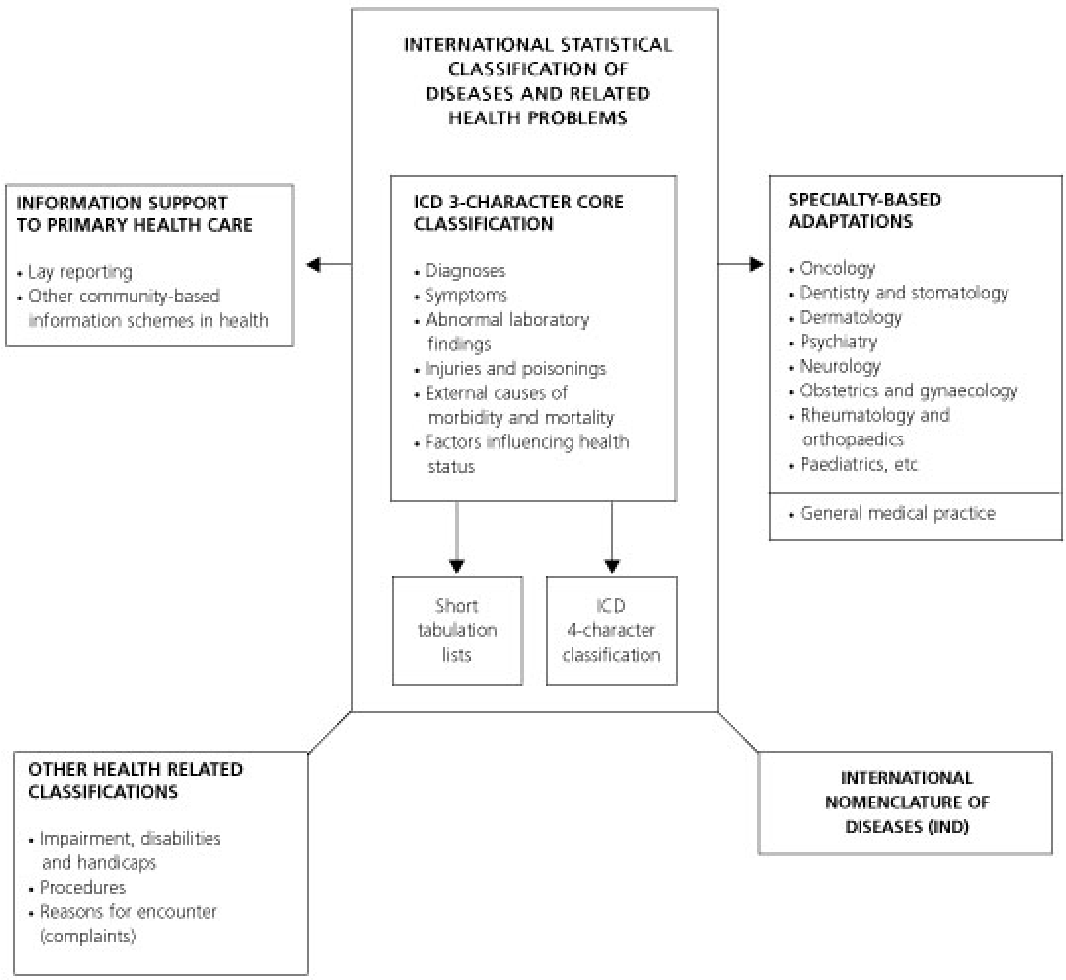


Figure 7.4: US Standard Certificate of Death. www.cdc.gov

U.S. STANDARD CERTIFICATE OF DEATH

LOCAL FILE NO. STATE FILE NO.

NAME OF DECEDENT ____________
For use by physician or institution

To Be Completed/ Verified By: FUNERAL DIRECTOR:

1. DECEDENT'S LEGAL NAME (Include AKA's if any) (First, Middle, Last) | 2. SEX | 3. SOCIAL SECURITY NUMBER

4a. AGE-Last Birthday (Years) | 4b. UNDER 1 YEAR Months Days | 4c. UNDER 1 DAY Hours Minutes | 5. DATE OF BIRTH (Mo/Day/Yr) | 6. BIRTHPLACE (City and State or Foreign Country)

7a. RESIDENCE-STATE | 7b. COUNTY | 7c. CITY OR TOWN

7d. STREET AND NUMBER | 7e. APT. NO. | 7f. ZIP CODE | 7g. INSIDE CITY LIMITS? □ Yes □ No

8. EVER IN US ARMED FORCES? □ Yes □ No | 9. MARITAL STATUS AT TIME OF DEATH □ Married □ Married, but separated □ Widowed □ Divorced □ Never Married □ Unknown | 10. SURVIVING SPOUSE'S NAME (If wife, give name prior to first marriage)

11. FATHER'S NAME (First, Middle, Last) | 12. MOTHER'S NAME PRIOR TO FIRST MARRIAGE (First, Middle, Last)

13a. INFORMANT'S NAME | 13b. RELATIONSHIP TO DECEDENT | 13c. MAILING ADDRESS (Street and Number, City, State, Zip Code)

14. PLACE OF DEATH (Check only one: see instructions)
IF DEATH OCCURRED IN A HOSPITAL: □ Inpatient □ Emergency Room/Outpatient □ Dead on Arrival
IF DEATH OCCURRED SOMEWHERE OTHER THAN A HOSPITAL: □ Hospice facility □ Nursing home/Long term care facility □ Decedent's home □ Other (Specify):

15. FACILITY NAME (If not institution, give street & number) | 16. CITY OR TOWN , STATE, AND ZIP CODE | 17. COUNTY OF DEATH

18. METHOD OF DISPOSITION: □ Burial □ Cremation □ Donation □ Entombment □ Removal from State □ Other (Specify): | 19. PLACE OF DISPOSITION (Name of cemetery, crematory, other place)

20. LOCATION-CITY, TOWN, AND STATE | 21. NAME AND COMPLETE ADDRESS OF FUNERAL FACILITY

22. SIGNATURE OF FUNERAL SERVICE LICENSEE OR OTHER AGENT | 23. LICENSE NUMBER (Of Licensee)

To Be Completed By: MEDICAL CERTIFIER

ITEMS 24-28 MUST BE COMPLETED BY PERSON WHO PRONOUNCES OR CERTIFIES DEATH | 24. DATE PRONOUNCED DEAD (Mo/Day/Yr) | 25. TIME PRONOUNCED DEAD

26. SIGNATURE OF PERSON PRONOUNCING DEATH (Only when applicable) | 27. LICENSE NUMBER | 28. DATE SIGNED (Mo/Day/Yr)

29. ACTUAL OR PRESUMED DATE OF DEATH (Mo/Day/Yr) (Spell Month) | 30. ACTUAL OR PRESUMED TIME OF DEATH | 31. WAS MEDICAL EXAMINER OR CORONER CONTACTED? □ Yes □ No

CAUSE OF DEATH (See instructions and examples)

32. **PART I.** Enter the chain of events--diseases, injuries, or complications--that directly caused the death. DO NOT enter terminal events such as cardiac arrest, respiratory arrest, or ventricular fibrillation without showing the etiology. DO NOT ABBREVIATE. Enter only one cause on a line. Add additional lines if necessary.

Approximate interval: Onset to death

IMMEDIATE CAUSE (Final disease or condition ---------> resulting in death) a. ____________ ______
Due to (or as a consequence of):

Sequentially list conditions, if any, leading to the cause listed on line a. Enter the **UNDERLYING CAUSE** (disease or injury that initiated the events resulting in death) **LAST**

b. ____________ ______
Due to (or as a consequence of):
c. ____________ ______
Due to (or as a consequence of):
d. ____________ ______

PART II. Enter other significant conditions contributing to death but not resulting in the underlying cause given in PART I | 33. WAS AN AUTOPSY PERFORMED? □ Yes □ No | 34. WERE AUTOPSY FINDINGS AVAILABLE TO COMPLETE THE CAUSE OF DEATH? □ Yes □ No

35. DID TOBACCO USE CONTRIBUTE TO DEATH? □ Yes □ Probably □ No □ Unknown

36. IF FEMALE: □ Not pregnant within past year □ Pregnant at time of death □ Not pregnant, but pregnant within 42 days of death □ Not pregnant, but pregnant 43 days to 1 year before death □ Unknown if pregnant within the past year

37. MANNER OF DEATH □ Natural □ Homicide □ Accident □ Pending Investigation □ Suicide □ Could not be determined

38. DATE OF INJURY (Mo/Day/Yr) (Spell Month) | 39. TIME OF INJURY | 40. PLACE OF INJURY (e.g., Decedent's home; construction site; restaurant; wooded area) | 41. INJURY AT WORK? □ Yes □ No

42. LOCATION OF INJURY: State: City or Town:
Street & Number: Apartment No.: Zip Code:

43. DESCRIBE HOW INJURY OCCURRED: | 44. IF TRANSPORTATION INJURY, SPECIFY: □ Driver/Operator □ Passenger □ Pedestrian □ Other (Specify)

45. CERTIFIER (Check only one):
□ Certifying physician-To the best of my knowledge, death occurred due to the cause(s) and manner stated.
□ Pronouncing & Certifying physician-To the best of my knowledge, death occurred at the time, date, and place, and due to the cause(s) and manner stated.
□ Medical Examiner/Coroner-On the basis of examination, and/or investigation, in my opinion, death occurred at the time, date, and place, and due to the cause(s) and manner stated.

Signature of certifier:____________

46. NAME, ADDRESS, AND ZIP CODE OF PERSON COMPLETING CAUSE OF DEATH (Item 32)

47. TITLE OF CERTIFIER | 48. LICENSE NUMBER | 49. DATE CERTIFIED (Mo/Day/Yr) | 50. **FOR REGISTRAR ONLY**- DATE FILED (Mo/Day/Yr)

To Be Completed By: FUNERAL DIRECTOR

51. DECEDENT'S EDUCATION-Check the box that best describes the highest degree or level of school completed at the time of death.
□ 8th grade or less
□ 9th - 12th grade; no diploma
□ High school graduate or GED completed
□ Some college credit, but no degree
□ Associate degree (e.g., AA, AS)
□ Bachelor's degree (e.g., BA, AB, BS)
□ Master's degree (e.g., MA, MS, MEng, MEd, MSW, MBA)
□ Doctorate (e.g., PhD, EdD) or Professional degree (e.g., MD, DDS, DVM, LLB, JD)

52. DECEDENT OF HISPANIC ORIGIN? Check the box that best describes whether the decedent is Spanish/Hispanic/Latino. Check the "No" box if decedent is not Spanish/Hispanic/Latino.
□ No, not Spanish/Hispanic/Latino
□ Yes, Mexican, Mexican American, Chicano
□ Yes, Puerto Rican
□ Yes, Cuban
□ Yes, other Spanish/Hispanic/Latino (Specify) ____________

53. DECEDENT'S RACE (Check one or more races to indicate what the decedent considered himself or herself to be)
□ White
□ Black or African American
□ American Indian or Alaska Native (Name of the enrolled or principal tribe) ____________
□ Asian Indian
□ Chinese
□ Filipino
□ Japanese
□ Korean
□ Vietnamese
□ Other Asian (Specify)____________
□ Native Hawaiian
□ Guamanian or Chamorro
□ Samoan
□ Other Pacific Islander (Specify)____________
□ Other (Specify)____________

54. DECEDENT'S USUAL OCCUPATION (Indicate type of work done during most of working life. DO NOT USE RETIRED).

55. KIND OF BUSINESS/INDUSTRY

Figure 7.5: Dairy Certificate of Death with Cause of Death Statement

DAIRY CERTIFICATE OF DEATH Completed by:

1. Dairy	2. Animal ID/Tag	3. USDA ID	3. Date of death (Mo/Day/Yr)

4. Date of birth (Mo/Day/Yr)	5. Source of origin ☐ Home ☐ Purchased	6. If purchased or raised off-farm--date of entry to farm (Mo/Day/Yr)

7. Dam ID	8. Sire ID	9. Sex	10. Breed	11. BCS	12. Last milk weight

13. 305ME milk	14. Average somatic cell count	15. Relative value	16. Lactation number

17. Lactation status ☐ Lactating ☐ Dry	18. Fresh date (Mo/Day/Yr)	19. Days in milk/Days dry	20. Calving ease score

21. DIM at first breeding	22. Pregnancy status ☐ Open ☐ Pregnant	23. Days carrying calf	24. ☐ Aborted this lactation DCC at time of abortion __________

25. Pen number	26. Location at death	27. Manner of death ☐ Unassisted ☐ Assisted	28. ☐ Down prior to death Days down ____________

29. Actual or presumed time of death	30. Was a veterinarian contacted? ☐ yes ☐ no	31. Was a necropsy performed? ☐ yes ☐ no

32. Were necropsy findings available to complete the cause of death? ☐ yes ☐no	33. Were adjunct diagnostics performed? ☐ yes ☐ no

34. **CAUSE OF DEATH. Part I.**

Enter the chain of events--diseases, injuries, or complications--that directly caused the death.
DO NOT ABBREVIATE. Enter only one cause on a line. Add additional lines if necessary.

Approximate interval: Onset to death

IMMEDIATE CAUSE (Final disease or condition resulting in death) → a.____ __________________

Due to (or as a consequence of):

b.____ __________________

Due to (or as a consequence of):

Sequentially list conditions, if any, leading to the cause listed on line 'a'. Enter the **UNDERLYING CAUSE** (disease or injury that initiated the events resulting in death) **LAST**

c.____ __________________

Due to (or as a consequence of):

d.____ __________________

Due to (or as a consequence of):

PART II. Enter other significant conditions contributing to death but not resulting in the underlying cause given in Part I.

35. Did injury play a role in death? ☐ yes ☐ no	36. Date of injury (Mo/Day/Yr)	37. Location of injury on body

38. Place on farm the injury occurred	39. Describe how injury occurred

40. Antecedent health events

☐ Mastitis ☐ Milk fever ☐ Ketosis ☐ Lameness ☐ Respiratory problems ☐ Diarrhea >48 hrs ☐ Ulcers/HBS
Date(s):

☐ Retained placenta ☐ Metritis ☐ Displaced abomasum ☐ Neurological problems ☐ Other (specify)________
Date(s):

41. Antecedent treatments

☐ IM/IV/SC antibiotics ☐ Intramammary abx ☐ Intrauterine abx/flush ☐ Antiinflammatories ☐ Vitamins
Date(s):

☐ IV/Oral fluids ☐ Abomasopexy ☐ Caesarian section ☐ Teat amputation ☐ Other (specify)______________
Date(s):

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APPENDIX A

COLORADO DAIRY HEALTH MANAGEMENT SURVEY

Operation ID__________ **Qualitative Form**

Date_____________

Facility Descriptors

1) Which of the following best describes this operation? (Circle one.)
   a) Conventional (majority of forage *fed* in the form of hay, silage, TMR, etc.)
   b) Grazing (majority of forage is *grazed* by cows)
   c) Combination of conventional and grazing
   d) Organic (operation meets USDA organic standards)
   e) Other? (Specify:_______________________________________)

2) For the majority of lactating cows, which best describes the feed line? (Circle one.)
   a) Tie stall c) Post and rail e) Elevated feed bunk in pen
   b) Stanchion d) Head locks f) Other (Specify:___________________)

3) What is the primary method used to restrain cows (for AI, pregnancy diagnosis, etc.)? (Circle one.)
   a) Head locks at feed bunk d) Chute f) Corner in free stalls or pen
   b) Palpation rail e) Parlor g) Other (Specify:___________________)
   c) Tie stall/stanchion

4) Where do the majority of cows on this operation usually calve: (Circle one.)
   a) Multiple animal area/pen? .... **yes/no**
   b) Individual animal area/pen cleaned between each calving?.. **yes/no**
   c) Individual animal area/pen cleaned after two or more calvings? .... **yes/no**
   d) Other? (Specify:____________________________________) .... **yes/no**

5) If cows calve in an individual area/pen, how long are they typically separated from other cows? ___**hrs**

6) Do any of the following cows enter the usual calving area/pen?
   a) Sick cows. .... **yes/no**
   b) Lame cows. .... **yes/no**
   c) Other (Specify:___________________) .... **yes/no**

7) Are heifers having their first calf separated from mature cows in close-up maternity housing?..... **yes/no**

8) Does this operation separate maternity cows from other dry cows? .... **yes/no**

9) Is maternity housing separate from housing used for lactating dairy cows? .... **yes/no**

10) At what frequency are cows added to the maternity pen?........................... **every ___________ day(s)**

11) Is fresh cow housing separate from housing used for sick/hospital cows? .... **yes/no**
    a) ***If "yes,"*** how distant is fresh cow housing from sick/hospital cow housing?. **adjacent** or ______ **ft**

12) Do fresh cows and sick/hospital cows share a water source?... **yes/no**

13) Are lactating heifers grouped separately from mature cows? .... **yes/no**

14) On average, how many pen moves does a cow make between one calving and the next (e.g. fresh pen + early lactating + late lactating + far-off dry + close-up dry + maternity = 6 moves)________ **pen moves**

15) How old are the primary housing facilities used for the following classes of cows (if facilities have been rebuilt/remodeled, count the years from the renovation completion):
    a) Lactating cows? _____**years** b) Dry cows? _____**years** c) Maternity cows? _____**years**

16) How old is the primary milking facility (if the milking facility has been rebuilt/remodeled, count the years from the renovation completion)?...___________**years**

17) During the last 12 months, what was the primary housing facility/outside area this operation used for the following animal classes during the summer (S) and winter (W)? (Choose only one for each class)

	Lactating Cows S	Lactating Cows W	Dry Cows S	Dry Cows W
a) Tie stall or stanchion				
b) Covered freestall				
c) Uncovered freestall				
d) Outside individual animal pen				
e) Inside individual animal pen				
f) Drylot/multiple animal outside area				
g) Multiple animal inside area				
h) Pasture				
i) Other (Specify:_____________________)				

18) Which of the following is the predominant flooring type lactating cows stand or walk on when not being milked? (Circle one.)

a) Concrete—groove/textured
b) Concrete—slat
c) Concrete—smooth
d) Rubber mats over concrete
e) Pasture
f) Dirt
g) Other (Specify:___________)

19) If concrete is the predominant flooring type, did any of the following cow areas have rubber belting or similar flooring that reduced the time cows spent standing directly on concrete?

a) Immediately in front of or behind feed bunk. .... **yes/no**
b) Walkway to parlor. .... **yes/no**
c) Holding pen. .... **yes/no**
d) Other (Specify:________________________) .... **yes/no**

20) Are there areas on the farm recognized to cause problems with cow footing and movement (e.g. water/ice accumulation, sharp corners, slick concrete, etc.)? .... **yes/no**

a) ***If "yes,"*** how many areas? .... ______**areas**
b) Specify: ____

21) During the last 12 months, which of the following was the primary bedding type used for lactating and dry cows? (Choose one for lactating and one for dry cows)

	Lactating	Dry
a) Straw and/or hay		
b) Sand		
c) Sawdust/wood products		
d) Composted/dried manure		
e) Rubber mats		
f) Rubber tires		
g) Shredded newspaper		
h) Mattresses		
i) Corn cobs and stalks		
j) Waterbeds		
k) Compacted dirt		
l) Other (Specify:________________)		

22) During summer months were the following heat abatement methods provided to lactating or dry cows?

	Lactating	Dry
a) Shade (other than inside building)	**yes/no**	**yes/no**
b) Sprinklers or misters	**yes/no**	**yes/no**
c) Fans	**yes/no**	**yes/no**
d) Tunnel ventilation	**yes/no**	**yes/no**
e) Other (Specify:________________________)	**yes/no**	**yes/no**

Herd Management Characteristics

23) How many times per day are the majority of fresh cows (≤30 DIM) milked? (Circle one.)
   a) Once a day   c) Three times a day
   b) Twice a day   d) More than three times a day

24) How many times per day are the majority of cows, other than fresh cows, milked? (Circle one.)
   a) Once a day   c) Three times a day
   b) Twice a day   d) More than three times a day

25) On average, how much time would be required to physically locate a cow on this farm?______**minutes**
   a) How many people would be required to locate the animal within this time?.......... ______**person(s)**

26) What type(s) of record keeping system(s) does this operation use to track individual dairy animals? Do you use:
   a) Handwritten records, such as a ledger or notebook? .... **yes/no**
   b) Dairy Herd Improvement Association (DHIA)? .... **yes/no**
   c) Off-farm computer record system other than DHIA? .... **yes/no**
   d) On-farm computer record system? .... **yes/no**
   e) Other systems? (Specify:________________________________) .... **yes/no**
   f) None? .... **yes/no**

   [If item *c* or *d* is YES, please answer to *g*.]

   g) What off-farm or on-farm (Items c or d) computer record system is primarily used? (Circle one.)
      i) Dairy Comp 305   iii) DHI Plus
      ii) PC Dart   iv) Other? (Specify:__________________________)

27) Does this operation utilize the services of a veterinarian? .... **yes/no**

28) If a veterinarian is used, which of the following services does the veterinarian provide and on average how many hours per service are required per month:

		Hours/month
a) Herd health/record analysis?..	**yes/no**	
b) Reproductive services:		
i) Rectal palpation (no ultrasound)?...	**yes/no**	
ii) Rectal palpation (ultrasound)?..	**yes/no**	
iii) Artificial insemination?..	**yes/no**	
c) Calving assistance?..	**yes/no**	
d) Fresh cow evaluation/treatment?...	**yes/no**	
e) Lameness evaluation/treatment?..	**yes/no**	
f) Sick cow evaluation/treatment?..	**yes/no**	
g) Calf evaluation, treatment, or routine processing?.........................	**yes/no**	
h) Nutritional consultation?...	**yes/no**	
i) Other? (Specify___________________________)………………..	**yes/no**	
Total hours per month:		

29) Which of the following categories best describes first service breeding practices for the majority of heifers and cows in the last 12 months? (Choose one for heifers and one for cows.)
   Heifers_____ Cows______
   a) Natural service (bull-bred)   b) AI   c) Other (Specify:__________________________)

30) Which of the following categories best describes second or greater service breeding practices for the majority of heifers and cows in the last 12 months? (Choose one for heifers and one for cows.)
   Heifers_____ Cows______
   a) Natural service (bull-bred)   b) AI   c) Other (Specify:__________________________)

31) If AI is used on this operation, which of the following best describes who performed the majority of AI services in the last 12 months? (Circle one.)
   a) Owner/operator c) General employee e) AI service/technician
   b) Herdsman d) Veterinarian f) Other (Specify:____________________)

32) Which of the following best describes who administered the majority of reproductive injections in the last 12 months? (Circle one.)
   a) Owner/operator d) Veterinarian f) No reproductive injections administered
   b) Herdsman e) AI service/technician g) Other (Specify:____________________)
   c) General employee

33) Which of the following best describes who performed the majority of rectal/pregnancy exams on this operation in the last 12 months? (Circle one.)
   a) Private veterinarian c) Employee veterinarian e) Owner/operator
   b) Veterinary technician d) Employee (nonveterinarian) f) Other (Specify:______________)

34) During the last 12 months, approximately what percentage of cows were treated with dry cow intramammary antibiotics at drying off? .... **______%**

35) Does this operation use an external teat sealant (e.g Stronghold™) at the time of dry off? (Circle one.)
   a) On all cows at drying off d) No external teat sealant used on this operation
   b) Cows with chronic mastitis e) Other (Specify:____________________________)
   c) Use on all cows at drying off but only during winter or adverse weather

36) Does this operation use an internal teat sealant (Orbeseal™) at the time of drying off? (Circle one.)
   a) On all cows at drying off d) No internal teat sealant used on this operation
   b) Cows with chronic mastitis e) Other (Specify:____________________________)
   c) Use on all cows at drying off but only during winter or adverse weather

37) Does this operation have a system for scoring calving difficulty? .... **yes/no**
   a) If calving difficulty is scored, is the calving difficulty score for assisted births recorded? ... **yes/no**

38) How often are cows body condition scored (BCS)? (Circle one.)
   a) Never.
   b) Evaluate at pen level every ________days.
   c) Evaluate cows individually every ________days.
   d) Evaluate at specific time points during lactation (e.g. drying off, etc.).
   (Specify: ____)
   e) Other (Specify:____)

39) If BCS is used, who typically does the BCS? (Circle one.)
   a) Owner/operator. c) Veterinarian e) Other hired worker (non-family member)
   b) Family member of owner. d) Nutritionist f) Other. (Specify:____________________)

40) What best describes the hoof care program? (Circle one.)
   a) Maintenance trimming and animals with sore feet treated. c) No hoof care program
   b) Treat animals with sore feet only. d) Other. (Specify:______________)

41) If maintenance trimming is used, how frequently does it take place per cow: (Circle one.)
   a) Less than once annually. c) Twice annually.
   b) Once annually. d) Three or more times annually.

42) If maintenance trimming is used, from which of the following groups are the majority of animals trimmed: (Circle one.)
   a) Dry cows? c) Mid-lactation? e) Other? (Specify:____________________)
   b) Late lactation? d) Fresh cows?

43) Does this operation normally vaccinate dairy heifers or cows for: Heifers Cows

a) BVD (Bovine Viral Diarrhea)? .... **yes/no** .... **yes/no**
b) IBR (Infectious Bovine Rhinotracheitis)? .... **yes/no** .... **yes/no**
c) PI3 (Parainfluenza Type 3)? .... **yes/no** .... **yes/no**
d) BRSV (Bovine Respiratory Syncytial Virus)? .... **yes/no** .... **yes/no**
e) *Haemophilus somnus*? .... **yes/no** .... **yes/no**
f) Lepto (Leptospirosis)? .... **yes/no** .... **yes/no**
g) *Salmonella*? .... **yes/no** .... **yes/no**
   (e.g. LeukoTox® MTD; SDT-Guard; Pro-Bac®; Bo-Bac 2X; Poly-sal™ B; Pulmo-guard™ PH-M/SDT; Cattle-val salmo; Salmo shield® T; Salmonella Dublin-Typhimurium Bacterin Endovac-Bovi®; Salmo shield® TD)
h) *E. coli* (Coliform) mastitis? .... **yes/no** .... **yes/no**
   (e.g. Master Guard® J5; J5 Shield™; J-5 bacterin™; J-5 E. coli bacterin; J-vac®)
i) Siderophore receptors and porins (SRPs) vaccines? .... **yes/no** .... **yes/no**
   (e.g. Salmonella Newport Bacterial Extract SRP)
j) *Mycoplasma* .... **yes/no** .... **yes/no**
   (e.g. Pulmo-guard PH-M/SDT; Myco-Bac B; Mycomune)
k) *Staphylococcus aureus*? .... **yes/no** .... **yes/no**
   (e.g. Lysigin®; Samato-Staph®)
l) Clostridia, such as black leg or enterotoxemia? .... **yes/no** .... **yes/no**
m) Hemorrhagic Bowel Syndrome (HBS) .... **yes/no** .... **yes/no**
   (e.g. commercial *Clostridium perfringens* type A toxoid)
n) Brucellosis? .... **yes/no** N/A
o) Johne's disease (*Mycobacterium paratuberculosis)?* .... **yes/no** N/A
p) *Neospora*? .... **yes/no** .... **yes/no**
q) Any disease using autogenous vaccines? .... **yes/no** .... **yes/no**
   (Specify:________________________________)
r) Other? (Specify:____________________) .... **yes/no** .... **yes/no**

44) If viral vaccination (BVD, IBR, PI3, BRSV) is used, does this operation normally use *modified-live* or *killed* vaccine for dairy heifers and cows? ...... __________ **Heifers** .... __________ **Cows**

Nutritional Management Practices

45) Which of the following best describes who is primarily responsible for formulating/balancing feed rations fed to dairy cows? (Circle one.)

a) Employee (nonveterinarian) c) Feed company nutritionist e) Owner/Operator
b) Independent nutritionist d) Veterinarian f) Other. (Specify:__________)

46) How many hours per month is the person responsible for formulating/balancing feed rations on the farm directly working with the ration? .... __________ **hours**

47) Does this operation use forage tests to balance feed rations? .... **yes/no**

48) Which of the following best describes this operation's use of milk urea nitrogen (MUN) testing to determine ration composition? (Circle one.)

a) Use routinely b) Use only if have a problem c) Never use

49) Does this operation rely on pasture during the growing season to provide part of the forage component of the ration to:

a) Heifers? .... **yes/no**
b) Lactating cows? .... **yes/no**
c) Dry cows? .... **yes/no**

50) Does this operation feed a total mixed ration (TMR)? .... **yes/no**

51) If a ration is fed, at what frequency is fresh feed delivered to the dairy cows? .... ______ **times/day**

52) If a ration is fed along a feed bunk line, at what frequency is leftover feed pushed up?_______**times/day**

53) How often are diets reformulated? ....approximately every __________**days or** _________**month(s)**

54) How often are the feeds tested?.............approximately every __________**days or** _________**month(s)**

55) Which of the following best describes how lactating cows are fed? (Circle one.)
- a) Feed all lactating cows the same ration
- b) Feed individuals or groups based on production/stage of lactation
- c) Feed individuals or groups based on lactation number
- d) Feed individuals or groups based on criteria other than lactation production/stage or number

56) During the last 12 months, what was the average expected forage to concentrate ratio (on a ***dry matter*** basis) fed to lactating and dry cows?.............................. **Lactating____________ Dry_____________**

57) For both the summer and the winter, what percentage (on a ***dry matter*** basis) of the primary source(s) of forage for this operation is home-raised and what percentage is purchased?

	Summer%	Winter%
a) Home-raised		
b) Purchased		

58) For dairy replacement heifers or dairy cows, does this operation normally use:

	Heifers	Cows
a) Dewormers?	**yes/no**	**yes/no**
b) Coccidiostats in feed?	**yes/no**	**yes/no**
c) Vitamins A-D-E injection?	**yes/no**	**yes/no**
d) Vitamins A-D-E in feed?	**yes/no**	**yes/no**
e) Selenium injection?	**yes/no**	**yes/no**
f) Selenium in feed?	**yes/no**	**yes/no**
g) Ionophores in feed (e.g. Rumensin®, Bovatec®)?	**yes/no**	**yes/no**
h) Probiotics?	**yes/no**	**yes/no**
i) Anionic salts (e.g. BioChlor, SoyChlor, ammonium chloride, etc.) in feeds?	**yes/no**	**yes/no**
j) Other? (Specify:____)	**yes/no**	**yes/no**

59) What is the primary source of water for lactating and dry cows and how many times per year are water sources drained and cleaned: (Check one source for lactating cows, and one source for dry cows.)

	Lactating	Dry	Clean/yr
a) A single cup/bowl waterer used by one cow only?	_______	___	_______
b) A single cup/bowl waterer used by multiple cows?	_______	___	_______
c) A water tank or trough (covered or uncovered)?	_______	___	_______
d) A lake, pond, stream, river, etc.?	_______	___	N/A
e) Another source? (Specify:__________________)	_______	___	_______

60) Is the water that cows drink usually chlorinated? .... **yes/no**

61) Is the water that cows drink ever tested for:
- a) Mineral content? .... **yes/no**
- b) Bacterial presence? .... **yes/no**

Biosecurity and Expansion Descriptors

62) Are you using any of the following biosecurity practices?
- a) Guidelines to determine which visitors (tour groups, etc.) are allowed in animal areas. ....**yes/ no visitors allowed /no**
- b) Guidelines regarding foreign travel by employees..**yes/ no employees /no**
- c) Written standard operating procedures (other than milking procedures). .... **yes/no**
- d) Training for employees in performing these practices. ....**yes/ no employees /no**

63) Have you used any of the following practices in the last 12 months?

a) Footbaths for visitors or temporary workers (tour groups, salespeople, service technicians, etc.) entering animal areas. .... **yes/no**

b) Disposable or clean boots for visitors or workers entering animal areas. .... **yes/no**

c) Insect control (such as sprays, foggers, treated ear tags, products administered to animals [topical/oral], etc.). .... **yes/no**

d) Rodent control (such as cats, traps, chemical/bait, etc.). .... **yes/no**

e) Bird control (such as traps, noise, chemical/bait, etc.). .... **yes/no**

f) Limit cattle contact with other livestock, elk, and deer. .... **yes/no**

g) Control access to cattle feed by other livestock and wildlife, such as elk, deer, and raccoons. **yes/no**

h) Closed herd (all replacements are from this operation, no contact with cattle from other operations).......... **yes/no**

i) Restrictions on vehicles entering animal area. .... **yes/no**

j) Restrictions on employee livestock ownership outside this operation. ....**yes/ no employees /no**

64) Does this operation participate in any test and control programs for the following diseases:

a) Johne's? (*Mycobacterium paratuberculosis*) .... **yes/no**

b) BVD? (*Bovine Viral Diarrhea*) .... **yes/no**

c) TB? (*Bovine Tuberculosis*) .... **yes/no**

d) Contagious mastitis? (*Staph. aureus, Strep. ag., Mycoplasma*) .... **yes/no**

e) Anything else? (Specify:______________________________) .... **yes/no**

65) How many dairy cow replacements (both heifers and adult cows) that entered the milking herd in the last 12 months were:

	Head
a) Born on this operation and raised on the operation?	
b) Born on this operation and raised by off-site heifer grower?	
c) Purchased directly from other dairies?	
d) Purchased from a dealer?	
e) Purchased from auction markets?	
f) Purchased from other source? (Specify:________________)	

If dairy heifers are raised off of the operation, answer the following question.

66) Which of the following best describes the off-site rearing facility? (Circle one.)

a) Dairy heifers sent to single rearing facility with no contact with cattle from other operations.

b) Dairy heifers sent to multiple rearing facilities with no contact with cattle from other operations.

c) Dairy heifers sent to single rearing facility with contact (commingled) with cattle from other operations.

d) Dairy heifers sent to multiple rearing facilities with contact (commingled) with cattle from other operations.

e) Other? (Specify:____)

Exclude heifers classified as 'a' or 'b' in the previous question when answering the following four questions (i.e. heifers raised off farm *without* commingling are not considered "brought on" the farm when returned).

67) Were any cattle (calves, heifers, cows, or bulls) brought on the operation in the last 12 months? . **yes/no**

If "no", skip the remainder of this and the next three questions. If "yes":

a) How many cattle were brought onto this operation in the last 12 months?.......... ______**head**

b) How many were quarantined upon arrival at the operation?.......... ______**head**

c) If quarantined, what was the average time cattle were quarantined/separated? .... ______**days**

d) How many of the following types of cattle were brought onto this operation in the last 12 months?

i) Dairy heifers weaned, but not bred .... ________**head**

ii) Bred dairy heifers? .... ________**head**

iii) Lactating dairy cows? .... ________**head**

iv) Dry dairy cows? .... ________**head**

v) Dairy bulls?.......... ________**head**

68) Before bringing cattle (either dairy or beef) on the farm, does this operation normally require vaccination for:

	Yes	Don't Know	No
a) Brucellosis?	___	________	___
b) BVD (*Bovine Viral Diarrhea*)?	___	________	___
c) IBR (*Infectious Bovine Rhinotracheitis*)?	___	________	___
d) Lepto (*Leptospirosis*)?	___	________	___
e) *Neospora*?	___	________	___
f) *Salmonella*?	___	________	___
g) Anything else? (Specify:_____________)	___	________	___

69) Before bringing cattle (either dairy or beef) onto the farm, does this operation normally require individual animal testing for:

	Yes	Don't Know	No
a) Brucellosis?	___	_______	___
b) Johne's disease?	___	_______	___
c) BVD? (*Bovine Viral Diarrhea*)	___	_______	___
d) TB? (*Bovine Tuberculosis*)	___	_______	___
e) Contagious mastitis pathogens? (*Staph. aureus, Strep. ag., Mycoplasma*)	___	_______	___
f) Anything else? (Specify:____________________)	___	_______	___

70) Before bringing cattle (either dairy or beef) onto the farm, does this operation normally require:

	Yes	Don't Know	No
a) Herd-of-origin BVD status?	___	_______	___
b) Herd-of-origin Johne's disease status?	___	_______	___
c) Herd-of-origin bulk milk somatic cell count?	___	_______	___
d) Herd-of-origin bulk tank milk culture to evaluate contagious mastitis pathogens?	___	_______	___
e) Anything else? (Specify:________________________)	___	_______	___

71) What other animals are on this operation, and do they have physical contact with any of this operation's dairy cows, dairy heifers, or their feed, minerals or water supply?

I.e. do dairy cows, dairy heifers, or their feed have any physical contact with:

a) Chickens or other poultry? .... **yes/no**
b) Horses, or other equine such as ponies, donkeys, mules, burros, etc.? .... **yes/no**
c) Pigs? .... **yes/no**
d) Sheep? .... **yes/no**
e) Goats? .... **yes/no**
f) Beef cattle? .... **yes/no**
g) Exotic species such as llamas, alpacas, emus, etc.? .... **yes/no**
h) Dogs? .... **yes/no**
i) Cats? .... **yes/no**
j) Deer or other members of the deer family such as elk, moose, etc.? .... **yes/no**

72) Were any of the following diseases confirmed via **laboratory testing** of cattle on this operation in the last 12 months?

a) Bovine Leukosis Virus (BLV) .... **yes/no**
b) Bovine Viral Diarrhea (BVD) .... **yes/no**
c) Leptospirosis .... **yes/no**
d) Neospora .... **yes/no**
e) Salmonella .... **yes/no**
f) Johne's Disease *(Mycobacterium paratuberculosis)* .... **yes/no**
g) Mycoplasma .... **yes/no**
h) *Staphylococcus aureus* .... **yes/no**
i) *Streptococcus agalactiae* .... **yes/no**

73) Who typically decides when it is appropriate to euthanize an animal? (Circle one.)
a) Owner/operator.
b) Family member of owner.
c) Veterinarian.
d) Other hired worker (non-family member).
e) Other. (Specify:______________________)

74) Who typically determines/classifies causes of death? (Circle one.)
a) Owner/operator.
b) Family member of owner.
c) Veterinarian.
d) Other hired worker (non-family member).
e) Other. (Specify:______________________)

75) Who typically records causes of death in an on-farm database? (Circle one.)
a) Owner/operator.
b) Family member of owner.
c) Veterinarian.
d) Other hired worker (non-family member).
e) Other. (Specify:______________________)

Labor Management Indices

76) How many years have the owner(s) been involved in dairy operations? .... ________**years**

77) Does dairying provide the primary source of income for the owner(s)? .... **yes/no**

78) What generation dairy farmer is the owner/operator? (Circle one.)
a) First. b) Second. c) Third. d) Fourth. e) Other. (Specify:________________)

79) Is it likely that a family member will take over primary responsibility for the dairy from the current owner(s)?.. **yes/no**

80) On average, how many hours per day is the owner or an owner's family member on the farm and participating in activities directly associated with animal care (i.e. milking, feeding, sick cow care, calvings, AI, etc.)? .... ________**hours**

81) On average, how many paid and unpaid people, including owners and family members, are assigned duties directly related to the operation of the dairy? (Exclude people that work exclusively with crop activities.)

	Number of people
a) Full-time	
b) Part-time	

82) Of the paid and unpaid people assigned duties directly related to operation of the dairy, how many are owners or owners' family members? (Exclude people that work exclusively with crop activities.)

	Number of people
a) Full-time	
b) Part-time	

83) What is the percentage of total on-farm labor supplied by owners or owners' family members?_____**%**

84) How close in proximity is the owner's house to the dairy? (If more than one owner, answer using the owner's house in closest proximity.)
a) On site.
b) Less than 1 mile.
c) 1 to 10 miles
d) Greater than 10 miles

85) On average, what is the duration of employment for paid, non-family member employees involved in the following activities?
a) Milking.. ________**months** or ________**years**
b) Cow management (calvings, fresh cows, sick cows, etc.)...... ________**months** or ________**years**

86) On average, how many total days of vacation are taken per year by a full-time employee whose duties are directly related to the operation of the dairy? (Exclude people that work exclusively with crop activities.)
   a) Owner/operator. .... ________**days**
   b) Family members of owner. .... ________**days**
   c) Hired worker(s) (non-family members). .... ________**days**

87) Who is the primary manager of daily operations for this operation? (Circle one.)
   a) Owner/operator   b) Family member of owner   c) Hired worker (non-family member)

88) Who is primarily responsible for: (Check only one per activity.)

	Owner/operator	Family member(s) of owner	Hired worker(s) (non-family members)
a) Delivering feed to the dairy cows?........	______	_______	______
b) Milking the majority of cows?	______	_______	______
c) Calving out cows?	______	_______	______
d) Monitoring fresh cows?	______	_______	______
e) Monitoring sick cows?	______	_______	______
f) Lameness evaluations?	______	_______	______
g) Artificially inseminating cows?	______	_______	______

89) Are there paid, non-family member employees for whom English is a second language? .... **yes/no**
   If "yes" answer the following four questions:

90) For what percentage of employees is English a second language? .... _________**%**

91) Who is the person primarily responsible for interactions with and oversight of the majority of employees for whom English is a second language? (Circle one.)
   a) Owner/operator   b) Family member of owner   c) Hired worker (non-family member)

92) On a scale of 1 to 5, how fluent in the employees' native language is the owner or a family member of the owner who is involved in day-to-day oversight of this operation? (1 = incapable of conversation; 5 = native speaker) .... __________

93) If group training sessions are used for employees, what is the primary language used? ____________

94) Are training sessions used for employees involved in any of the following activities:

   a) Milking?... **yes/no**

   If 'yes', which of the following methods are used:
   i) Video training. .... **yes/no**
   ii) Discussion/lecture/practicum. .... **yes/no**
   iii) On-the-job training. .... **yes/no**
   iv) Other training (Specify:_____________________). .... **yes/no**

   How frequently? (Circle one.)
   i) Trained as new employees only
   ii) 1 to 2 times per year
   iii) 3 to 4 times per year
   iv) More than 4 times per year
   v) Other (Specify:__________________________)

   Who performs the training? (Circle one.)
   i) Owner/operator.
   ii) Family member of owner
   iii) Veterinarian
   iv) Outside consultant/trainer
   v) Other hired worker (non-family member)
   vi) Other. (Specify:______________________)

b) Calving? .... **yes/no**

If 'yes', which of the following methods are used:

i) Video training. .... **yes/no**
ii) Discussion/lecture/practicum. .... **yes/no**
iii) On-the-job training. .... **yes/no**
iv) Other training (Specify:______________________). .... **yes/no**

How frequently? (Circle one.)

i) Trained as new employees only
ii) 1 to 2 times per year
iii) 3 to 4 times per year
iv) More than 4 times per year
v) Other (Specify:___________________________)

Who performs the training? (Circle one.)

i) Owner/operator.
ii) Family member of owner
iii) Veterinarian
iv) Outside consultant/trainer
v) Other hired worker (non-family member)
vi) Other. (Specify:______________________)

c) Fresh cow monitoring? .... **yes/no**

If 'yes', which of the following methods are used:

i) Video training. .... **yes/no**
ii) Discussion/lecture/practicum. .... **yes/no**
iii) On-the-job training. .... **yes/no**
iv) Other training (Specify:______________________). .... **yes/no**

How frequently? (Circle one.)

i) Trained as new employees only
ii) 1 to 2 times per year
iii) 3 to 4 times per year
iv) More than 4 times per year
v) Other (Specify:___________________________)

Who performs the training? (Circle one.)

i) Owner/operator.
ii) Family member of owner
iii) Veterinarian
iv) Outside consultant/trainer
v) Other hired worker (non-family member)
vi) Other. (Specify:______________________)

Operation ID__________________ **Quantitative**
Date_________________ **Form**

** indicates that the question requires individual input, not simply record analysis

Dairy Herd Inventory and Information

1) **What were the minimum and maximum numbers of cows on this operation in the **last 12 months**?
   ____________cows at minimum **___________cows at maximum**

2) **How many dairy cows (lactating and dry) were housed on this operation **in past years?**
   a) Total dairy cows ....1 year ago:_________ .....2 years ago:_________ .....5 years ago:_________

3) **What is the anticipated herd size five years from now? ....________**cows**

4) How many dairy cattle of the following types are housed on this operation **today**?

a) Lactating cows	
b) Dry cows	
c) Total dairy cows (a + b)	

5) How many of the (Item 4c) dairy cows on hand are:

a) Holstein?	
b) Jersey?	
c) Brown Swiss?	
d) Other? (Specify:_______________________________________)	
Total (should equal (Item 4c) dairy cows on hand):	

6) **What percent of (Item 4c) dairy cows are registered with a breed association (purebred)?._______**%**

7) How many, or what percentage of the herd is:

	%	or	#
a) 1st lactation			
b) 2nd lactation			
c) 3rd lactation or greater			
Total (should equal 100% or Item 4c):			

8) **Does this operation use bST (bovine Somatotropin, trade name Posilac®)? .... **yes/no**
   a) If 'yes', what percentage of dairy cows receive bST?... _____________**%**

9) What is the current 305 mature equivalent (ME) for milk production?

	Holstein	Jersey	Brown Swiss	Other	Total Average
lbs/cow 305 ME:					

10) **What is the approximate summer and winter milk production per cow during the last 12 months?
    Summer lbs/day/cow ____________ **Winter lbs/day/cow** _____________

11) **What is the average bulk tank somatic cell count during the last 12 months? ... ______________**SCC**

12) During the last 12 months what was the average number of days that dairy cows were dry? ______**days**

13) During the last 12 months what was the average calving interval for dairy cows? (Calving interval is the time from one calving to the next calving for an individual cow.)._______**days or** _______**months**

14) What is the average age, in months, of dairy heifers at time of first calving?............ _________**months**

15) During the last 12 months, how many dairy heifers and dairy cows calved on this operation:_____**head**
    a) How many cattle required **any** assistance during birth (dystocia)?..... **don't know** or ______**head**

** indicates that the question requires individual input, not simply record analysis

16) During the last 12 months, how many calves (bulls and heifers) born to dairy heifers and dairy cows on this operation were:
   a) Born and alive at 48 hours?.. **don't know** or ______**head**
   b) Stillborn (born dead or died with 48 hours of birth)?............................ **don't know** or ______**head**
   c) Total calves born? ....______**head**

17) During the last 12 months on this operation, how many dairy cows (Item 4c):

a) **Died (not euthanized)?	
b) **Were euthanized?	
c) Total deaths (a + b)?	

18) **Approximately what percentage of cows that died over the last 12 months were necropsied in an effort to determine the cause of death? .... **don't know** or ________**% necropsied**

19) During the last 12 months, what percentage or how many of these dead cows were:

	%	or	# dead
a) 15 days in milk or less? (peripartum)			
b) 16 to 30 days in milk?			
c) 31 to 60 days in milk?			
d) >60 days in milk? (late lactation or dry)			
Total (should equal 100% or Item 17c):			

20) During the last 12 months, what percentage or how many of these dead cows were:

	%	or	# dead
a) First lactation?			
b) 2 to 4 lactations?			
c) 5 lactations or more?			
Total (should equal 100% or Item 17c):			

21) **Approximately what ***percentage*** of cows died (including euthanasias) due to the following:

a) Scours, diarrhea, or other digestive problems (not including HBS)?	
b) Hemorrhagic bowel syndrome (HBS)?	
c) Respiratory problems?	
d) Milk fever?	
e) Lameness or injury?	
f) Mastitis?	
g) Calving problems?	
h) Johne's Disease (*Mycobacterium paratuberculosis*)?	
i) Neoplasia (i.e. lymphoma)	
j) Other known reasons? (Specify:____________________________________)	
k) Unknown reason?	
Total (should equal 100%):	

22) **Using cutoffs for the following parameters, on average you decide to cull **nonpregnant** cows at:

	Heifers	Cows
a) What number of failed inseminations?..........	______**inseminations**.............	______**inseminations**
b) How many days postpartum?.......................	______**DIM**............................	______**DIM**
c) What level of milk production?....................	______**lbs**...............................	______**lbs**

23) Permanent removals are defined as cows (1st lactation or greater) removed from the herd for reasons other than death. These include cows sent to other dairies, auction markets, stockyards, packers, or slaughter plants.
How many dairy cows were permanently removed in the last 12 months? ....________**head**

** indicates that the question requires individual input, not simply record analysis

24) During the last 12 months, what percentage or how many of these permanently removed cows were:

	%	or	# removed
a) 15 days in milk or less? (peripartum)			
b) 16 to 30 days in milk?			
c) 31 to 60 days in milk?			
d) >60 days in milk? (late lactation or dry)			
Total (should equal 100% or Item 23):			

25) During the last 12 months, what percentage or how many of these permanently removed cows were:

	%	or	# removed
a) First lactation?			
b) 2 to 4 lactations?			
c) 5 lactations or more?			
Total (should equal 100% or Item 23):			

26) **During the last 12 months, what percentage or how many of these permanently removed cows were:

	%	or	# removed
a) Sent directly to another dairy?			
b) Sent to market, auction, or stockyard?			
c) Sent directly to a packer or slaughter plant?			
d) Sent elsewhere? (Specify________________________)			
Total (should equal 100% or Item 23):			

27) **For permanently removed cows approximately what ***percentage*** were removed primarily because of:

a) Mastitis problems?	
b) Udder conformation/pathology (excepting mastitis)?	
c) Lameness or injury?	
d) Reproductive problems?	
e) Aggressiveness or belligerence (kickers)?	
f) Abortion?	
g) Johne's Disease?	
h) Poor production not related to above problems?	
i) Other diseases?	
j) Sold as replacement animals to another dairy?	
k) Other reasons? (Specify:__________________________________)	
Total (should equal 100%):	

28) **During the last 12 months, approximately what ***percentage*** of the total dairy cows (item 4c) had:

a) Clinical mastitis (presence of abnormal milk and/or inflamed udder)?	
b) Lameness?	
c) Respiratory problems?	
d) A retained placenta (more than 24 hours after delivery)?	
e) Other reproductive problems (e.g., dystocia, metritis)?	
f) Diarrhea for more than 48 hours?	
g) Milk fever?	
h) Displaced abomasum?	
i) Neurological problems?	
j) Hemorrhagic Bowel Syndrome (HBS)?	
k) Johne's Disease (*Mycobacterium paratuberculosis*)	
l) Neoplasia (i.e. lymphoma)	
m) Other health-related problems? (Specify:____________________)	

** indicates that the question requires individual input, not simply record analysis

29) **Using the layout below or a computer printout, list pen numbers for *adult cows* (i.e. lactation >0), the associated group classifications (i.e. fresh/transition, early lactation, mid/late lactation, dry, far-off, close-up, maternity, sick, clean-up pens, etc.), pen occupancy as of today, freestall or drylot classification, and the number of stalls in a freestall pen .

Pen #s	**Classification**	**Pen Occupancy Today**	**Freestall or Drylot**	# of Stalls if Freestall
Total pen occupancy (should equal item 4c):				

Operation ID__________________
Date_________________

Crowding Assessment via Pen Walks

1) Dry (Far off): Pen #_____
   a) Description (freestall/drylot; covered/no cover; etc):___________________________________
   b) Occupancy: .... _____________**cows**
   c) Pen square footage: .... _______________**ft^2**
   d) Bunk space **(ft)**_____________ *or* Lock-ups **(#)** ________________
      i) Head lock-up width.. ______________**in**
   e) Number of stalls: .... ____________**stalls**
      i) Number of rows: .... ____________**rows**
      ii) Stall dimensions...................._____________ **inches long** *by* ____________**inches wide**
   f) Number of water sources: .... ____________**water sources**

2) Maternity (Close up): Pen#_____
   a) Description (freestall/drylot; covered/no cover; etc):___________________________________
   b) Occupancy: .... _____________**cows**
   c) Pen square footage: .... _______________**ft^2**
   d) Bunk space **(ft)**_____________ *or* Lock-ups **(#)** ________________
      i) Head lock-up width.. ______________**in**
   e) Number of stalls: .... ____________**stalls**
      i) Number of rows: .... ____________**rows**
      ii) Stall dimensions...................._____________ **inches long** *by* ____________**inches wide**
   f) Number of water sources: .... ____________**water sources**

3) Fresh/transition (average <50 DIM): Pen#_____
   a) Description (freestall/drylot; covered/no cover; etc):___________________________________
   b) Occupancy: .... _____________**cows**
   c) Historic occupancy:... _____________**cows**
   d) Pen square footage: .... _______________**ft^2**
   e) Bunk space **(ft)**_____________ *or* Lock-ups **(#)** ________________
      i) Head lock-up width.. ______________**in**
   f) Number of stalls: .... ____________**stalls**
      i) Number of rows: .... ____________**rows**
      ii) Stall dimensions...................._____________ **inches long** *by* ____________**inches wide**
   g) Number of water sources: .... ____________**water sources**

Survey Details

1) Total time on farm: arrival time (military)_________; exit time (military)_________.
2) Total travel distance (round trip):___________ miles
3) Producer data quality:
   a) good to excellent
   b) OK
   c) poor
4) Did the producer use written or computerized records to assist in answering this survey:
   a) yes
   b) no
5) Which of the following best describes the respondent's position with this operation:
   a) owner
   b) family member other than owner or manager (specify:______________)
   c) partner
   d) manager
   e) other hired employee
   f) other (specify:___________________)

Comments: